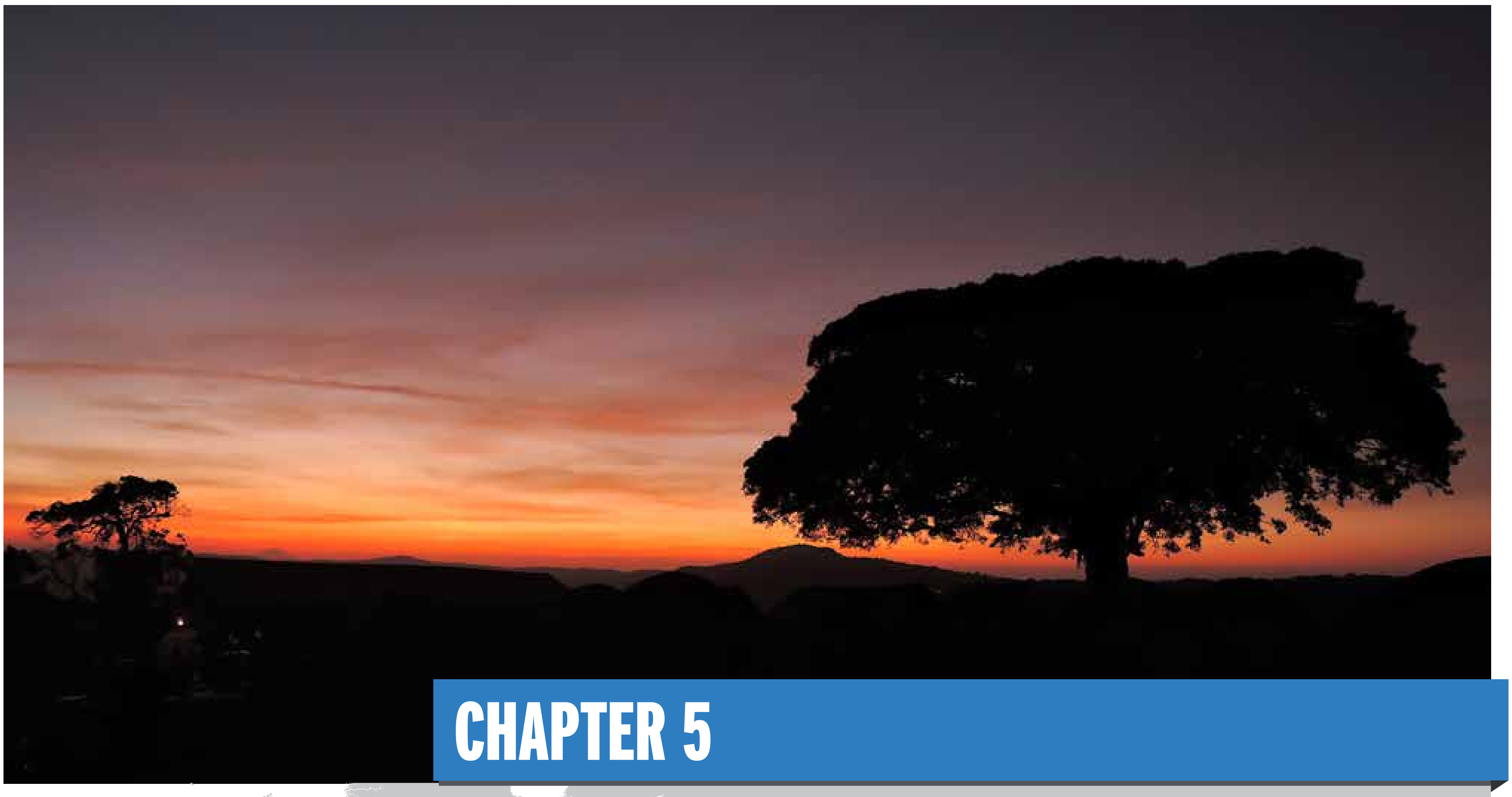
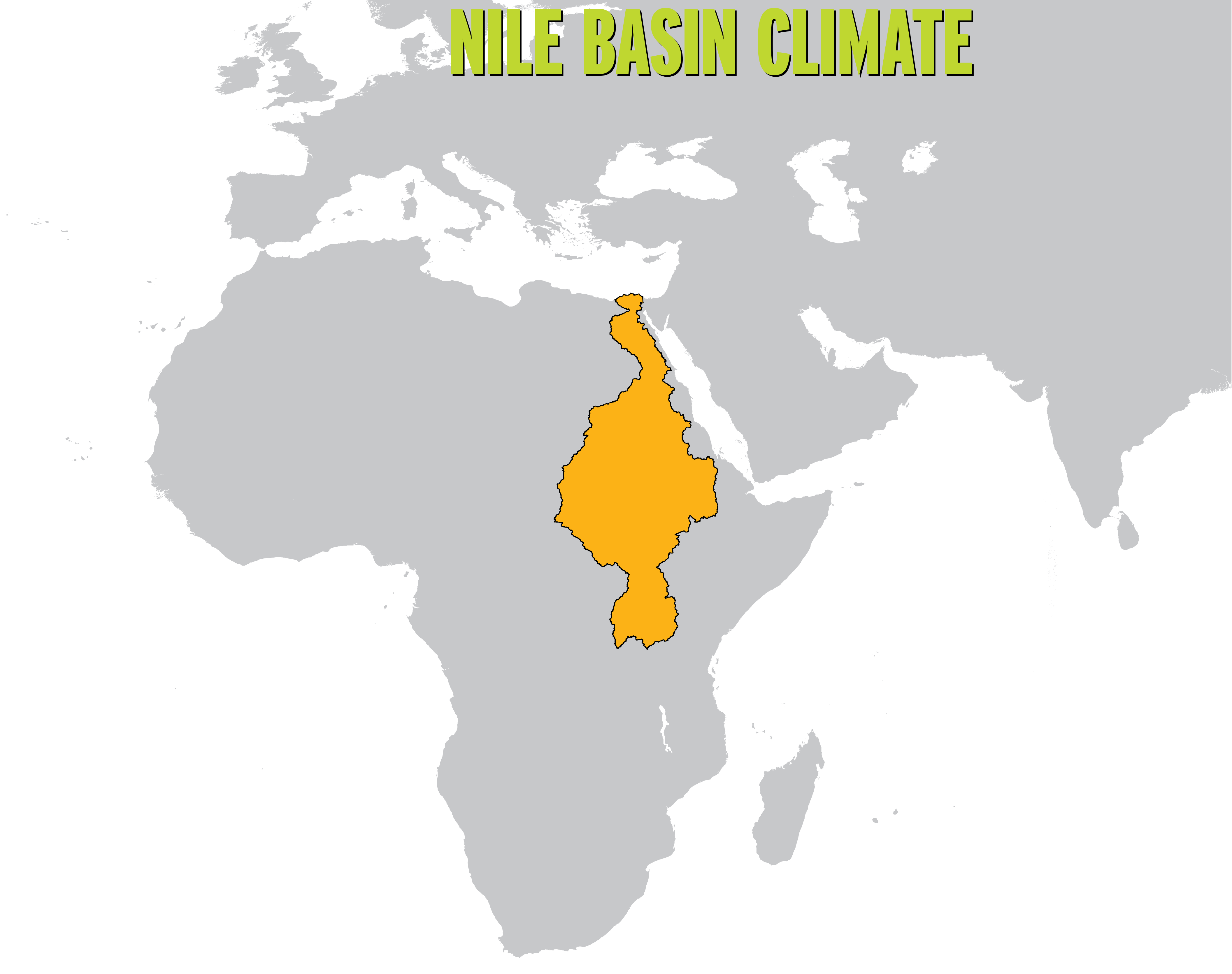


CHAPTER 5

NILE BASIN CLIMATE



KEY MESSAGES

The River Nile is extremely sensitive to changes in precipitation with variations impacting lake levels and river discharges. Increases in temperature can also affect the rates of evaporation and evapotranspiration influencing the water balance of the basin. Given the centrality of the fresh water resources to economic and social development of the Nile basin region, it is important to have a good understanding of these variables.

The historical flow records of the Main Nile river clearly highlight the significance of the natural variability of the upper basin for an efficient management of the water resources in the downstream regions. The analysis using the water balances of sub-basins shows that these changes can be explained by the minor changes in rainfall and evaporation.

Although both the Equatorial lakes region and the Blue Nile region are sensitive to changes in the climate, the flows in the Main Nile is mainly controlled by climate changes in the Ethiopian highlands. This is because any change in the runoff in the Equatorial lake area will be completely dampened by the marshes in southern Sudan, the Sudd area.

Apart from the Blue Nile the inflow changes are determined by changes in River Atbara. This river has a comparable setting as the Blue Nile and the sensitivity of the outflow can be assumed comparable to that of the Blue Nile.

Analysis of observed precipitation, evaporation and outflow, reveals that rainfall and evaporation in the equatorial lakes region are large terms compared to the outflow. This means that small changes in rainfall or evaporation easily lead to large changes in outflow of the lake.

INTRODUCTION


Photo: The World Bank

Rehabilitated landscape under PSNP in Sire District

The Nile basin exhibits large variations in climate ranging from the tropical climate at the sources of the Blue and White Nile to the Mediterranean climate at the mouth of the Nile. This variation reflects the latitude range; 4°S to 32°N and the altitude range; from sea level to more than 3,000 m. The tropics; East African lakes region and southwestern Ethiopia, exhibit climates with well-distributed rainfall in excess of 1,000mm per year whereas northern Sudan all across Egypt, there is negligible rainfall (sometimes falling below 50mm a year) except for the Mediterranean coast which gets about 180mm a year.
Depending on the location and altitude in the equatorial lakes region, there is generally little variation in the mean annual temperature ranging from 16 to 27°C whereas in the semi-arid areas up to Egypt, the temperature ranges are quite high; 10 – 45°C.

There is evidence that the global climate is changing due to human-induced emissions of greenhouse gasses. The emissions lead to increasing atmospheric concentrations of these gasses. In turn increased concentration of these gases affects the global radiation balance. The general expectations that this will results in a warmer world and that the hydrological cycle will accelerate. On a global scale the climatic changes mean an increasing temperature, known as global warming, more precipitation and more evaporation. However, although the general trends are recognised, regionally the magnitude and even the direction of change are still far from clear.

Changes in climate in the Nile basin may lead to changes in the discharge of the river Nile. Such changes have occurred in the far past. Geological records of the Nile basin reveal an alternation between relative wet and dry periods during the last 20,000 years. Relatively wet periods appeared between 12,000 and 7500 BP and between 6000 and 2500 BP. The periods 20,000-12,000 BP, 7500 – 6000 BP as well as the period 2500-1000 BP were relatively dry. More recently the observed discharges indicate that the last 3 decades of the 19th century were relatively wet. Well known is the very dry period between 1980 and 1990.

If the flow of the river Nile would change considerably, this will have effect on the water management in the Nile. Current dam operation and release strategies, that are able to meet the water demand in the various Nile countries under the actual conditions, may not be sufficient to meet the demands in future, this because both the supply as well as the demand changes in time.

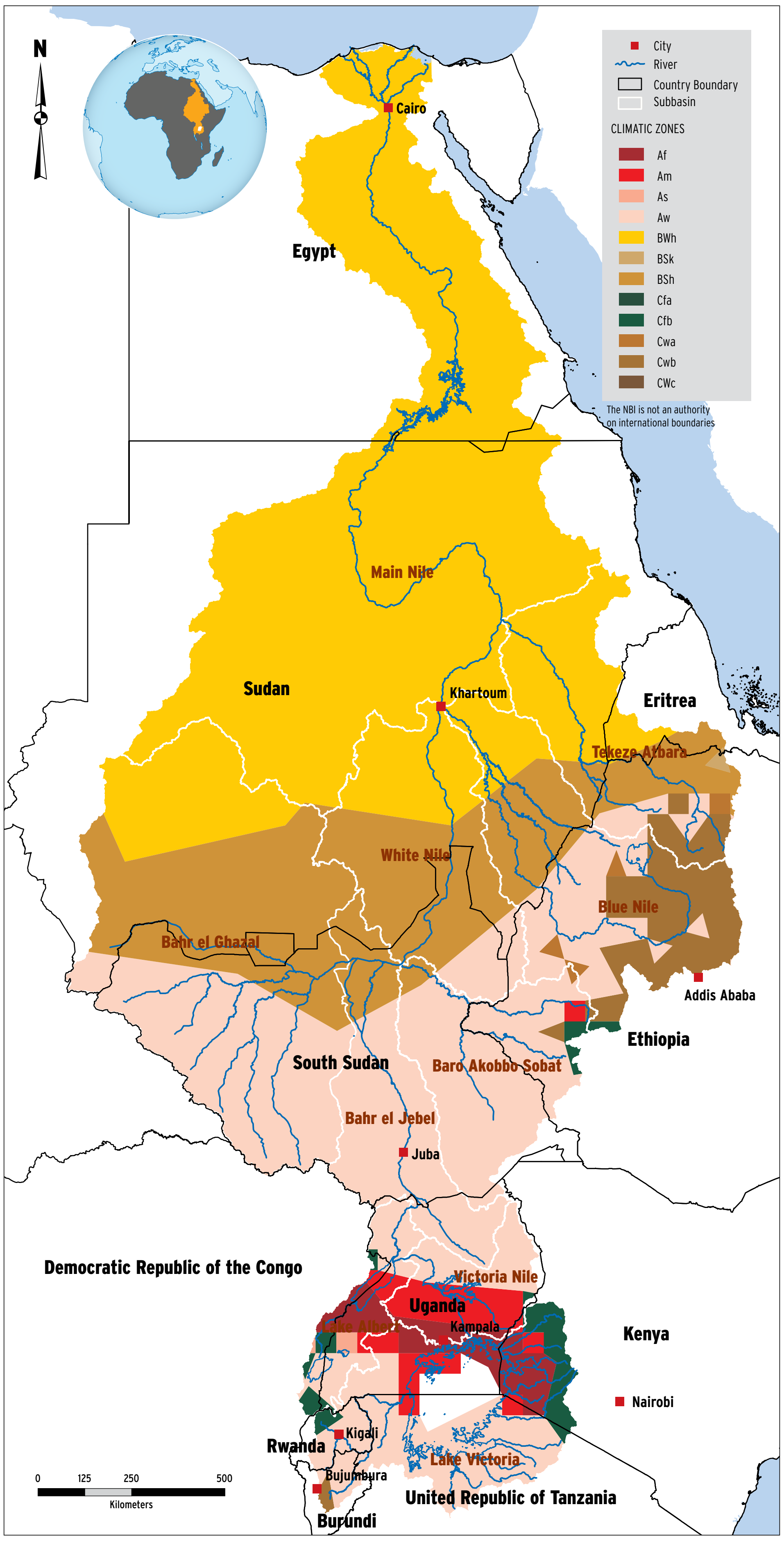
This chapter presents the main climate variables for which data/information was gathered (rainfall, temperature, relative humidity, evapotranspiration, and wind speed) mainly in terms of their monthly distribution within the Sub-basins.

NILE BASIN CLIMATE ZONES

The two most important components of climate are temperature and precipitation. Regional climates can be classified according to these two components and other characteristics. The Köppen Climate Classification System is the most widespread system used to classify the climates of places and is the one that has been presented in this atlas. This system classifies a location's climate mainly using annual and monthly averages of temperature and precipitation and comprises a total of 31 climate classes described by a code of letters. The first letter describes the main classes, the second letter accounts for precipitation and the third letter for temperature classes as seen in the table below. The basin is mainly dominated by tropical wet and dry climate in the equatorial lakes region and part of Ethiopia, sub-tropical dry arid (desert) in Sudan and Egypt, sub-tropical dry semi-arid in the southern part of Sudan as well as the tropical wet and tropical monsoonal around the Lake Victoria and some parts of the Ethiopian highlands. Here, only 12 out of 31 classifications which are reflected within the Nile basin have been fully provided.

Main Climates	Precipitation	Temperature
A: equatorial	W: desert	h: hot humid
B: arid	S: steppe	k: cold arid
C: warm temperate	f: fully humid	a: hot summer
D: snow	s: summer dry	b: warm summer
E: polar	w: winter dry	d: extremely continental
	m: monsoonal	F: polar frost
		T: polar tundra

The basin extends over five climatic zones – Mediterranean, arid, semiarid, subtropical and tropical (Karyabwite 2000). Its landscapes range from mountains, grasslands, forests and woodlands, wetlands, lakes and desert to a wave dominated delta. This combination results in an array of ecosystems that are home to a rich biodiversity that provide a multitude of benefits to the population through cultural and ecological services, trade, tourism, food, medicines and other products. The Congo-Nile divide in Rwanda, the Fayoum lakes in the Egyptian desert, the Sudd wetlands in Sudan and the Albertine Rift on the border of the DRC with Uganda are some of the areas with a unique or rich biodiversity. The three sub-basins of the Nile (Equatorial lakes, Ethiopian plateau and Bahr El Ghazal) each receive extremely variable amounts of precipitation according to the climate zones in which they are situated. Rainfall and river flow records show that the basin has had its share of droughts and floods. These natural events have seriously impacted on the livelihoods of many people and the environment.



Code	Name	Description
Af	Tropical Wet	No dry season. The driest month has at least 60 mm (2.4") of rain. Rainfall is generally evenly distributed throughout the year. All average monthly temperatures are greater than 18°C (64°F).
Am	Tropical Monsoonal	Pronounced wet season. Short dry season. There are one or more months with less than 60 mm (2.4"). All average monthly temperatures are greater than 64°F (18°C). Highest annual temperature occurs just prior to the rainy season.
Aw	Tropical Wet & Dry	Winter dry season. There are more than two months with less than 60 mm (2.4"). All average monthly temperatures are greater than 18°C (64°F).
BSh	Subtropical Dry Semiarid (Steppe	Low-latitude dry. Evaporation exceeds precipitation on average but is less than potential evaporation. Average temperature is more than 18°C (64°F).
BSk	Mid-latitude Dry Semiarid (Steppe)	Mid-latitude dry. Evaporation exceeds precipitation on average but is less than potential evaporation. Average temperature is less than 18°C (64°F).
BWh	Subtropical Dry Arid (Desert)	Low-latitude desert. Evaporation exceeds precipitation on average but is less than half potential evaporation. Average temperature is more than 18°C (64°F). Frost is absent or infrequent.
BWk	Mid-latitude Dry Arid (Desert)	Mid-latitude desert. Evaporation exceeds precipitation on average but is less than half potential evaporation. Average temperature is less than 18°C (64°F). Winter has below freezing temperatures.
Cfa	Humid Subtropical	Mild with no dry season, hot summer. Average temperatures of warmest months are over 22°C (72°F). Average temperature of coldest month is under 18°C (64°F). Year around rainfall but highly variable.
Cfb	Marine - Mild WInter	Mild with no dry season, warm summer. Average temperature of all months is lower than 22°C (72°F). At least four months with average temperatures over 50°F (10°C). Year around equally spread rainfall.
Cfc	Marine - Cool Winter	Mild with no dry season, cool summer. Average temperature of all months is lower than 22°C (72°F). There are one to three months with average temperatures over 50°F (10°C). Year around equally spread rainfall.
Csa	Interior Mediterranean	Mild with dry, hot summer. Warmest month has average temperature more than 72°F (22°C). At least four months with average temperatures over 50°F (10°C). Frost danger in winter. At least three times as much precipitation during wettest winter months as in the driest summer month.
Csb	Coastal Mediterranean	Mild with cool, dry summer. No month with average temperature of warmest months is over 22°C (72°F). At least four months with average temperatures over 50°F (10°C). Frost danger in winter. At least three times as much precipitation during wettest winter months as in the driest summer month.

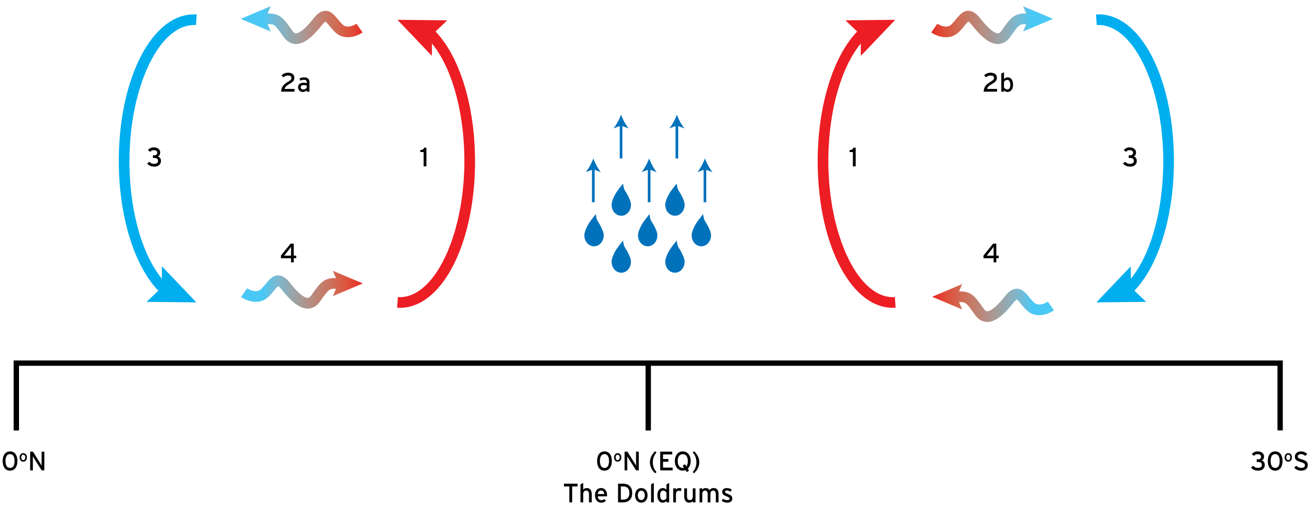
ATMOSPHERIC ACTIVITY AND INFLUENCE ON NILE CLIMATE

Photo: istock

Nile river

The climate in the Nile basin results from atmospheric patterns of air, heat, and moisture circulation that vary over time and space, and the interaction of these atmospheric patterns with the landscape. General atmospheric circulation patterns include convergence and rising of air in the equatorial region, movement of air towards the poles high in the atmosphere, downward movement of air near 30° latitude north or south of the equator, and movement of air back towards the equator. Near the equator, intense solar radiation and the convergence of the warm, moist trade winds cause air to rise, carrying heat and moisture into the atmosphere (1). As the air masses become trapped between the stratosphere above and the air moving upward from beneath, they are forced to move either north or south toward the poles (2a, 2b). The air masses lose heat as they move poleward, and begin to descend at about 30° latitude north or south of the equator (3). As the air masses spread out over the surface of the earth, air flows back towards the equator as the trade winds (4). This generalized circuit is known as the Hadley cell circulation. The intensity, geographical extent, and latitudinal position of these patterns can vary seasonally.

A schematic diagram of the Hadley cell circulation pattern



Source: D. Windrim, 2004.

Intense solar radiation and the convergence of the warm, moist trade winds cause air to rise, carrying heat and moisture into the atmosphere.

- As the air masses become trapped between the stratosphere above and the air moving upward from beneath, they are forced to move either north or south (b) toward the poles.
- The air masses lose heat as they move poleward, and begin to descend at about 30° latitude north or south of the equator.
- As the air masses spread out over the surface of the earth, air flows back towards the equator as the trade winds.

The Intertropical Convergence Zone or ITCZ

The Intertropical Convergence Zone, or ITCZ, is the region encircling the earth between the Hadley cells of the northern and southern hemisphere. The ITCZ is formed by the convergence of the trade winds, which flow towards the equator as part of the Hadley cell circulation pattern, and is characterized by rising air masses and low pressure. The convergence and rising of warm, moist air masses into the atmosphere is followed by condensation and cloud formation. Cloudiness and release of rainfall in a series of thunderstorms are the dominant climatic features of the ITCZ. Precipitation typically exhibits a diurnal pattern, where clouds form in the late morning and early afternoon, and lead to convectional thunderstorms and rainfall in the late afternoon. Due to the predominance of vertically rising air masses and lack of horizontal air movement, the ITCZ has been termed the "doldrums" by sailors. The ITCZ is also known as the Intertropical Front or the Equatorial Convergence Zone.

The location of the ITCZ is not constant, but varies semiannually back and forth across the equator according to the sun's zenith point. The movement of the ITCZ in response to the position of the sun is responsible for the rainy and dry seasons experienced in tropical latitudes. Droughts and flooding can result from long-term or extreme changes in the position of the ITCZ.

The subtropical highs refer to areas of high pressure between 20° and 40° latitude, resulting from the downward movement of air masses. These high-pressure areas affect the climate of these latitudes, which is dominated by cloud-free and windless days. The size, intensity, and geographical position of the subtropical highs vary seasonally due to other seasonal atmospheric effects such as the movement of the ITCZ.

Average Annual Rainfall

The Nile basin, like many parts of the world, has many areas where rainfall data is either sparse or unevenly distributed and in some cases nonexistent. In many cases, weather observation networks are deteriorating leaving a challenge to planners requiring the use of such data. In such an area, satellite based observations present themselves as an option since they provide essential, and at times the only spatiotemporal data for use.

In this atlas, rainfall estimates are based on observed data collected from countries and on Tropical Rainfall Measuring Mission (TRMM). TRMM is a research satellite that was designed to improve our understanding of the distribution and variability of precipitation within the tropics.

Overall, TRMM: 3B43 v7data indicates that there is wide rainfall variability in the basin which is also confirmed by the ground measurements. The mean annual rainfall, presented here, compares well with the recorded observations within the Nile basin, with the minimum seen to be less than 50mm in the arid areas of the northern part of Sudan and Egypt and the maximum being registered in the equatorial lakes region in areas around lake Victoria and the Ethiopian highlands, like it is with the recorded observations.

Generally, it can be seen that the equatorial lakes region and the Ethiopian highlands generally receives annual rainfall of over 1,000mm and the other parts of the basin receive less than 700mm. The high altitude area (Rwenzori mountains in western Uganda, Mount Elgon, and the Ethiopian highlands) register rainfall in excess of 1,500mm and these are considered to be the water towers of the basin.

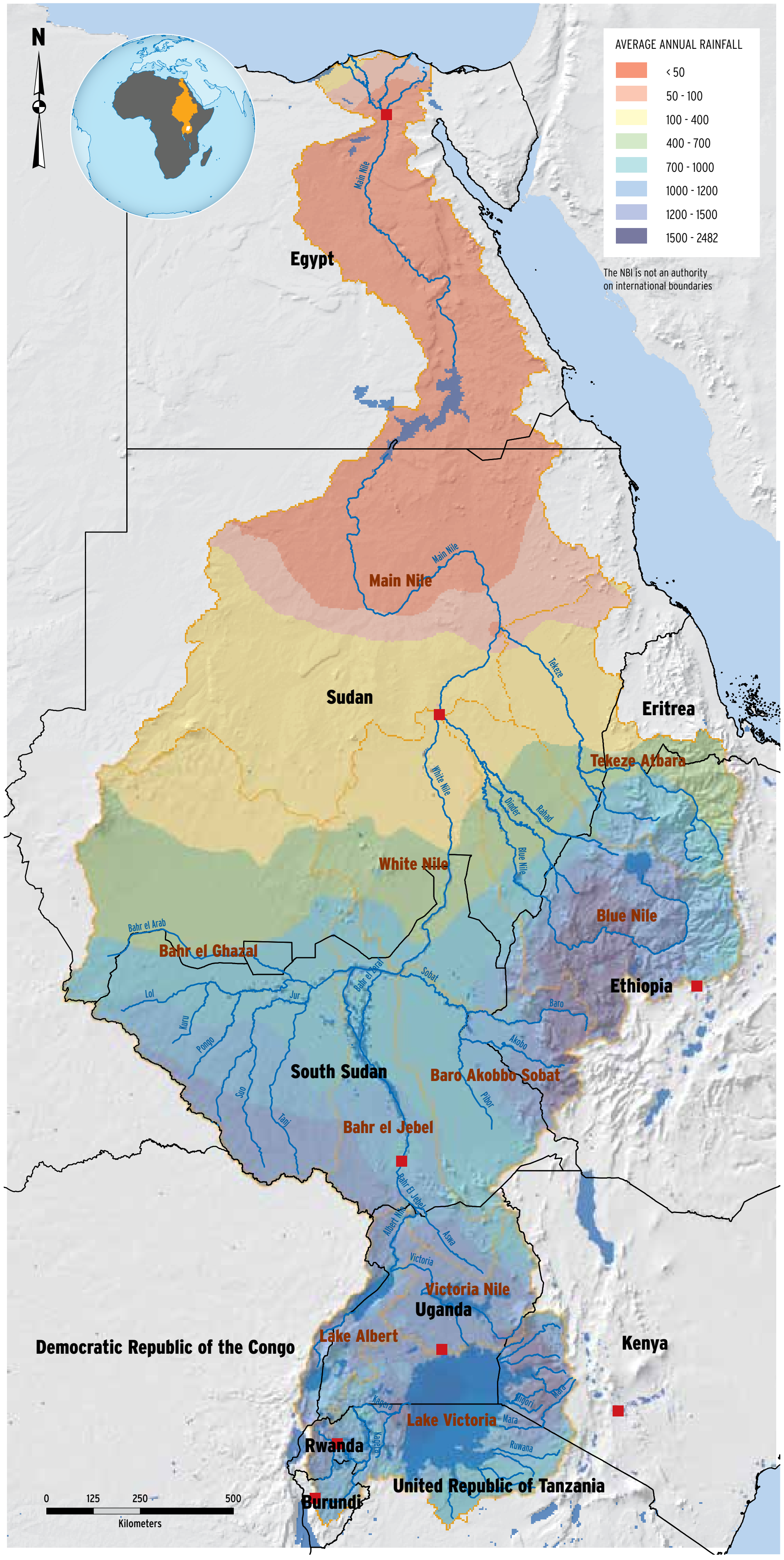
Rainfall is a major hydrological feature of the Nile basin and exhibits spatial and temporal variation at both the basin and country level. The Inter-Tropical Convergence Zone (ITCZ), which fluctuates seasonally, drives the region's rainfall regime and influences the hydrology of the Nile (Camberlin 2009, Sutcliffe and Parks 1999). Precipitation generally increases from north to south and with elevation (Beyene and others 2007).

The total amount of precipitation over the Nile basin countries is 7 000 BCM/yr, of which 1660 BCM/yr falls in the Nile basin. The mean for the entire Nile basin is 615 mm/yr (Ribbe and Ahmed 2006). About 28% of the basin receives less than 100 mm of rain annually, part of it experiences hyper-arid conditions and another substantial area (about 34%) has sub-humid conditions and receives between 700 and 1300 mm of rain. Only the southwestern part of South Sudan, the Lake Victoria basin region and the Ethiopian highlands receive over 1000 mm of rainfall a year (Camberlin 2009).

Rainfall within the basin is modified by the presence of the different water bodies and therefore varies in different sub-basins. For example, in the Blue Nile basin of Ethiopia, the mean annual rainfall ranges from 1 000 mm in the northeast to 2000 mm in the southeast (Ribbe and Ahmed 2006). In the Equatorial lakes region, it varies between 950 mm and 2450 mm. South of the Blue Nile River Basin, precipitation reaches over 2400 mm in the Baro River basin, recharging the Baro River, which joins the White Nile before Khartoum (Conway 2000).

Average annual rainfall over key catchments in the Nile basin

Basin Area	Sutcliffe and parks Up to 1972 (mm/yr)[1]	CRU CL 2.) 1960-1991 (mm/yr) [2]
Lake Victoria basin (Excluding the lake)	1186	1196
Lake Kyoga basin	1276	1224
Lake Albert basin	1214	1175
Lake Albert to Mongalla	1180	1154
Mongalla to lake No	871	961
Bahr el Ghazel basin	1169	1105
River Baro basin	1503	1555
Ethiopian Nile Catchment	1227	1184
Main Nile downstream of Atbara confluence	36	46
Water body: Lake Victoria	1650-1858	1326



Data Source: TRMM: 3B43 v7

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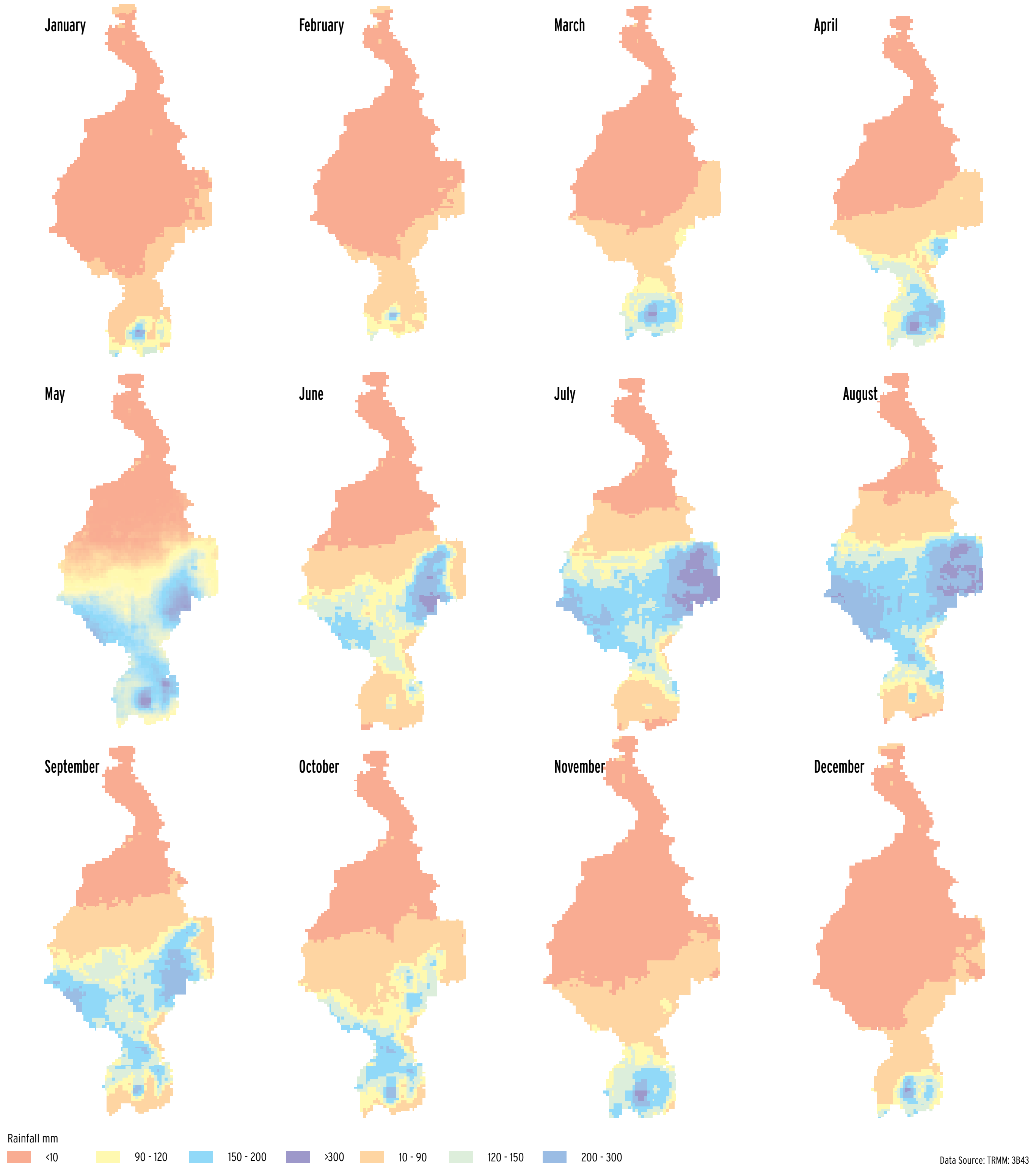
[1] Rainfall average up to 1972 for the stations available, the periods of record vary (Source: Sutcliffe and Parks 1999)
[2] CRU CL 2.0: Climate Research Unit Climatology data base version 2

Rainfall Distribution

Monthly observed rainfall data was collected mainly from the NBI database which was originally gathered from the member countries, other sources being GHCN, NBE, MWE, and NBRP. The selection of the stations for use in this atlas was based on the length of the records, quality of the data, and the spatial location of the station with an idea to get a fair spatial distribution of the stations across the basin. Most of the data used had been quality controlled by the Nile Basin Initiative Secretariat. Spatially, there is a gradual decrease of rainfall amounts from upstream to downstream with some upstream areas registering up to monthly maximums of 700mm in the rainy seasons (March-May) and the lower arid parts of the basin registering maximums of up to 60mm in the wet season (July – September). There are two distinct wet seasons separated by dry seasons in the equatorial lakes region, which gradually transform into a single wet season, followed by a dry one in the other parts of the basin.

This section of the atlas presents the monthly rainfall distribution over the Nile Basin presented at sub-basin level and clearly indicating the variations in seasons and rainfall amounts. The background map for the sub-basins shows the average rainfall distribution as derived from satellite data. The mean monthly rainfall distribution based on satellite data (TRMM: 3B43 v7) for the period 2000-2012 is presented for comparison purposes.

SPATIAL AND TEMPORAL VARIATION OF RAINFALL IN THE NILE BASIN



Data Source: TRMM: 3B43

Average Country Rainfall

On average, annual rainfall in the Nile basin is approximately 650 mm. However, rainfall differs substantially by country, with low rainfall in Egypt and high rainfall in Ethiopia and the countries of the Equatorial Lakes Plateau.

Egypt is the country with the least rainfall averaging 200 mm per year. The capital city, Cairo, receives about 25 mm per year. Ninety per cent of the country receives rain only once every couple of years. An estimated 30% of Sudan is desert, where drought is common. Rainfall here averages about 254 mm per year. This area borders a semi-arid Sahelian region of low mountains in the central area of the Sudan, giving way to a swamp-covered south which receives approximately 1015 mm of rain a year.

Rainfall in Ethiopia ranges from 510 mm up to 1 525 mm in the rainy season from mid-June to September. In absolute terms, there is an overall large amount of rainfall in Ethiopia, but the effects vary widely, and are often not beneficial. For example, heavy downpours in the rainy season cause severe erosion leading to losses in soil fertility and productivity; while the rest of the year is extremely dry, making farming almost impossible without irrigation. Precipitation is generally higher in the upstream countries.

The climate in Burundi is tropical and moderated by its altitude. The average annual rainfall ranges from 1000 mm to 1 500 mm.

Rainfall in the DRC falls throughout the year and ranges from 1524 mm in the north, to 1270 mm in the south. 20% of Uganda is covered by open water and precipitation is between 1000 mm and 1500 mm a year. In some of the countries, the amount of precipitation received in their portion of the Nile basin exceeds the national average. This fact is important for policy and decision making especially in countries where there is a lack of additional water resources. Examples include Egypt, Sudan and Ethiopia which do not have significant water resources within their borders outside of the Nile and its tributaries.

Rainfall by country

Country	Avg. Country Rainfall (mm/yr.)[3]	Avg. Nile rainfall (mm/yr.)
Burundi	1275	1202
DR Congo	1543	1146
Egypt	51	19
Ethiopia	848	1184
Kenya	630	1149
Rwanda	1212	1137
Sudan	250	487
South Sudan	900	900
Tanzania	1071	1043
Uganda	1180	1193

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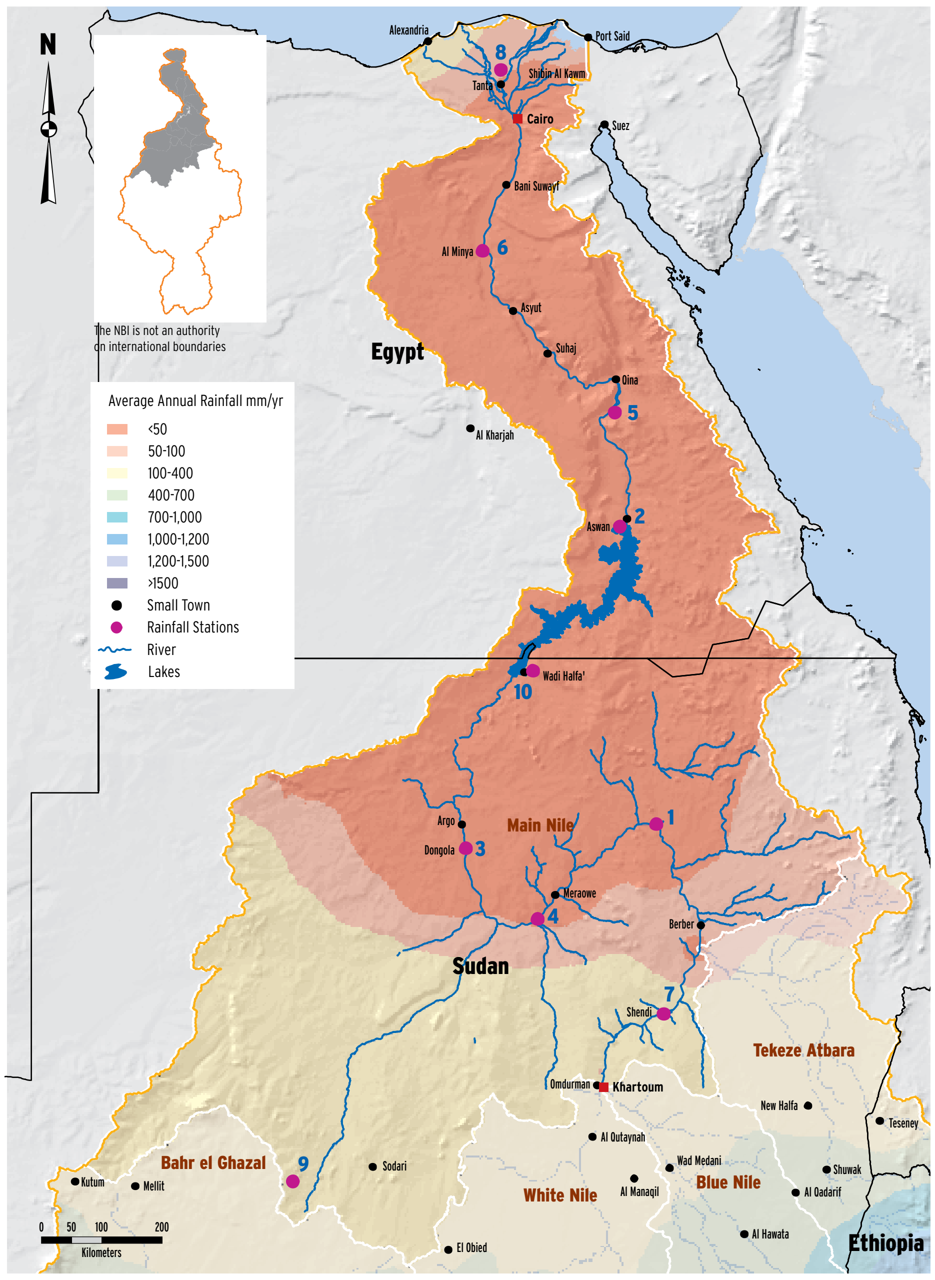
[3] Source: World Development Indicators, 2015

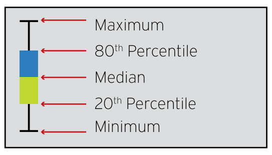
Mean monthly rainfall distribution – Main Nile Sub-basin



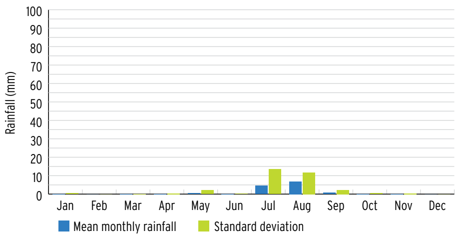
This part of the Nile basin experiences the driest conditions with very few rainfall amounts registered mainly in July and August. As you move further down to the Mediterranean Sea, there is some substantial rainfall recorded there and the rainfall pattern within the lower part of the basin is maintained. The box plot clearly depicts a situation where such type of rainfall cannot be used for any purpose like agriculture.

Station Identification

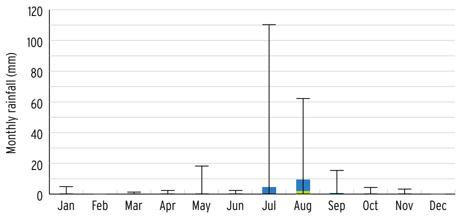
Station Name	Label No.	Record Length	Station Name	Label No.	Record Length
Abu-Hamed	1	1908-2011	Tanta	8	1904-2004
Asswan	2	1926-2011	Umm Badr	9	1902-2011
Dongola	3	1908-2011	Wadi-Halfa	10	1935-2011
Korti	4	1908-2011			
Luxor	5	1926-2011			
Minya	6	1925-1990			
Shendi	7	1937-1999			



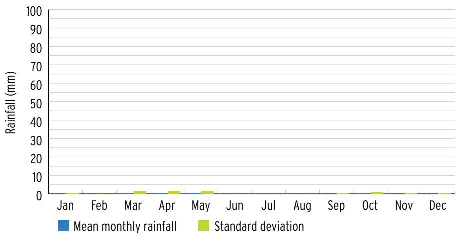
1 Mean monthly rainfall distribution - Abu Hamed



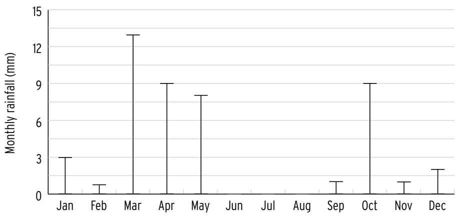
1 Monthly rainfall statistics - Abu Hamed



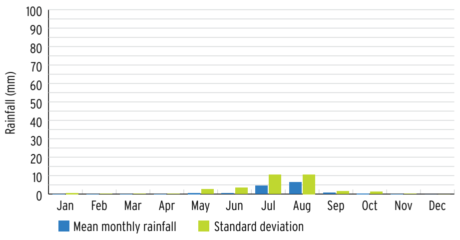
2 Mean monthly rainfall distribution - Aswan



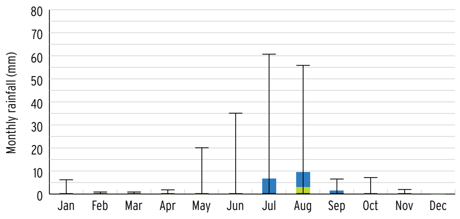
2 Monthly rainfall statistics - Aswan



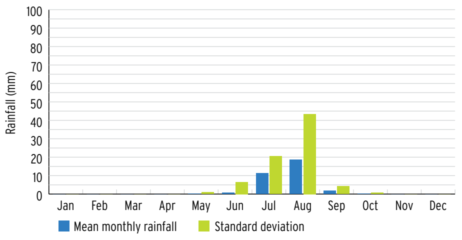
3 Mean monthly rainfall distribution - Dongola



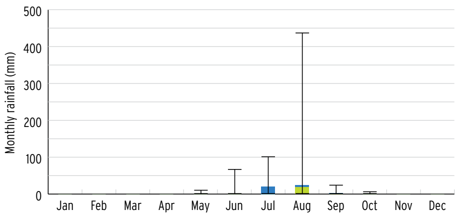
3 Monthly rainfall statistics - Dongola



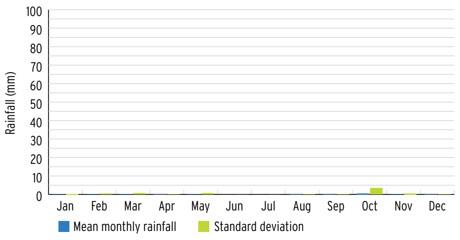
4 Mean monthly rainfall distribution - Korti



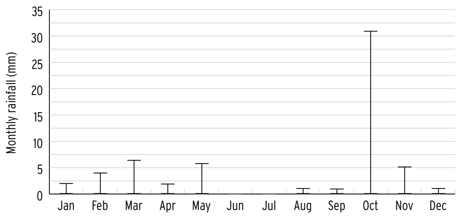
4 Monthly rainfall statistics - Korti



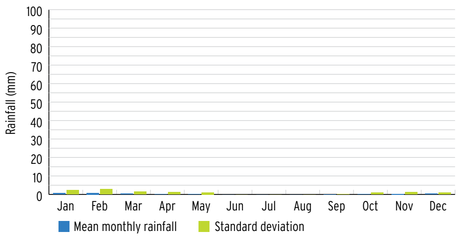
5 Mean monthly rainfall distribution - Luxor



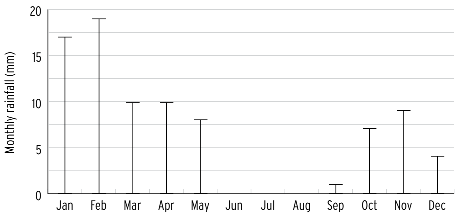
5 Monthly rainfall statistics - Luxor



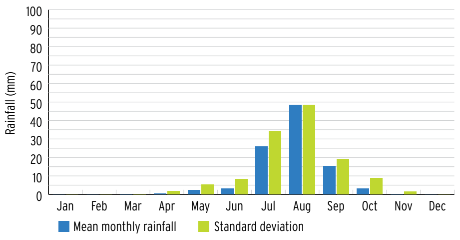
6 Mean monthly rainfall distribution - Minya



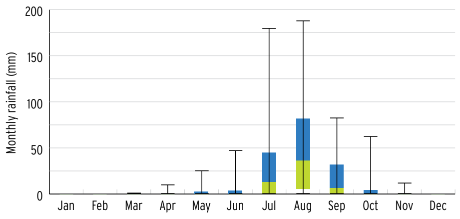
6 Monthly rainfall statistics - Minya



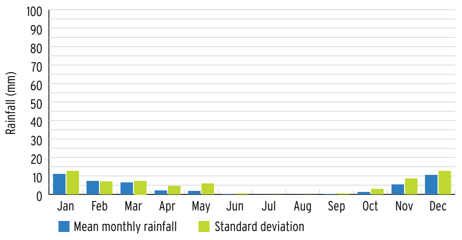
7 Mean monthly rainfall distribution - Shendi



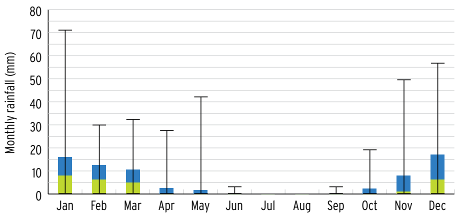
7 Monthly rainfall statistics - Shendi



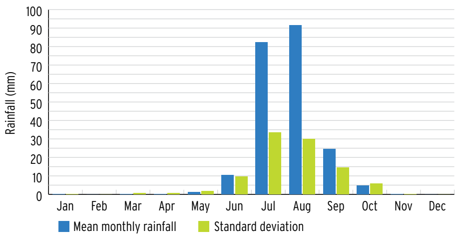
8 Mean monthly rainfall distribution - Tanta



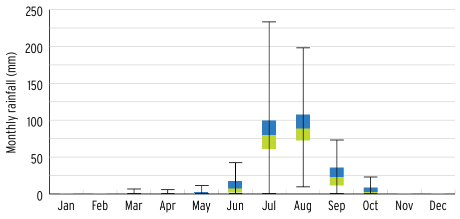
8 Monthly rainfall statistics - Tanta



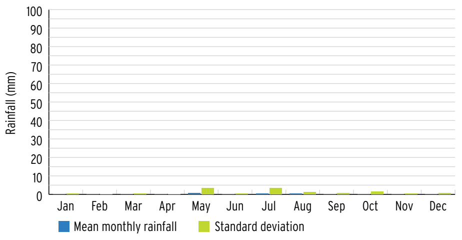
9 Mean monthly rainfall distribution - Umm Badr



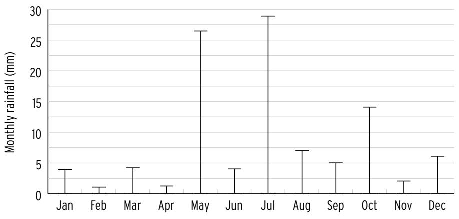
9 Monthly rainfall statistics - Umm Badr



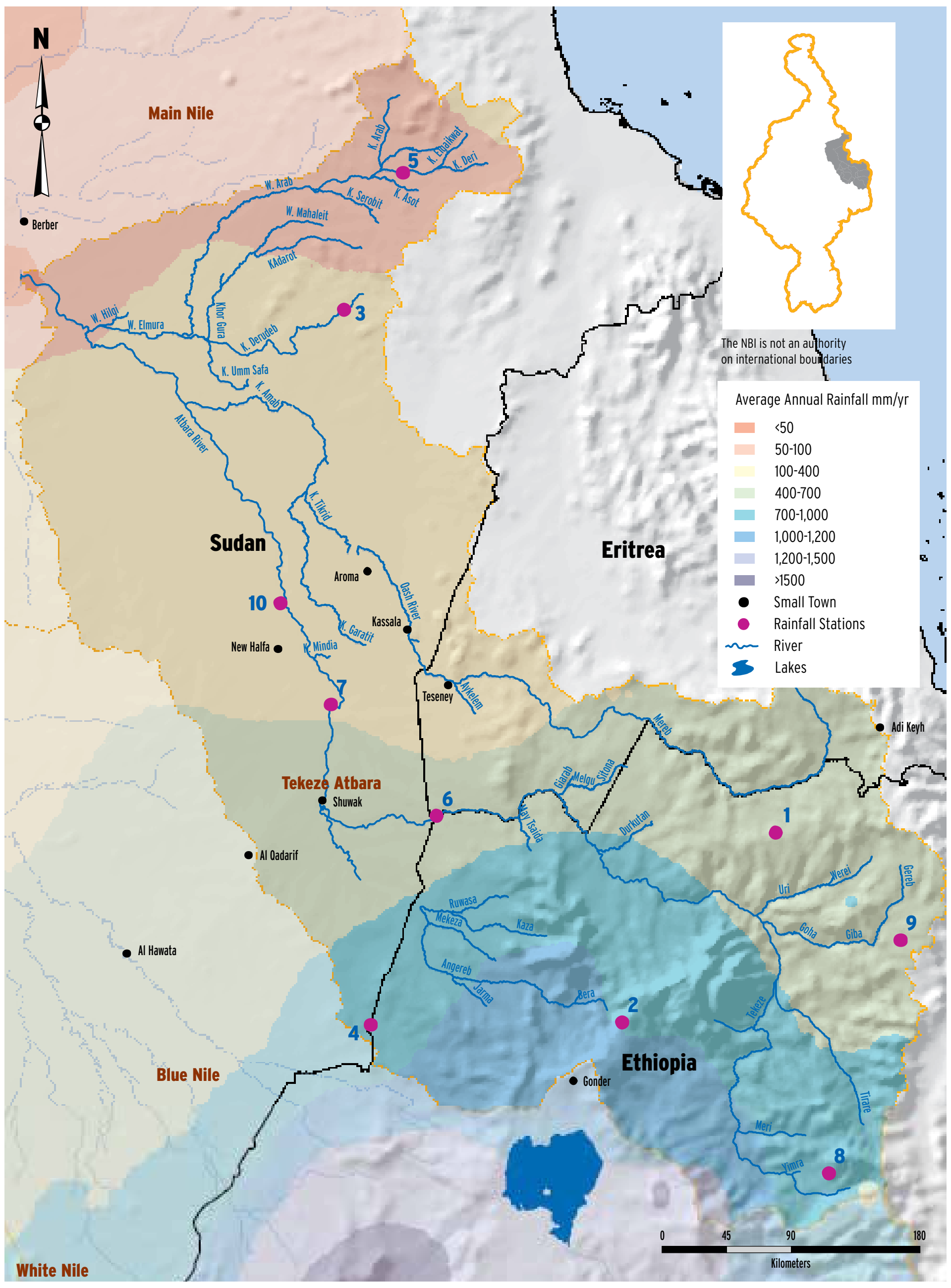
10 Mean monthly rainfall distribution - Wadi Halfa



10 Monthly rainfall statistics - Wadi Halfa



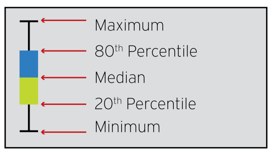
Mean monthly rainfall distribution – Tekeze Atbara Sub-basin



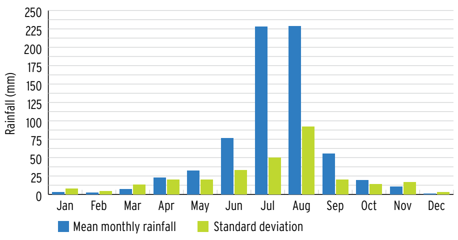
The Tekeze Atbara Sub-basin experiences rainfall in its upper part only in little amounts mainly in the months of July and august, and is relatively dry the other part of the year. The lower part of the Sub-basin lies in Sudan and is mainly dry with very few rainfall amounts recorded in the wet season.

Station Identification

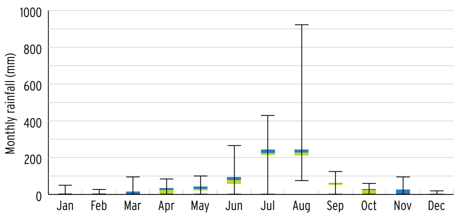
Station Name	Label No.	Record Length	Station Name	Label No.	Record Length
Axum	1	1920-2001	Lalibela	8	1973-1989
Dabat	2	1970-1988	Mekele	9	1912-2002
Derudeb	3	1912-1991	New-Halfa	10	1901-2011
Gallabat	4	1901-2007			
Haiya	5	1912-1991			
Humera	6	1901-2011			
Khashm El Girba	7	1901-2000			



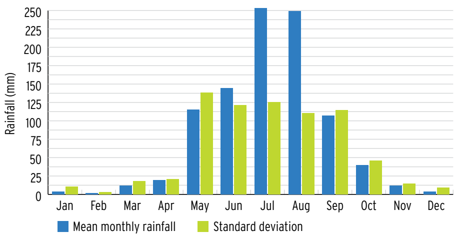
1 Mean monthly rainfall distribution - Axum



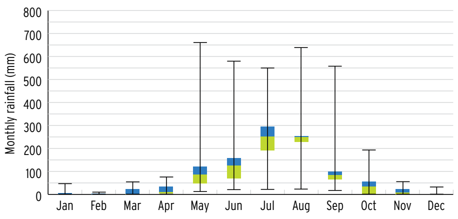
1 Monthly rainfall statistics - Axum



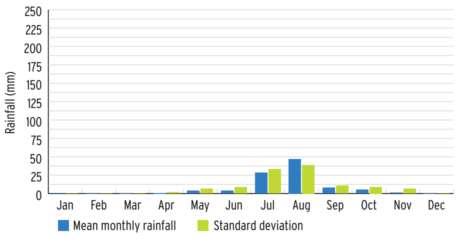
2 Mean monthly rainfall distribution - Dabat



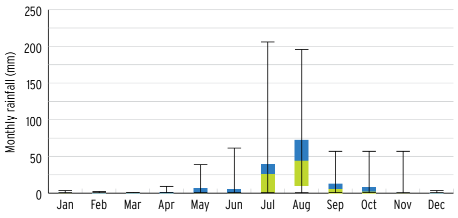
2 Monthly rainfall statistics - Dabat



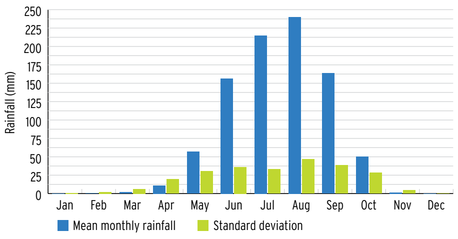
3 Mean monthly rainfall distribution - Derudeb



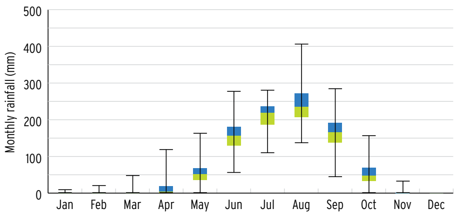
3 Monthly rainfall statistics - Derudeb



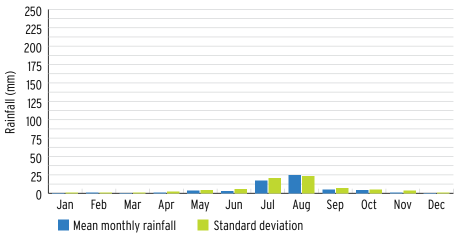
4 Mean monthly rainfall distribution - Gallabat



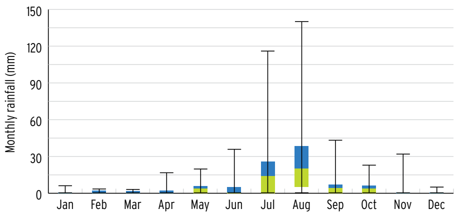
4 Monthly rainfall statistics - Gallabat



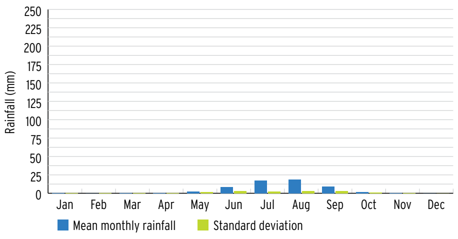
5 Mean monthly rainfall distribution - Haiya



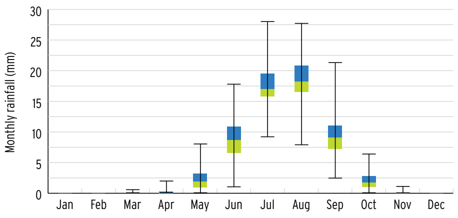
5 Monthly rainfall statistics - Haiya



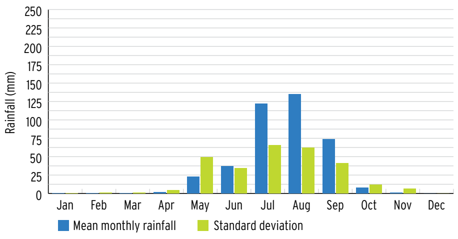
6 Mean monthly rainfall distribution - Humera



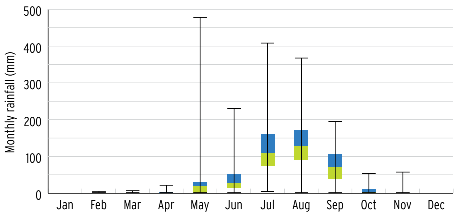
6 Monthly rainfall statistics - Humera



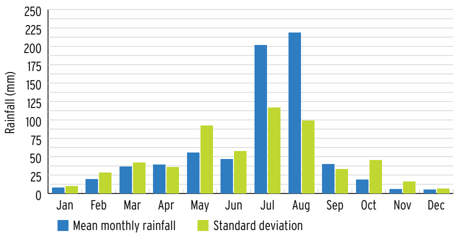
7 Mean monthly rainfall distribution - Khashm El Girba



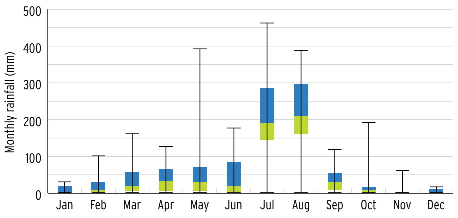
7 Monthly rainfall statistics - Khashm El Girba



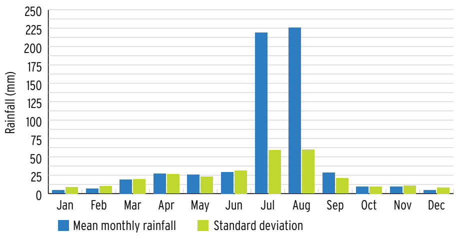
8 Mean monthly rainfall distribution - Lalibea



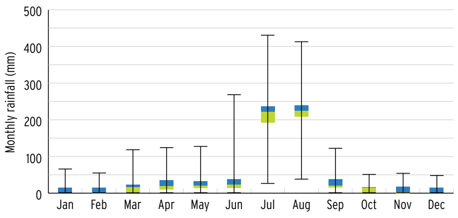
8 Monthly rainfall statistics - Lalibela



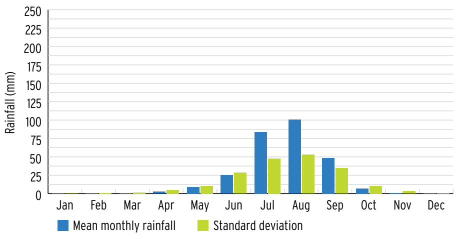
9 Mean monthly rainfall distribution - Mekele



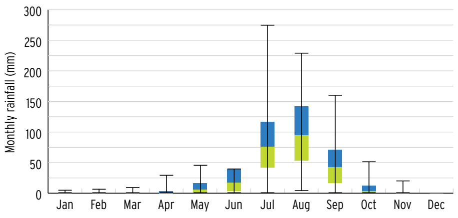
9 Monthly rainfall statistics - Mekele



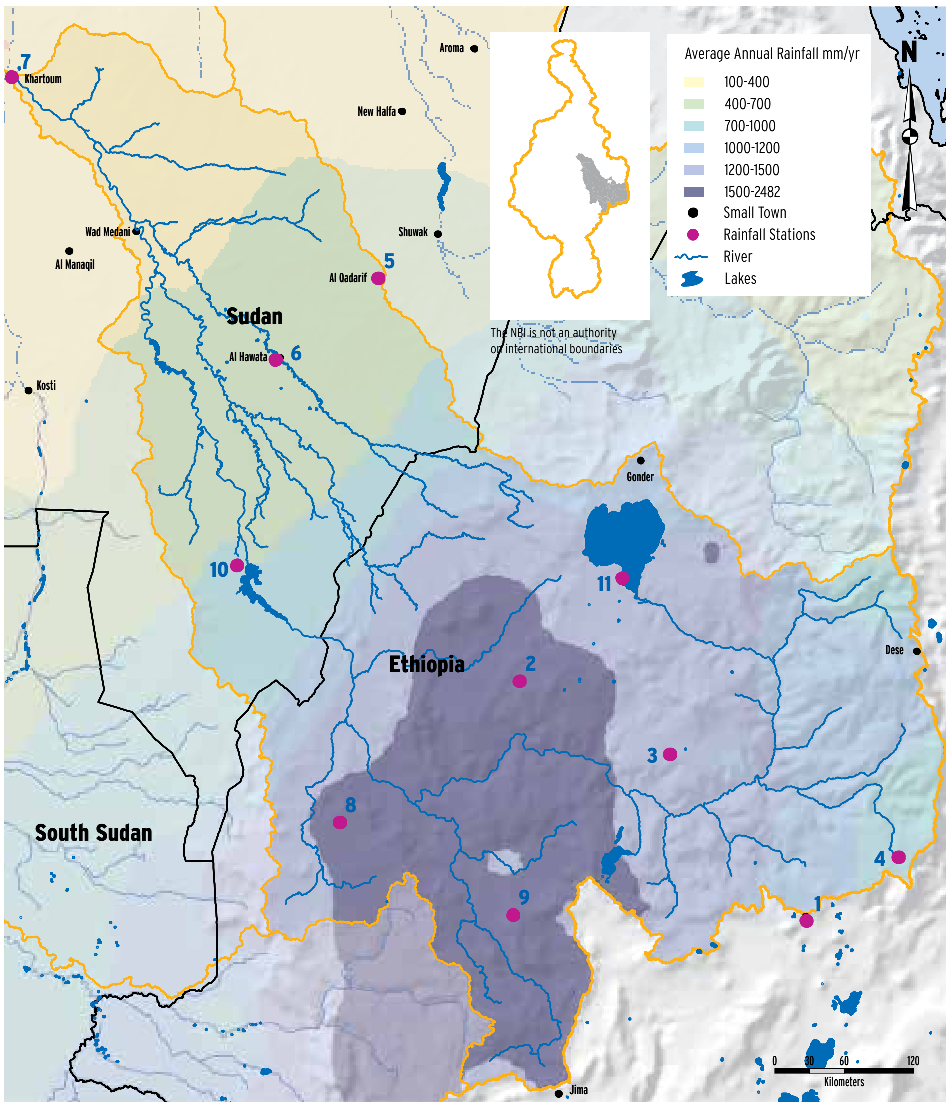
10 Mean monthly rainfall distribution - New Halfa



10 Monthly rainfall statistics - New Halfa



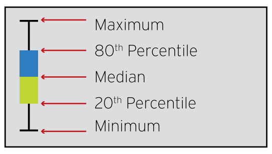
Mean monthly rainfall distribution – Blue Nile Sub-basin



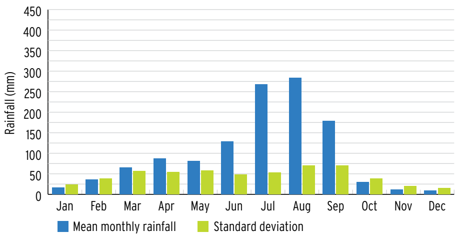
The upper part of Blue Nile records rainfall almost all year round in varying amounts but the main season occurs between May – October when very high amounts of rainfall are recorded. As you move downstream into Sudan, the amounts recorded diminishes almost registering rainfall only in the wet season and nothing in the remaining part of the year, however, the rainfall pattern remains. The monthly rainfall variation is seen to be quite low as compared to the other Sub-basins.

Station Identification

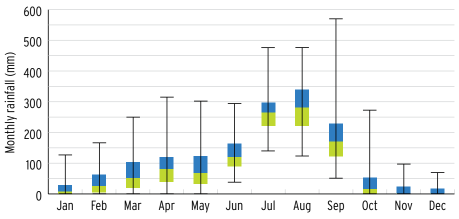
Station Name	Label No.	Record Length	Station Name	Label No.	Record Length
Addis Ababa	1	1900-2011	Mendi	8	1903-2001
Chagni	2	1903-2001	Nekemtewelega	9	1903-2001
Debremarcos	3	1953-2001	Roseires	10	1903-2001
Debresina	4	1900-2011	Zege	11	
El Gedarif	5	1901-2011			
Hawata	6	1900-2011			
Khartoum	7	1900-2011			



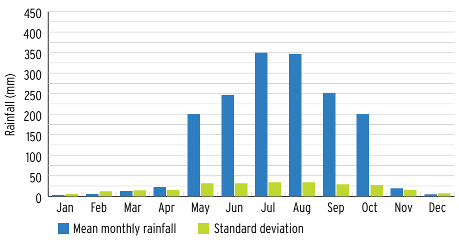
1 Mean monthly rainfall distribution - Addis Ababa



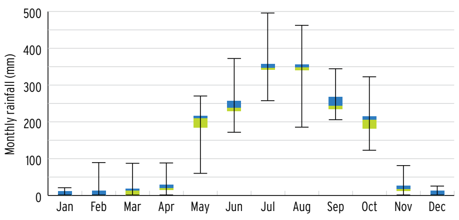
1 Monthly rainfall statistics - Addis Ababa



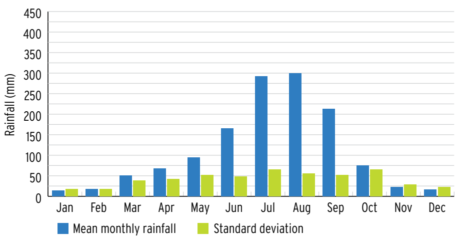
2 Mean monthly rainfall distribution - Chagni



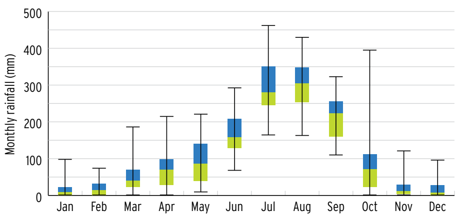
2 Monthly rainfall statistics - Chagni



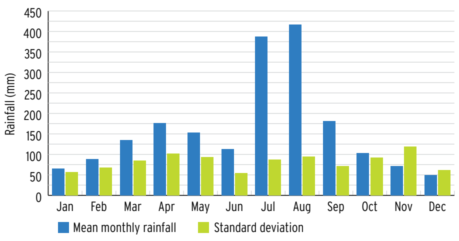
3 Mean monthly rainfall distribution - Debremarkos



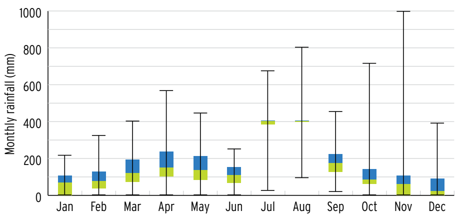
3 Monthly rainfall statistics - Debremarkos



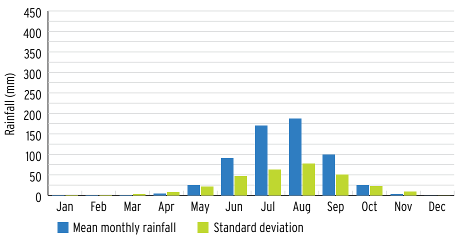
4 Mean monthly rainfall distribution - Debresina



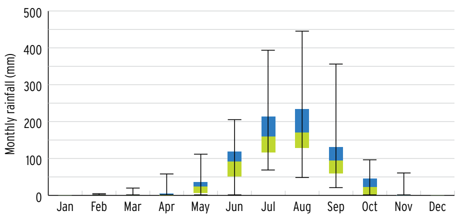
4 Monthly rainfall statistics - Debresina



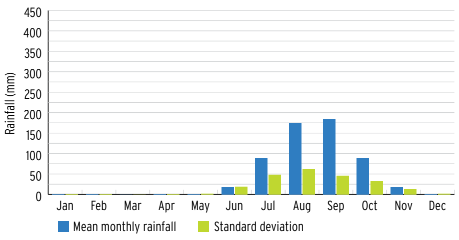
5 Mean monthly rainfall distribution - El Gedarif



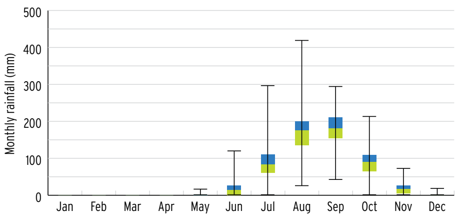
5 Monthly rainfall statistics - El Gedarif



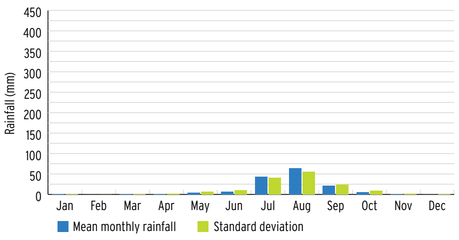
6 Mean monthly rainfall distribution - Hawata



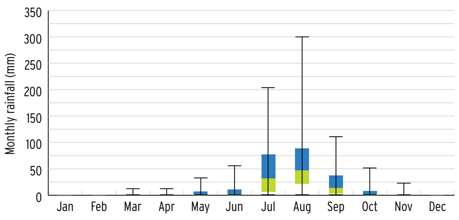
6 Monthly rainfall statistics - Hawata



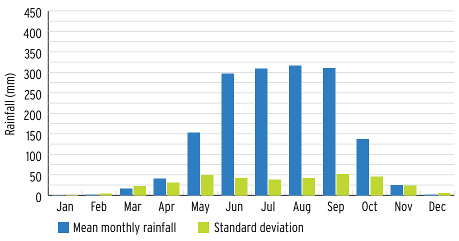
7 Mean monthly rainfall distribution - Khartoum



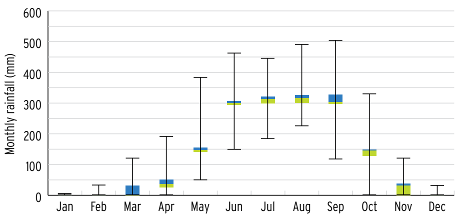
7 Monthly rainfall statistics - Khartoum



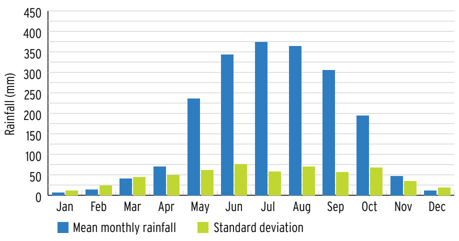
8 Mean monthly rainfall distribution - Mendi



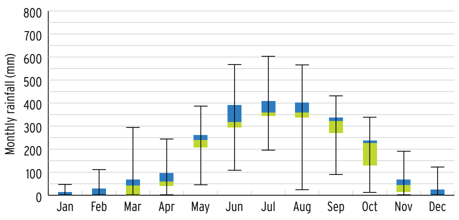
8 Monthly rainfall statistics - Mendi



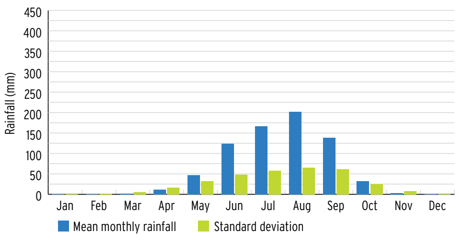
9 Mean monthly rainfall distribution - Nekemteweleg



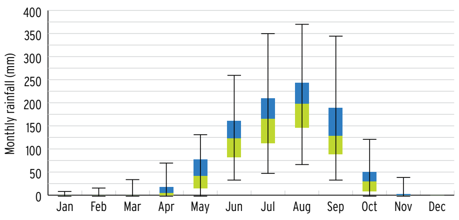
9 Monthly rainfall statistics - Nekemteweleg



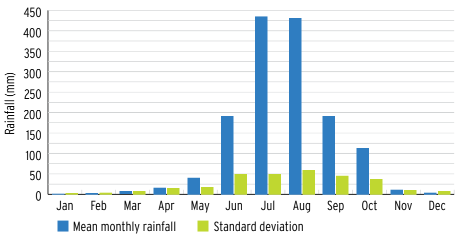
10 Mean monthly rainfall distribution - Roseires



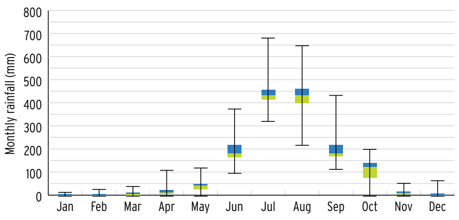
10 Monthly rainfall statistics - Roseires



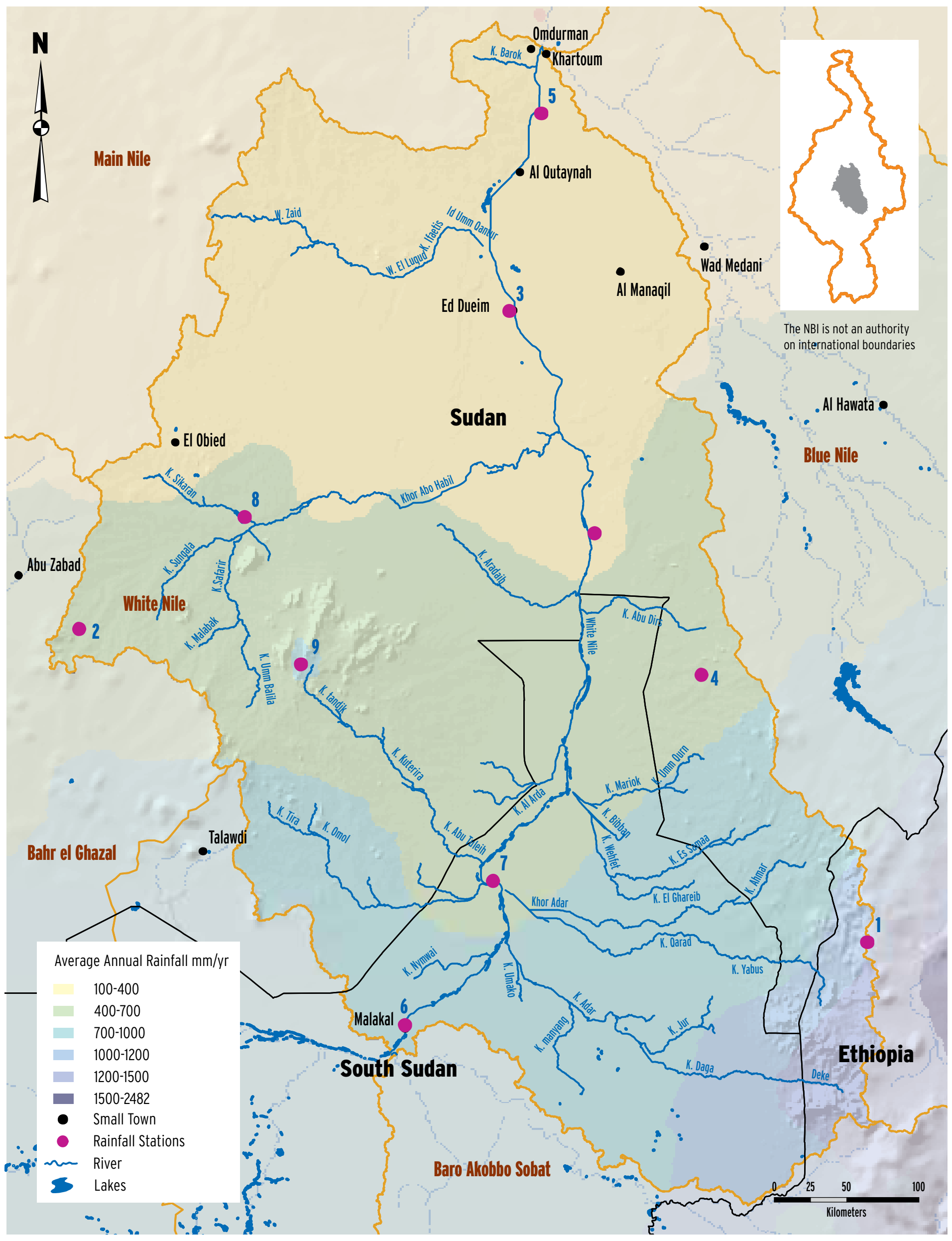
11 Mean monthly rainfall distribution - Zege



11 Monthly rainfall statistics - Zege



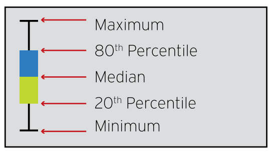
Mean monthly rainfall distribution – White Nile Sub-basin



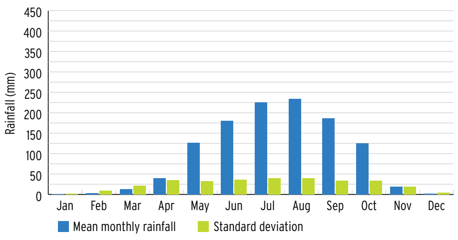
The Nile basin rainfall gets reduced towards downstream the basin. In the White Nile (which covers parts of north-eastern South Sudan, a very small part of south western part of Ethiopia and the south part of Sudan), there is generally low rainfall recorded in the single wet season; May – October with very low deviations across months and almost zero to negligible rainfall registered in the other parts of the year.

Station Identification

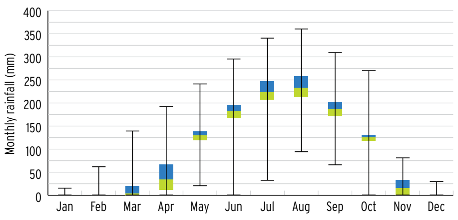
Station Name	Label No.	Record Length	Station Name	Label No.	Record Length
Asosa	1	1903-2001	Melut	7	1900-1984
Dilling	2	1909-2011	Rahad	8	1902-2011
Ed Dueim	3	1900-2011	Rashad	9	1909-2011
J.Guli	4	1903-2001			
Jebel Aulia	5	1900-2011			
Malakal	6	1909-2004			



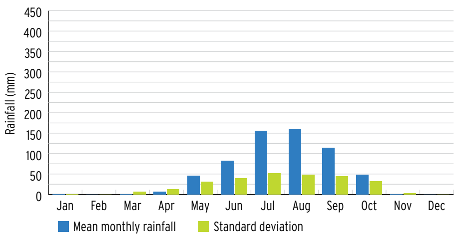
1 Mean monthly rainfall distribution - Asosa



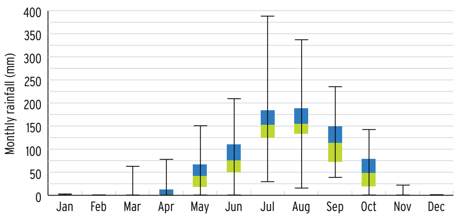
1 Monthly rainfall statistics - Asosa



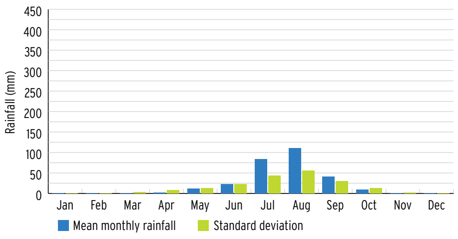
2 Mean monthly rainfall distribution - Dilling



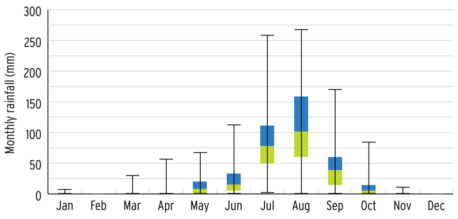
2 Monthly rainfall statistics - Dilling



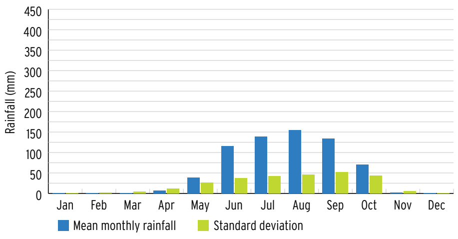
3 Mean monthly rainfall distribution - Ed Dueim



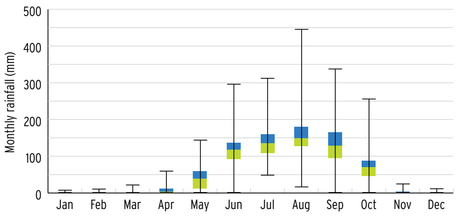
3 Monthly rainfall statistics - Ed Dueim



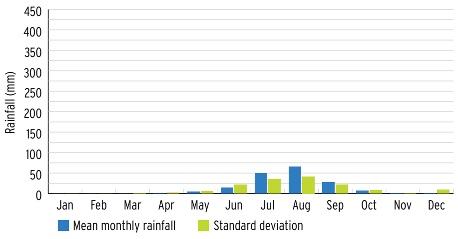
4 Mean monthly rainfall distribution - J. Guli



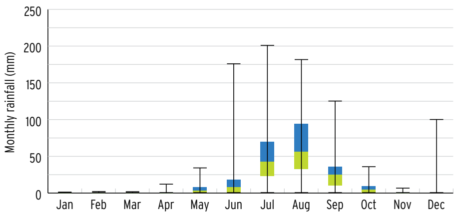
4 Monthly rainfall statistics - J. Guli



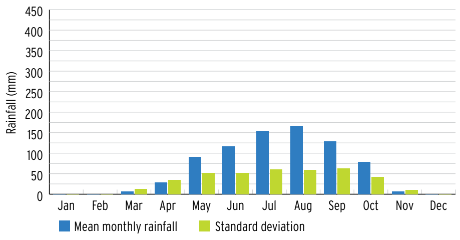
5 Mean monthly rainfall distribution - Jebel Aulia



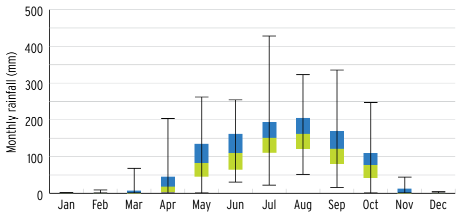
5 Monthly rainfall statistics - Jebel Aulia



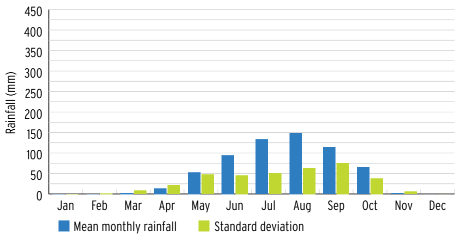
6 Mean monthly rainfall distribution - Malakal



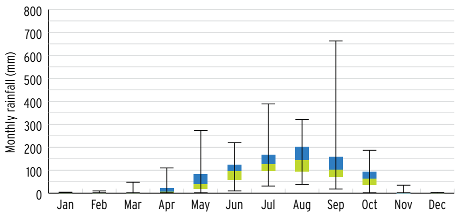
6 Monthly rainfall statistics - Malakal



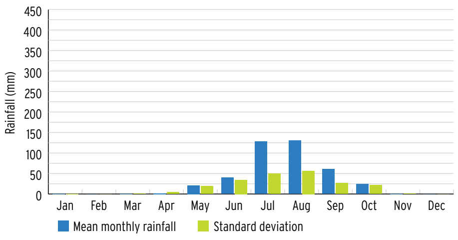
7 Mean monthly rainfall distribution - Melut



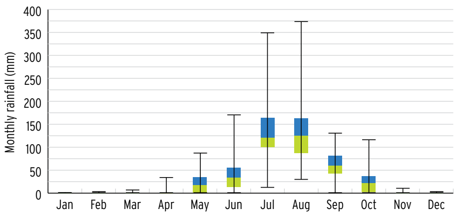
7 Monthly rainfall statistics - Melut



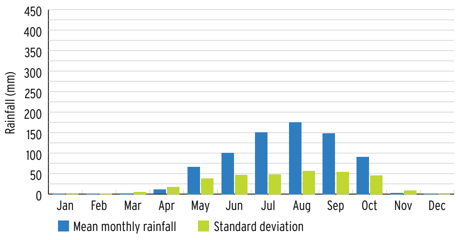
8 Mean monthly rainfall distribution - Rahad



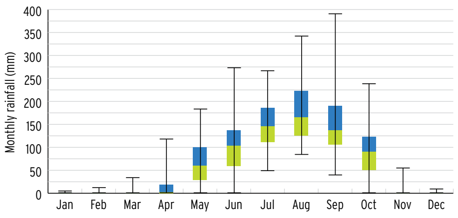
8 Monthly rainfall statistics - Rahad



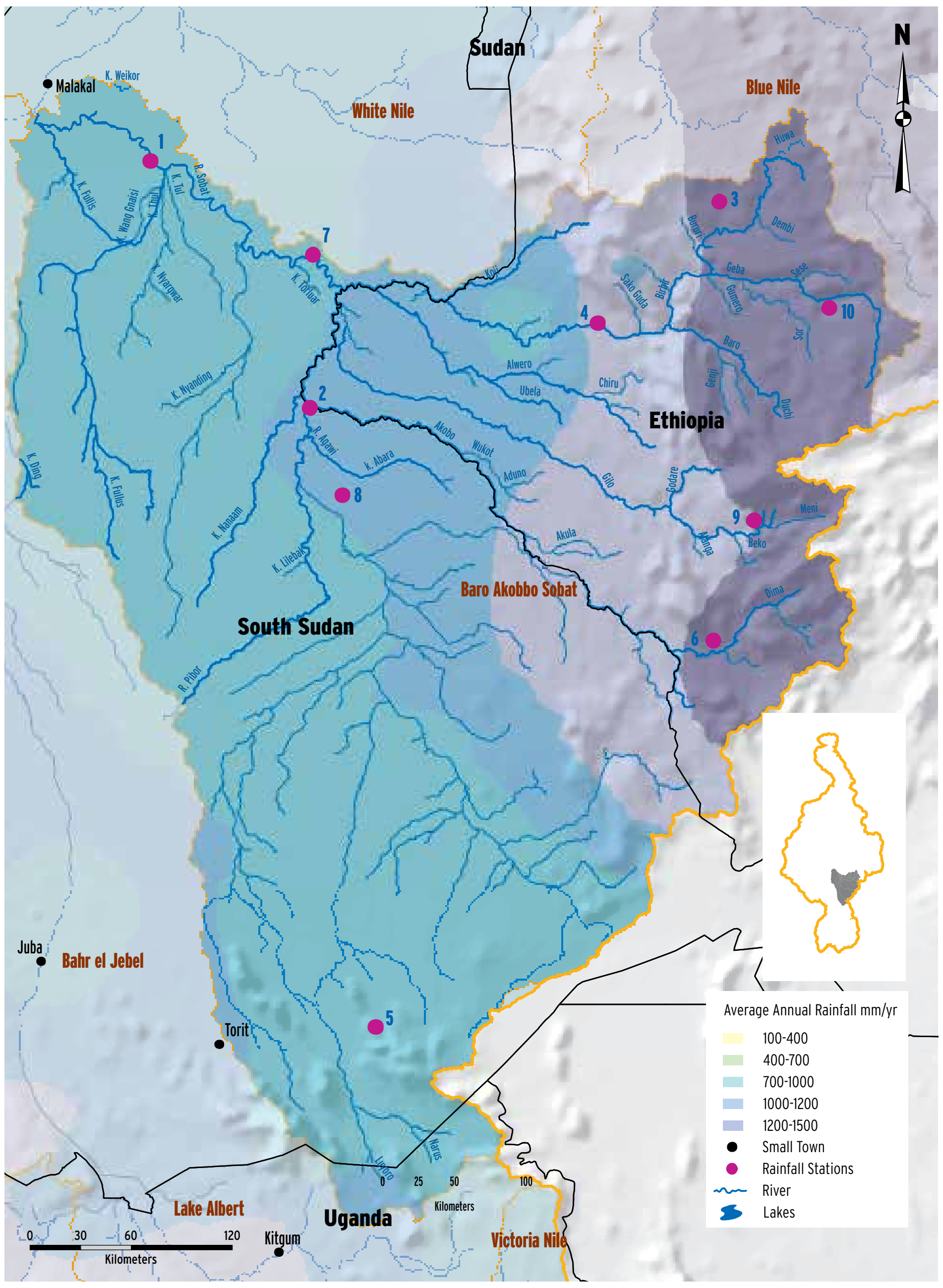
9 Mean monthly rainfall distribution - Rashad



9 Monthly rainfall statistics - Rashad



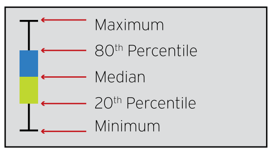
Mean monthly rainfall distribution – Baro Akobo Sobat Sub-basin



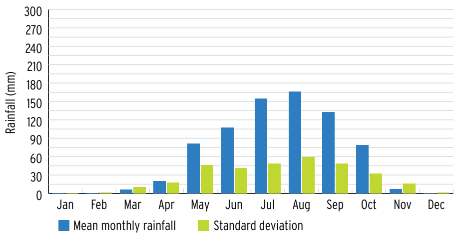
The Baro Akobo Sobat Sub-basin also exhibits a single wet season between May – October, however rainfall occurs all year round in varying amounts as seen from the mean monthly distribution plot. The monthly variation of this rainfall is big, especially in the wet season but it seems to be well distributed along the median as seen from the box plot.

Station Identification

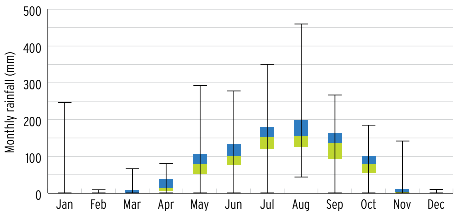
Station Name	Label No.	Record Length	Station Name	Label No.	Record Length
Abwong	1	1909-2003	Pibor	8	1905-2002
Akobo	2	1905-2002	Tepi	9	1952-2002
Alem Teferi School	3	1970-1989	Yayu	10	1952-1992
Gambella	4	1903-2002			
Kapoeta	5	1922-2002			
Mizan Teferi	6	1952-2011			
Nasser	7	1909-2003			



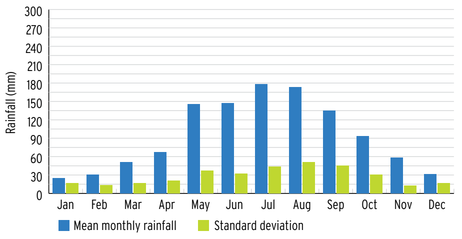
1 Mean monthly rainfall distribution - Abwong



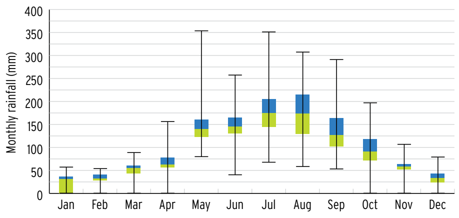
1 Monthly rainfall statistics - Abwong



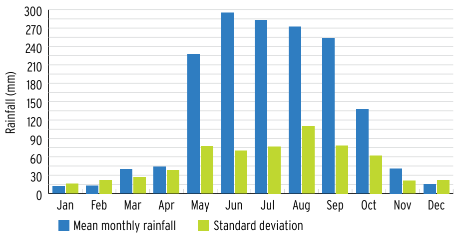
2 Mean monthly rainfall distribution - Akobo



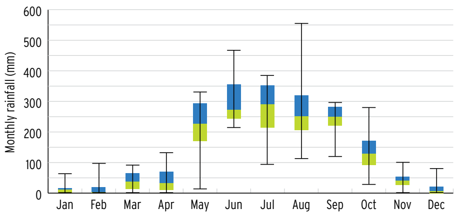
2 Monthly rainfall statistics - Akobo



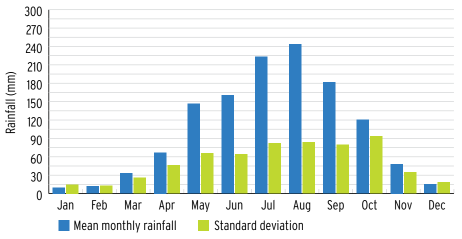
3 Mean monthly rainfall distribution - Alem Teferi



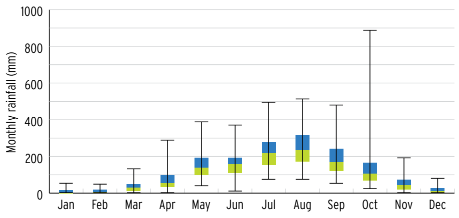
3 Monthly rainfall statistics - Alem Teferi



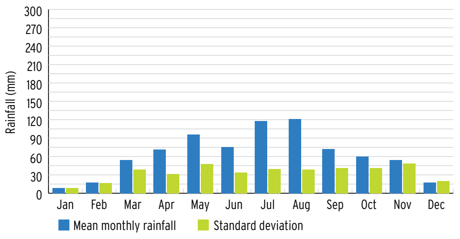
4 Mean monthly rainfall distribution - Gembella



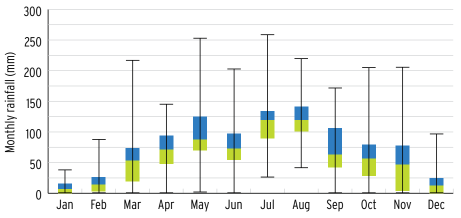
4 Monthly rainfall statistics - Gembella



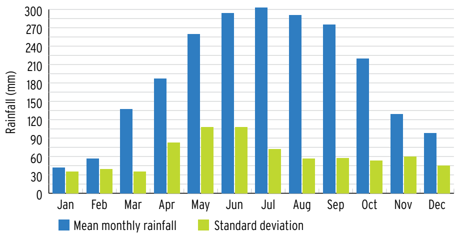
5 Mean monthly rainfall distribution - Kapoeta



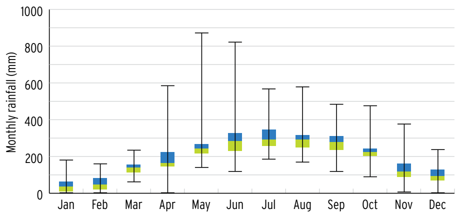
5 Monthly rainfall statistics - Kapoeta



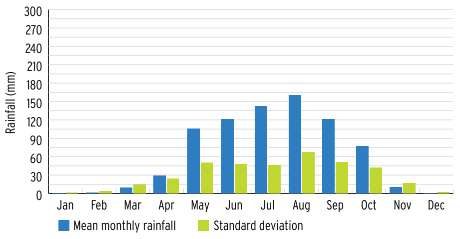
6 Mean monthly rainfall distribution - Mizan Teferi



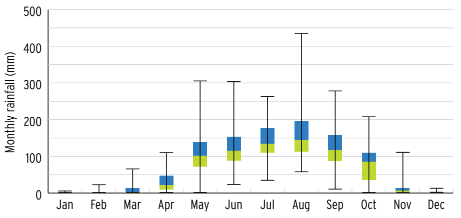
6 Monthly rainfall statistics - Mizan Teferi



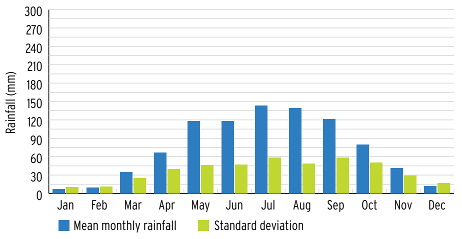
7 Mean monthly rainfall distribution - Nasser



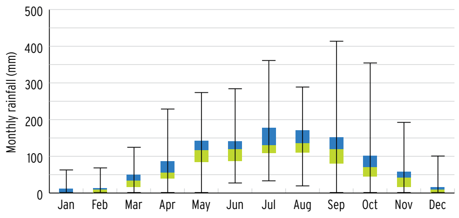
7 Monthly rainfall statistics - Nasser



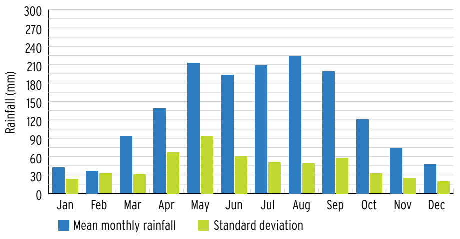
8 Mean monthly rainfall distribution - Pibor



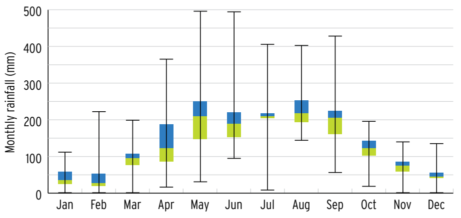
8 Monthly rainfall statistics - Pibor



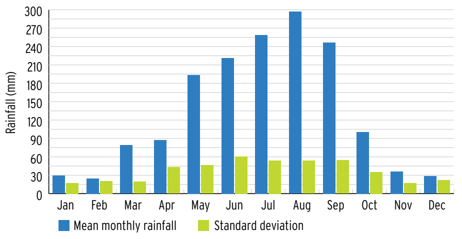
9 Mean monthly rainfall distribution - Tepi



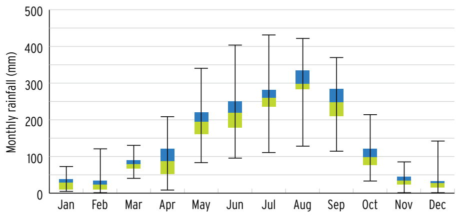
9 Monthly rainfall statistics - Tepi



10 Mean monthly rainfall distribution - Yayu

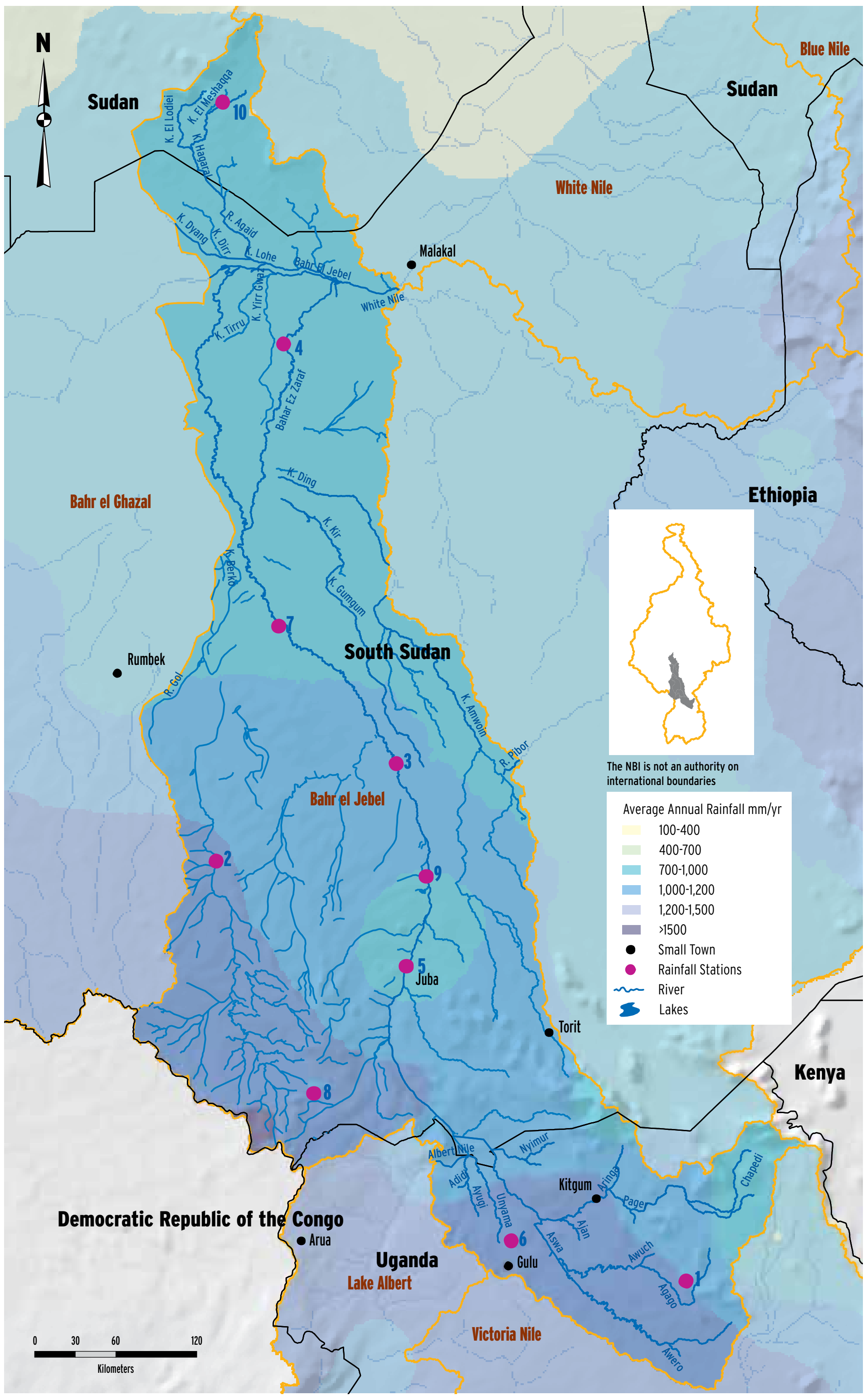


10 Monthly rainfall statistics - Yayu



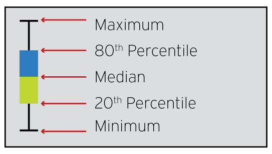
Mean monthly rainfall distribution – Bahr el Jebel Sub-basin

In this part of the basin, as you move downstream in the Sub-basin, we see the bimodal rainfall pattern transforming into a single pattern with only one wet season occurring between May - October and its counterpart dry season between Nov. - April. During the wet season, the Sub-basin records very high rainfall amounts which are centered on the median apart from Juba. This indicates fairly low monthly variations

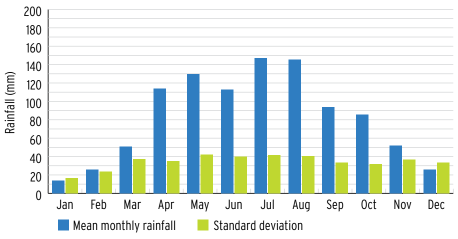


Station Identification

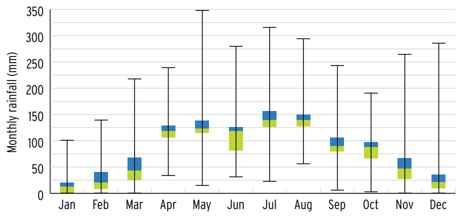
Station Name	Label No.	Record Length	Station Name	Label No.	Record Length
Adilang	1	1911-2003	Tambura	8	1914-2000
Amadi	2	1901-2004	Terakeka	9	1901-2004
Bor	3	1901-2004	Talodi	10	1909-2003
Fangak	4	1906-2003			
Juba	5	1901-2004			
Patiko	6	1911-1966			
Shambe	7	1907-1985			



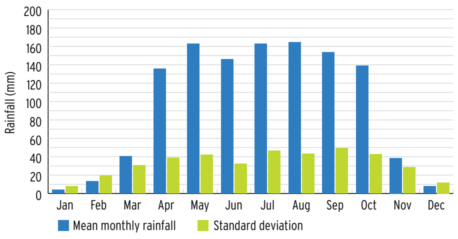
1 Mean monthly rainfall distribution - Adilang



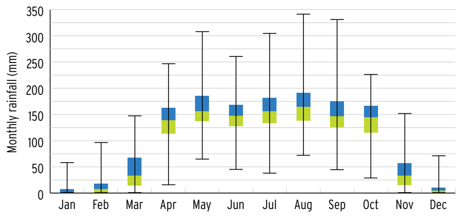
1 Monthly rainfall statistics - Adilang



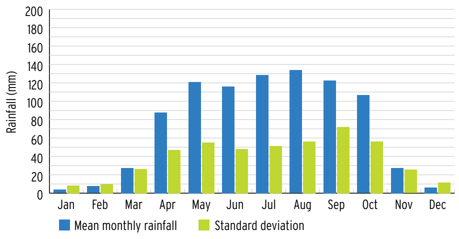
2 Mean monthly rainfall distribution - Amadi



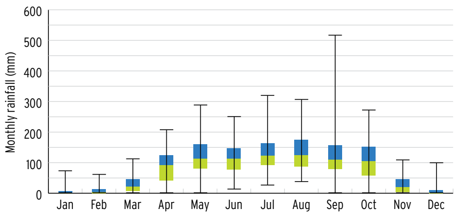
2 Monthly rainfall statistics - Amadi



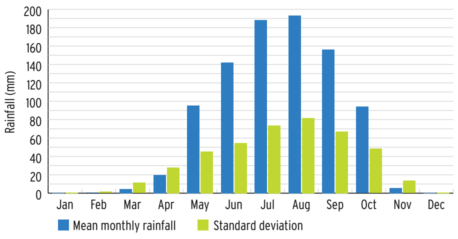
3 Mean monthly rainfall distribution - Bor



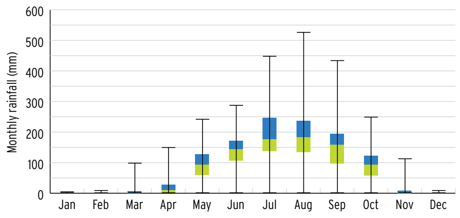
3 Monthly rainfall statistics - Bor



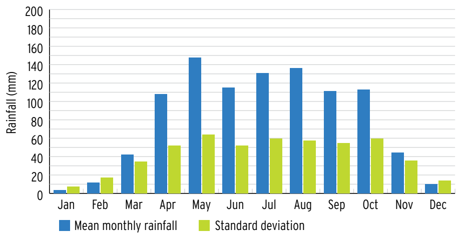
4 Mean monthly rainfall distribution - Fangak



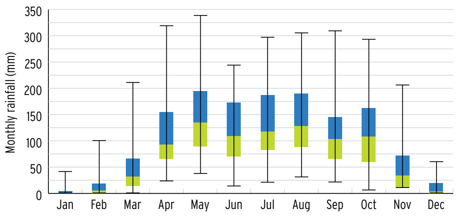
4 Monthly rainfall statistics - Fangak



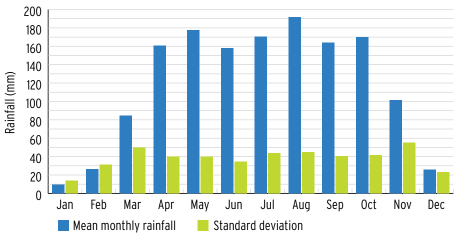
5 Mean monthly rainfall distribution - Juba



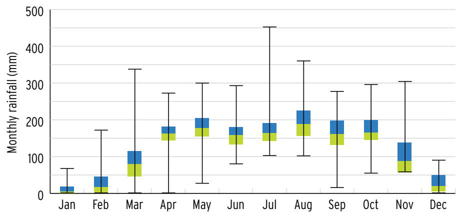
5 Monthly rainfall statistics - Juba



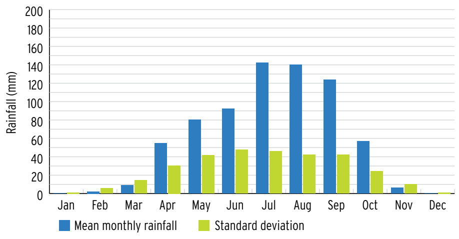
6 Mean monthly rainfall distribution - Patiko



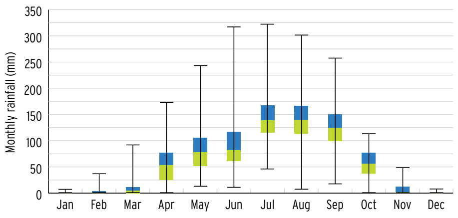
6 Monthly rainfall statistics - Patiko



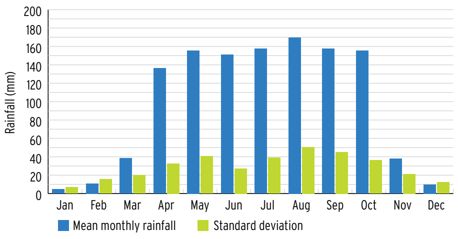
7 Mean monthly rainfall distribution - Shambe



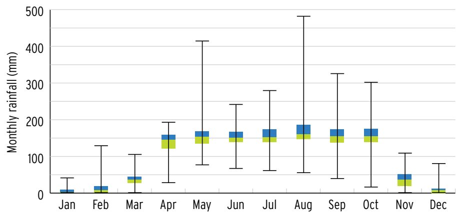
7 Monthly rainfall statistics - Shambe



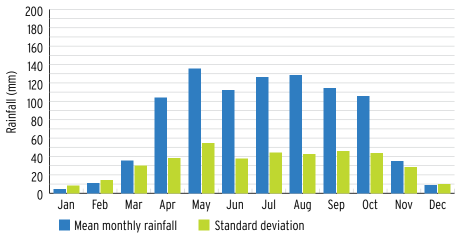
8 Mean monthly rainfall distribution - Tambura



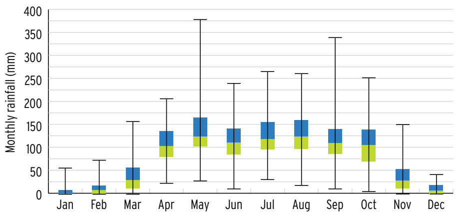
8 Monthly rainfall statistics - Tambura



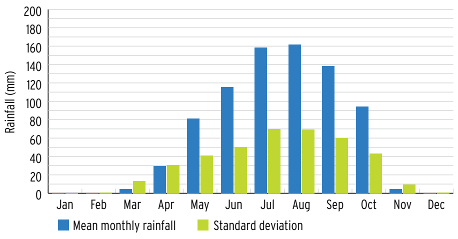
9 Mean monthly rainfall distribution - Terakeka



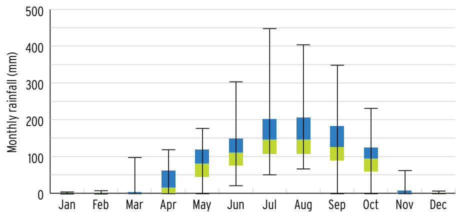
9 Monthly rainfall statistics - Terakeka



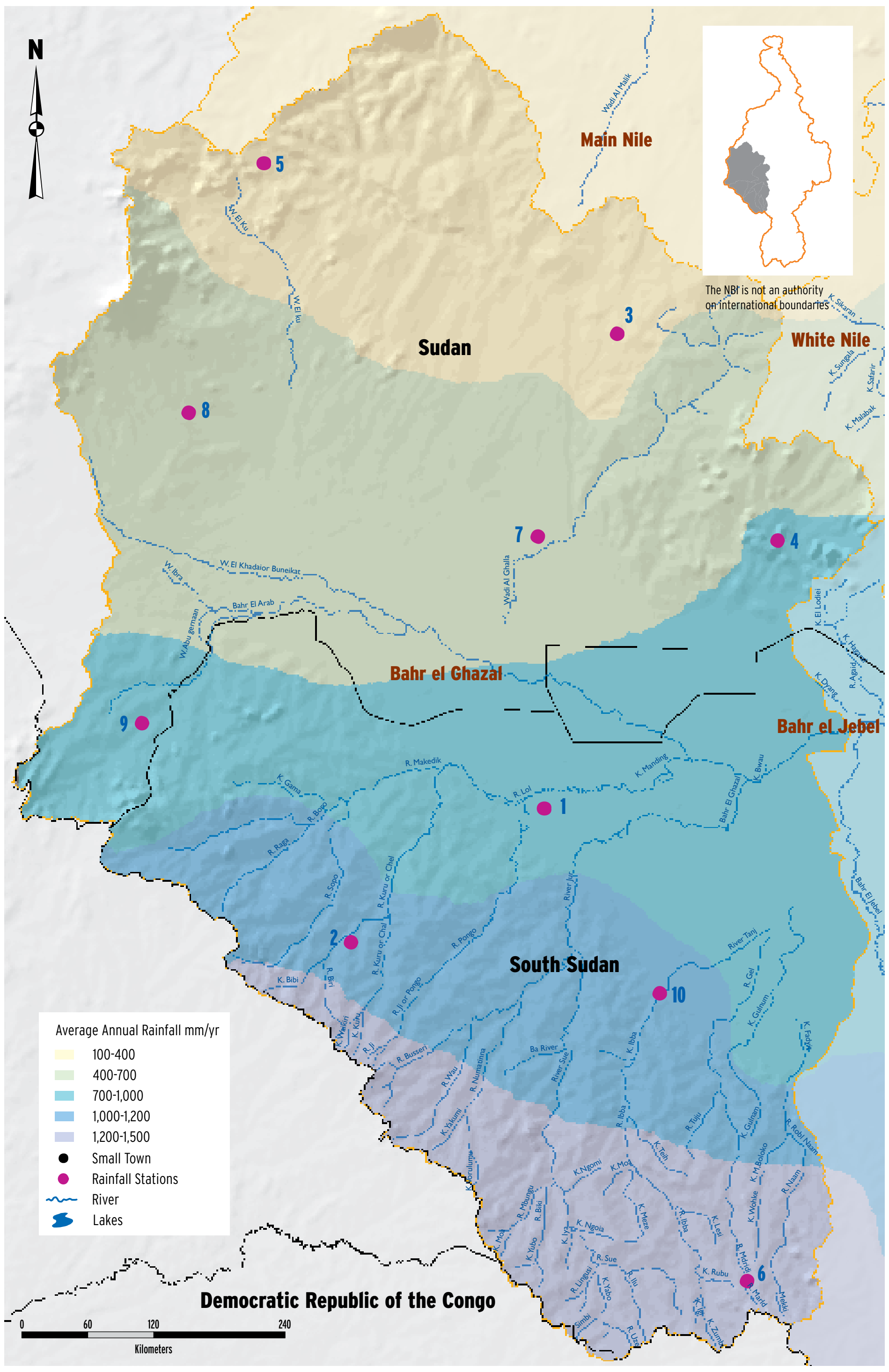
10 Mean monthly rainfall distribution - Tolodi



10 Monthly rainfall statistics - Tolodi



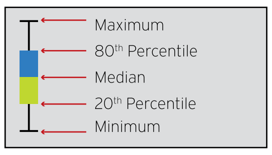
Mean monthly rainfall distribution - Bahr el Ghazal sun basin



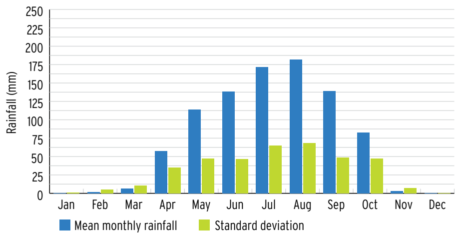
The rainfall in this Sub-basin exhibits a single wet season between April-October and the rest of the time in the year is generally dry. Within the months July - Sept., the basin hardly records zero monthly rainfall, however the northern part of the Sub-basin which lies in Sudan is seen to be dryer than the southern part of the Sub-basin.

Station Identification

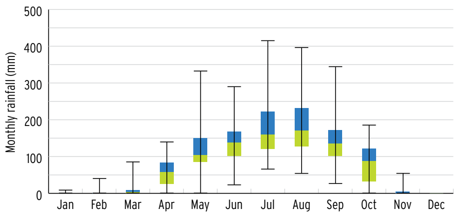
Station Name	Label No.	Record Length	Station Name	Label No.	Record Length
Aweil	1	1904-2002	Nyala	8	1911-2006
Deim Zubeir	2	1904-2002	Radom	9	1943-1993
En Nahud	3	1909-2011	Tonj	10	1904-2002
Kadugli	4	1909-2011			
Mellit	5	1950-1988			
Meridi	6	1901-2004			
Muglad	7	1911-2006			



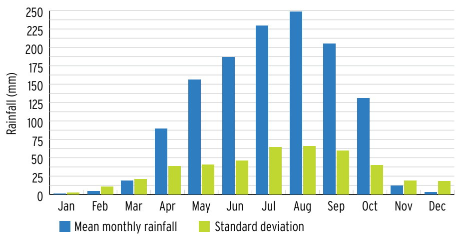
1 Mean monthly rainfall distribution - Aweil



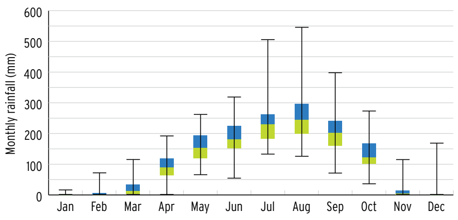
1 Monthly rainfall statistics - Aweil



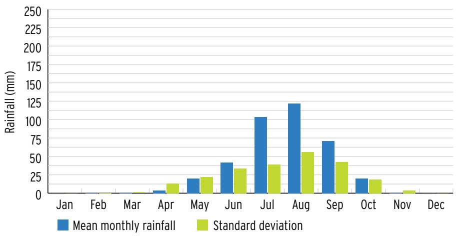
2 Mean monthly rainfall distribution - Deim Zubeir



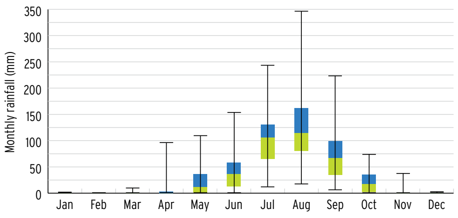
2 Monthly rainfall statistics - Deim Zubeir



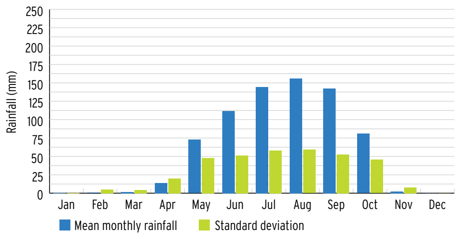
3 Mean monthly rainfall distribution - En Nahud



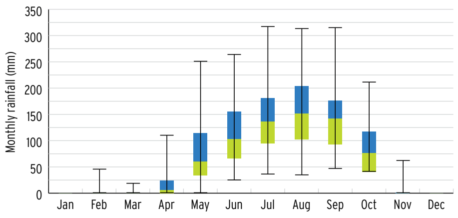
3 Monthly rainfall statistics - En Nahud



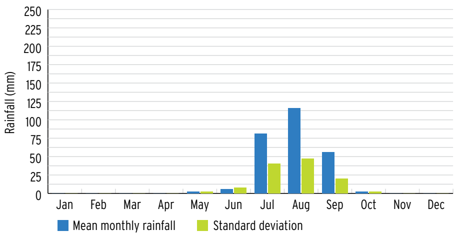
4 Mean monthly rainfall distribution - Kadugli



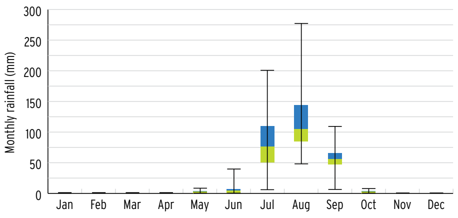
4 Monthly rainfall statistics - Kadugli



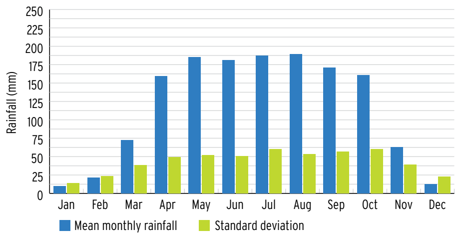
5 Mean monthly rainfall distribution - Mellit



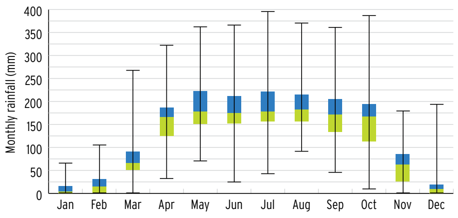
5 Monthly rainfall statistics - Mellit



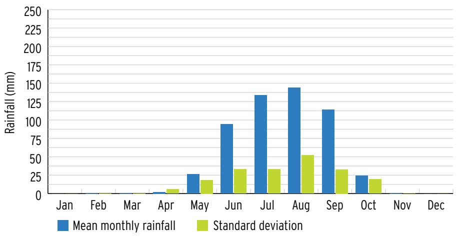
6 Mean monthly rainfall distribution - Meridi



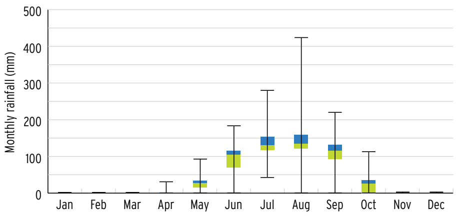
6 Monthly rainfall statistics - Meridi



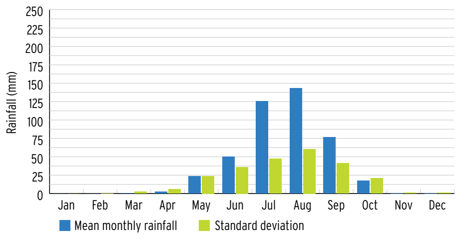
7 Mean monthly rainfall distribution - Muglad



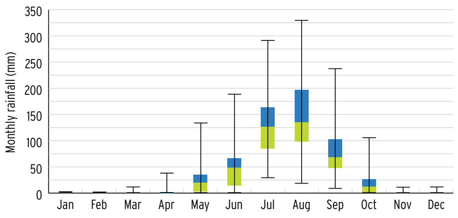
7 Monthly rainfall statistics - Muglad



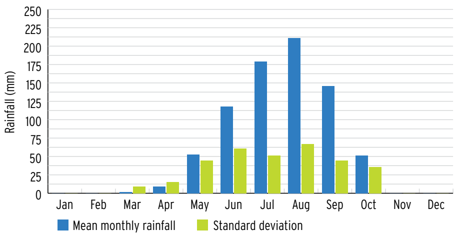
8 Mean monthly rainfall distribution - Nyala



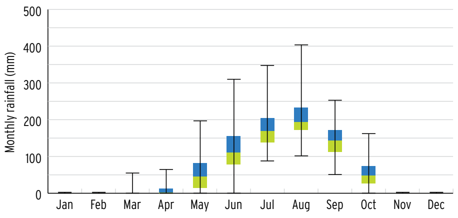
8 Monthly rainfall statistics - Nyala



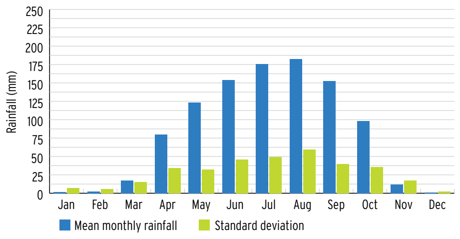
9 Mean monthly rainfall distribution - Radom



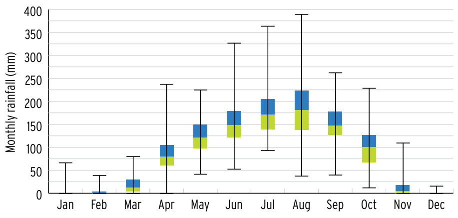
9 Monthly rainfall statistics - Radom



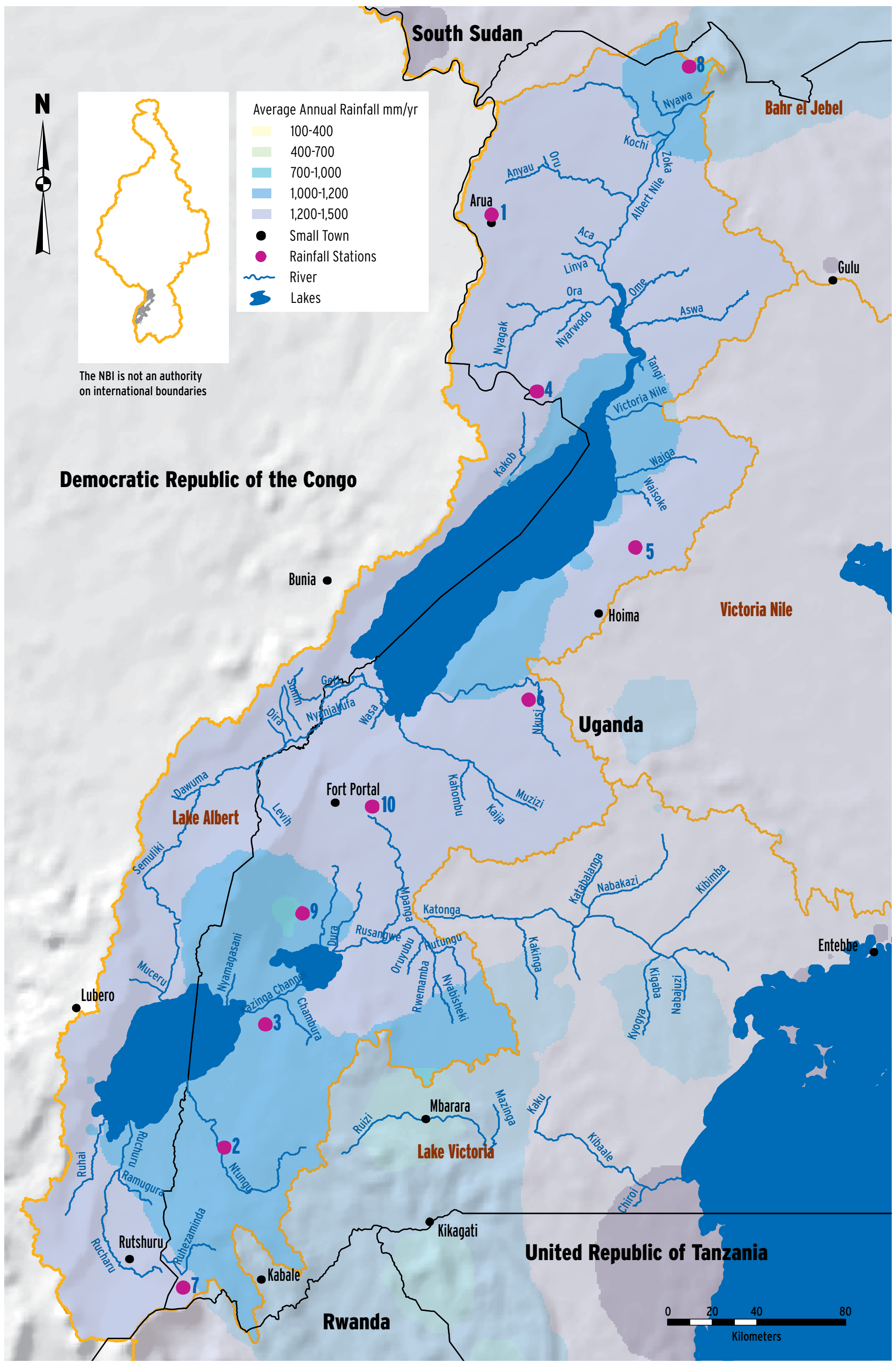
10 Mean monthly rainfall distribution - Tonj



10 Monthly rainfall statistics - Tonj



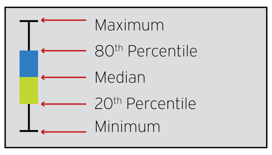
Mean monthly rainfall distribution – Lake Albert Sub-basin



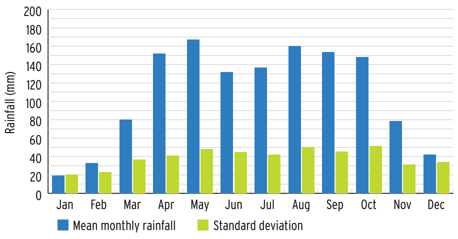
Similar to the other parts of the upper equatorial lakes region, the Lake Albert Sub-basin also has a bimodal rainfall pattern with competing rainfall amounts. Rainfall amounts recorded in the mountainous area (Mubuku and Kisoro) are seen to have low variations for the individual months as compared to the other areas. The Sub-basin also registers high values for the 80th percentile indicating high chances of dependence on rainfall for agricultural purposes.

Station Identification

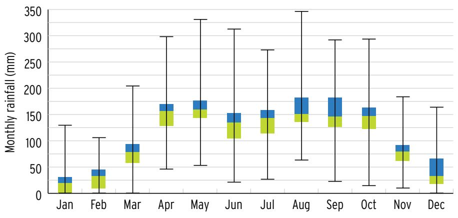
Station Name	Label No.	Record Length	Station Name	Label No.	Record Length
Arua Met Station	1	1906-2002	Moyo Boma	8	1938-2000
Bugangari Dispensary	2	1917-2005	Mubuku Giant prison Farm	9	1900-2005
Bunyaruguru	3	1903-2003	Rwebitaba Tea Res Station	10	1911-2005
Erusi Forest Station	4	1904-2002			
IHUNGU	5	1906-2001			
Kiryanga Gombolola	6	1940-1979			
KISORO	7	1910-2005			



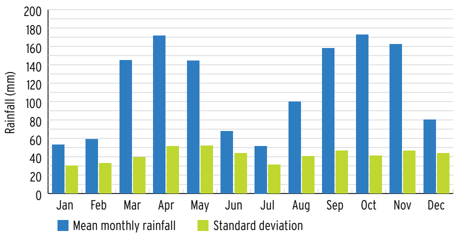
1 Mean monthly rainfall distribution - Arua



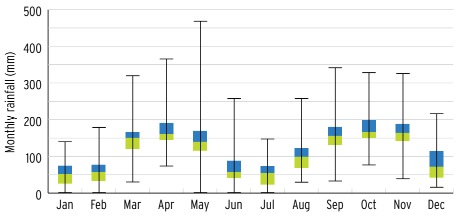
1 Monthly rainfall statistics - Arua



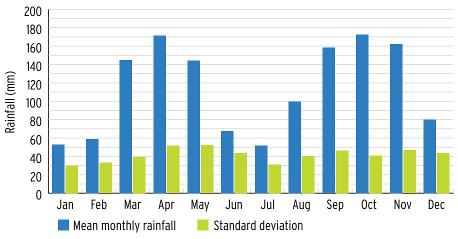
2 Mean monthly rainfall distribution - Bugangari



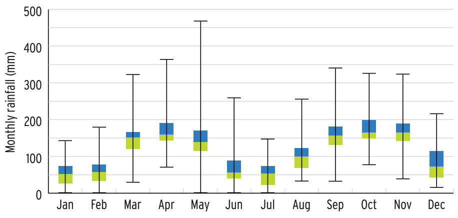
2 Monthly rainfall statistics - Bugangari



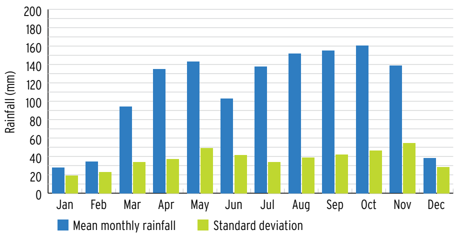
3 Mean monthly rainfall distribution - Bunyaruguru



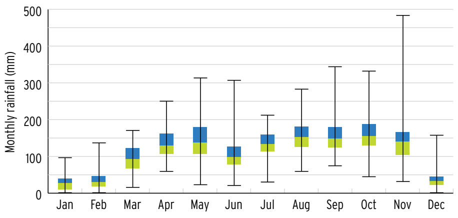
3 Monthly rainfall statistics - Bunyaruguru



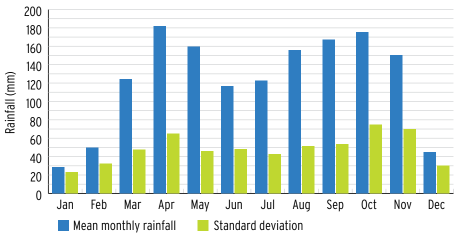
4 Mean monthly rainfall distribution - Erusi



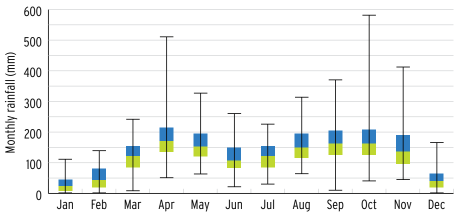
4 Monthly rainfall statistics - Erusi



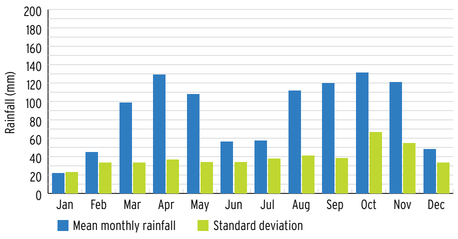
5 Mean monthly rainfall distribution - Ihungu



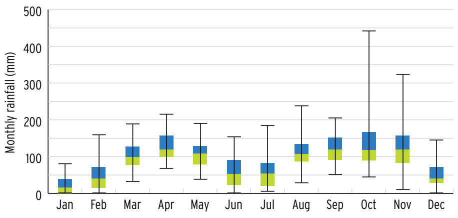
5 Monthly rainfall statistics - Ihungu



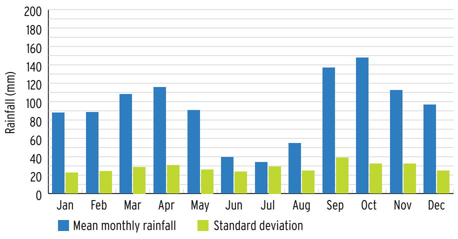
6 Mean monthly rainfall distribution - Kiryanga



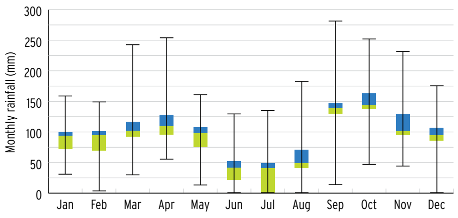
6 Monthly rainfall statistics - Kiryanga



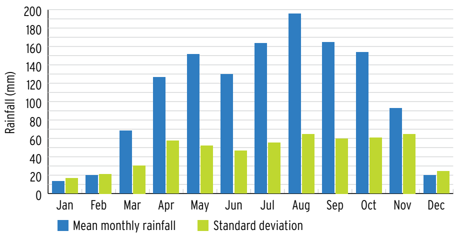
7 Mean monthly rainfall distribution - Kisoro



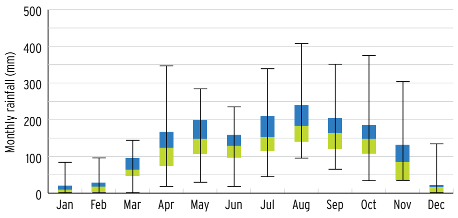
7 Monthly rainfall statistics - Kisoro



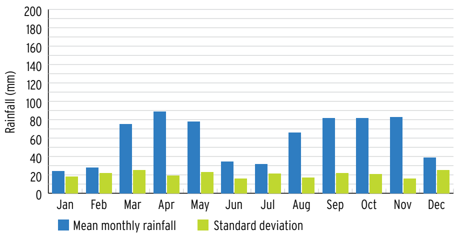
8 Mean monthly rainfall distribution - Moyo Boma



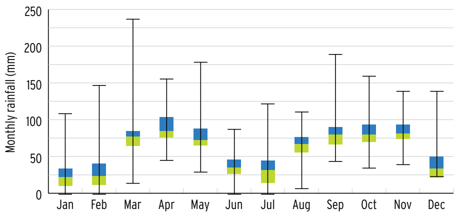
8 Monthly rainfall statistics - Moyo Boma



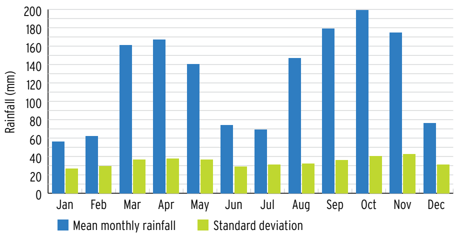
9 Mean monthly rainfall distribution - Mubuku



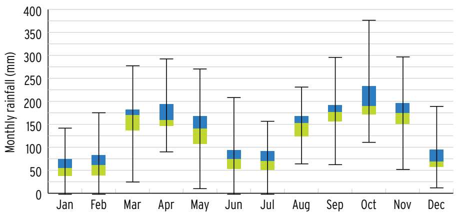
9 Monthly rainfall statistics - Mubuku



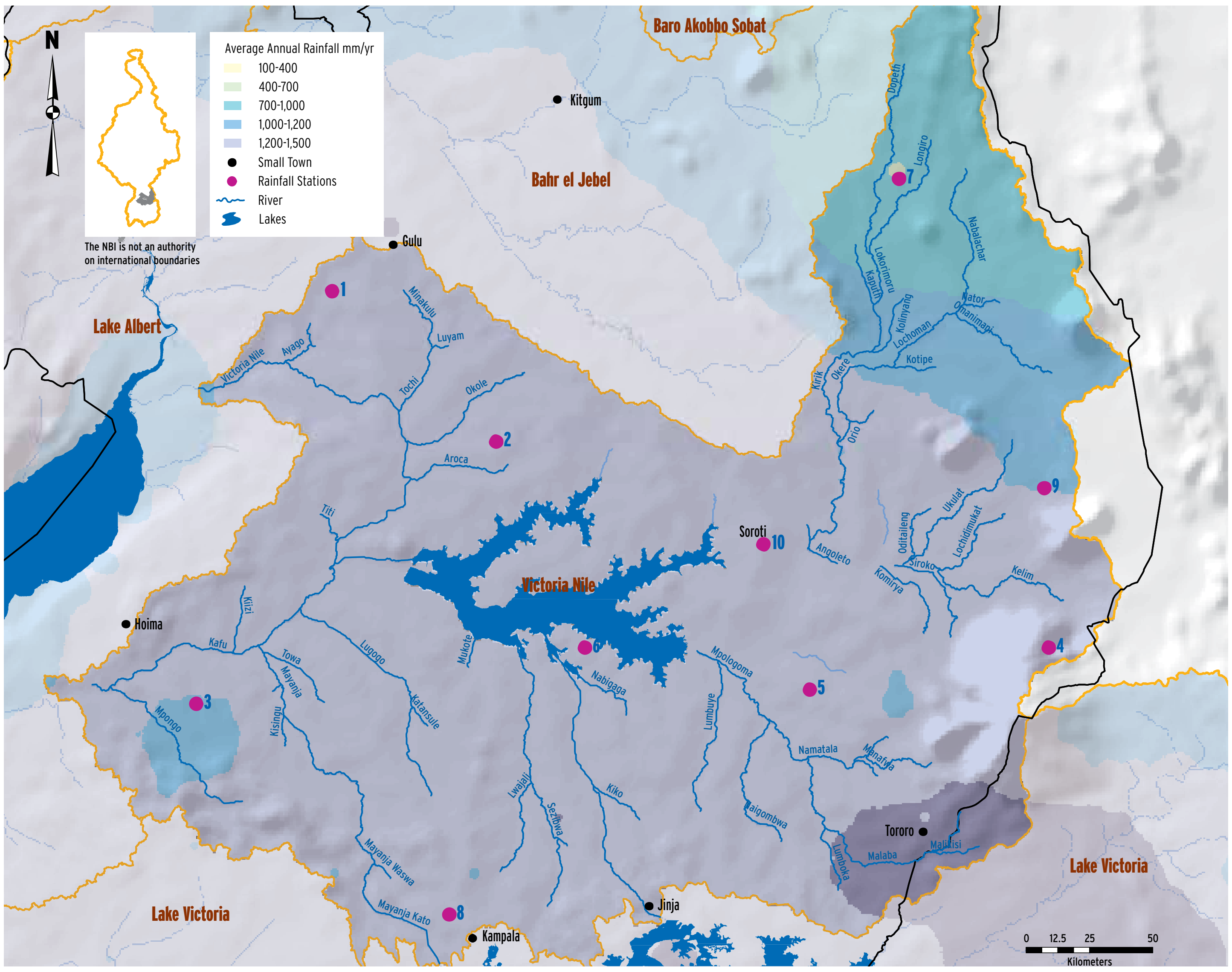
10 Mean monthly rainfall distribution - Rwebitaba



10 Monthly rainfall statistics - Rwebitaba



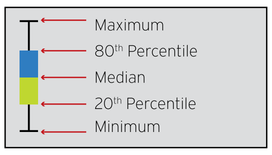
Mean monthly rainfall distribution – Victoria Nile Sub-basin



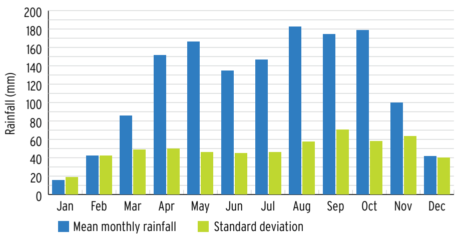
The Victoria Nile also depicts two wet rainfall seasons with fairly competing amounts and two dry seasons with the lowest rainfall amounts occurring between Dec – Feb. The standard deviation is seen to be high for the individual months and the 20th percentile registers more rainfall than in any other part of the Nile basin, seemingly suggesting that there is high rainfall reliability especially for agricultural purposes.

Station Identification

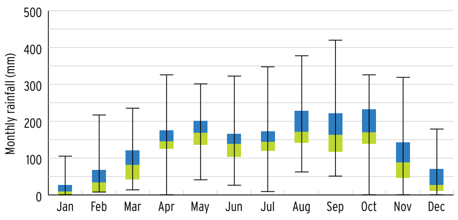
Station Name	Label No.	Record Length
Amar	1	1911-2000
Aninolal Mechanised Div	2	1940-2005
Butemba	3	1940-1981
Kapkwta Forest Station	4	1908-2004
Kibale	5	1900-2004
Kidera	6	1915-2006
Kotido	7	1922-2004
MATUNGA	8	1943-2005
Napianyenya	9	1908-2004
Soroti Met Station	10	1908-2004



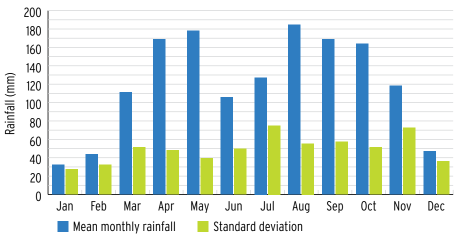
1 Mean monthly rainfall distribution - Amar



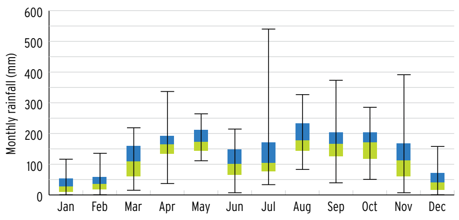
1 Monthly rainfall statistics - Amar



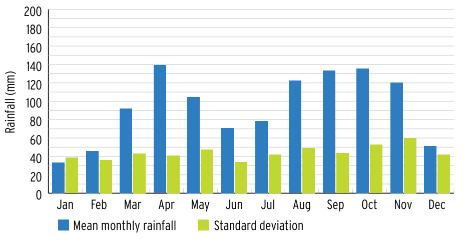
2 Mean monthly rainfall distribution - Aninolal



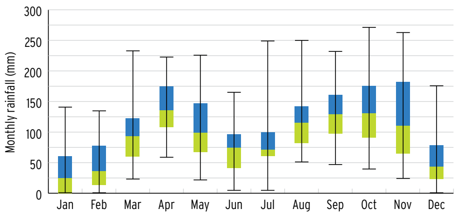
2 Monthly rainfall statistics - Aninolal



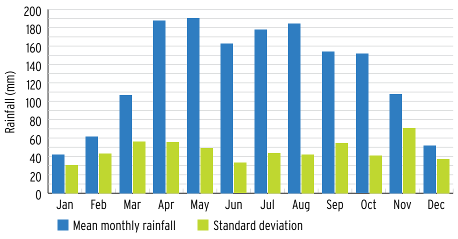
3 Mean monthly rainfall distribution - Butemba



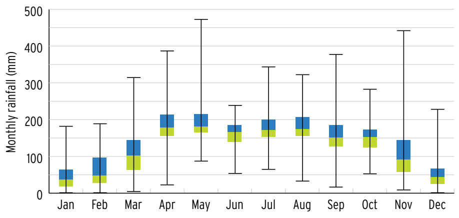
3 Monthly rainfall statistics - Butemba



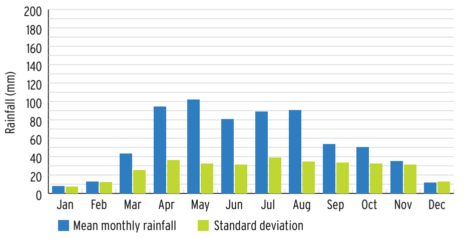
4 Mean monthly rainfall distribution - Kapkwta



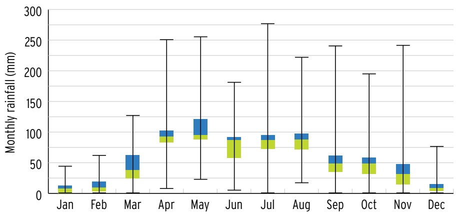
4 Monthly rainfall statistics - Kapkwta



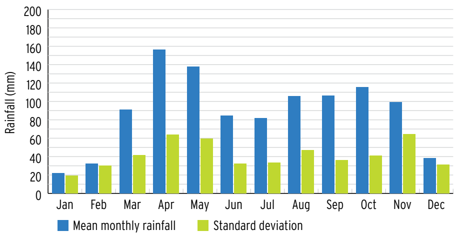
5 Mean monthly rainfall distribution - Kibale



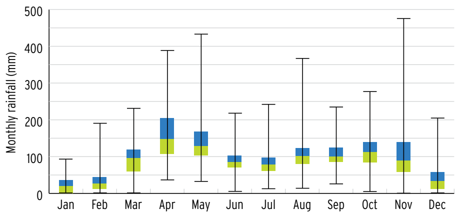
5 Monthly rainfall statistics - Kibale



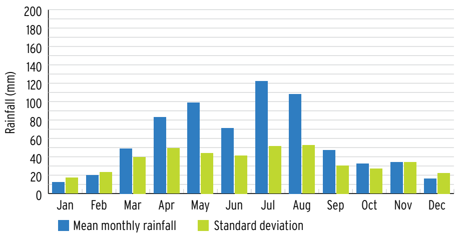
6 Mean monthly rainfall distribution - Kidera



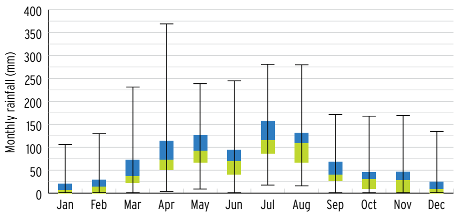
6 Monthly rainfall statistics - Kidera



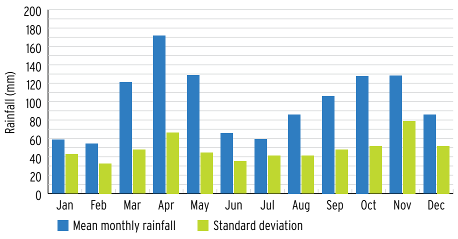
7 Mean monthly rainfall distribution - Kotido



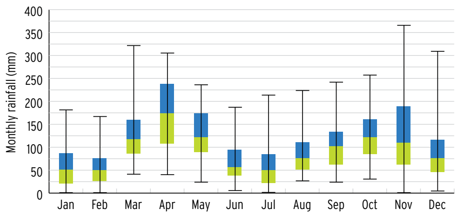
7 Monthly rainfall statistics - Kotido



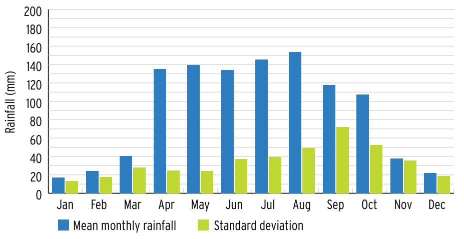
8 Mean monthly rainfall distribution - Matunga



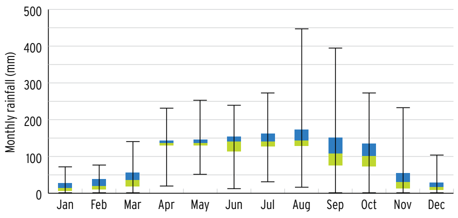
8 Monthly rainfall statistics - Matunga



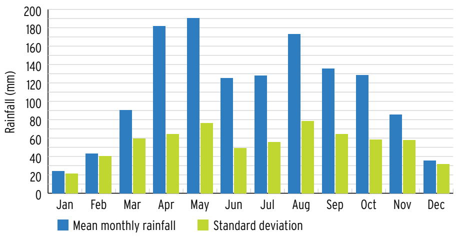
9 Mean monthly rainfall distribution - Napianyenya



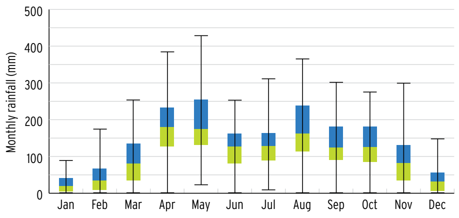
9 Monthly rainfall statistics - Napianyenya



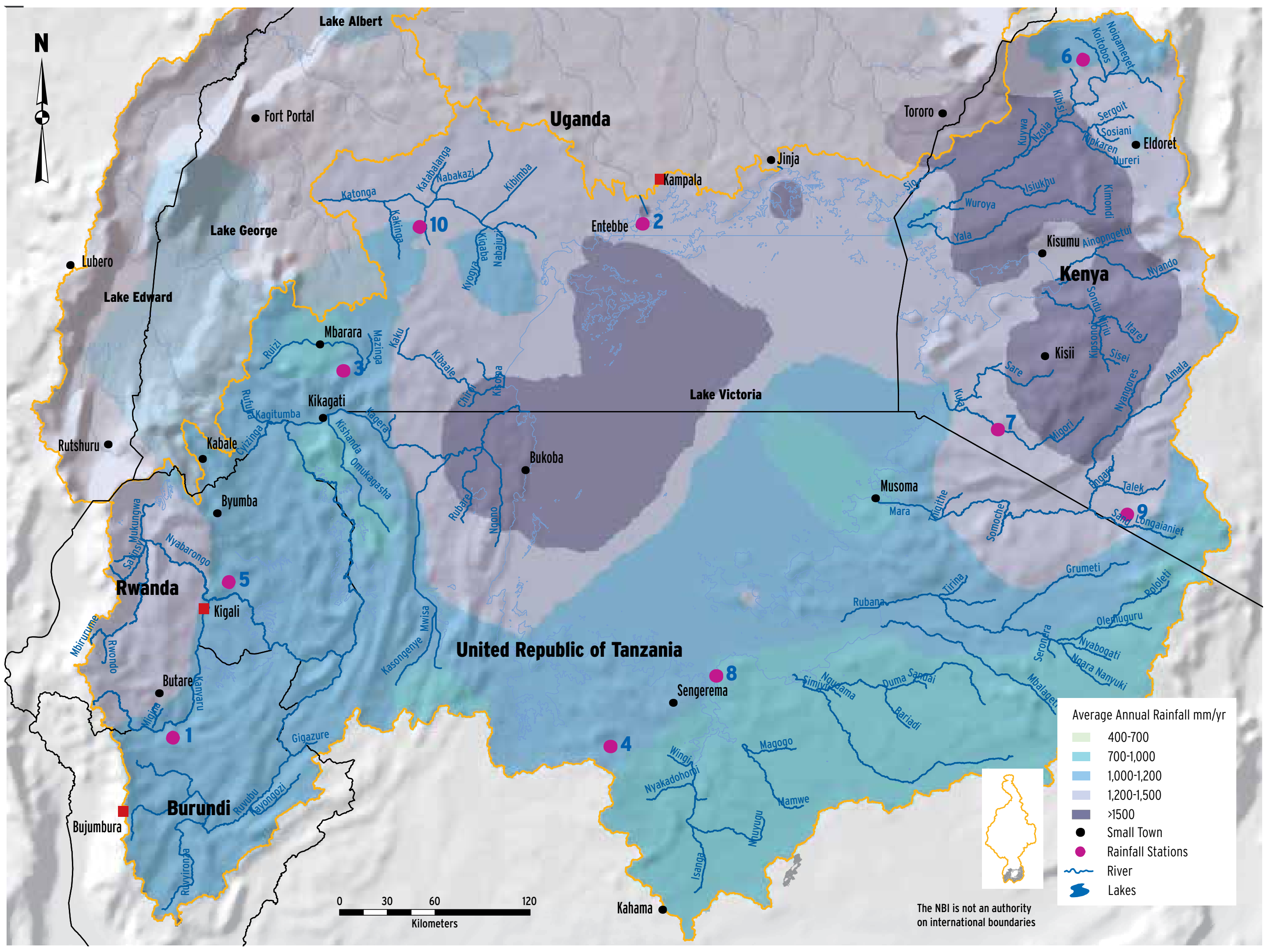
10 Mean monthly rainfall distribution - Soroti



10 Monthly rainfall statistics - Soroti



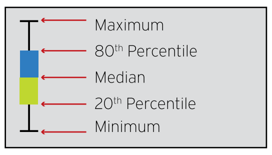
Mean monthly rainfall distribution – Lake Victoria Sub-basin



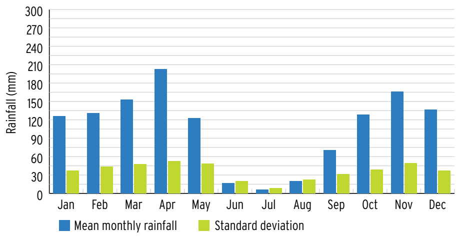
The Lake Victoria Sub-basin depicts a bimodal rainfall pattern with the main dry season occurring between June – August. Generally, wide variation in the monthly rainfalls can be seen from the standard deviation plots. The lake region indicates high dependable rainfall amounts (80th percentile) throughout the year apart from the south eastern part of the lake, around Mwanza in Tanzania which registers very little amounts of about 10mm in the dry season.

Station Identification

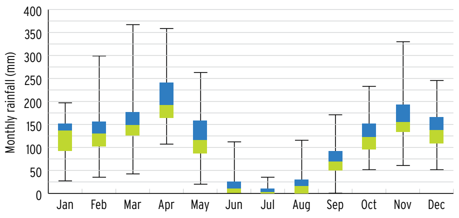
Station Name	Label No.	Record Length
Buye	1	1927-2001
Entebbe	2	1900-2006
Gayaza Isingiro	3	1917-2005
Geita, District Off.	4	1902-2004
Kigali Aero Nyabarongo	5	1960-2005
Kitale Meteorological Station	6	1908-2004
Migori Agric. Off.	7	1911-2004
Mwanza Met	8	1943-2005
Narok, Keekorok Game Lodge	9	1908-2004
Ntusi	10	1908-2004



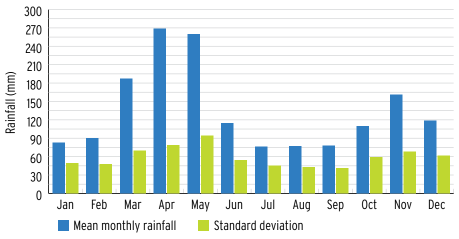
1 Mean monthly rainfall distribution - Buye



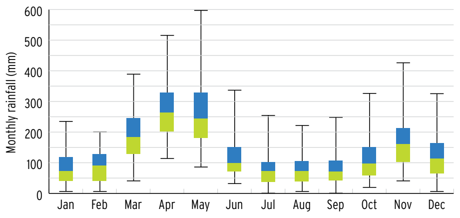
1 Monthly rainfall statistics - Buye



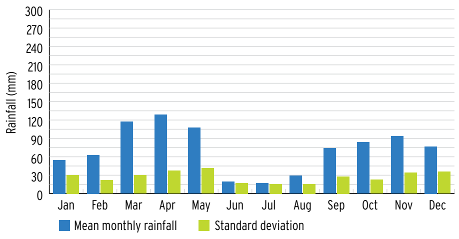
2 Mean monthly rainfall distribution - Entebbe



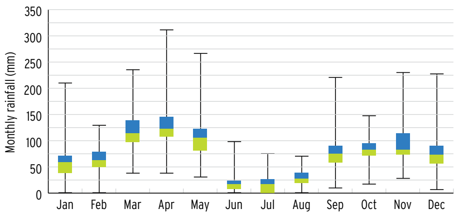
2 Monthly rainfall statistics - Entebbe



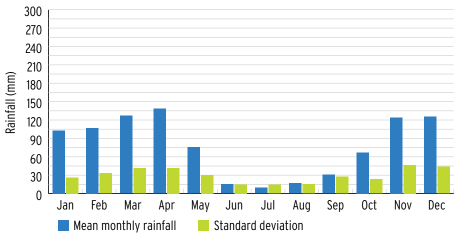
3 Mean monthly rainfall distribution - Gayaza



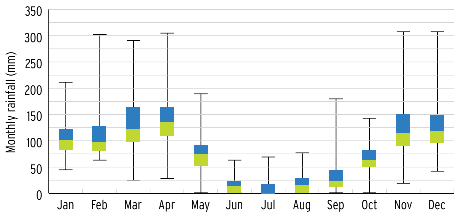
3 Monthly rainfall statistics - Gayaza



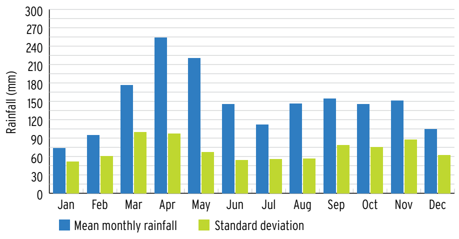
4 Mean monthly rainfall distribution - Geita



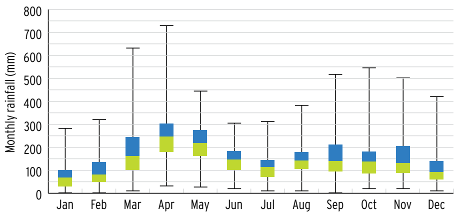
4 Monthly rainfall statistics - Geita



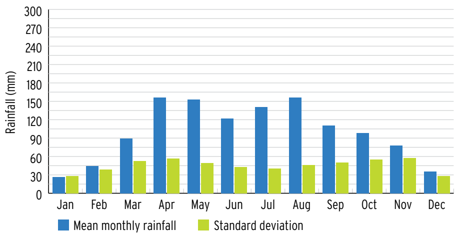
5 Mean monthly rainfall distribution - Kibangu



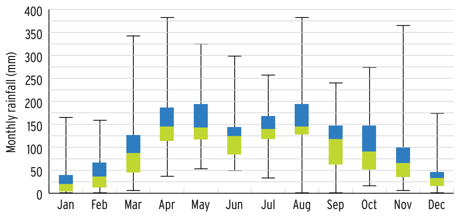
5 Monthly rainfall statistics - Kibangu



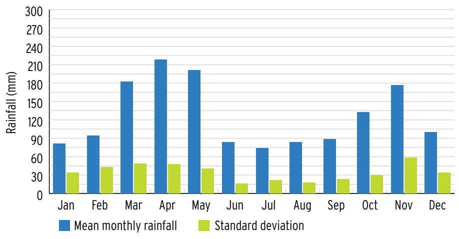
6 Mean monthly rainfall distribution - Kitale



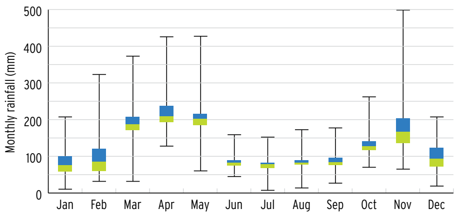
6 Monthly rainfall statistics - Kitale



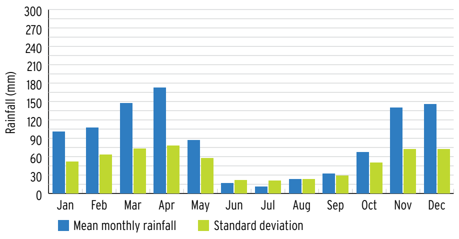
7 Mean monthly rainfall distribution - Migori



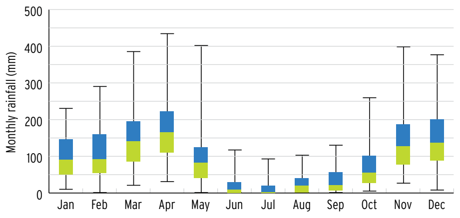
7 Monthly rainfall statistics - Migori



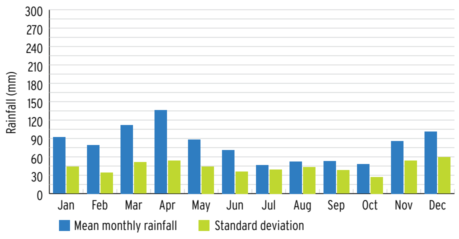
8 Mean monthly rainfall distribution - Mwanza



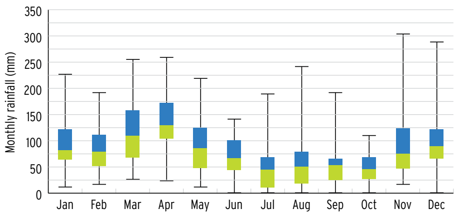
8 Monthly rainfall statistics - Mwanza



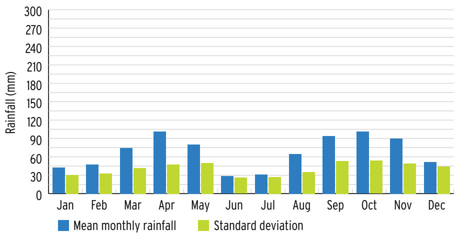
9 Mean monthly rainfall distribution - Narok Keekorok



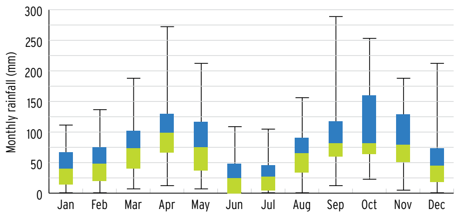
9 Monthly rainfall statistics - Narok Keekorok



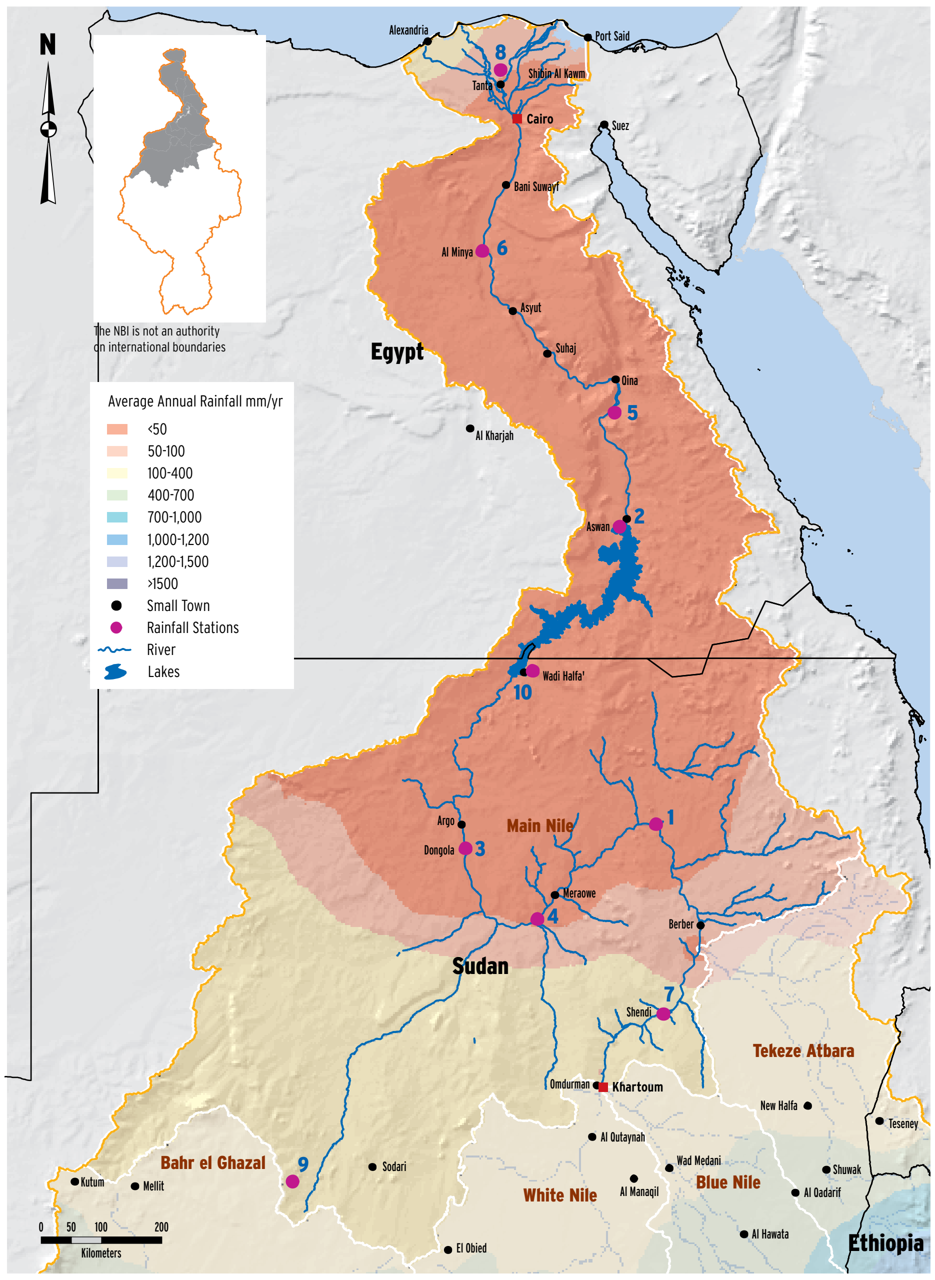
10 Mean monthly rainfall distribution - Ntusi



10 Monthly rainfall statistics - Ntusi



Annual rainfall patterns – Main Nile Sub-basin

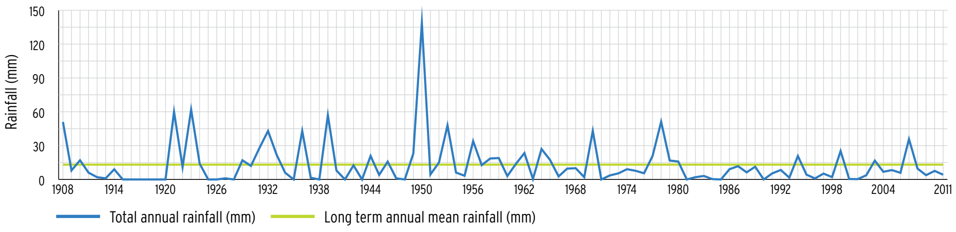


The main Nile is the part of the Nile Basin which receives the least rainfall, with fairly small spatial variation across the sub-basin. The sub-basin receives mean annual rainfall of, sometimes, less than 50mm, with high inter annual variation, sometimes registering 0mm.The most downstream part of the sub-basin; at the Mediterranean Sea receives relatively high amounts of rainfall than any other part of the basin of about 200mm.

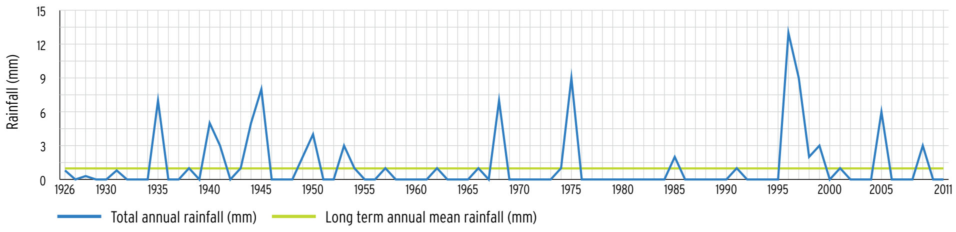
Station Identification

Station Name	Label No.	Record Length	Station Name	Label No.	Record Length
Abu-Hamed	1	1908-2011	Minya	6	1925-1990
Asswan	2	1926-2011	Shendi	7	1937-1999
Dongola	3	1908-2011	Tanta	8	1904-2004
Korti	4	1908-2011	Umm Badr	9	1902-2011
Luxor	5	1926-2011	Wadi-Halfa	10	1935-2011

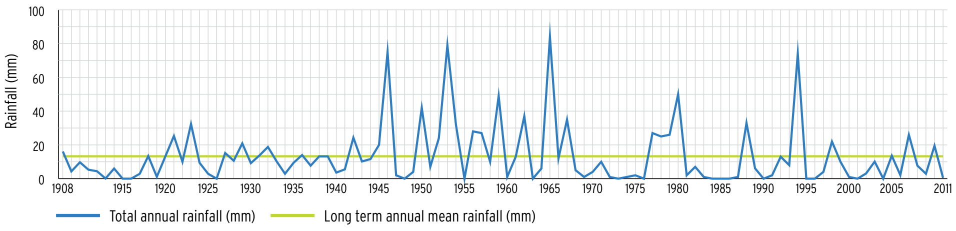
1 Annual rainfall pattern - Abu Hamed



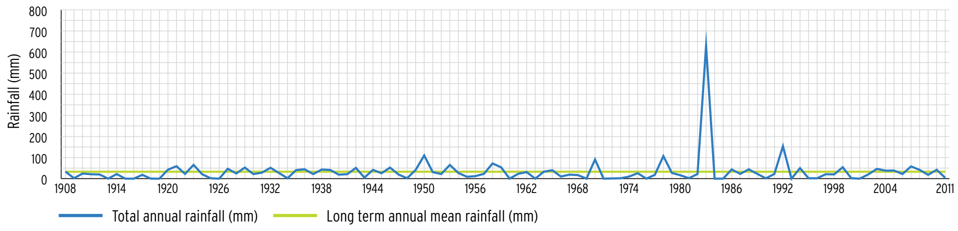
2 Annual rainfall pattern - Asswan



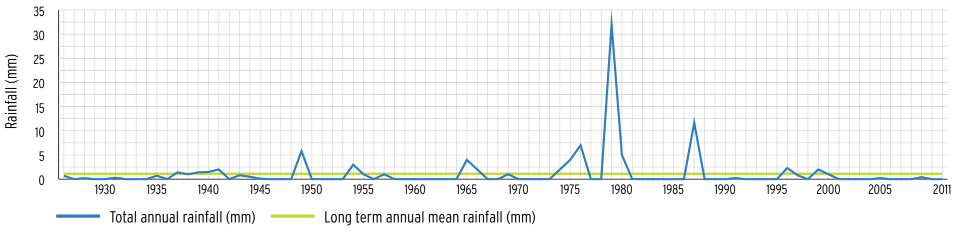
3 Annual rainfall pattern - Dongola



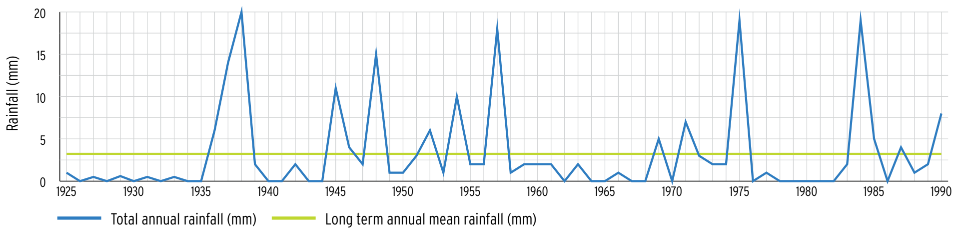
4 Annual rainfall pattern - Korti



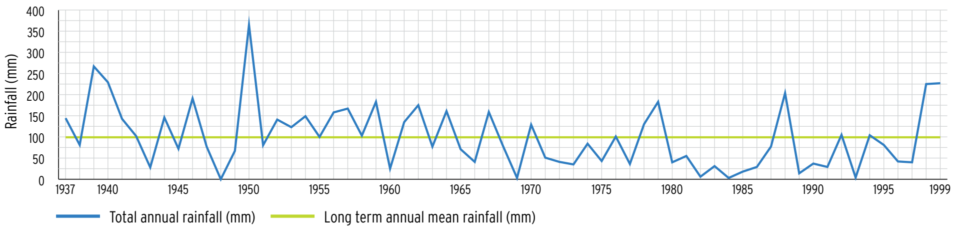
5 Annual rainfall pattern - Luxor



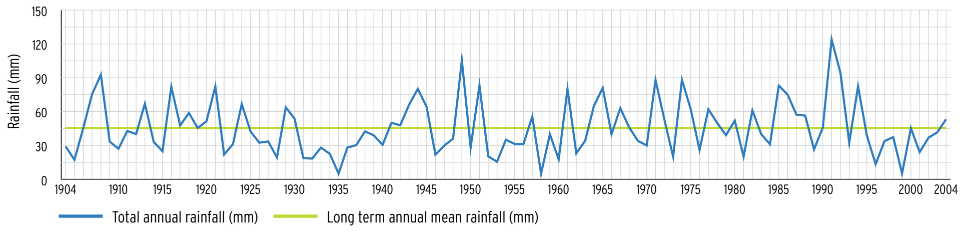
6 Annual rainfall pattern - Minya



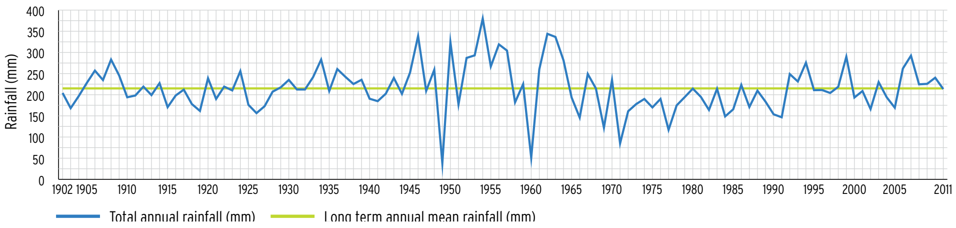
7 Annual rainfall pattern - Shendi



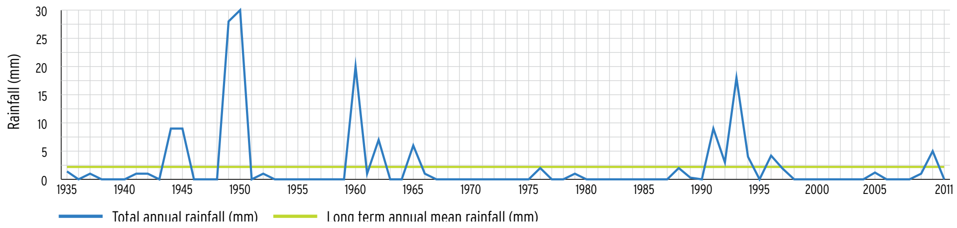
8 Annual rainfall pattern - Tanta



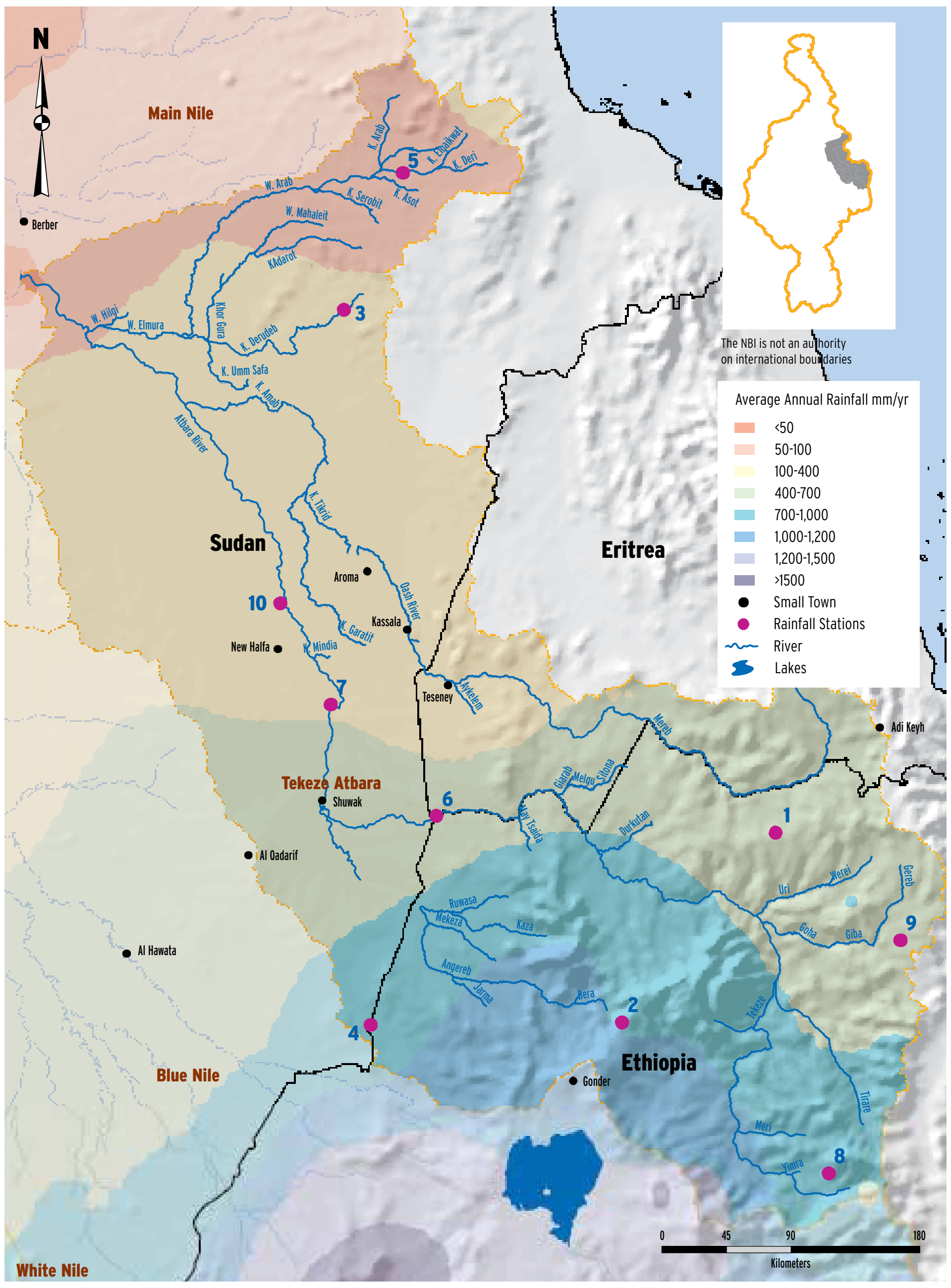
9 Annual rainfall pattern - Umm Badr



10 Annual rainfall pattern - Wadi Halfa



Annual rainfall patterns - Tekeze Atbara Sub-basin



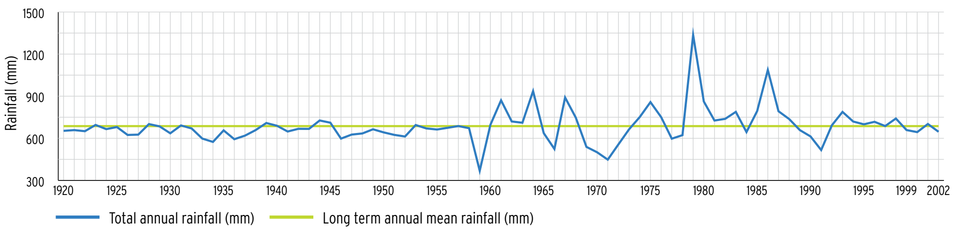
Tekeze Atbaba, like the Blue Nile, has its boundaries spanning from Ethiopia, Eritrea and down to Sudan and also receives highly spatially variable rainfall amounts. The upstream parts of the sub-basin receive mean annual rainfall amounts in excess of 800mm and some areas in Sudan receive less than 300mm with high inter-annual variation of these amounts across the years considered.

> The entire Atbara sub-basin is quite large. It covers an estimated 166,875km². The average annual precipitation over the area is 553mm, the lowest among the Nile sub-basins. The relatively high value of more than 1,300mm of annual rainfall over the Ethiopian Highlands decreases to less than 90mm downstream at the junction of the Atbara River with the Main Nile.

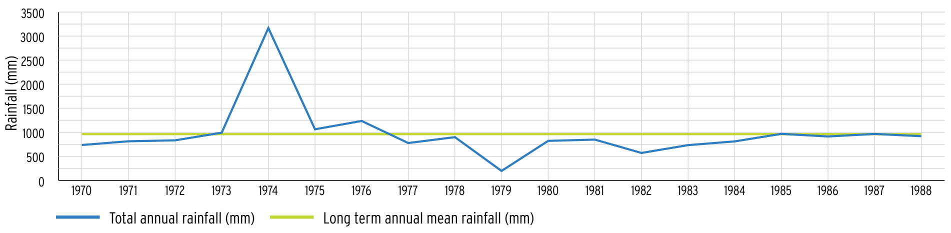
Station Identification

Station Name	Label No.	Record Length	Station Name	Label No.	Record Length
Axum	1	1920-2001	Humera	6	1901-2011
Dabat	2	1970-1988	Khashm El Girba	7	1901-2000
Derudeb	3	1912-1991	Lalibela	8	1973-1989
Gallabat	4	1901-2007	Mekele	9	1912-2002
Haiya	5	1912-1991	New-Halfa	10	1901-2011

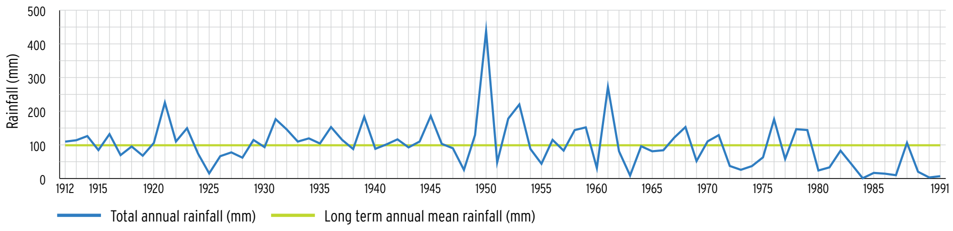
1 Annual rainfall pattern - Axum



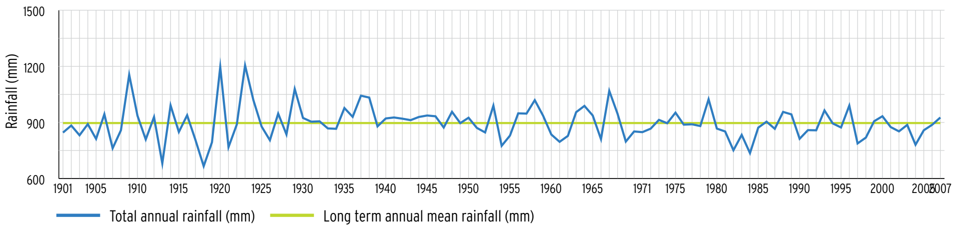
2 Annual rainfall pattern - Dabat



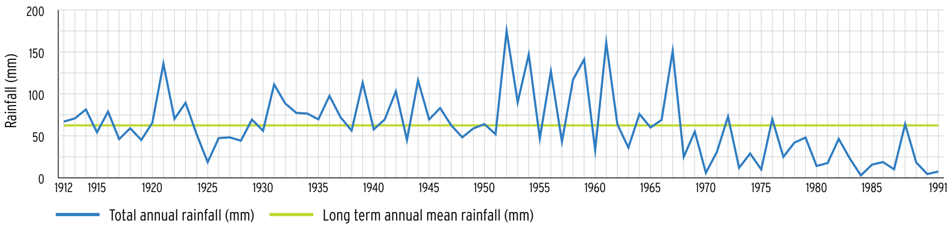
3 Annual rainfall pattern - Derudeb



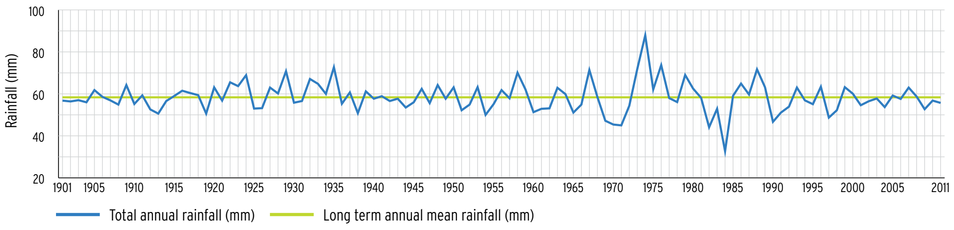
4 Annual rainfall pattern - Gallabat



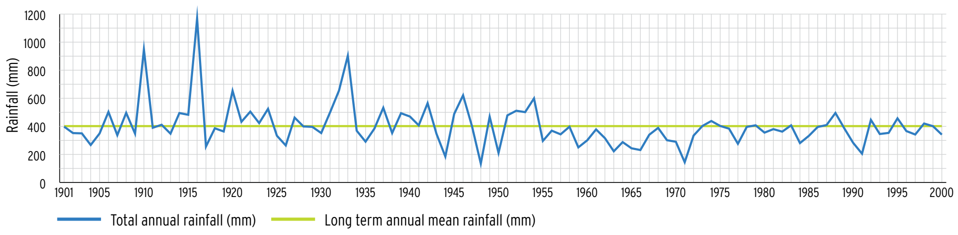
5 Annual rainfall pattern - Haiya



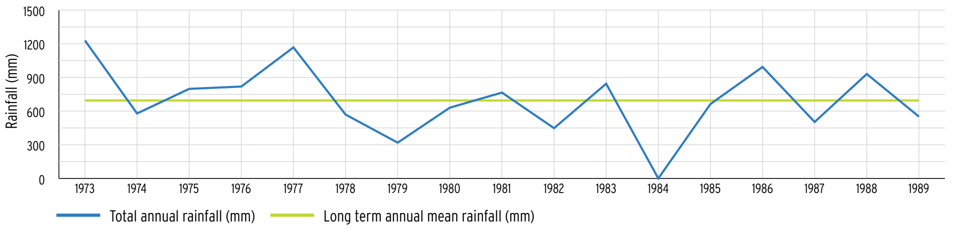
6 Annual rainfall pattern - Humera



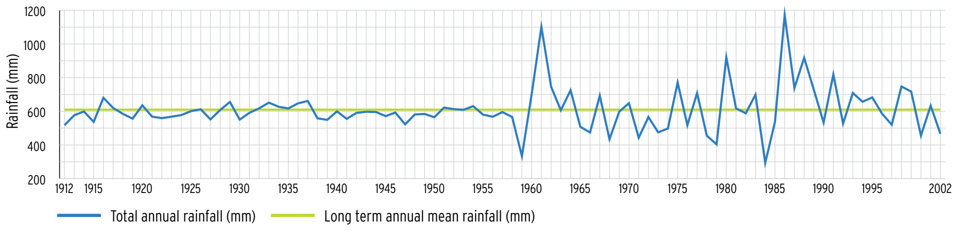
7 Annual rainfall pattern - Khashm El Girba



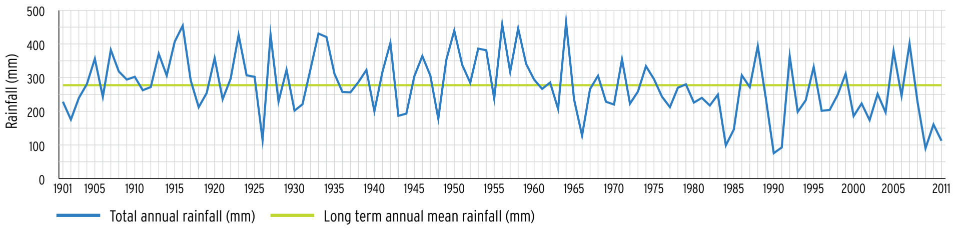
8 Annual rainfall pattern - Lalibela



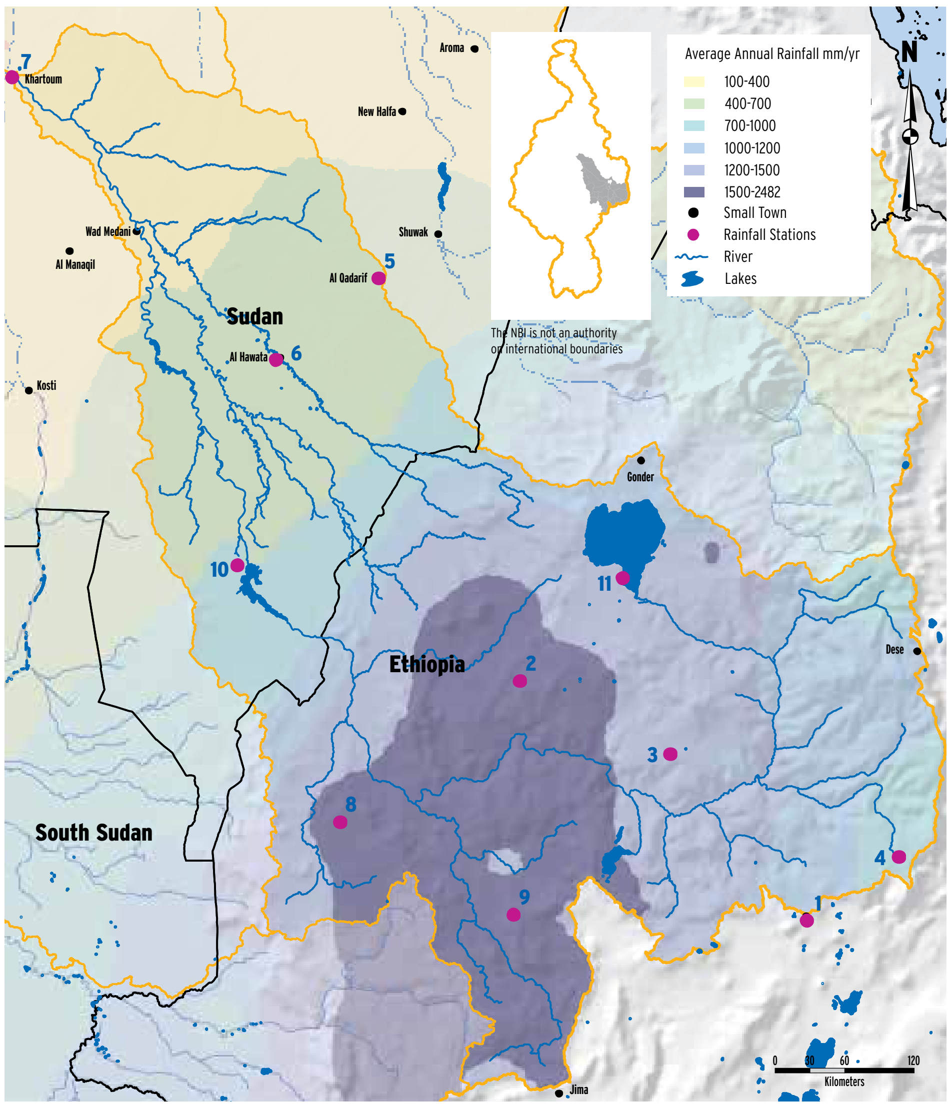
9 Annual rainfall pattern - Mekele



10 Annual rainfall pattern - New Halfa



Annual rainfall patterns – Blue Nile Sub-basin



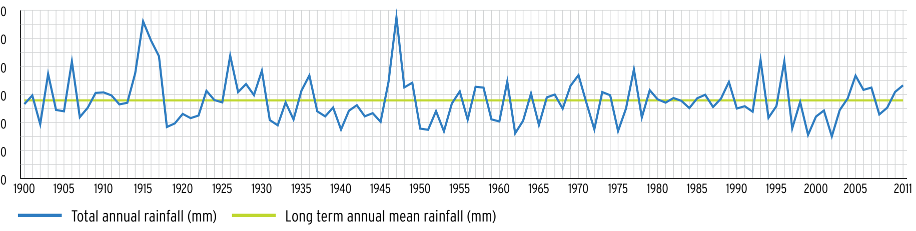
The Blue Nile with its spatial extent ranging from the Ethiopian highlands down to Sudan, receives highly spatially distributed rainfall amounts, with the highlands receiving mean annual rainfall amounts in excess of 1,200mm and some areas in Sudan receiving less than 400mm. There is also a noticeable variation of these amounts across the years.

The main control on rainfall over the Blue Nile basin is the east circulation flowing over the Blue Nile and the extent and timing of the seasonal migration of the Inter Tropical Converge Zone (ITCZ). This gives the rainfall distribution over the year in the Blue Nile basin a strong seasonal character. The mean annual rainfall over the Blue Nile sub basin ranges from 1 000 mm in the northeast to 2 000 mm in the southeast (Ribbe and Ahmed 2006). The average annual precipitation over the sub-basin is 1,346 mm, making it the highest among all the sub-basins of the Nile. Changes in temperature and rainfall would affect the flow of the Blue Nile mainly through runoff variability and changing upstream demand.

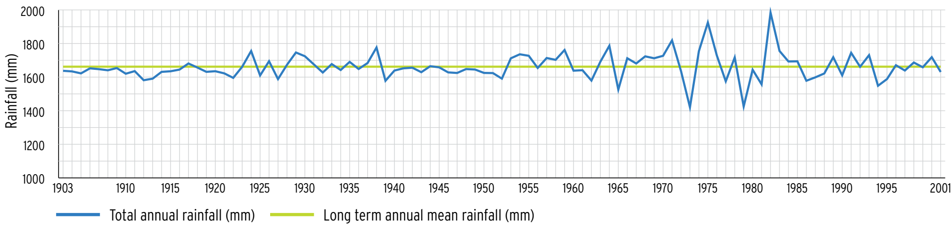
Station Identification

Station Name	Label No.	Record Length	Station Name	Label No.	Record Length
Addis Ababa	1	1900-2011	Khartoum	7	1900-2011
Chagni	2	1903-2001	Mendi	8	1903-2001
Debremarcos	3	1953-2001	Nekemtewelega	9	1903-2001
Debresina	4	1900-2011	Roseires	10	1903-2001
El Gedarif	5	1901-2011	Zege	11	
Hawata	6	1900-2011			

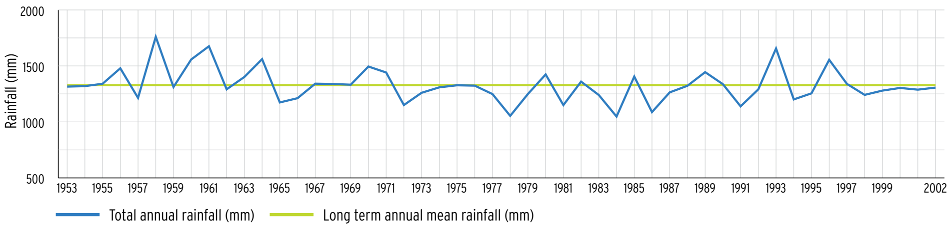
1 Annual rainfall pattern - Addis Ababa



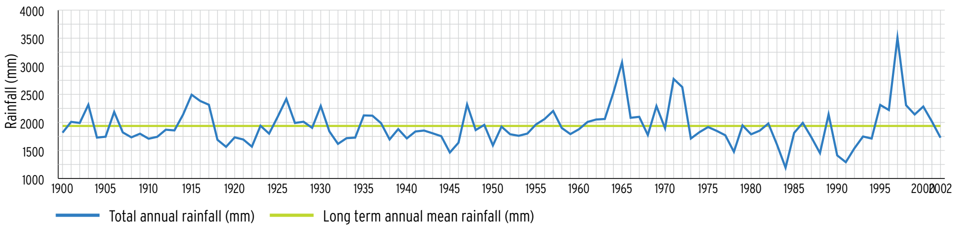
2 Annual rainfall pattern - Chagni



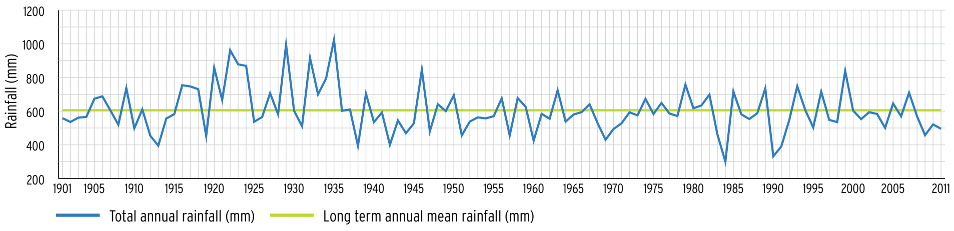
3 Annual rainfall pattern - Debremarkos



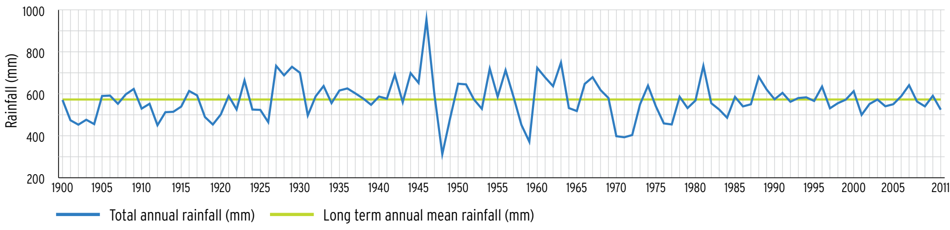
4 Annual rainfall pattern - Debresina



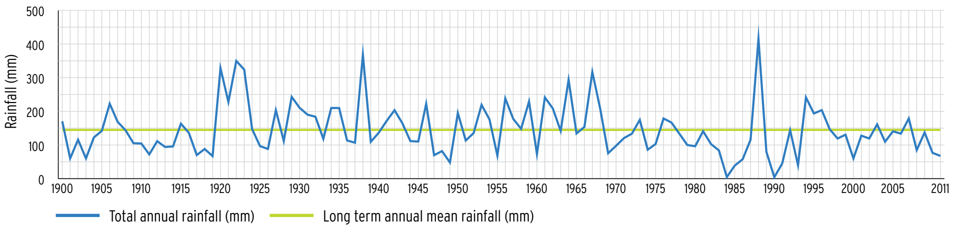
5 Annual rainfall pattern - El Gedarif



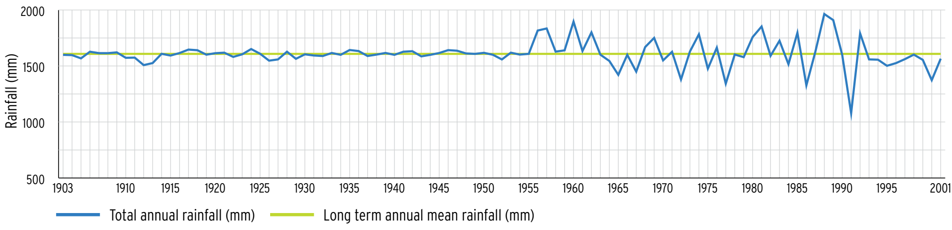
6 Annual rainfall pattern - Hawata



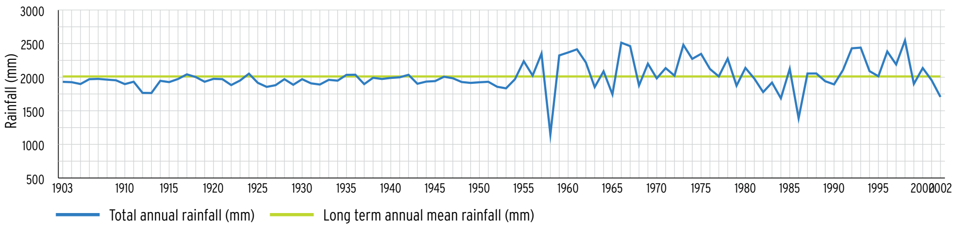
7 Annual rainfall pattern - Khartoum



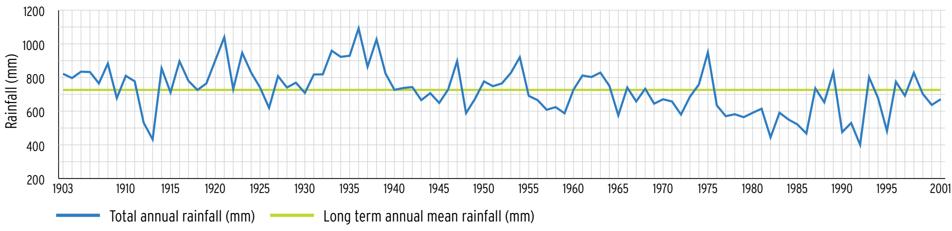
8 Annual rainfall pattern - Mendi



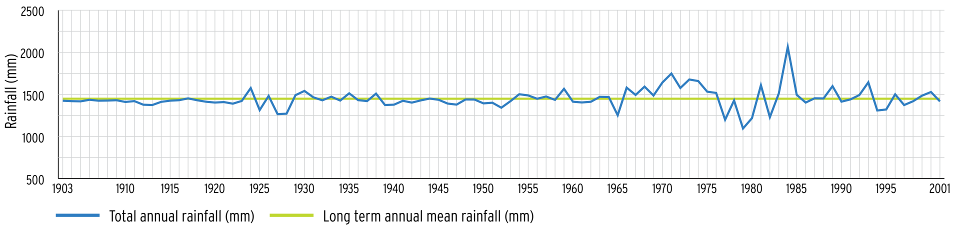
9 Annual rainfall pattern - Nekemteweleg



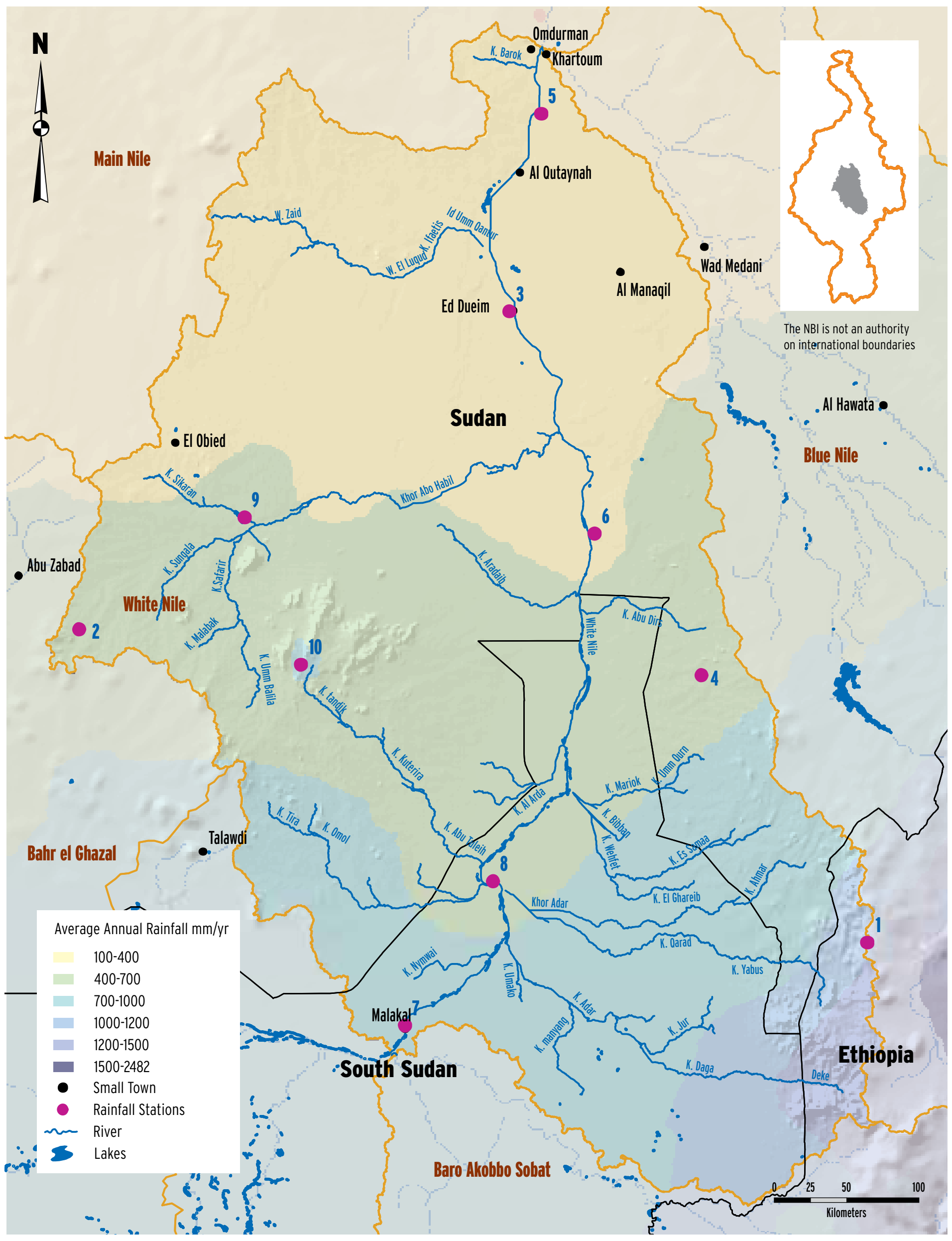
10 Annual rainfall pattern - Roseires



11 Annual rainfall pattern - Zege



Annual rainfall patterns - White Nile Sub-basin



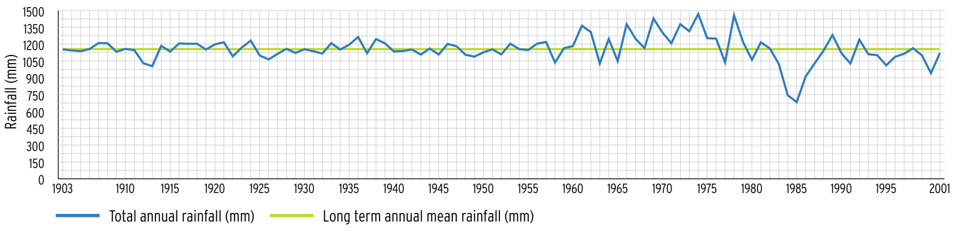
The upstream parts of the White Nile; western Ethiopia, receive high rainfall amounts in excess of 1,000mm whereas the downstream parts in Sudan receive less than 300mm indicating a wide spatial variation in rainfall within the sub-basin. As seen from the plots, the inter-annual variation is also very high all across the sub-basin.

> On the stretch from Malakal to Khartoum, the White Nile flows into increasingly semi-arid conditions. There are no permanent tributaries and it is only in years of very heavy precipitation that there is any addition of importance to the river flow

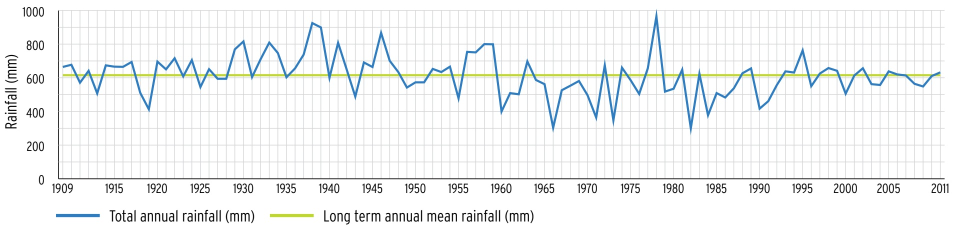
Station Identification

Station Name	Label No.	Record Length	Station Name	Label No.	Record Length
Asosa	1	1903-2001	Jebelein	6	1952-1992
Dilling	2	1909-2011	Malakal	7	1909-2004
Ed Dueim	3	1900-2011	Melut	8	1900-1984
J.Guli	4	1903-2001	Rahad	9	1902-2011
Jebel Aulia	5	1900-2011	Rashad	10	1909-2011

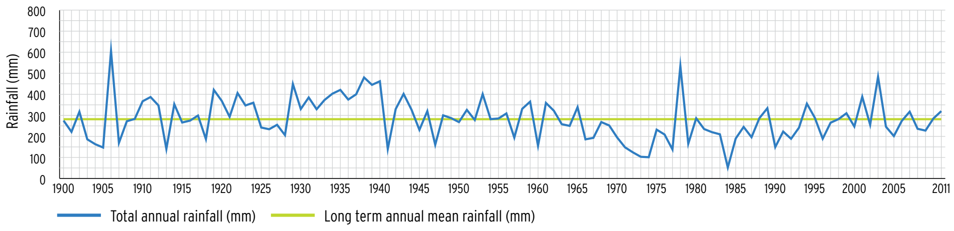
1 Annual rainfall pattern - Asosa



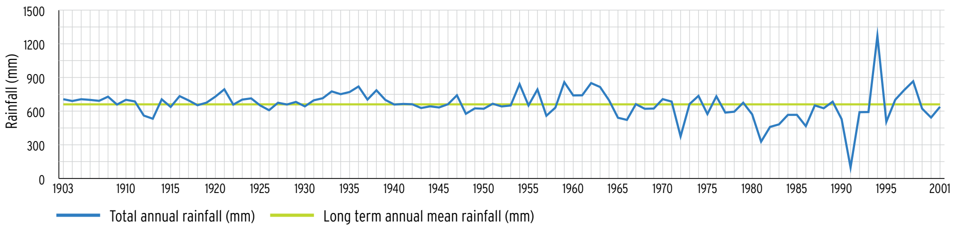
2 Annual rainfall pattern - Dilling



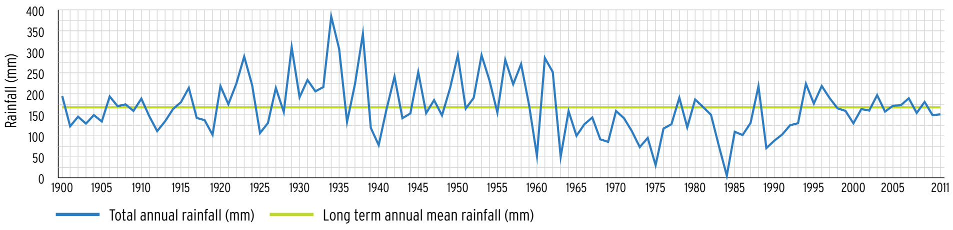
3 Annual rainfall pattern - Ed Dueim



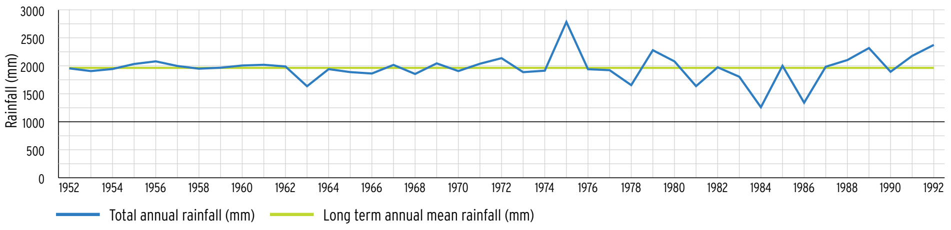
4 Annual rainfall pattern - J. Guli



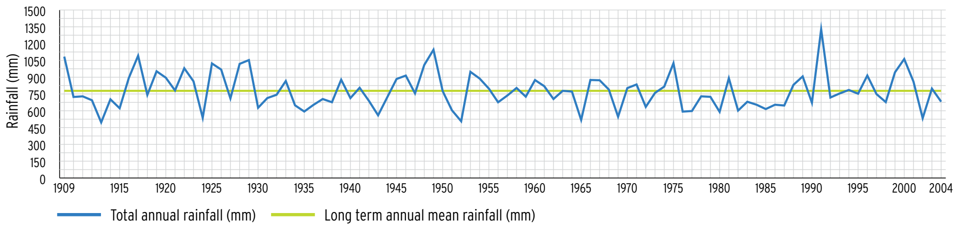
5 Annual rainfall pattern - Jebel Aulia



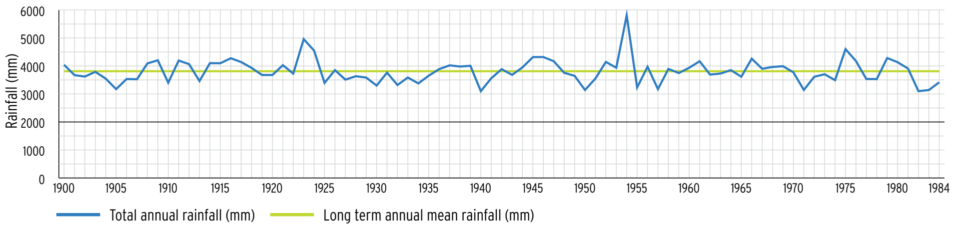
6 Annual rainfall pattern - Jebelein



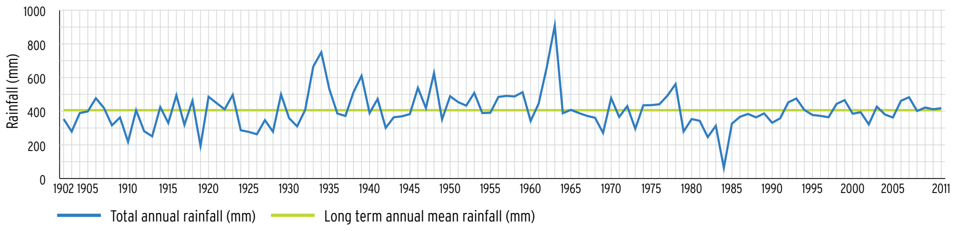
7 Annual rainfall pattern - Malakal



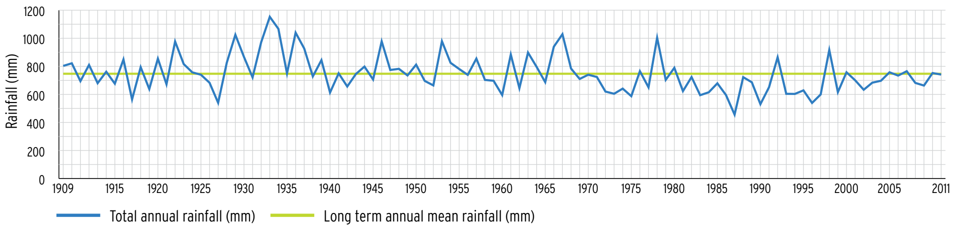
8 Annual rainfall pattern - Melut



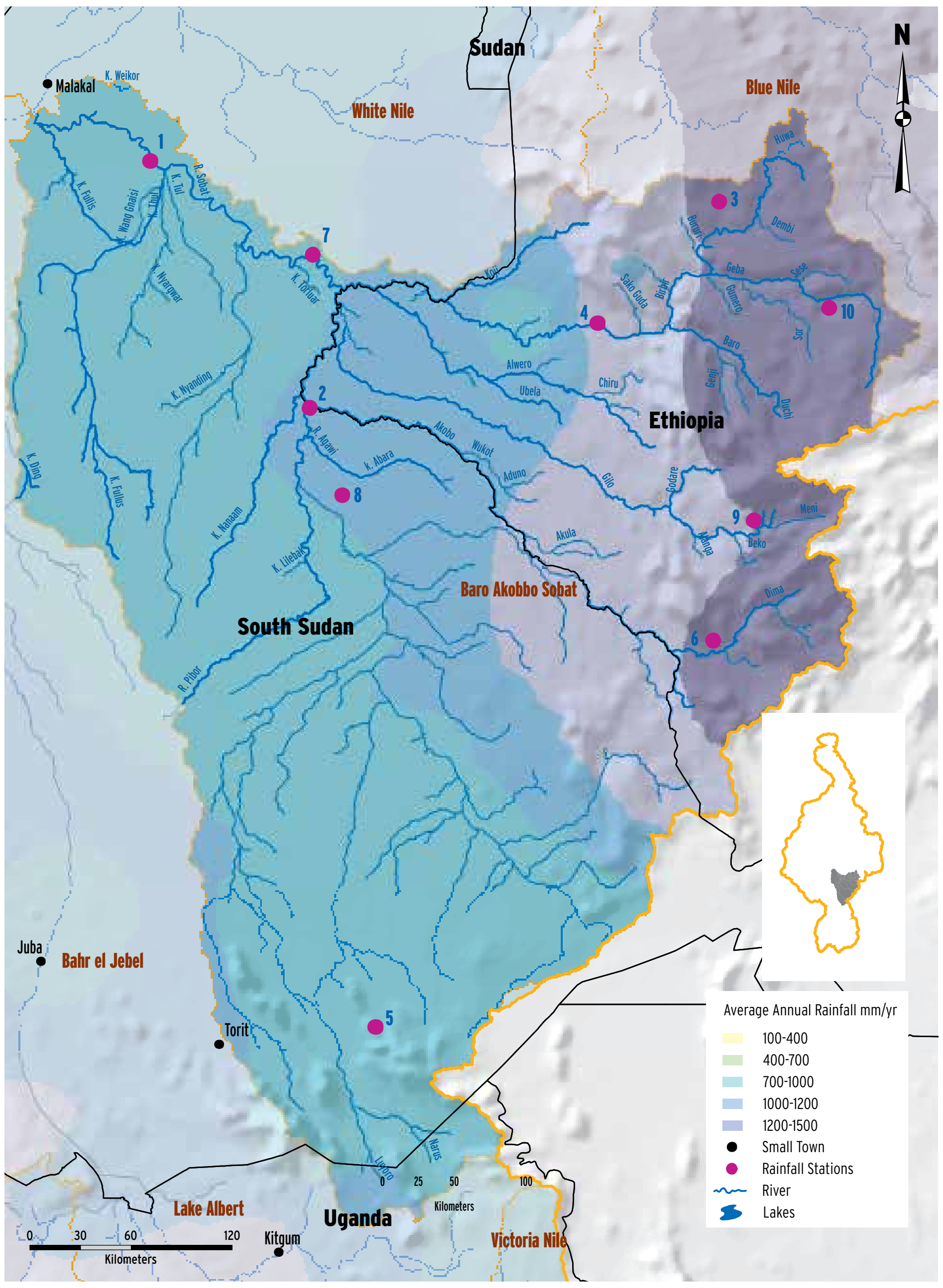
9 Annual rainfall pattern - Rahad



10 Annual rainfall pattern - Rashad



Annual rainfall patterns – Baro Akobo Sobat Sub-basin



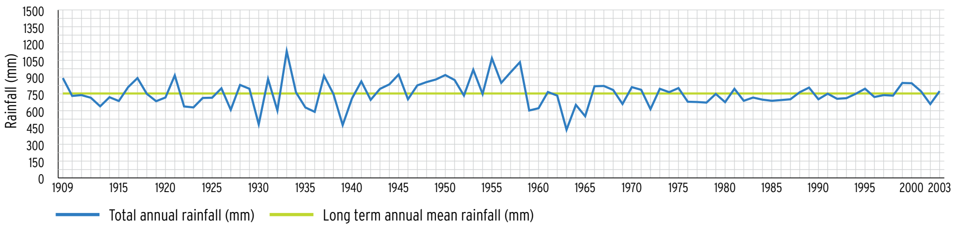
Generally, the spatial distribution of rainfall across the sub-basin is fairly reasonable with most areas receiving amounts of over 1,000mm but there is noticeable inter-annual variation. Specifically, areas in the Ethiopian part of the sub-basin receive more rainfall amounts as opposed to those in South Sudan and in the northern part of Uganda.

> This basin is strongly similar to that of the Sudd. This means that variations in the climate leading to changes in inflow from the Baro and Pibor, will lead to variations in spill to the Machar Marches. In turn this would lead to variations in the area of the Marches and the effect on the outflow of the basin will be dampened. This makes the outflow of this sub-basin also relatively insensitive to changes in rainfall.

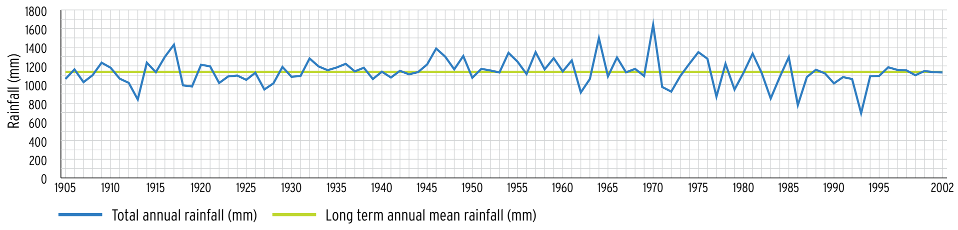
Station Identification

Station Name	Label No.	Record Length	Station Name	Label No.	Record Length
Abwong	1	1909-2003	Mizan Teferi	6	1952-2011
Akobo	2	1905-2002	Nasser	7	1909-2003
Alem Teferi School	3	1970-1989	Pibor	8	1905-2002
Gambella	4	1903-2002	Tepi	9	1952-2002
Kapoeta	5	1922-2002	Yayu	10	1952-1992

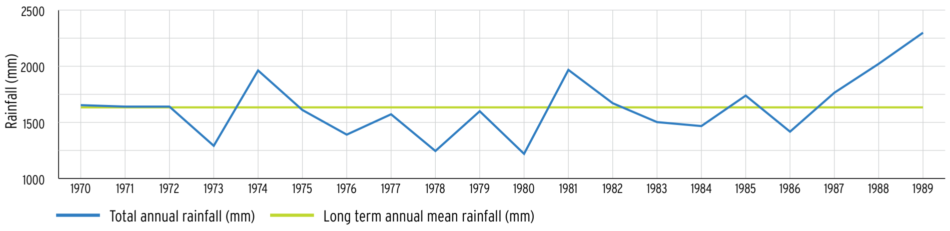
1 Annual rainfall pattern - Abwong



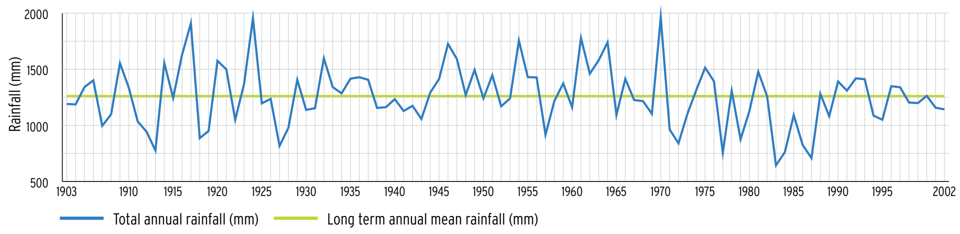
2 Annual rainfall pattern - Akobo



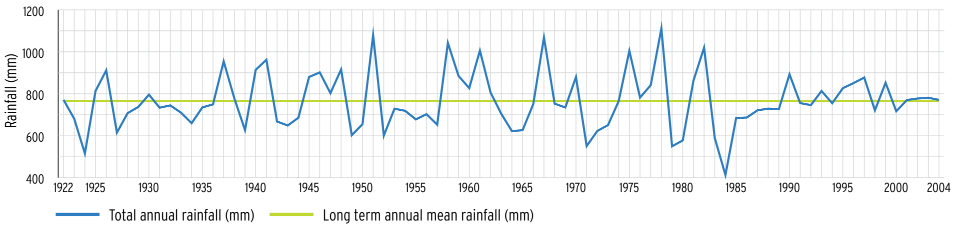
3 Annual rainfall pattern - Alem Teferi



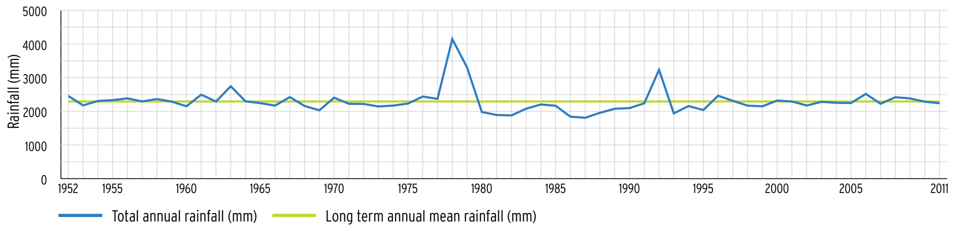
4 Annual rainfall pattern - Gambella



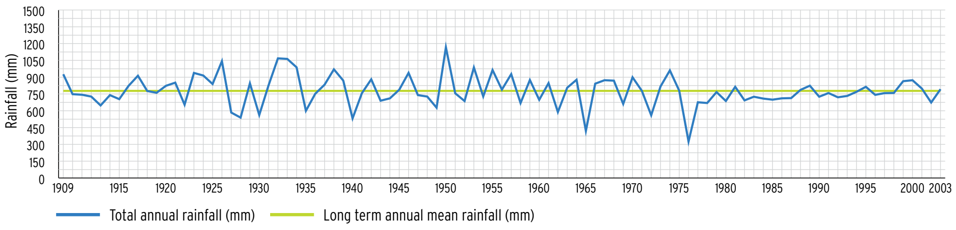
5 Annual rainfall pattern - Kapoeta



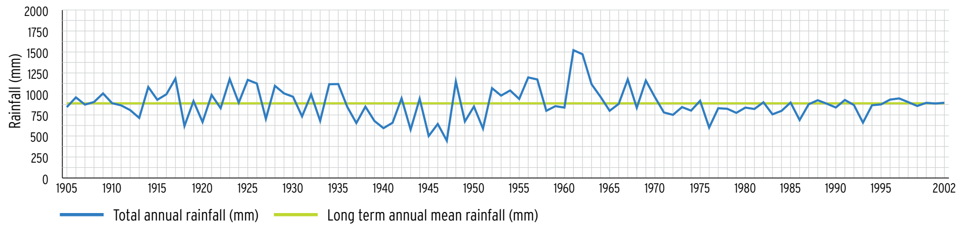
6 Annual rainfall pattern - Mizan Teferi



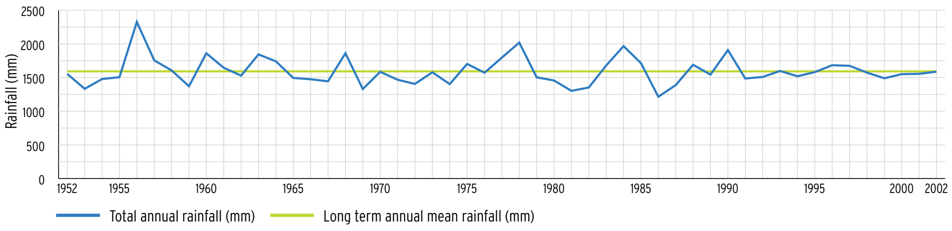
7 Annual rainfall pattern - Nasser



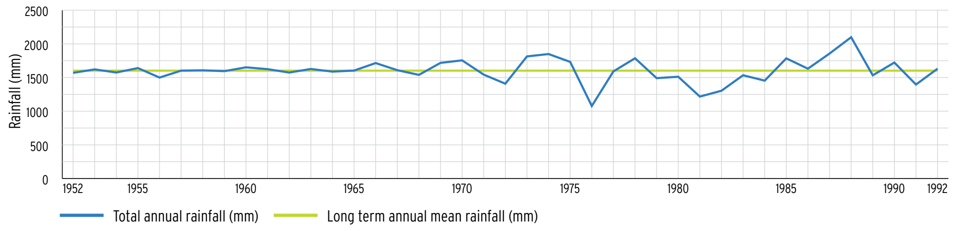
8 Annual rainfall pattern - Pibor



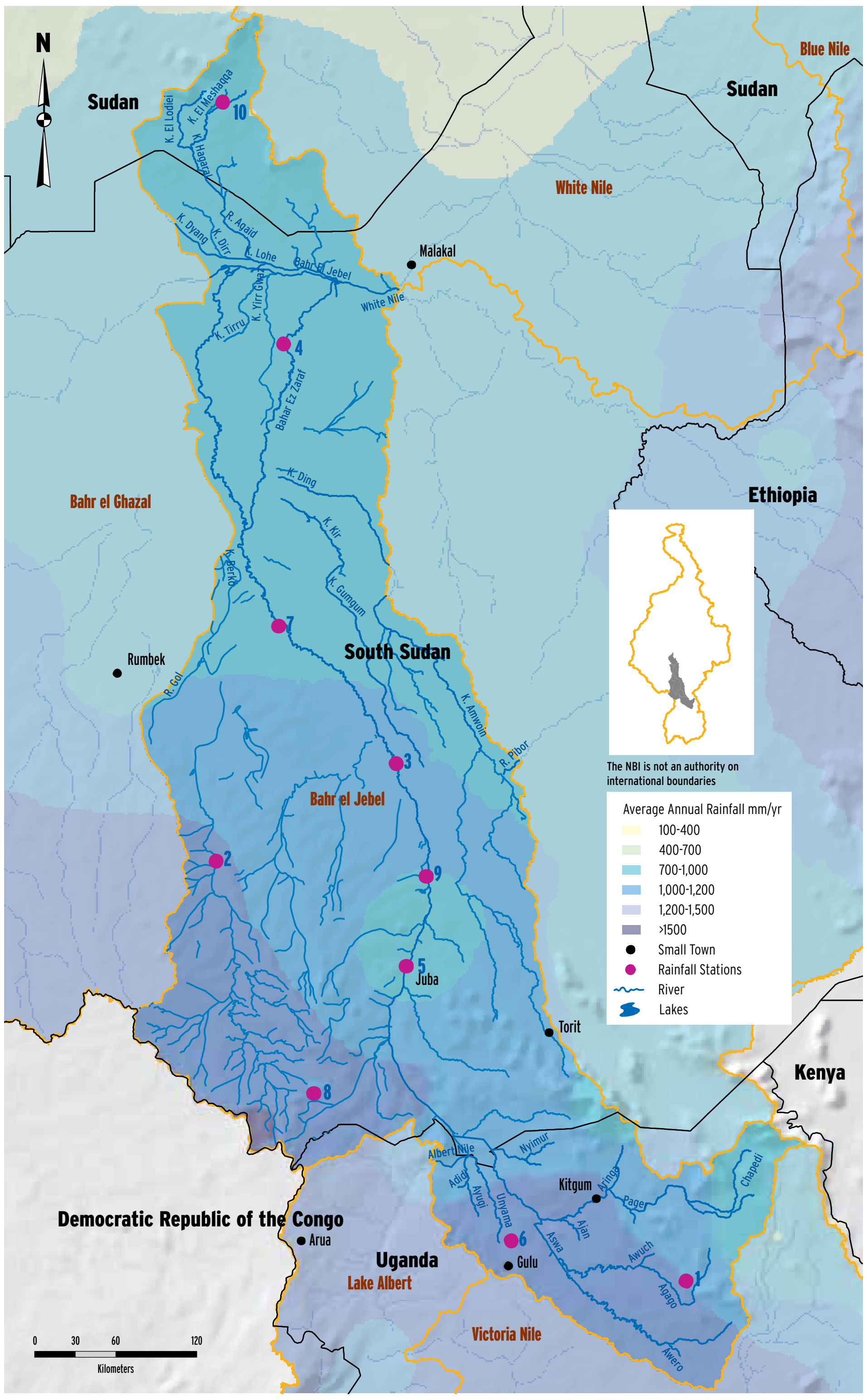
9 Annual rainfall pattern - Tepi



10 Annual rainfall pattern - Yayu



Annual rainfall patterns - Bahr el Jebel Sub-basin

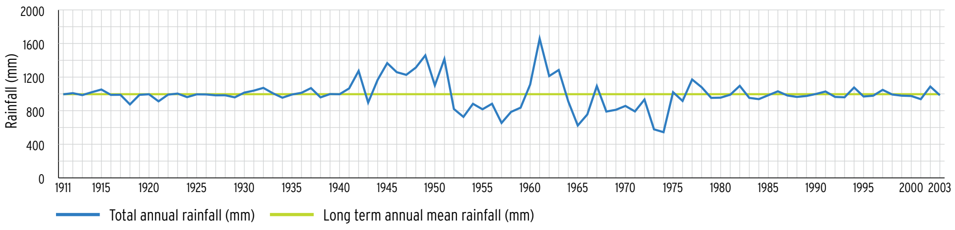


Rainfall stations in the Bahr el Jebel sub-basin reveal inter annual variations in the mean annual rainfall and reduction in the rainfall amounts is realized as we move further downstream in the sub-basin. The upstream part of the Sub-basin realizes mean annual rainfall of over 1,000mm whereas the downstream parts of the in South Sudan receive less than 1,000mm.

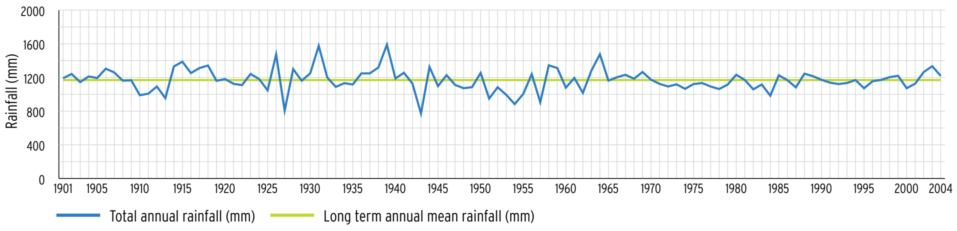
Station Identification

Station Name	Label No.	Record Length	Station Name	Label No.	Record Length
Adilang	1	1911-2003	Patiko	6	1911-1966
Amadi	2	1901-2004	Shambe	7	1907-1985
Bor	3	1901-2004	Tambura	8	1914-2000
Fangak	4	1906-2003	Terakeka	9	1901-2004
Juba	5	1901-2004	Talodi	10	1909-2003

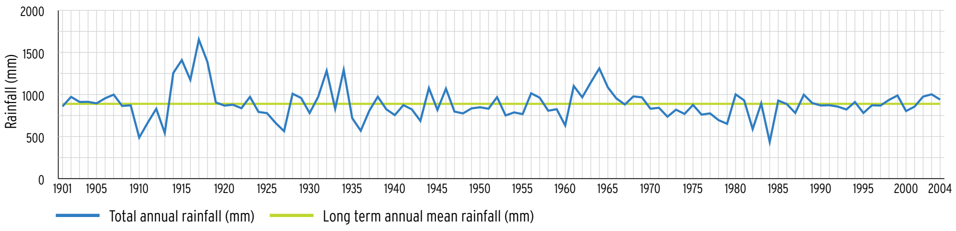
1 Annual rainfall pattern - Adilang



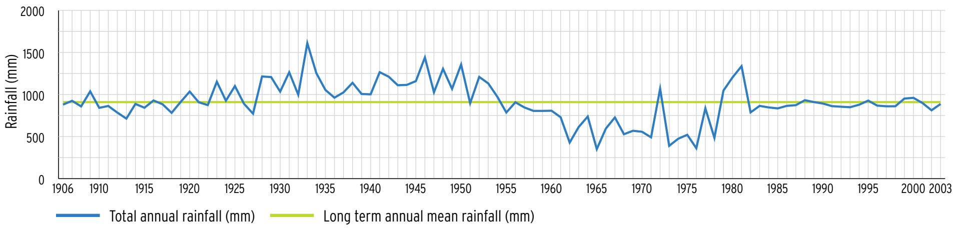
2 Annual rainfall pattern - Amadi



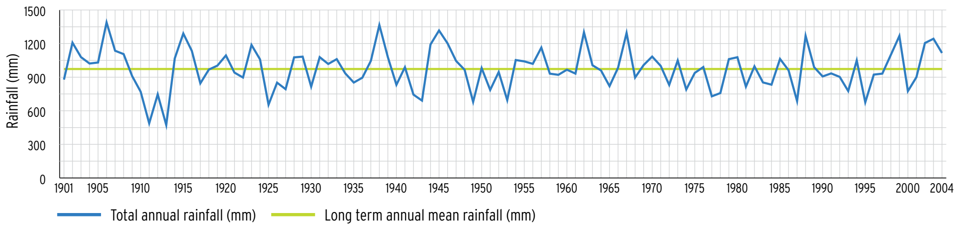
3 Annual rainfall pattern - Bor



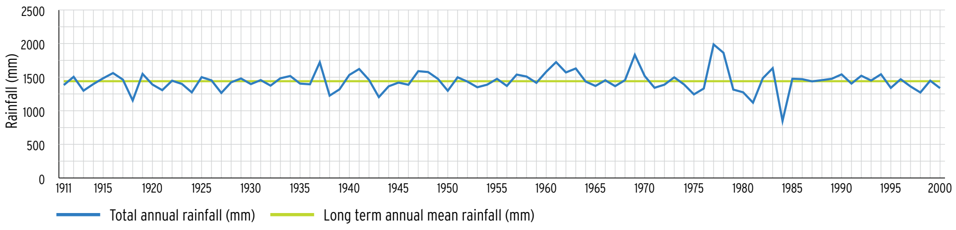
4 Annual rainfall pattern - Fangak



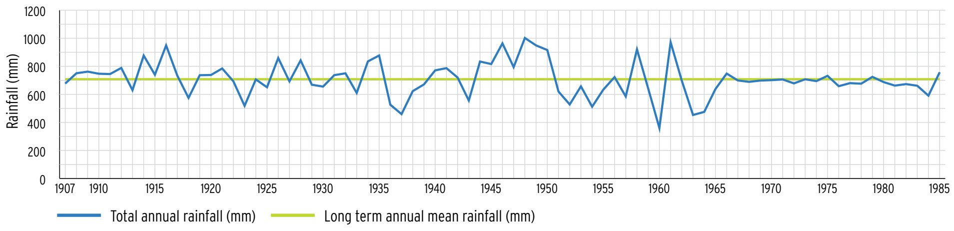
5 Annual rainfall pattern - Juba



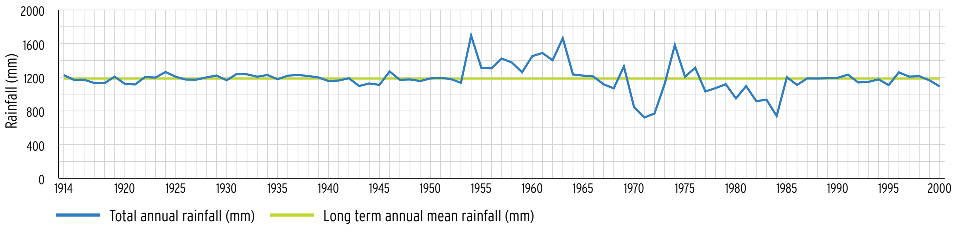
6 Annual rainfall pattern - Patiko



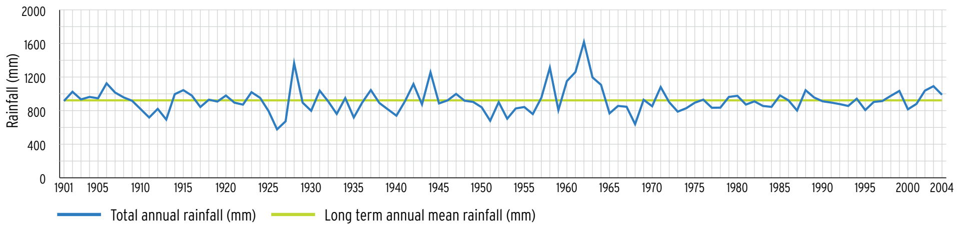
7 Annual rainfall pattern - Shambe



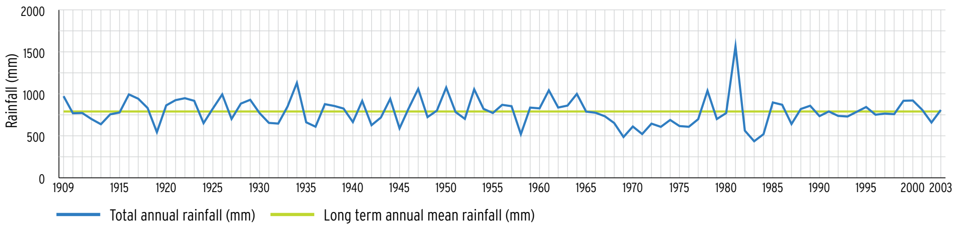
8 Annual rainfall pattern - Tambura



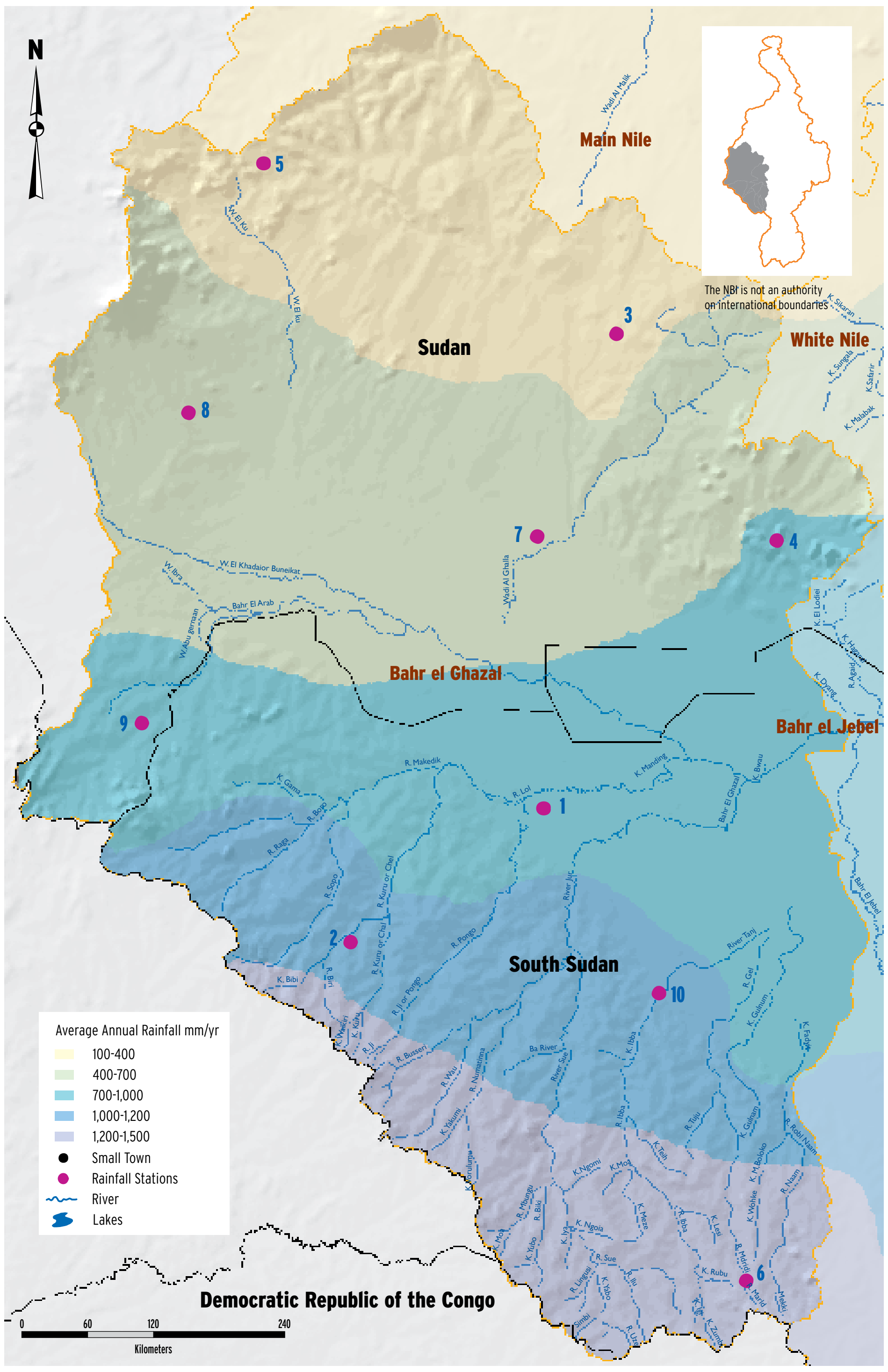
9 Annual rainfall pattern - Terakeka



10 Annual rainfall pattern - Tolodi



Annual rainfall patterns – Bahr el Ghazal sub-basin



The rainfall stations within the Bahr el Ghazal exhibit high inter annual variation together with spatial variation in amounts.

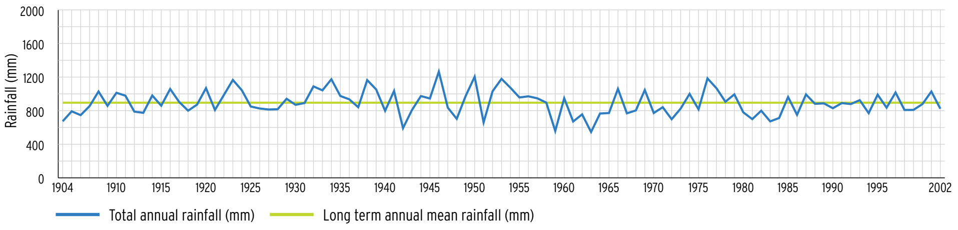
Stations in Sudan record mean annual values of about 500mm whereas those in South Sudan receive on average 900mm of rain.

> The Bahr el Ghazal basin is a large and highly complex, where evaporation in its downstream swamps makes it almost an endoergic system. The rainfall of 1200-1400mm in the upper basin is the highest in the Sudan and gives rise to a number of seasonal tributaries, which converge towards the confluence of the Bahr el Ghazal with the White Nile. While collecting a large amount of runoff, the flows of the different tributaries are mostly spilled into swamps and floodplains along the river course where they evaporate. Only a negligible amount of flow reaches the Bahr el Jebel at Lake No. The Bahr el Ghazal is therefore unique among the Nile tributaries in that its outflow to the White Nile is almost negligible.

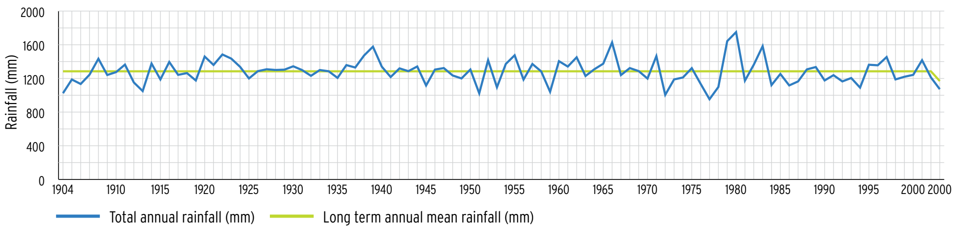
Station Identification

Station Name	Label No.	Record Length	Station Name	Label No.	Record Length
Aweil	1	1904-2002	Meridi	6	1901-2004
Deim Zubeir	2	1904-2002	Muglad	7	1911-2006
En Nahud	3	1909-2011	Nyala	8	1911-2006
Kadugli	4	1909-2011	Radom	9	1943-1993
Mellit	5	1950-1988	Tonj	10	1904-2002

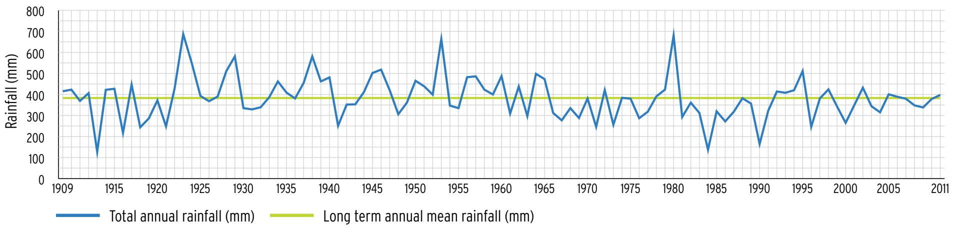
1 Annual rainfall pattern - Aweil



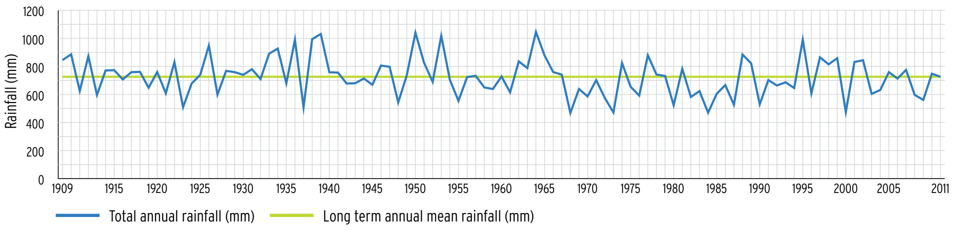
2 Annual rainfall pattern - Deim Zubeir



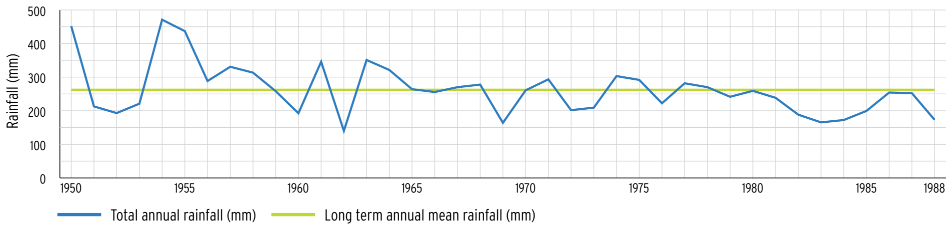
3 Annual rainfall pattern - En Nahud



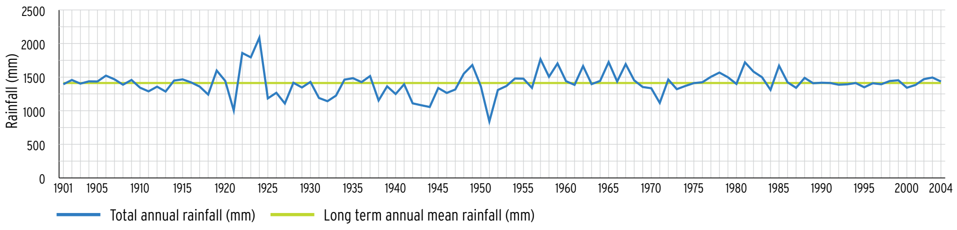
4 Annual rainfall pattern - Kadugli



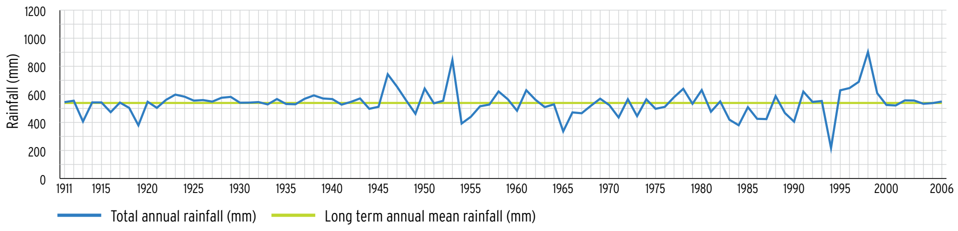
5 Annual rainfall pattern - Mellit



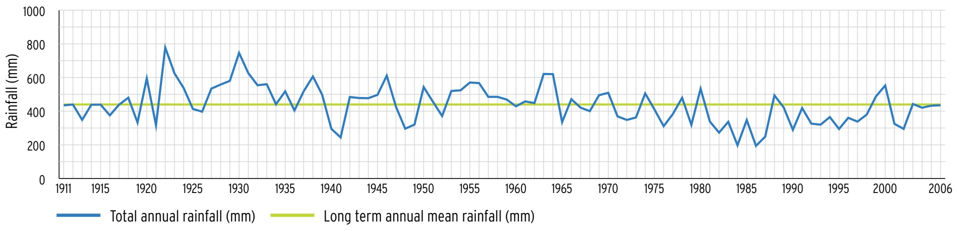
6 Annual rainfall pattern - Meridi



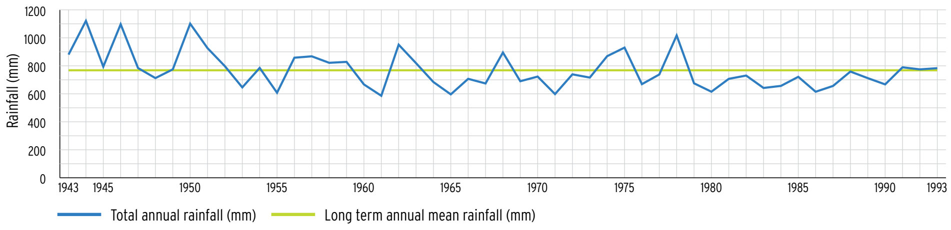
7 Annual rainfall pattern - Muglad



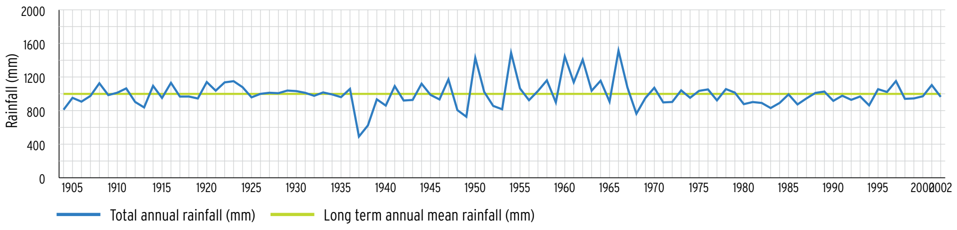
8 Annual rainfall pattern - Nyala



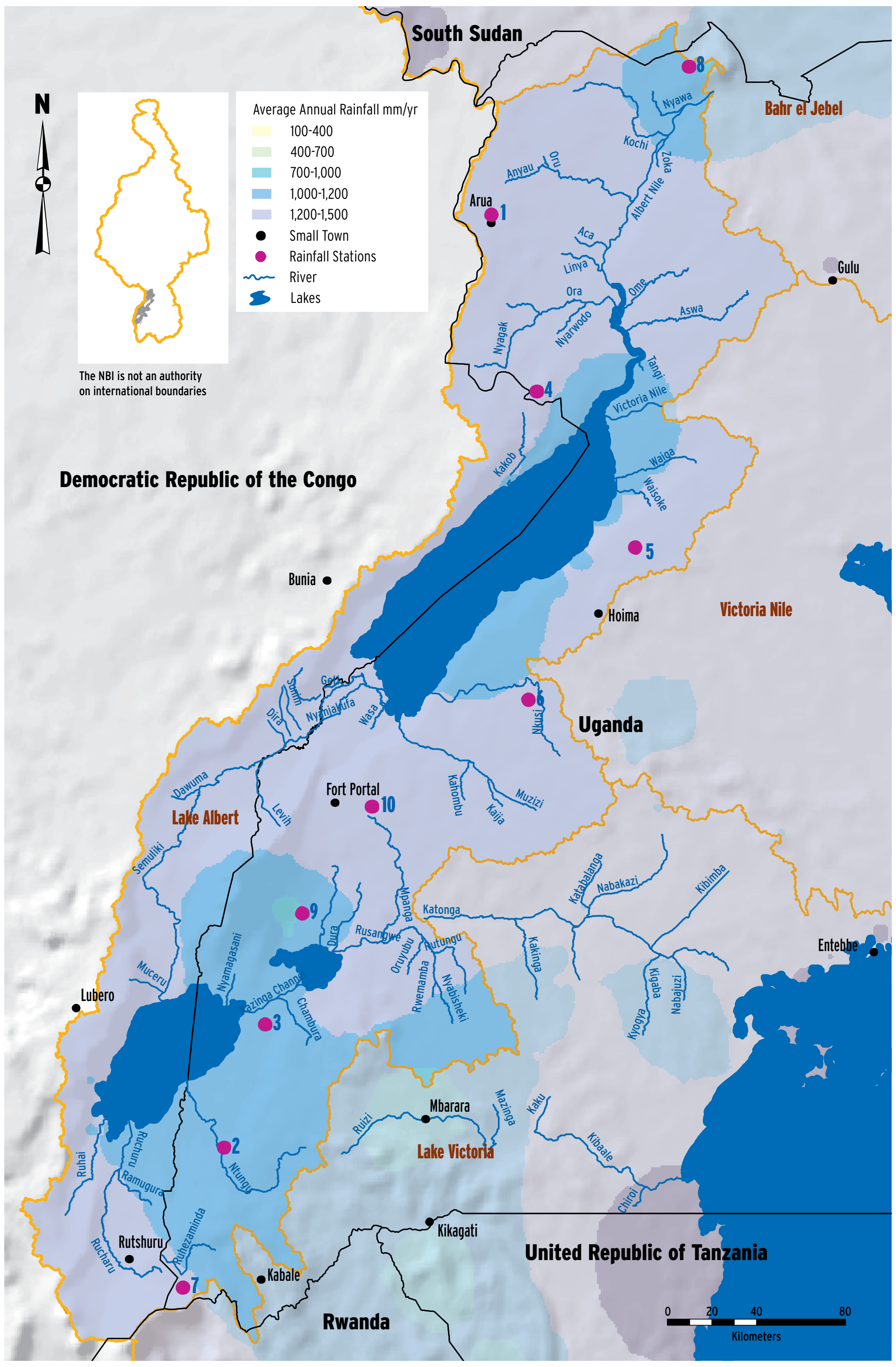
9 Annual rainfall pattern - Radom



10 Annual rainfall pattern - Tonj



Annual rainfall patterns - Lake Albert Sub-basin

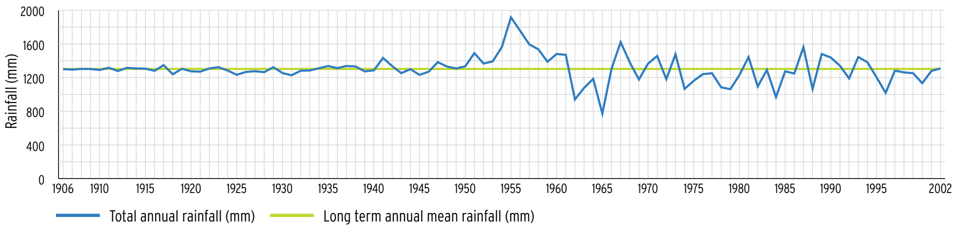


The average annual rainfall within the Lake Albert sub-basin is fairly constant with small inter-annual variations. However, there is a noticeable increment in rainfall amounts in the early 1960s'. This area is also influenced by the Rwenzori Mountains and most of the stations record a mean annual rainfall of over 1,200mm apart from the Mubuku, whose case is not clear.

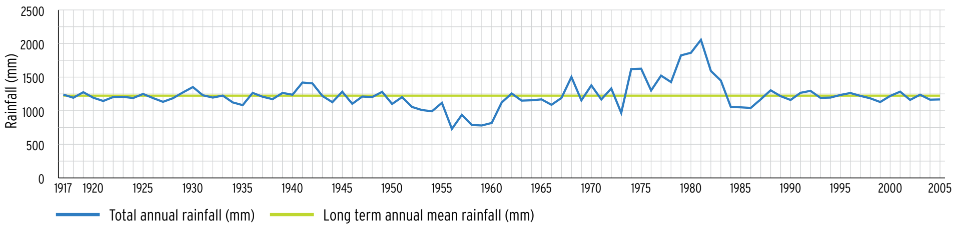
Station Identification

Station Name	Label No.	Record Length	Station Name	Label No.	Record Length
Arua Met Station	1	1906-2002	Kiryanga Gombolola	6	1940-1979
Bugangari Dispensary	2	1917-2005	KISORO	7	1910-2005
Bunyaruguru	3	1903-2003	Moyo Boma	8	1938-2000
Erusi Forest Station	4	1904-2002	Mubuku Giant prison Farm	9	1900-2005
IHUNGU	5	1906-2001	Rwebitaba Tea Res Station	10	1911-2005

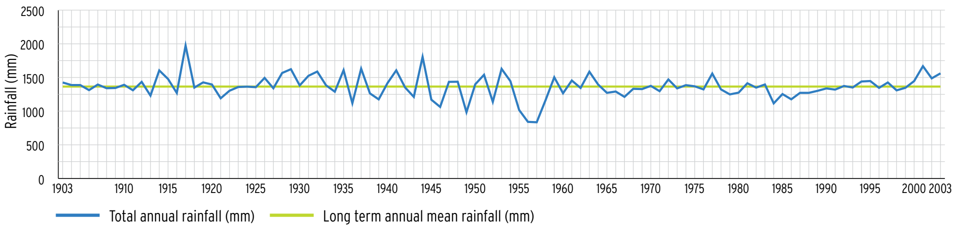
1 Annual rainfall pattern - Arua



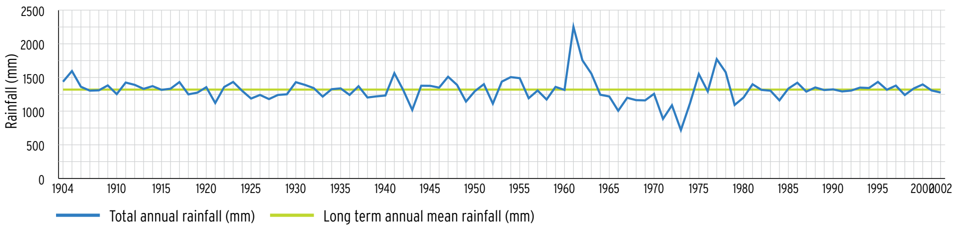
2 Annual rainfall pattern - Bugangari



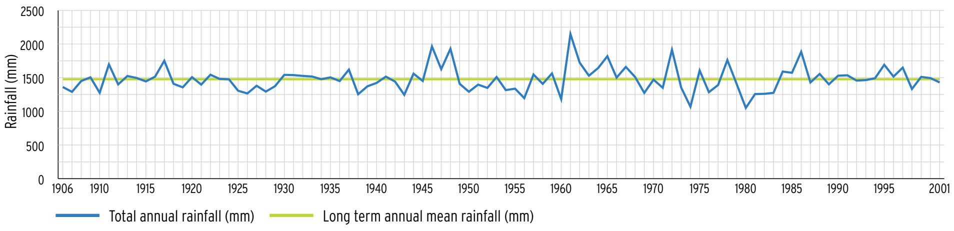
3 Annual rainfall pattern - Bunyaruguru



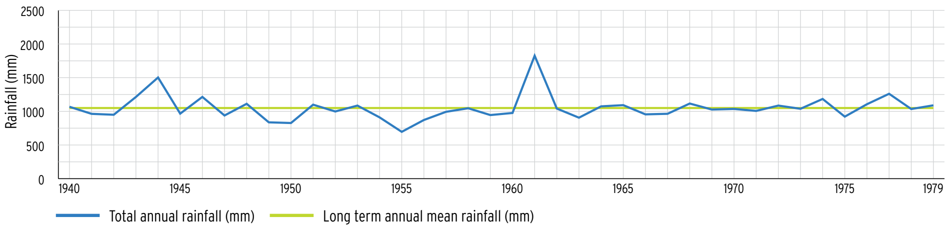
4 Annual rainfall pattern - Erusi



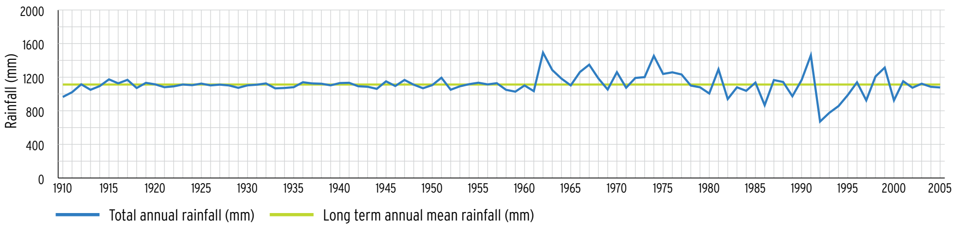
5 Annual rainfall pattern - Ihungu



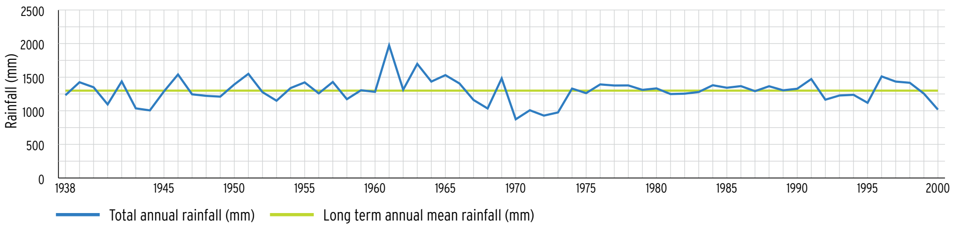
6 Annual rainfall pattern - Kiryanga



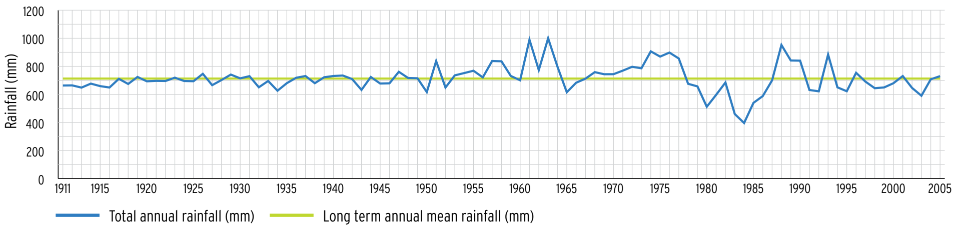
7 Annual rainfall pattern - Kisoro



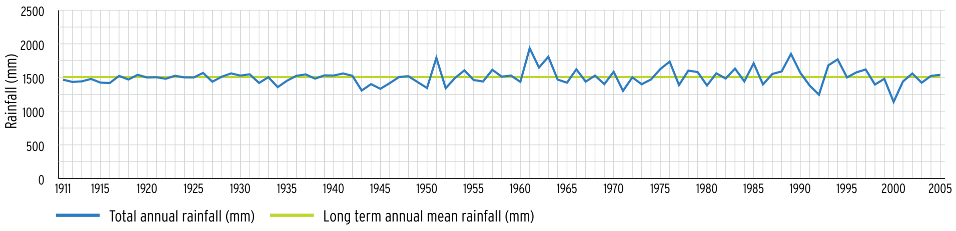
8 Annual rainfall pattern - Moyo Boma



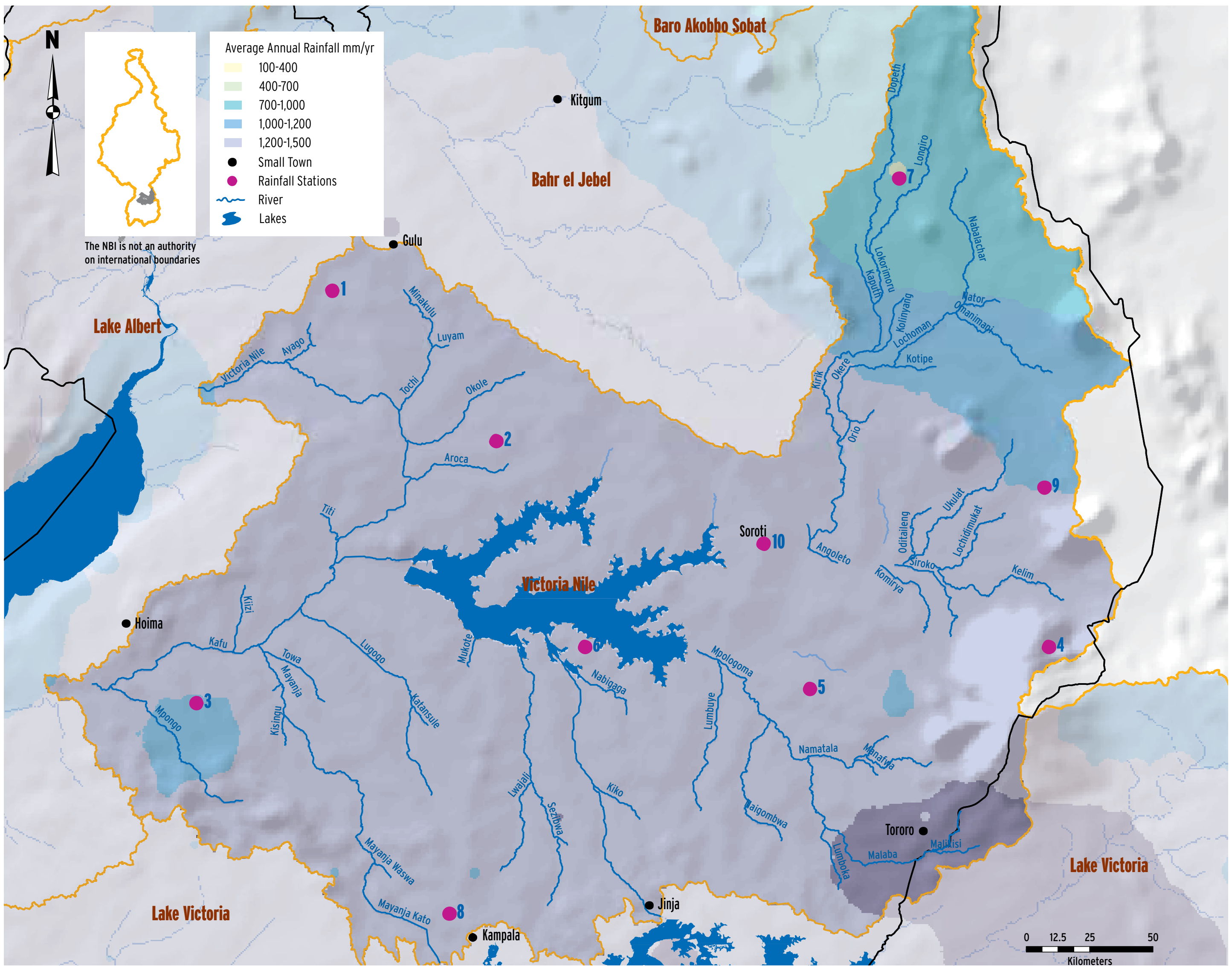
9 Annual rainfall pattern - Mubuku



10 Annual rainfall pattern - Rwebitaba



Annual rainfall patterns – Victoria Nile Sub-basin

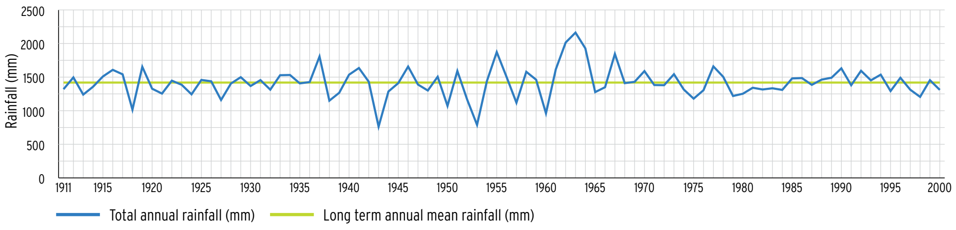


The mean annual rainfall within the Victoria Nile sub-basin is seen to exhibit high inter-annual variation with a vivid increase in the 1960s for most of the stations. Stations in the north eastern part of Uganda are seen to register almost half of the rainfall amounts recorded in the upstream stations, just downstream of Lake Victoria. The upper part of the sub-basin; downstream of Lake Victoria, records mean annual rainfall in excess of 1,300mm whereas the north eastern part of the Sub-basin records about 700mm.

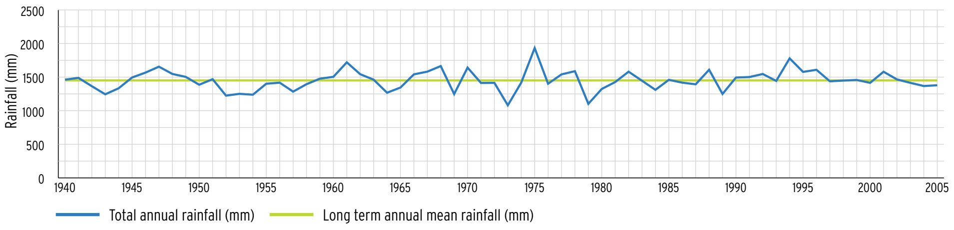
Station Identification

Station Name	Label No.	Record Length
Amar	1	1911-2000
Aninolal Mechanised Div	2	1940-2005
Butemba	3	1940-1981
Kapkwta Forest Station	4	1908-2004
Kibale	5	1900-2004
Kidera	6	1915-2006
Kotido	7	1922-2004
MATUNGA	8	1943-2005
Napianyenya	9	1908-2004
Soroti Met Station	10	1908-2004

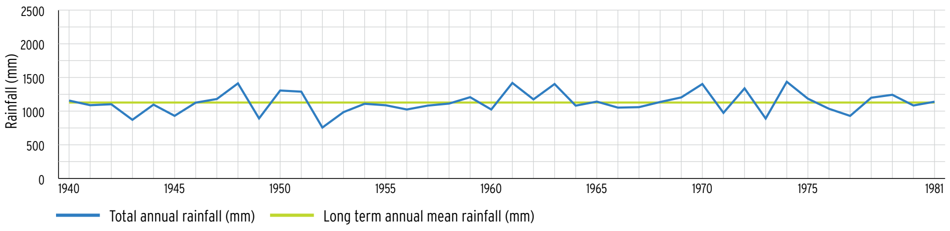
1 Annual rainfall pattern - Amart



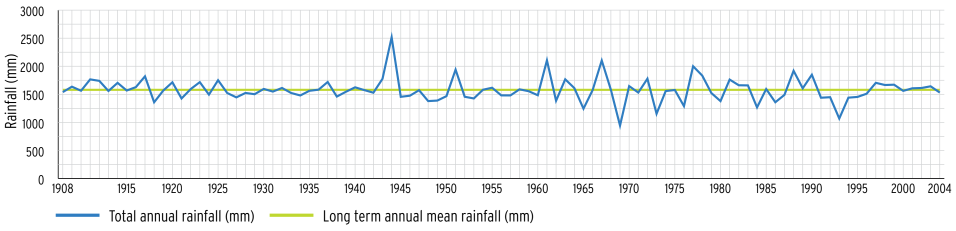
2 Annual rainfall pattern - Aninolal



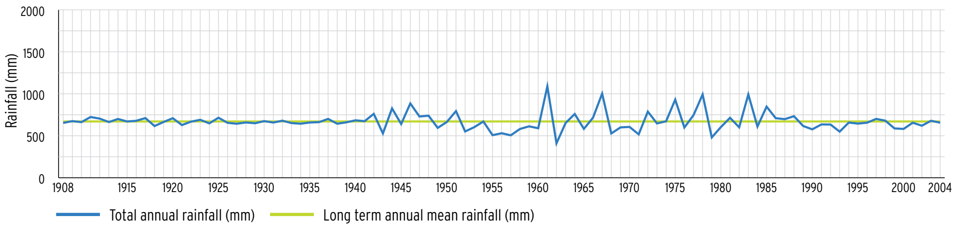
3 Annual rainfall pattern - Butemba



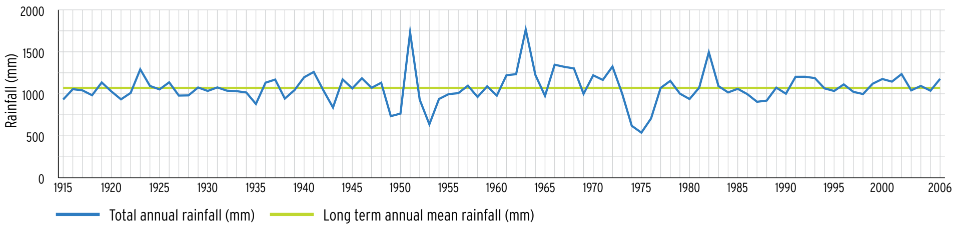
4 Annual rainfall pattern - Kapkwta



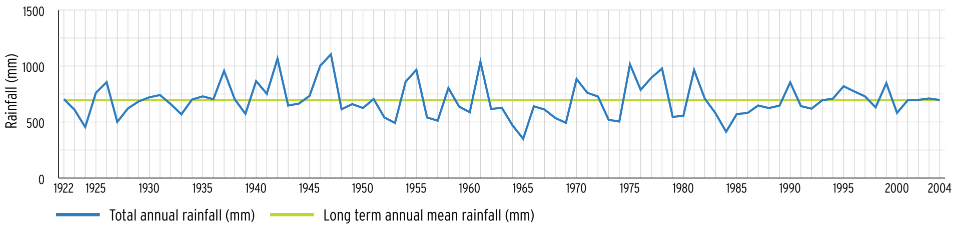
5 Annual rainfall pattern - Kibale



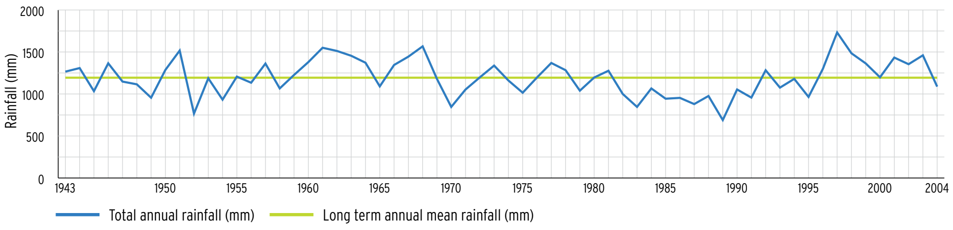
6 Annual rainfall pattern - Kidera



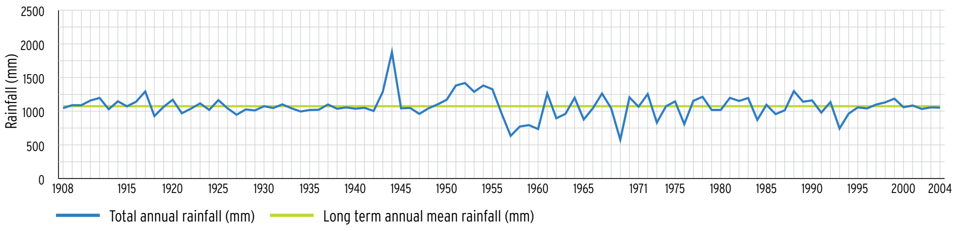
7 Annual rainfall pattern - Kotido



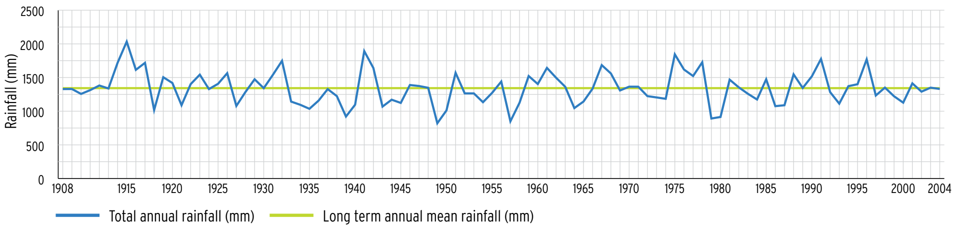
8 Annual rainfall pattern - Matunga



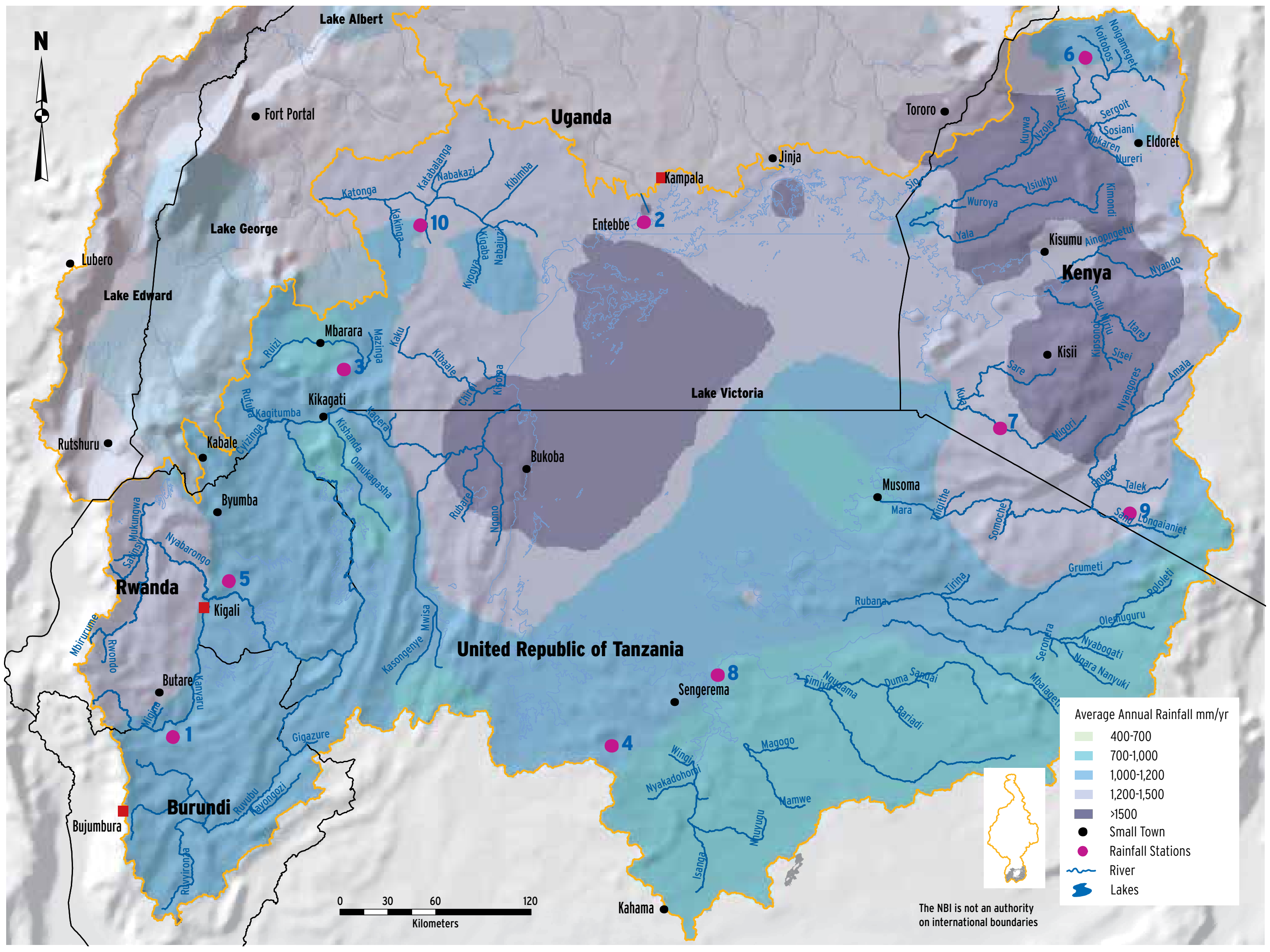
9 Annual rainfall pattern - Napianyenya



10 Annual rainfall pattern - Soroti



Annual rainfall patterns - Lake Victoria Sub-basin

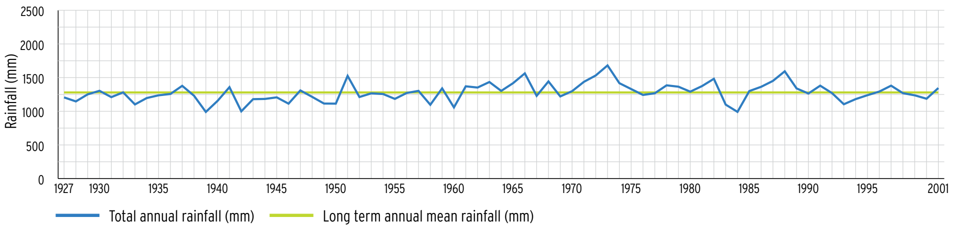


Generally, most of the rainfall stations within the Lake Victoria sub-basin record annual rainfall amounts in excess of 1,000mm with some (in the western part of the sub-basin) going up to as high as 1,600mm. Apart from the noticeable increment in the early 1960s, there is relatively small inter annual variations in rainfall recorded within the basin. This rainfall is a very important component of the Lake Victoria water balance as it is believed to balance evaporation over the lake.

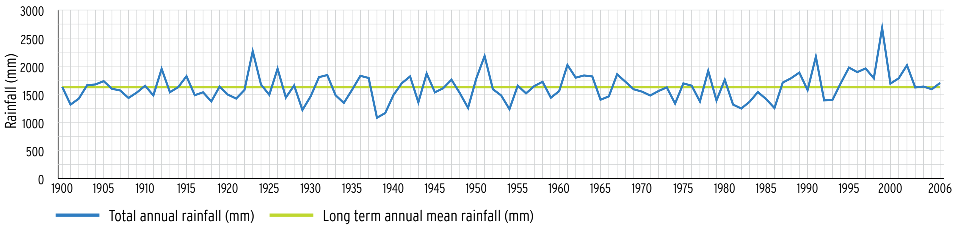
Station Identification

Station Name	Label No.	Record Length
Buye	1	1927-2001
Entebbe	2	1900-2006
Gayaza Isingiro	3	1917-2005
Geita, District Off.	4	1902-2004
Kigali Aero Nyabarongo	5	1960-2005
Kitale Meteorological Station	6	1908-2004
Migori Agric. Off.	7	1911-2004
Mwanza Met	8	1943-2005
Narok, Keekorok Game Lodge	9	1908-2004
Ntusi	10	1908-2004

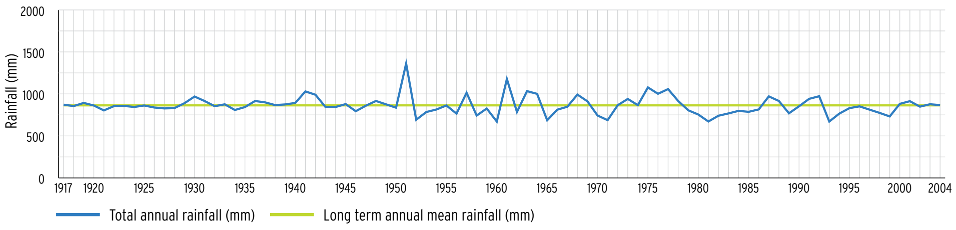
1 Annual rainfall pattern - Buye



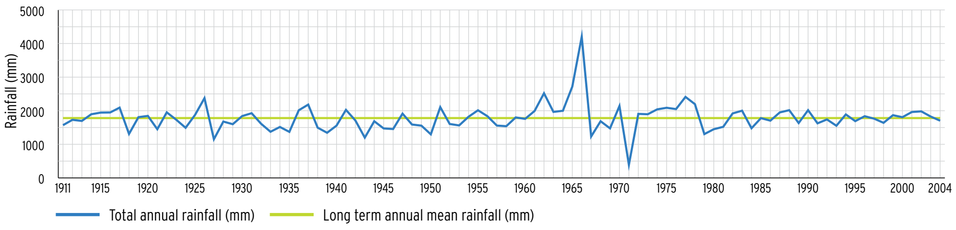
2 Annual rainfall pattern - Entebbe



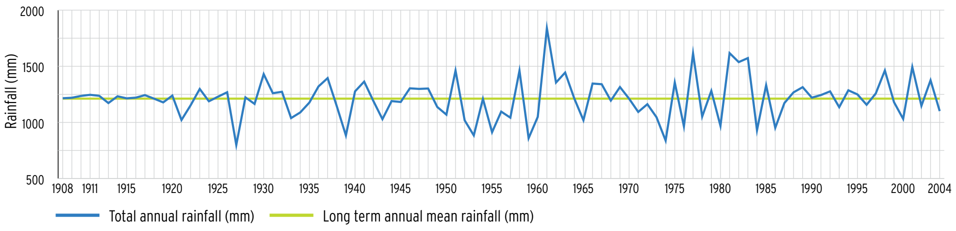
3 Annual rainfall pattern - Gayaza



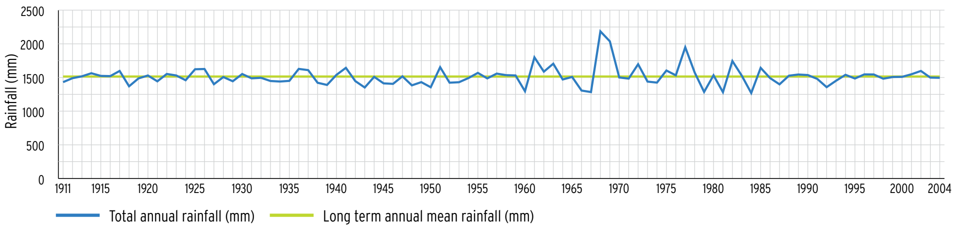
4 Annual rainfall pattern - Geita



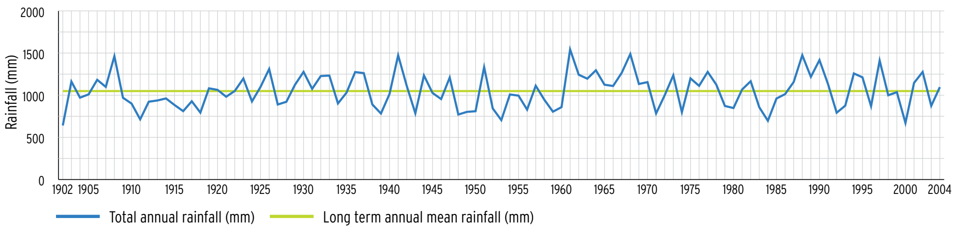
5 Annual rainfall pattern - Kitale



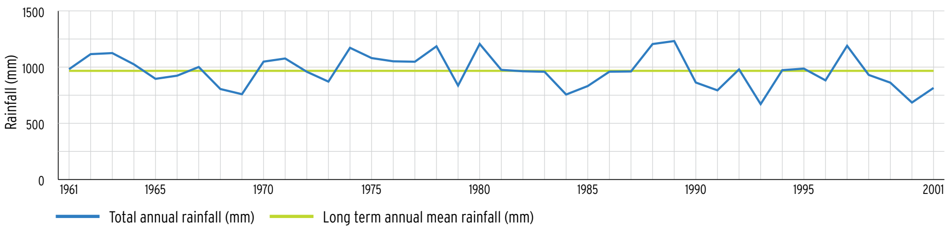
6 Annual rainfall pattern - Migori



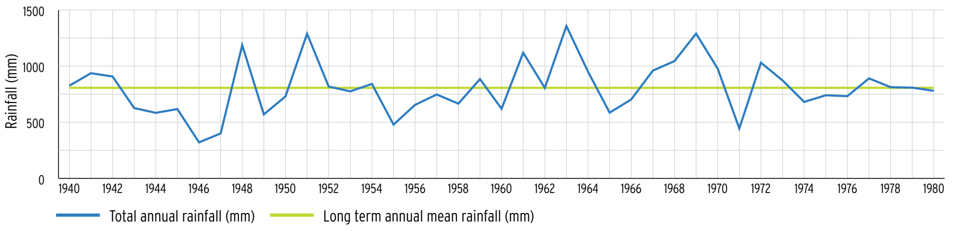
7 Annual rainfall pattern - Mwanza



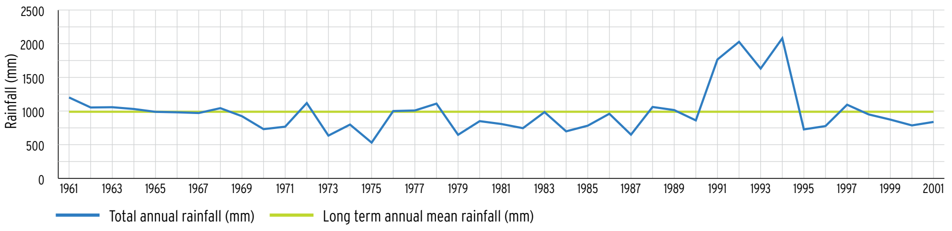
8 Annual rainfall pattern - Narok Keekorok



9 Annual rainfall pattern - Ntusi



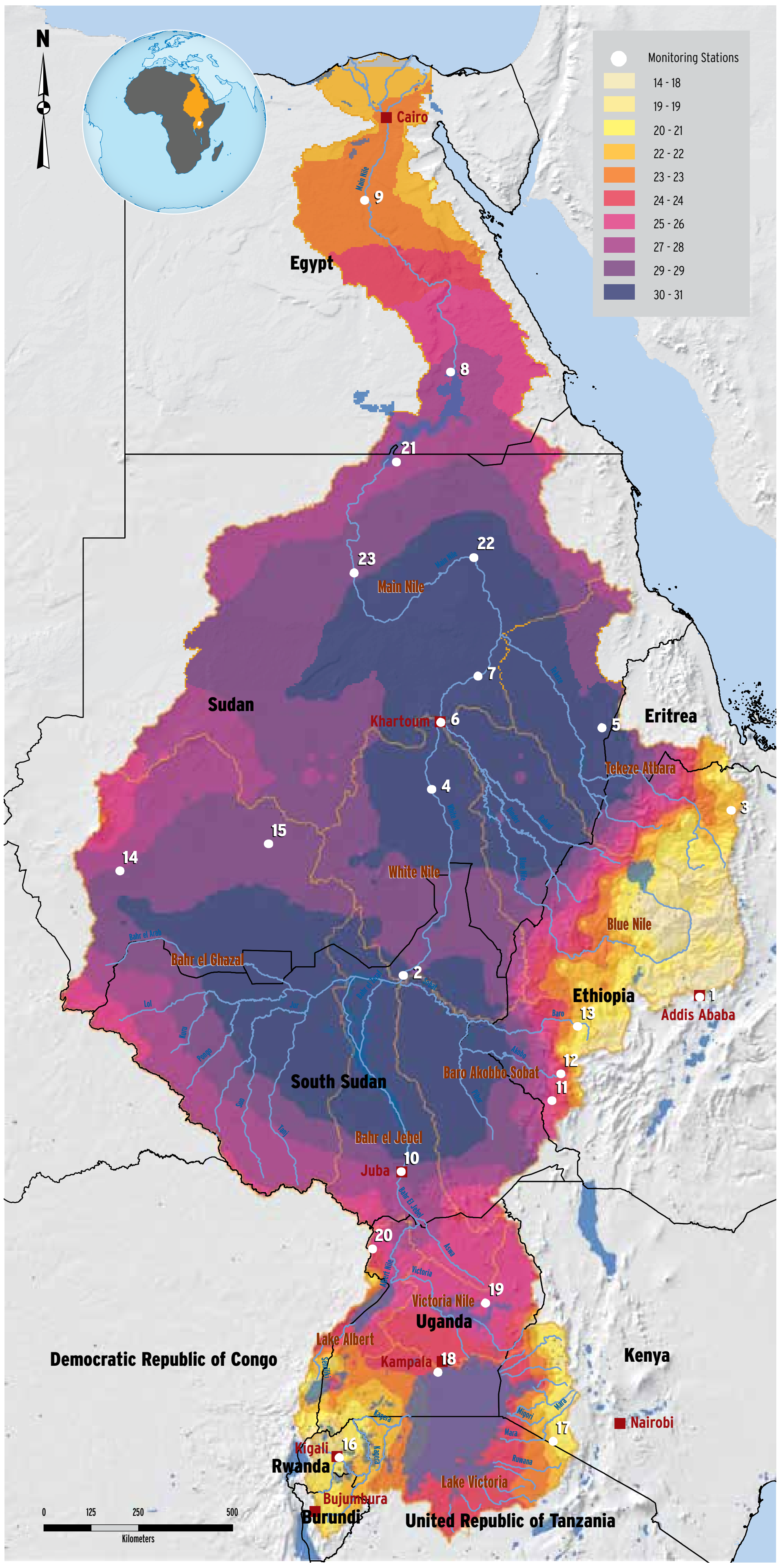
10 Annual rainfall pattern - Seronera



TEMPERATURE

The map below is the average temperature as derived from CRU data for the years 2000 – 2013 together with observed temperature data for selected stations within the basin. Generally, there is a wide variation in temperature across the basin with the equatorial lakes region and the Ethiopian highlands receiving maximum temperatures of up to 30ºC and the main Nile, parts of the Blue Nile, Tekeze Atbara and the White Nile in Sudan receiving maximum temperatures of up to 45ºC. The most downstream part of the basin, close to the sea also received relatively low temperatures compared to the other parts of the main Nile, with maximums of about 38ºC.

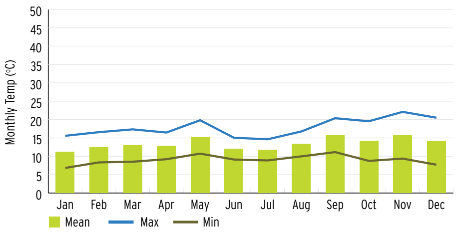
Station Name	Label No.	Station Name	Label No.	Station Name	Label No.	Station Name	Label No.	Station Name	Label No.	Station Name	Label No.	Station Name	Label No.	Station Name	Label No.
Addis Ababa	1	Ed-Dueim	4	Shendi	7	Juba	10	Yayu	13	Kigali	16	Soroti	19	Abu Hamad	22
Malakal	2	Kassala	5	Asswan	8	Mizan Teferi	11	Nyala	14	Narok	17	Arua	20	Dongola	23
Mekelle	3	Khartoum	6	Minya	9	Tepi	12	En Nahud	15	Entebbe	18	Wadi Halfa	21		



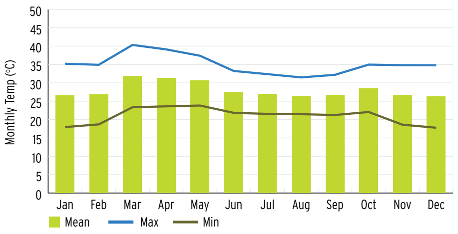
As with rainfall, temperature exhibits temporal and spatial differences over the basin. There are larger variations in temperature in the arid regions of northern Sudan and most of Egypt, with smaller deviations around the equator (Mohammed 2006).


Photo: istock

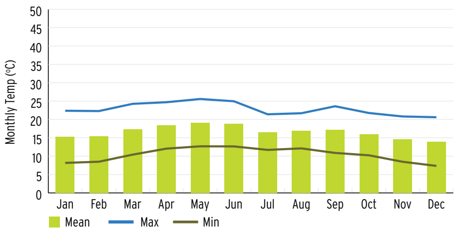
1 Addis Ababa: 2004 - 2008



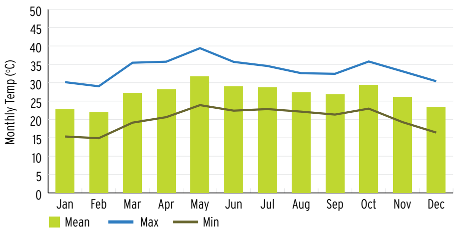
2 Malakal: 1950-1999



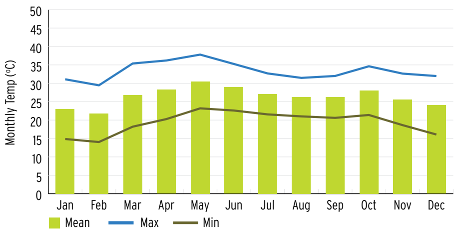
3 Mekelle: 1964-1994



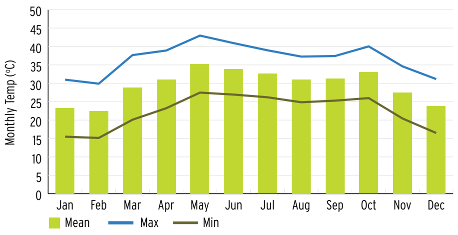
4 Ed Dueim: 1950-1999



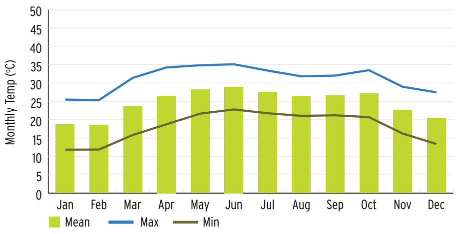
5 Kassala: 1950-2008



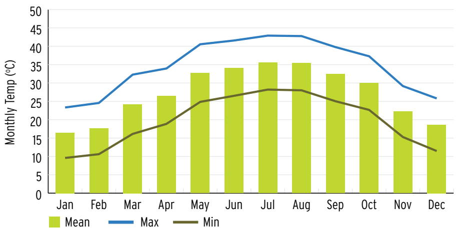
6 Khartoum: 1950-1999



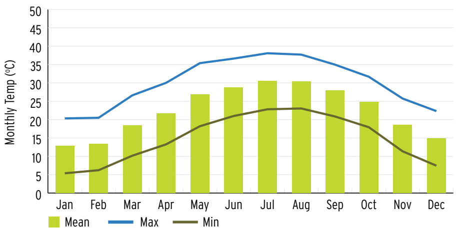
7 Shendi: 1950-1999



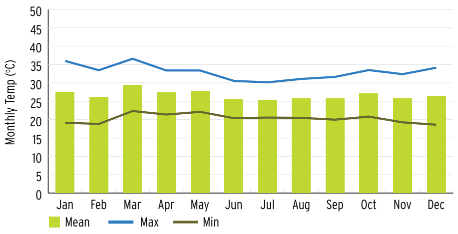
8 Asswan: 2004-2008



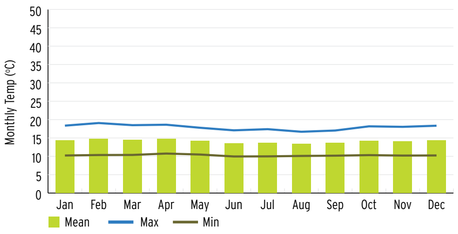
9 Minya: 2004-2008



10 Juba: 1950-1999



11 Mizan Teferi: 1977-1988



12 Tepi: 1981-1988

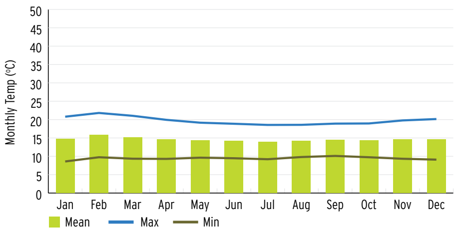
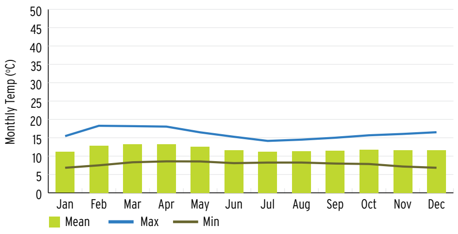
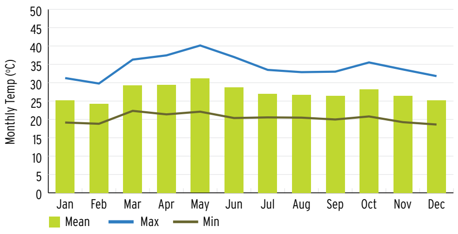


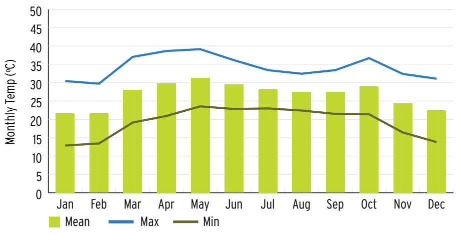
Photo: istock



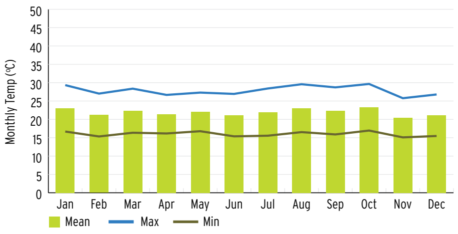
13 Yayu: 1982-1988



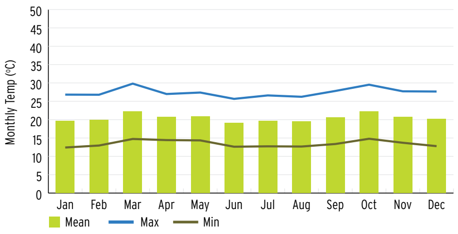
14 Nyala: 1950-1999



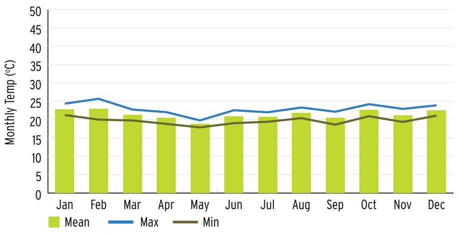
15 En Nahud: 1950-1999



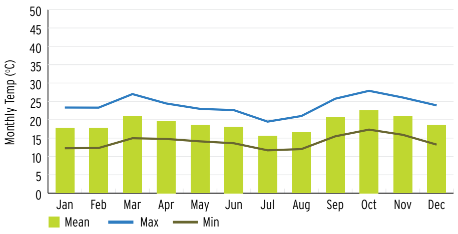
16 Kigali: 1971-2000



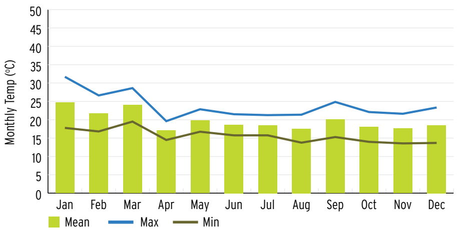
17 Narok: 1970-1990



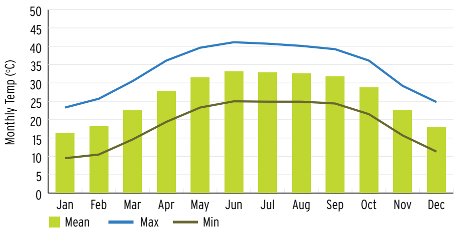
18 Entebbe: 1960-2000



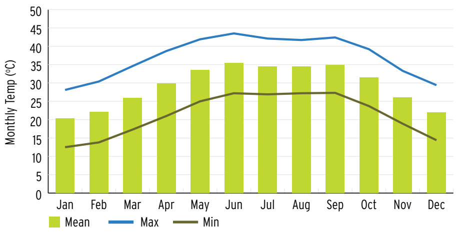
19 Soroti: 2004-2008



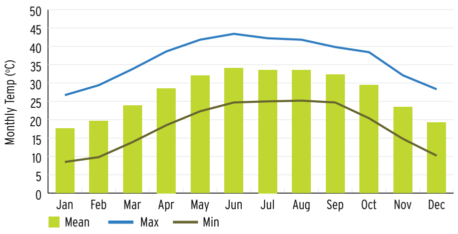
20 Arua: 1992-2000



21 Wadi Halfa



22 Abu Hamad



23 Dongola

CHANGES IN TEMPERATURE AND RAINFALL

The earth scale temperature rise estimated in the IPCC reports ranges between +1,4 to 6,4°C, depending on the model and scenario, with a mean increase of 2.8°C (1.7 to 2. 4°C) for the A1B scenario. Bates and others (2008) indicate that since the 1960s, temperatures over Africa have been increasing. And while this is the general trend, there are variations across the Nile basin. For instance, in Ethiopia, minimum temperatures have increased slightly faster than maximum or mean temperatures (Conway and others 2004). A summary of projected temperature trends for the Nile basin is shown in the table 1

The results show a clear trend towards higher temperatures in the Nile basin. There appears to be little difference between the seasons both for the central estimate and for the high and low estimates. The hydrological consequences of this trend is that evaporation in the Nile basin will rise, consequently the losses in the Nile basin will increase.

In the Nile Equatorial Lakes Region, projections indicate a positive evolution of the temperatures but the uncertainty about the intensity of this evolution is high. This uncertainty is mainly due to GHG scenarios The mean annual temperatures have increased by 1.0°C since 1960 in Kenya and Tanzania, 1.3°C in Uganda. Daily temperature observations for Uganda and Kenya show significantly increasing trends in the frequency of hot days, and much larger increasing trends in the frequency of hot nights. Between 1960 and 2003, the average number of 'hot' days per year increased by 57 (+15.6%) in Kenya, and by 74 (+20.4%) in Uganda (Source: UNDP Climate Change Countries Profiles). The average number of 'hot' nights per year increased by 113 (+31%) in Kenya, and by 136 (+37.4%) in Uganda. The frequencies of cold days and nights also significantly decreased (about -5% for the cold days, and -11% for the cold nights. Rising temperatures have implications for evaporation and evapotranspiration with impacts on water availability.

Climate studies in the NEL region recommend the use of results estimated in the SSEA study, for 2 SRES scenarios: A1B and A1FI and resumed in the table 2 (difference of temperature in °C between 1961-90 and 2100)

The trend for precipitation is very difficult to ascertain. Modelling outputs do not converge for the Nile basin and this results in a very wide range of possible trends: a significant fall to a significant rise in precipitation. The geographical variations can be significant and climate change in terms of precipitation must be evaluated at a local scale (ideally the river catchment). The extreme events - droughts, floods - will possibly be more frequent, but this cannot be verified by the present models and does not appear from historical analysis. A summary of projected temperature trends for the Nile basin is shown in table 3.

According to the central estimates, relatively small increases can be expected in annual rainfall. However, both magnitude and even the signal of the trends differ a lot between the seasons. For the winter period the central estimate envisages a large increase in rainfall. This will lead to a large increase in runoff from the equatorial lakes. For the runoff from the Ethiopian mountains the change in the period June, July, August is more important as this is the rainy period. In this period the change is a very small decrease. This decrease however has a relatively large effect on the inflow into Lake Nasser as 80% of the water origins from this area.

Strikingly, however is the huge range between the low and the high estimated changes, where even the signal, wetter or drier, conditions are not consistent. For the winter period, the overall picture is an increase in rainfall. For the summer period, the central estimate suggests a small decrease of the rainfall, the different models, however, vary substantially in their predictions, even in the direction of the signal. This uncertainty will be exacerbated in the resulting runoff changes due to the great sensitivity of the Nile discharge to rainfall variations.

Table 1: Temperature change (Celcius)

Year	Annual			DJF			JJA		
	low	central	high	low	central	high	low	central	high
2030	0.81	1	1.19	0.78	1	1.22	0.77	1	1.23
2050	1.13	1.4	1.67	1.18	1.5	1.82	1.17	1.5	1.83
2100	2.03	2.5	2.97	1.94	2.5	3.06	2.03	2.6	3.17

Table 2

Year	A1B scenario	A1FI scenario
DJF	2.5	4.1
MAM	3.1	4.9
JJA	3.5	5.8
SON	2.8	4.5
Annual	3.0	4.8

Table 1: Temperature change (Celcius)

Year	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	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

Possible future precipitation in the NEL Region

Through the synthetic results of the different GCMs, the NELSAP SSEA studies note that possible changes in terms of precipitations are less convergent than for temperatures. The studies indicate a range of variation for precipitation going from negative to significantly positive, with a global increasing trend for the annual precipitation. Model simulations show wide disagreements in projected changes in the amplitude of future El Niño events (Christensen et al., 2007). East Africa's seasonal rainfall can be strongly influenced by ENSO, and this contributes to uncertainty in climate projections, particularly in the future inter-annual variability, for this region. The SSEA study gives a percentage variation for precipitation for quarters.

The SSEA models project a global increase in precipitation, both annually and for each season. The largest percentage increase is projected for the dry months of June through August. The range is however relatively important for some quarters, in particular for the dry months (June to August), for which the wet model indicates negative trends.

Impacts of Climate Change on Evaporation

Although great uncertainty in terms of evaporation exists due to the uncertainty mainly regarding precipitation, the impact on evaporation seems to be significant but relatively small. The rise expected is of the order of 70 mm / year (0.2 mm/day), compared to actual evaporation of the order of 1000 mm/year (less than 10% /year variation).

Precipitation projections for area 5°N to 5° S by 25°E to 35°E (Southern NEL region) Changes are relative to the year 2000 (evolution for the period 2000 / 2050)

Year	A1B scenario			A1FI scenario
	Wet model	Average model	Dry model	Average model
DJF	85.5%	16.6%	4.5%	28.4%
MAM	4.8%	8.3%	10.8%	14.1
JJA	-13.6	16.3%	147.8%	17.5%
SON	-0.9%	3.7%	1.6%	11.5%
Annual	14.2%	7.4%	4.3%	17.5%

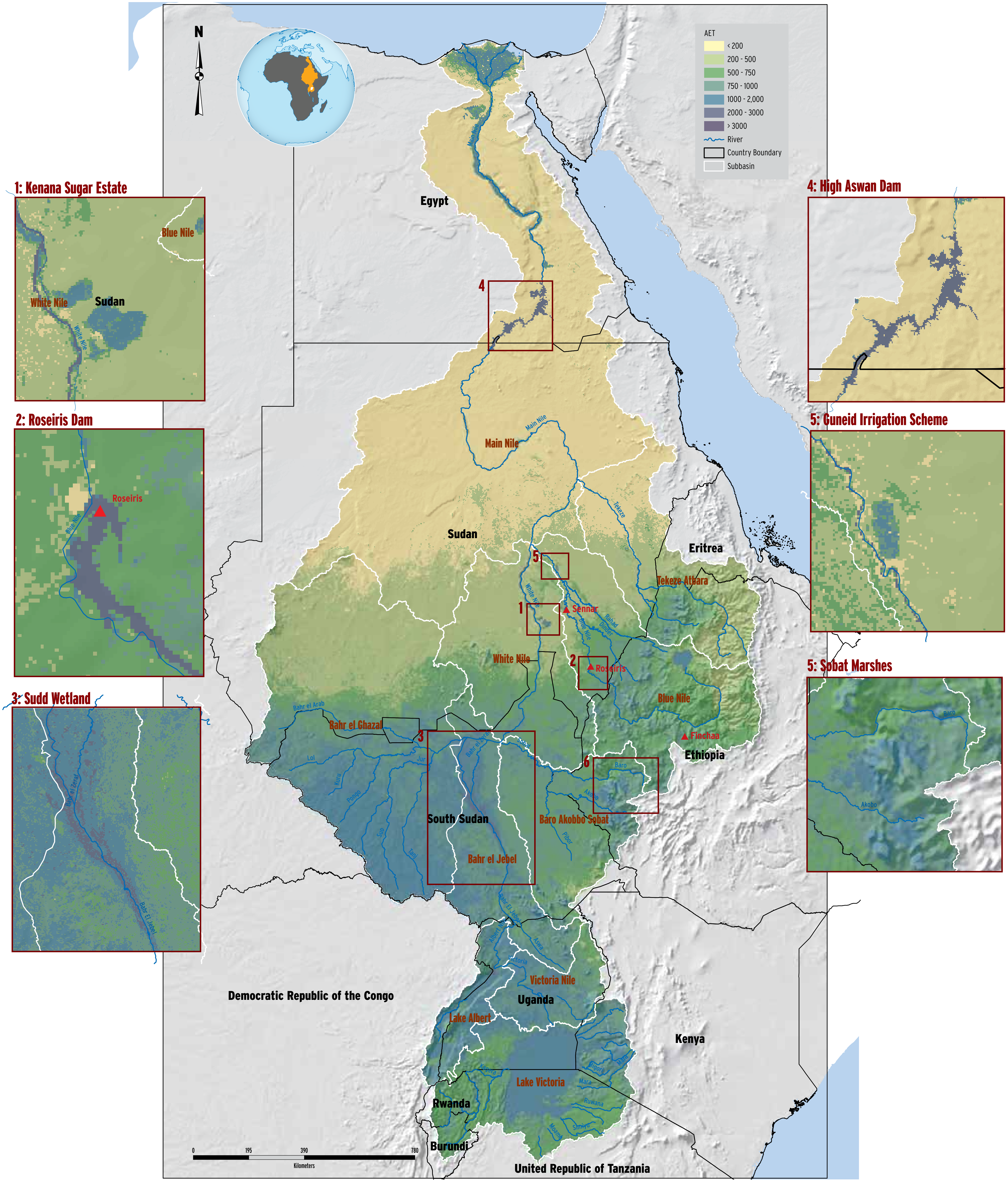
Precipitation projections for area 5°N to 5° S by 25°E to 35°E (Southern NEL region) Changes are relative to the year 2000 (evolution for the period 2000 / 2050)

Year	A1B scenario			A1FI scenario
	Wet model	Average model	Dry model	Average model
DJF	212.0%	28%	4.8%	52.7%
MAM	10%	16.4%	21.7%	28.4%
JJA	-10.4%	41.3%	518.3%	83.1%
SON	1.0%	8.5%	4.8%	14.6%
Annual	27.3%	13.8%	8.3%	24.0%

EVAPORATION AND EVAPOTRANSPIRATION

Evapotranspiration (ET), which is one of the major components of the water balance over the Nile basin, accounts for about 87% of the basins rainfall but varies from one sub-basin to another based on land use/cover and the prevailing climatic conditions. It is difficult to measure ET but recent advances in satellite observations have enabled its estimation over large areas such as the Nile basin. As seen from the maps provided, the Nile basin exhibits very wide ranges of evapotranspiration due to the variations in altitude and climate within the basin. Wetlands and irrigation schemes are seen to have a lot of evapotranspiration within the sub-basins where they belong. The Nile Basin also exhibits a wide range of evaporation depending on the location and size of the water body within the basin. The major open water bodies (Lakes and dams); Lake Victoria, Lake Nasser, Lake Tana, Lake Albert and Lake Kyoga are the major culprits to water loss in the basin due to evaporation.

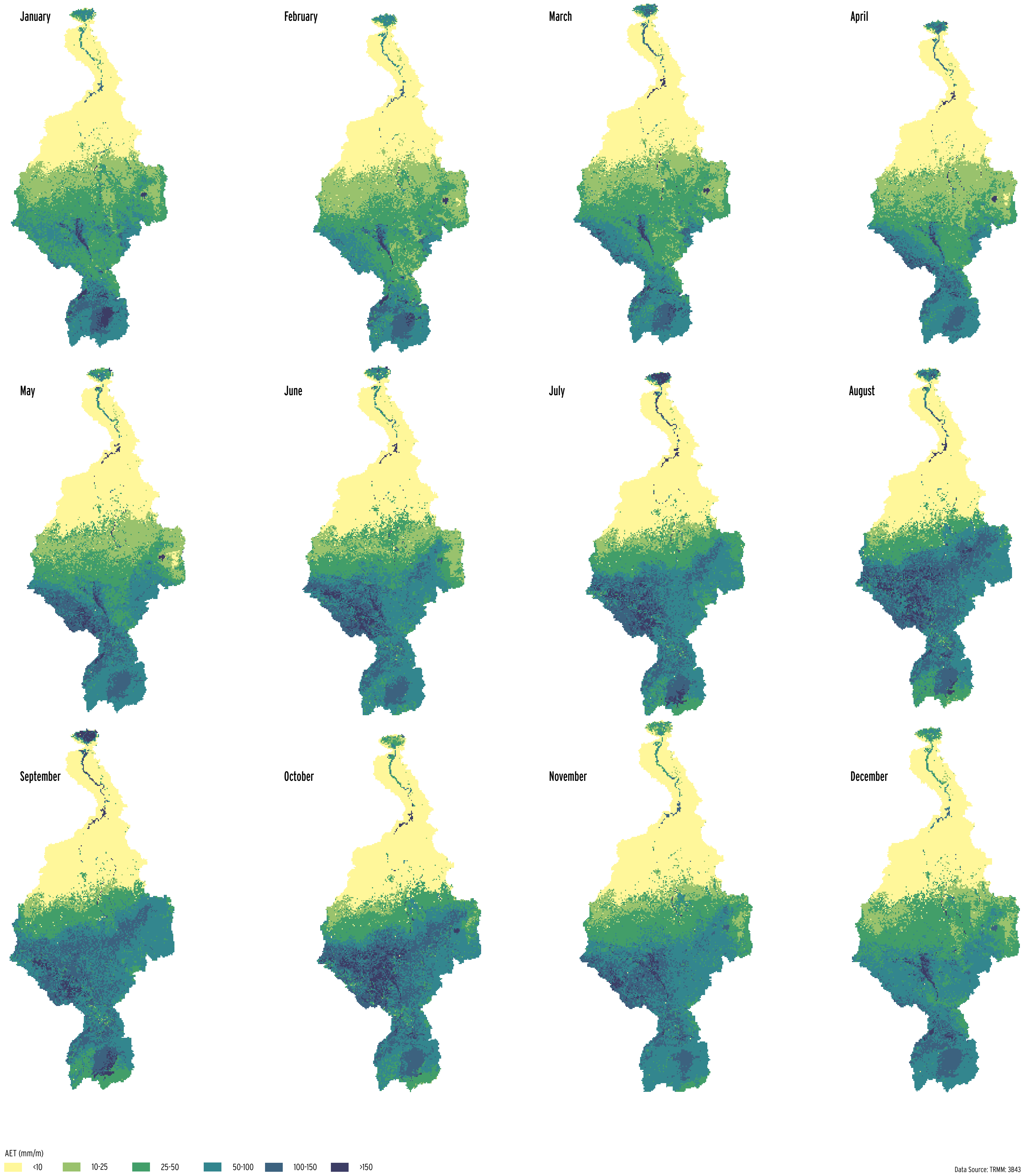
In this atlas, we present the mean annual actual evapotranspiration, the mean monthly actual evapotranspiration, and the actual evapotranspiration for lakes Victoria and Tana. From the maps, it can be observed that the equatorial lakes region and the Ethiopian highlands as well as the open water bodies have very high values of actual evapotranspiration compared to the downstream parts of the basin. These actual evapotranspiration maps are based on MOD16ET product for the period 2000 – 2012 prepared by the NBI.



MEAN MONTHLY ACTUAL EVAPOTRANSPIRATION FOR NILE BASIN

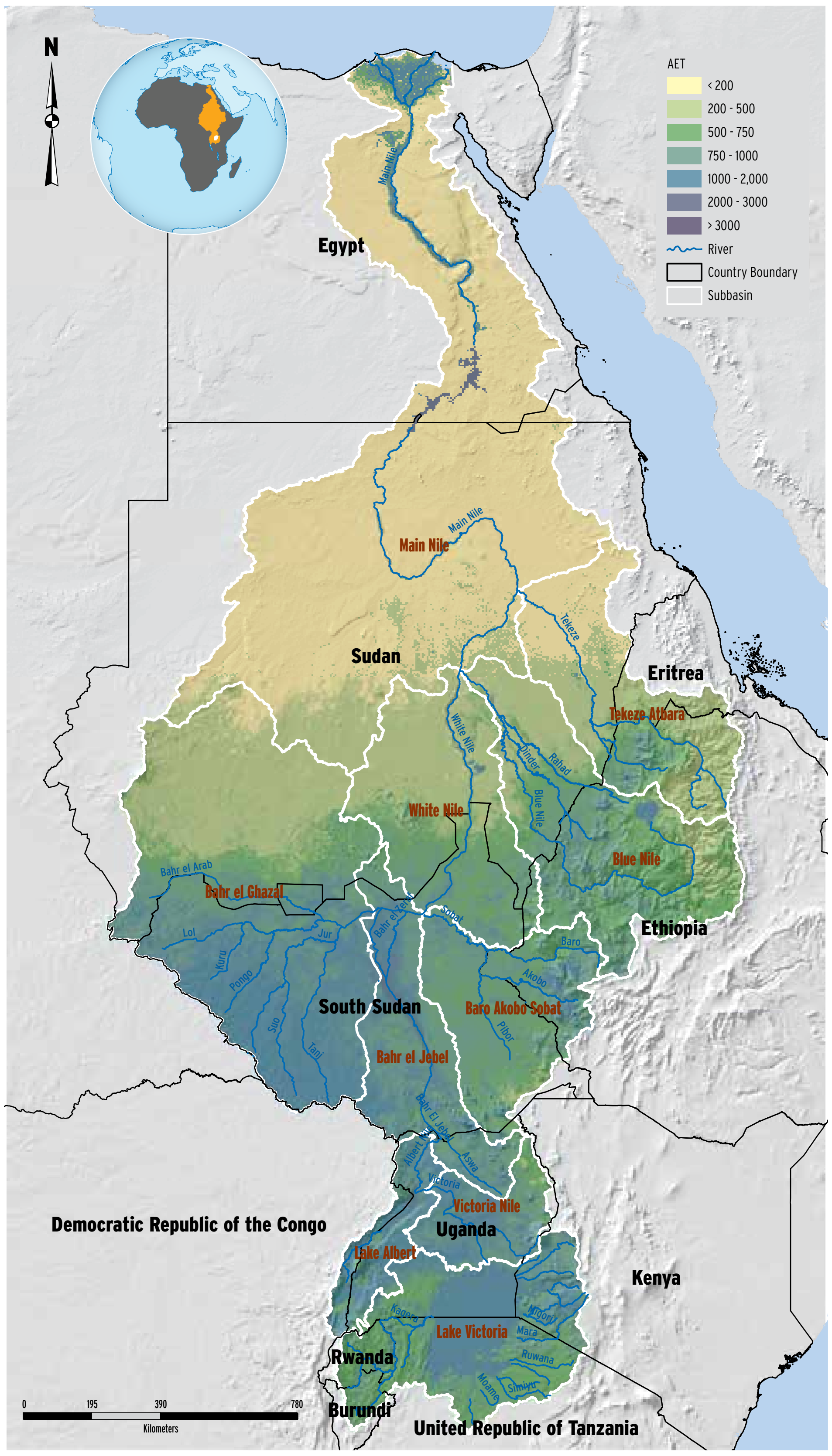
The mean monthly actual evapotranspiration presented in the map below shows a clear seasonal pattern, which follows the rainfall seasons within the basin. Within the equatorial lakes region and the Ethiopian highlands, which experience high losses due to evapotranspiration, it is seen that the highest actual evapotranspiration losses occur within the months of June – October with the highest being in August. Low values within this part of the basin are registered within the months December - February

AVERAGE MONTHLY ACTUAL EVAPOTRANSPIRATION OVER THE NILE BASIN

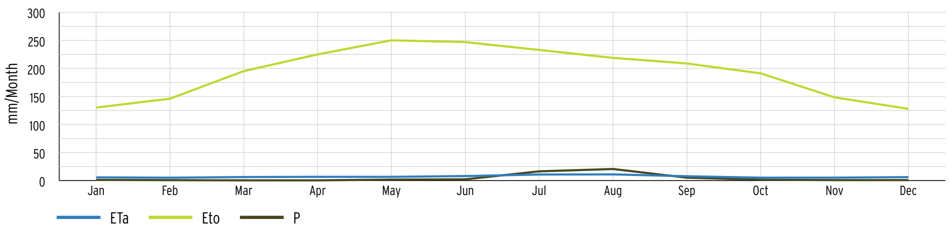


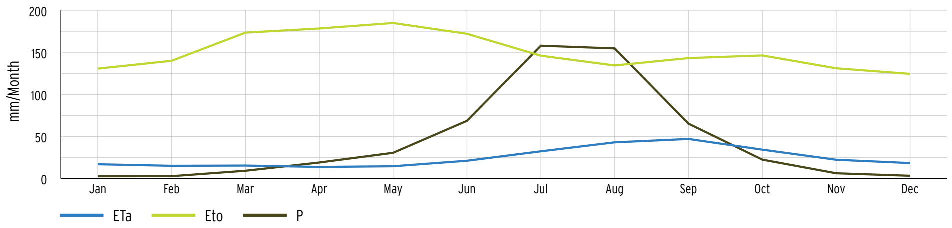
Data Source: TRMM: 3B43

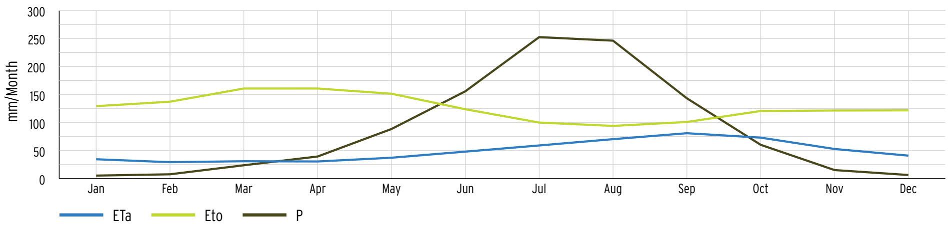
MEAN MONTHLY ACTUAL EVAPOTRANSPIRATION FOR SUB-BASINS

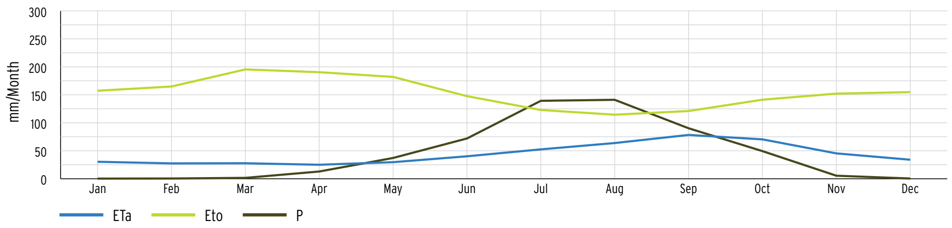


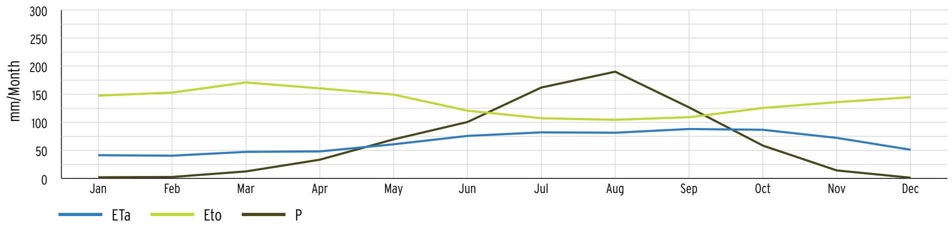
A comparison of the mean monthly actual evapotranspiration for the sub-basins within the Nile basin is presented here together with the precipitation and the potential evapotranspiration. The rainfall seasons can be seen on each of the sub-basin graphs. In some cases, the rainfall is much higher than both the actual and potential evapotranspiration, indicating a surplus apart from the main Nile. The equatorial lakes region shows a bimodal type of rainfall pattern (with peaks in April-May and October-November), and in both wet seasons, the rainfall exceeds the actual evapotranspiration whereas the eastern Nile has a unimodal pattern (with its peak in July-August) in which the rainfall exceeds the actual evapotranspiration during the wet season. The sub-basins with open water bodies, wetlands, and/or irrigation schemes exhibit higher evapotranspiration compared to the rest.

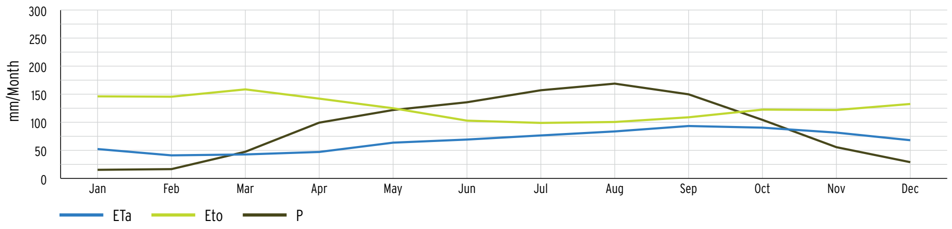

Main Nile

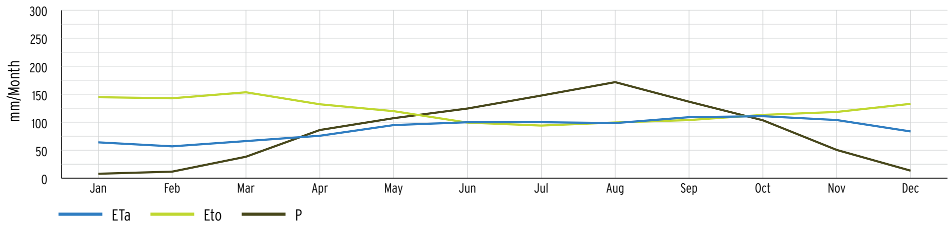

Tekeze Atbara

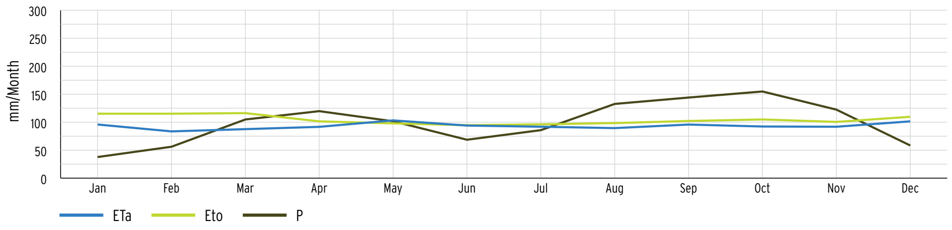

Blue Nile

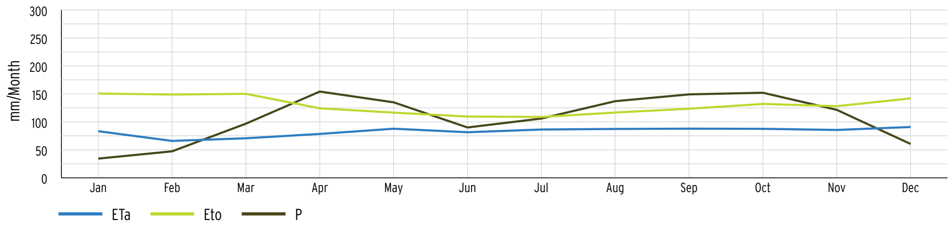

White Nile

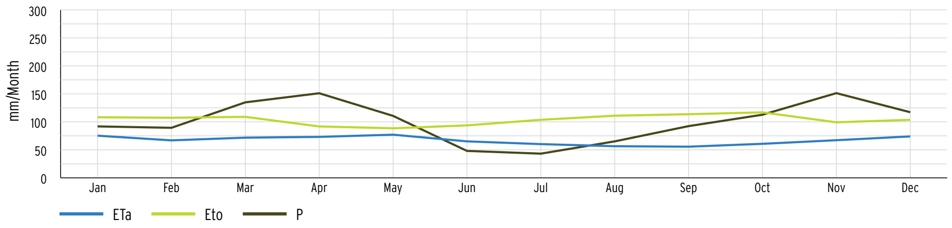

Bahr El Gazal


Baro Akobbo Sobat


Bahr El Jebel


Lake Albert


Victoria Nile

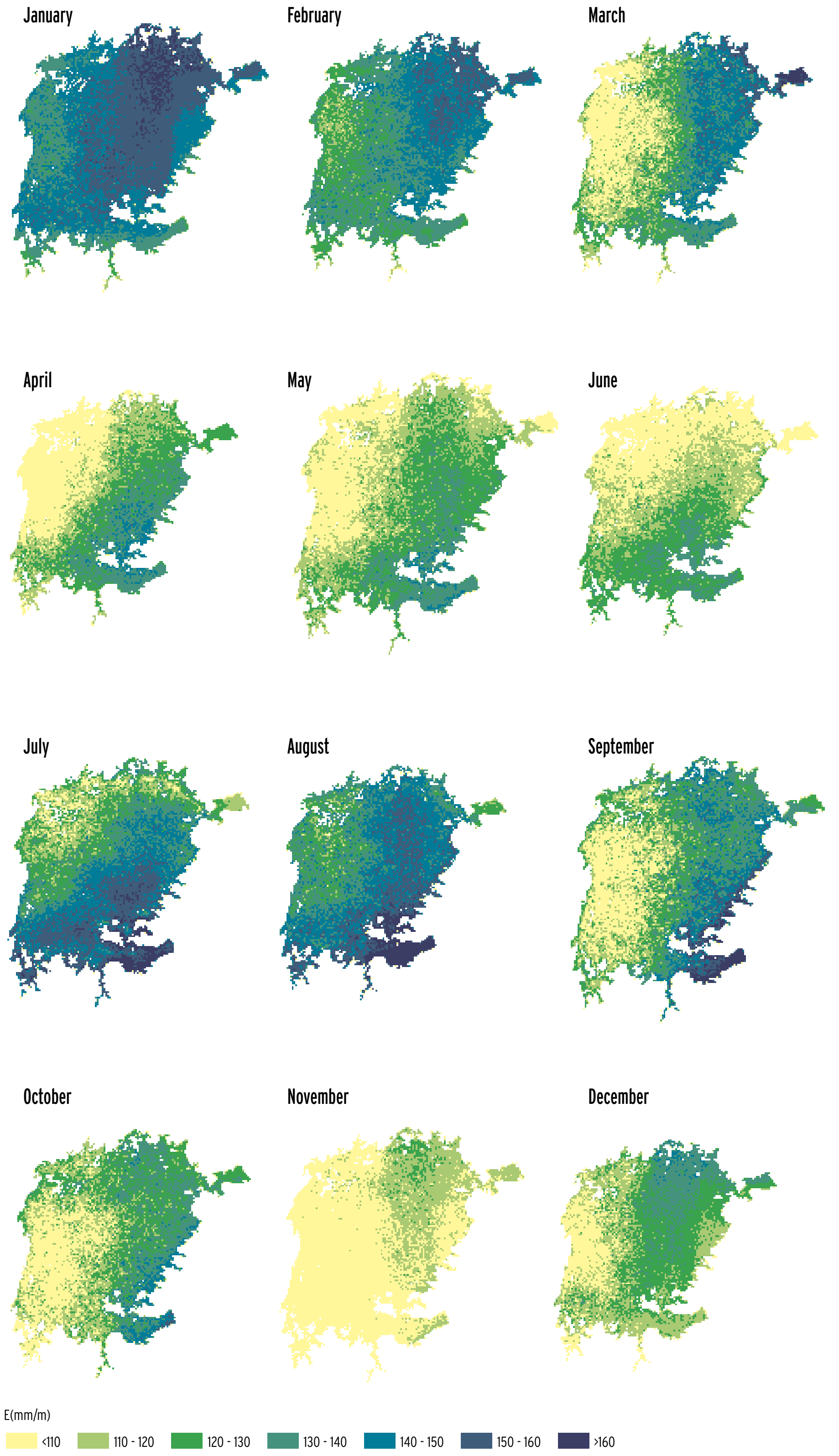

Lake Victoria

MEAN MONTHLY EVAPORATION OVER NILE BASIN LAKES

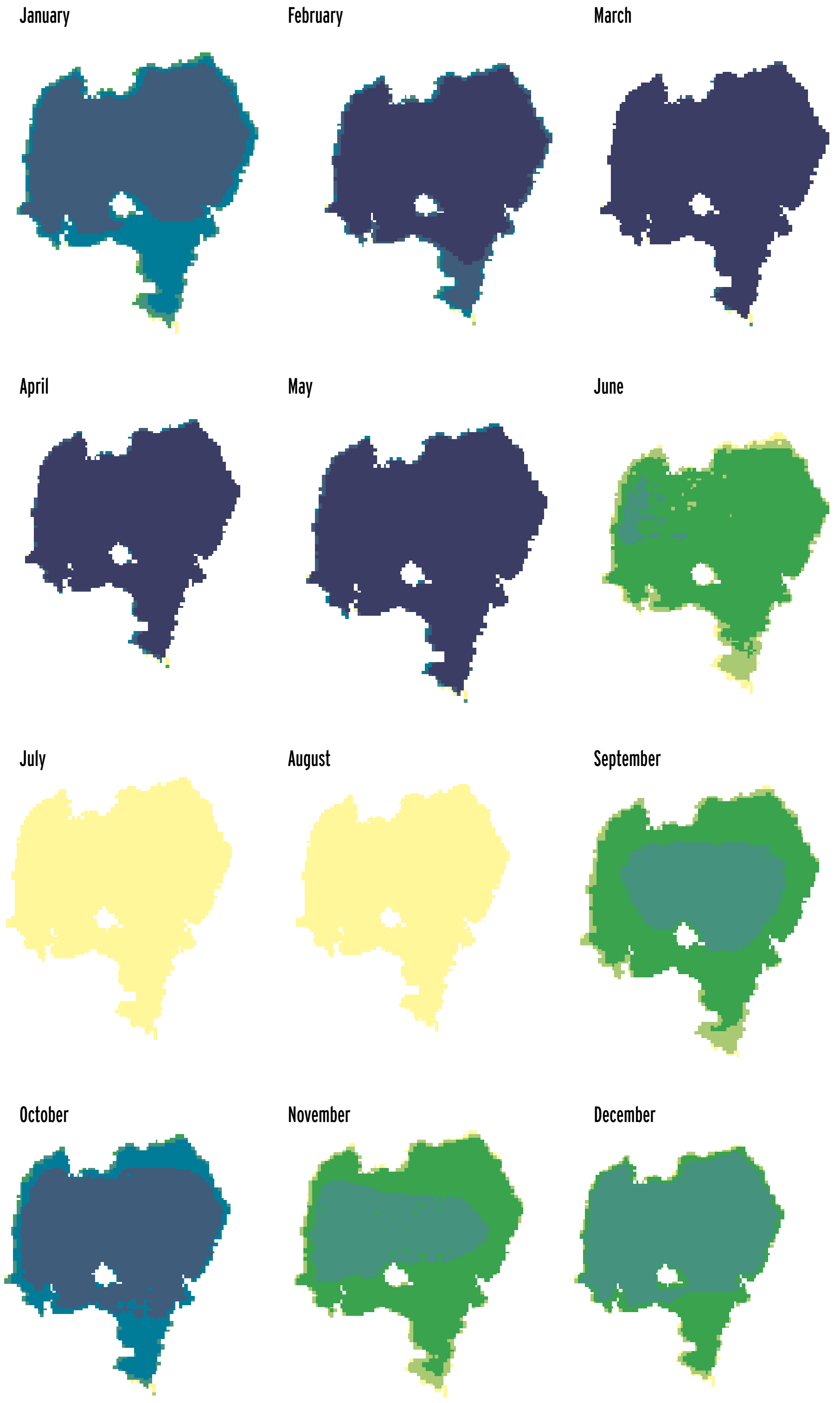
Open water bodies also experience high evaporation losses depending on the prevailing climatic conditions within their locality with very high values registered in the dry seasons. Lake Victoria experiences very high values in the months of January – February and July – August during which time, low rainfall amounts are registered in and around the lake. Similarly, Lake Tana registers very high evaporation losses in the months of January - May during which period, low rainfall amounts are registered in and around the lake.

ET represents a certain amount of water lost from the catchment area. By understanding how much water is available after such losses, it is possible to plan for efficient and effective usage of the existing resource, especially where water scarcity and drought are important issues. Evapotranspiration is also an indicator of climatic trends, as in periods of depressed rainfall there will be a tendency towards lower evapotranspiration values.

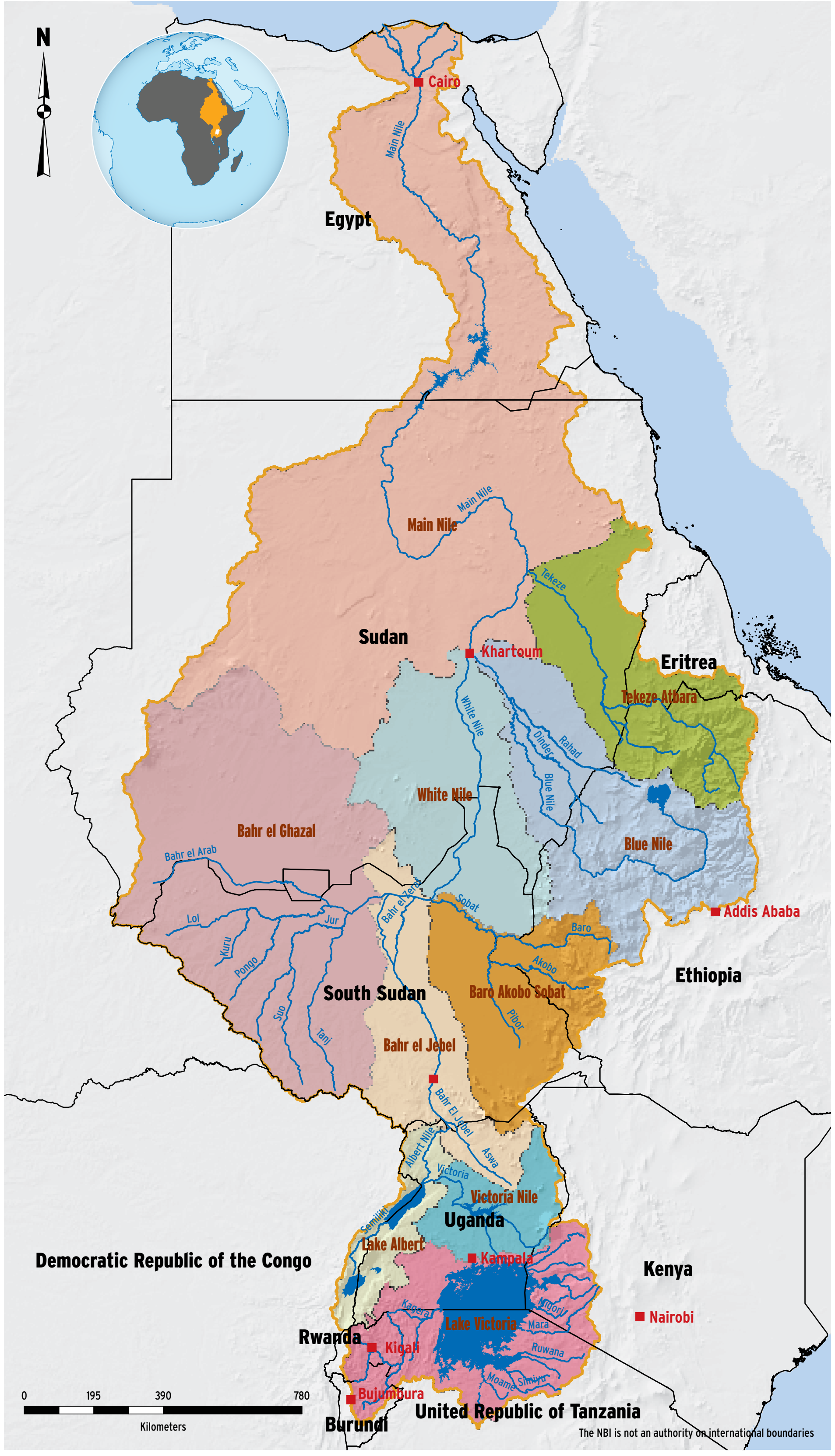
AVERAGE MONTHLY EVAPORATION OVER LAKE VICTORIA



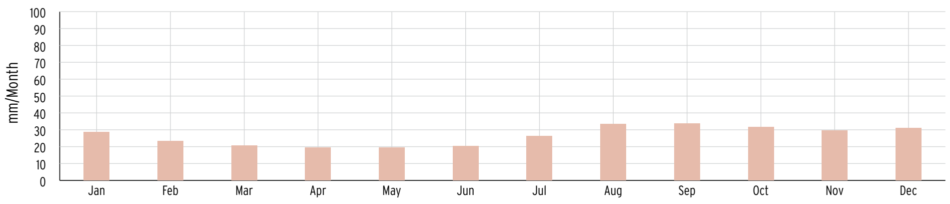
AVERAGE MONTHLY EVAPORATION OVER LAKE TANA

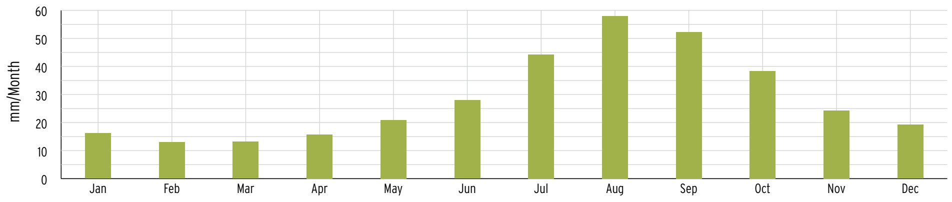


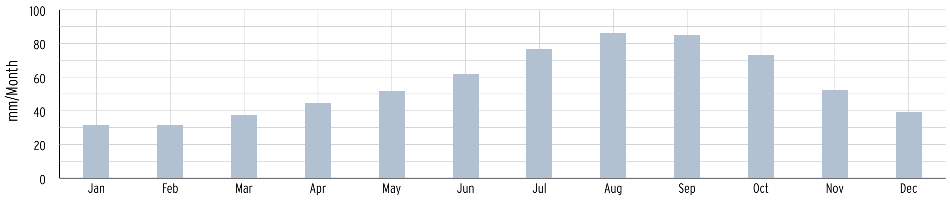
RELATIVE HUMIDITY

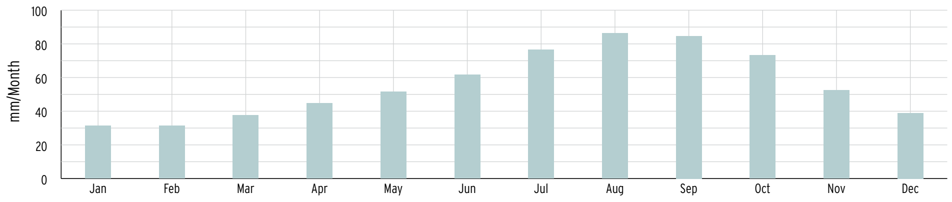


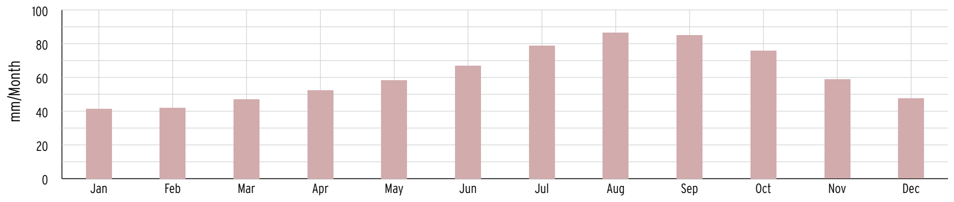
Relative humidity data was obtained from the Earth System Research Laboratory (ESRL, http://www.esrl.noaa.gov/psd/data/timeseries/) covering a period 1948 – 2014 on monthly time step. The mean monthly relative humidity for each sub-basin is presented here, which indicates that the equatorial lakes region has relatively high values with very little variation across the months compared to the eastern Nile and main Nile.

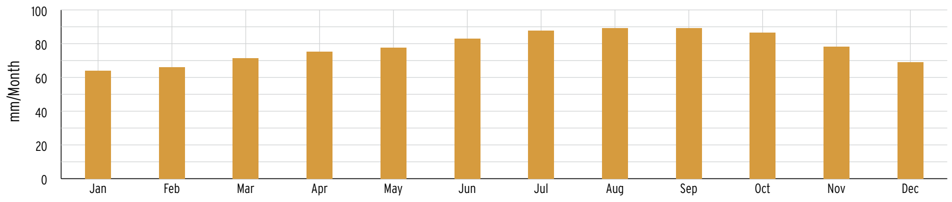

Main Nile: 1948-2014

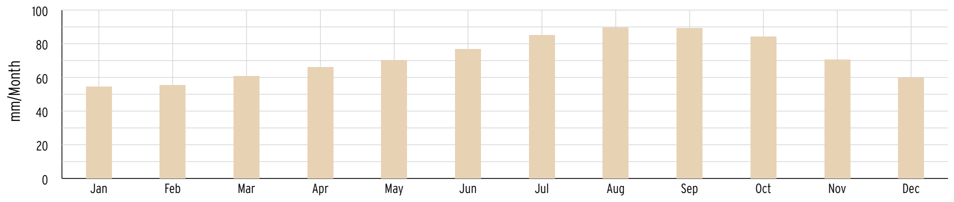

Tekeze Atbara: 1948-2014

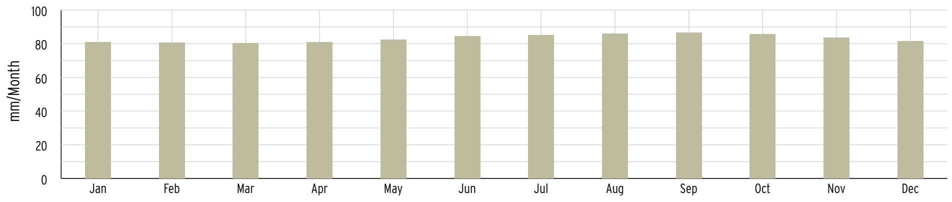

Blue Nile: 1948-2014

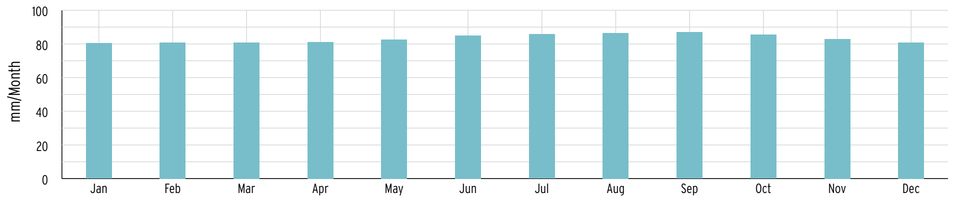

White Nile: 1948-2014

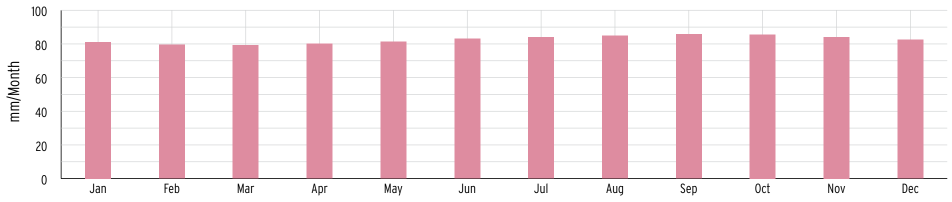

Bahr El Ghazal: 1948-2014


Baro Akobo: 1948-2014


Bahr El Jebel: 1948-2014


Lake Albert: 1948-2014

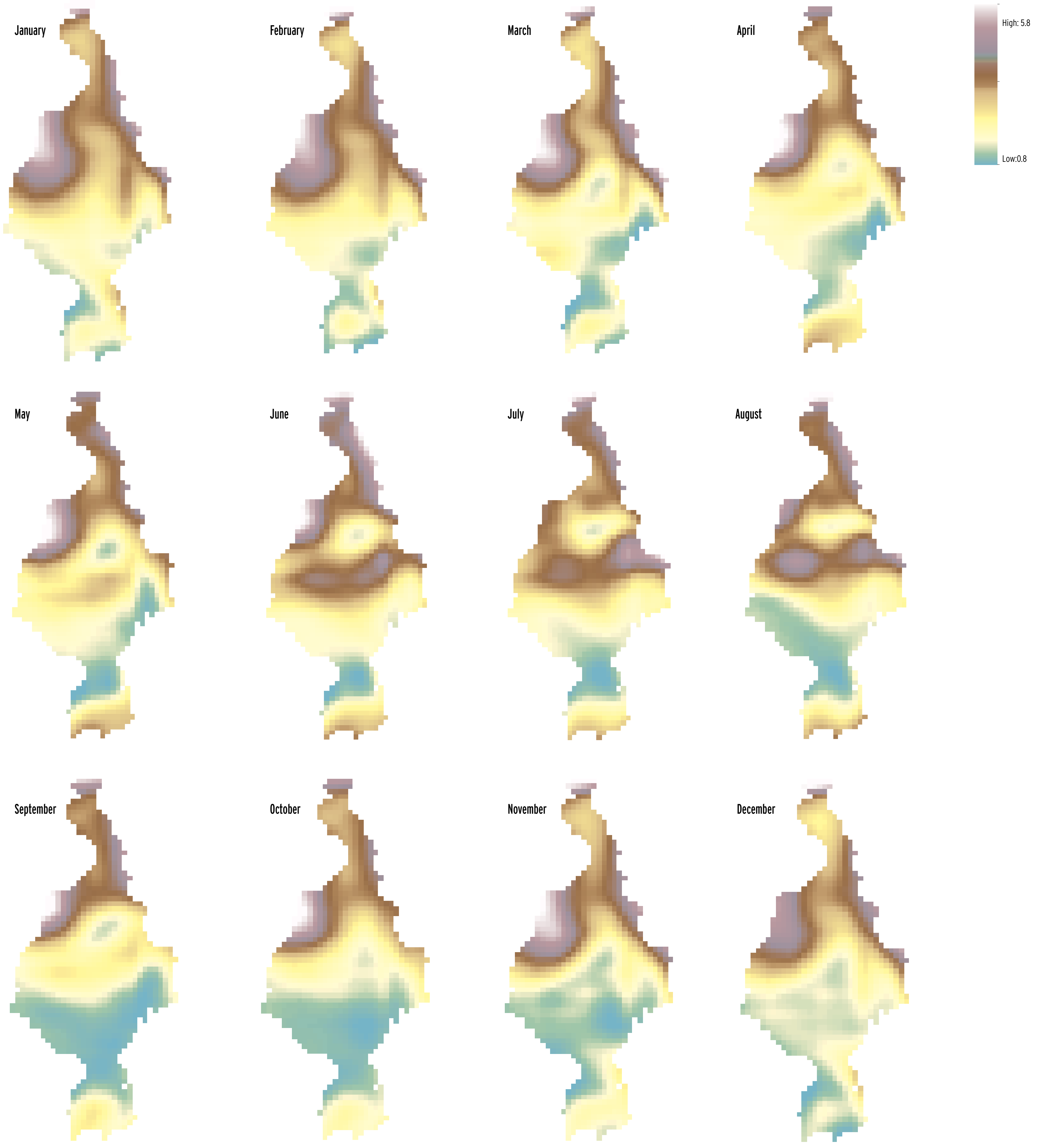

Victoria Nile: 1948-2014


Lake Victoria: 1948-2014

WIND SPEED

Wind speed data were obtained from the CRU on monthly basis for the period 1948 – 2008. However, only one year; 2008, is plotted in the map below to indicate the pattern. The monthly average wind speed (m/s) is measured at 10m height. The lower part of the basin generally registers higher wind speeds as opposed to the upstream parts of the basin and a clear wave of increase in speed can be seen in the eastern Nile in the months of June – August.

AVERAGE MONTHLY WIND SPEED OVER THE NILE BASIN



CONCLUSION

Photo: istock

Mwanza city- Tanzania

The Nile River spatial extent from south-north (range in latitude of 40 S to 350 N), creates various climates zones with distinct features, diverse and rich natural resources of wetlands, water resources, biophysical and ecological zones.

Climate change is not necessarily a threat for the water supply, however the uncertainty is very large. Within the range of the uncertainty many scenarios are thinkable that are very beneficial. However, adopting one of these scenarios and optimize the water management system to these conditions cannot be recommended, as the economic losses could be large if the climate trend goes the other way. Given the uncertainties on the future water supply, flood and drought frequencies, the most sensible option to cope with climate change in the design of water management structures and strategies is to prepare for more variable conditions than currently recorded. For example if the design criteria for a structure is to protect against the 1/10 flood, analyse how much extra it would cost to protect against a 1/50 flood. Designing in this manner provides time to react if the climate and water supply would change and additional measures can be taken.

As the Nile is very sensitive to any change in climate, it is of utmost importance to accurately monitor the flows of the Nile and its tributaries. This also counts for regular data validation and time series analysis. As the potential changes, reflected by the wet and dry scenarios, are beyond the capacity of one country to adapt better co-operation in the Nile basin between the Nile countries is a prerequisite.

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