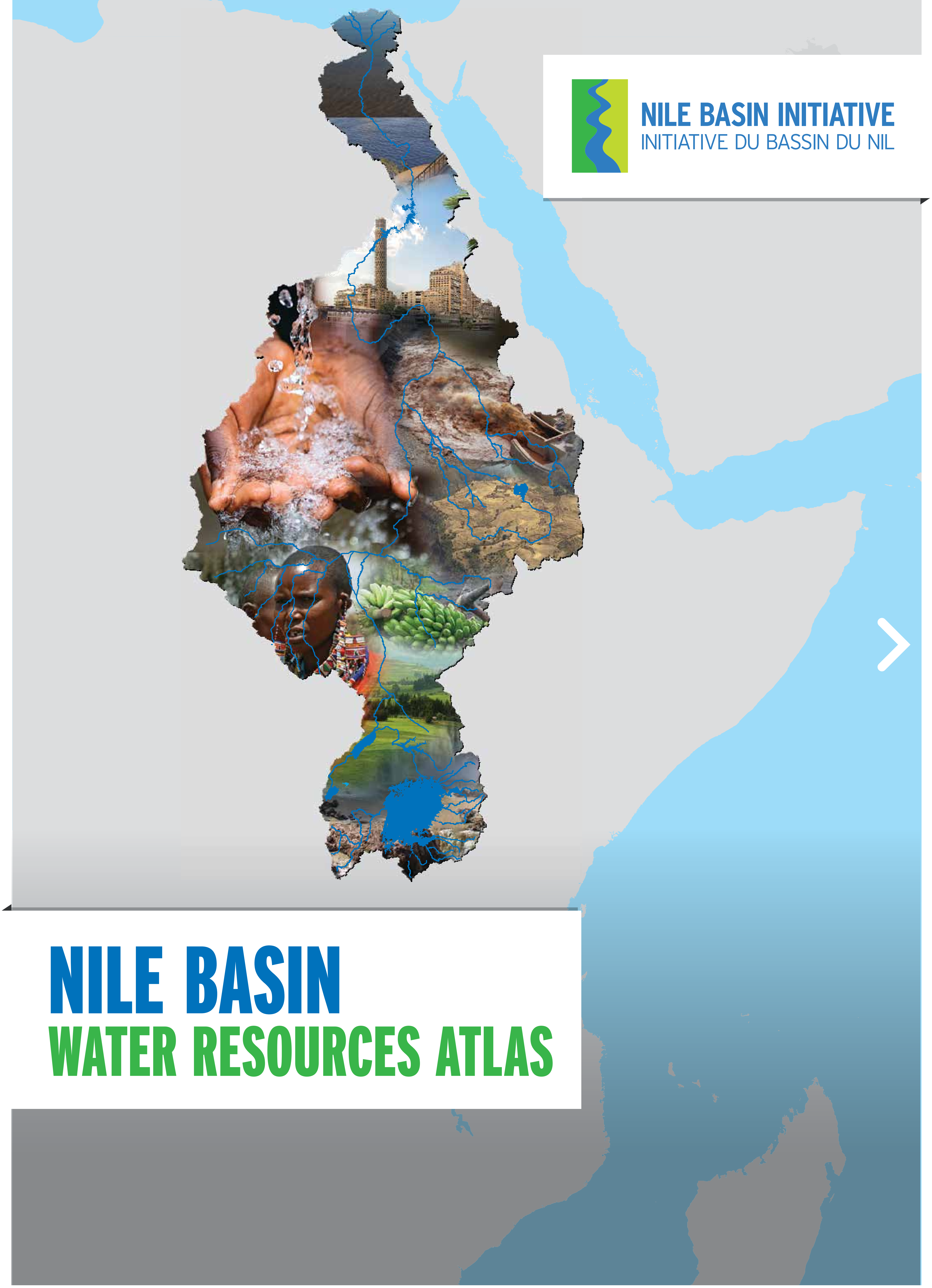
NILE BASIN INITIATIVE
INITIATIVE DU BASSIN DU NIL



NILE BASIN
WATER RESOURCES ATLAS

NILE BASIN
WATER RESOURCES ATLAS

NILE BASIN INITIATIVE
INITIATIVE DU BASSIN DU NIL

Burundi
DR Congo
Egypt
Ethiopia
Kenya
Rwanda
South Sudan
The Sudan
Tanzania
Uganda

ISBN: 978-9970-444-02-1

The Nile Basin Initiative (NBI) is an intergovernmental partnership of ten Nile riparian countries that is seeking to manage and develop the common Nile water resources in a cooperative manner and promote regional peace and security.

Nile Basin Initiative Secretariat (NBI)
P.O. Box 192, Entebbe, Uganda
Tel: +256 414 321 424/ +256 417 705 000
Fax: + 256 414 320 971
Email: nbisec@nilebasin.org
Website: www.nilebasin.org

Graphic Designer: Vivek Bahukhandi, KAZI KUNI, (vivek@kazikuni.com)

Printed by: New Vision Printing and Publishing Company Ltd. Kampala, Uganda

Disclaimer

The views expressed in this publication are not necessarily those of the Nile riparian countries, or that of the NBI. Trademark names and symbols are used to enhance editorial work with no intention of infringement on trademark or copyright laws. The Nile Basin Initiative regrets any errors or omissions that may have been unwittingly made in the Atlas.

The NBI is not an authority on International administrative boundaries. All country boundaries used in this atlas are based on FAO Global Administrative Unit Layers (GAUL).

The designations and presentations in this publication do not imply the expression of any opinion whatsoever on the part of FAO, NBI, concerning the legal status of any country, territory or city, or the delineation of its frontiers or boundaries.

Statistics for South Sudan prior to its independence in July 2011 is included under Sudan except where separate statistics for South Sudan is provided.

german
cooperation
DEUTSCHE ZUSAMMENARBEIT

Implemented by giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

FOREWORD

Esteemed Reader,

The Nile Basin is one of the few basins of the world that has given birth to early human civilization. The Basin is as relevant to humanity today as it was in the past millennia. This said though, the Basin is facing huge challenges. While economies of most of its countries are growing, the Basin is faced with a rising population, which increases degradation of natural resources and puts pressure on economic infrastructure including water. It also increases food security concerns and leads to rural urban migration with the attendant problems of rapid urbanization.

These and more developments are one way or the other predicated on continued availability of Nile waters. But the Nile is, as it were, a very finite and fragile resource, marked by alteration of extreme events of either prolonged droughts or floods of biblical proportions. In the midst of this, the Nile is going to face growing pressure in the coming decades due to continued steady rise in the demand for water. All this requires: more - and not less - basin wide cooperation; smarter, forward looking, knowledge based and prudent basin-wide water resources management and development policies, which ultimately should result in enhanced water use efficiency and productivity across economic sectors and countries.

The Nile Basin Water Resources Atlas is one such knowledge tool developed by NBI. The Atlas makes the data and information accessible in a format that is easy, succinct and visually attractive. By providing a bird's eye view of the potentials, problems and trends in the Basin, I hope this Atlas contributes to advancing our mission of encouraging thoughtful deliberation among basin policy makers, citizens and all concerned for the future of this great River of ours - the Nile!

With best wishes,

Hon. Eng Gerson Lwenge (MP)
Chairperson, Nile Council of Water Ministers
& Minister of Water and Irrigation,
United Republic of Tanzania

STATEMENT BY EXECUTIVE DIRECTOR, NILE BASIN INITIATIVE

Dear Esteemed Reader,

I am most delighted to welcome you to the first Nile Basin Water Resources Atlas.

Water resources development is vitally important for enabling the Nile Basin countries to meet their development objectives. However, interventions that are not founded on a sound understanding of the water resources potential are unsustainable.

The complexity of the large number of countries sharing the Nile Basin, combined with the uneven distribution of the water resources among these countries, population pressure and urbanisation pose significant challenges for sustainable management and development of the shared resource. Coupled with these is the complex hydrology of the Nile system as well as climate change.

In order to develop the Nile Basin resources to address urgent social and economic needs of the basin communities while ensuring equitable utilisation and benefit from the common resource, decision makers need well synthesized and factual information to enable them make evidence based decisions.
As part of the Water Resources Management function of the Nile Basin Initiative, and in line with its overarching goal of fostering evidence-based water resources management and development, NBI has prepared a Water Resources Atlas for the Nile Basin. The Atlas presents well synthesized and interpreted information with a special focus on spatial and temporal distribution of the resources within the Basin. Together with the State of Basin Report, the Atlas will also be used as a basin monitoring tool.

The 200-page document is delivered in seven chapters presenting the physiography of the Basin, socio economic profiles of Nile Basin countries, water availability in terms of climate and hydrology as well as water demand and use infrastructure.

The Atlas is expected to enlighten ongoing deliberations on Nile issues among policy makers, senior government officials, water resources officers, academia and the general public on broad basin issues.

The Nile Basin Water Resources Atlas is part of NBI's sustained efforts to build trust and confidence among Member States and to nurture a conducive environment for cooperative management and development of the shared water and related resources, through provision of factual and impartial knowledge and information. It is therefore my hope that you will find it a very useful document.

I take this opportunity to thank the staff of NBI as well as members of the Regional Working Group who have tremendously contributed towards the successful preparation of this key knowledge product.

Finally, I extend my gratitude to Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) for their immeasurable technical and financial support towards the preparation of this inaugural Water Resources Atlas for the Nile Basin.

I wish you an enjoyable reading.

John Rao Nyaoro, HSC (PhD)
Executive Director
Nile Basin Initiative

ACKNOWLEDGEMENT

The following persons contributed to the preparation of the Nile Water Resources Atlas.

TECHNICAL LEAD

Abdulkarim H Seid, PhD	Head Water Resources Management Department, NBI Secretariat

TECHNICAL EDITING

Abdulkarim H Seid, PhD	Head Water Resources Management Department, NBI Secretariat
Ms. Milly Mbuliro	GIS and Remote Sensing Specialist, NBI Secretariat
Dr. Mohsen Alarabawy	Basin Management Specialist, NBI Secretariat

PRODUCTION TEAM

GIS AND MAP WORK

Ms. Milly Mbuliro	GIS and Remote Sensing Specialist, NBI Secretariat

DESIGN AND LAYOUT

Mr. Vivek Bahukhandi	Graphic Designer, KAZI KUNI, India

REVIEWERS

Mr. Jan Hassing	Water Resources Management Adviser, Hassing Water
Eng Ahmed Khalid ELDAW	Consultant on Water and Related Environment, Khartoum, Sudan
Eng Emmanuel Olet	Consulting Civil and Hydraulic Engineer, Kampala, Uganda

MAIN CONTRIBUTORS

Mr. Philip J. Akol	Assistant Inspector of Haffirs and Leaves, South Sudan
Mr. Robert P. Z. Galla	Inspector for Hydrology, South Sudan
Mr. Sabuni Wanyonyi	Regional Manager, Lake Victoria South Catchment Area (WRMA), Kenya
Mr. David K. Bosuben	Senior Principal Water Research Officer, Kenya
Mr. Rutandura Jacques	Cadre au Departement de Gestion Integree des Ressources en Eau (GIRE), Burundi
Mr. Kiruri Ferdinant	Cadre au l'Institut Geographique du Burundi (IGEBU), Burundi
Mr. Bienvenu Mulwa	Democratic Republic of Congo
Mr. BopeLapwong Jean Marie	Democratic Republic of Congo
Dr. Balla Shaheen	Sudan
Eng. Abdelrahman Saghayroon	Sudan
Mr. Marc Manyifika	Rwanda
Mr. Damascene Kayiranga	Rwanda
Ms. Caroline Nakalyango Wafula	Senior Water officer/Information Management Officer, Uganda
Mr. Benon Zaake	Assistant Commissioner Monitoring and Assessment, Uganda
Mr. Solomon Cherie	Director, Irrigation and Drainage Directorate Ministry of Water, Irrigation and Energy, Ethiopia
Mr. Mohamed Ali	Ethiopia
Mr. Ongoma Mangasa	Hydrologist – Lake Victoria Basin Water Board, Tanzania
Ms. Paskalia Bazil	Hydrogeologist – Ministry of Water and Irrigation, Tanzania
Abdulkarim H Seid, PhD	Head, Water Resources Management, NBI Secretariat
Dr. Mohsen Alarabawy	Basin Management Specialist, NBI Secretariat
Ms. Milly Mbuliro	GIS/Remote Sensing Specialist, NBI Secretariat
Mr. Vincent Ssebuggwawo	Regional Water Resources Modeller - NELSAP-CU, Kigali, Rwanda
Ms. Azeb Marsha	Water Resources Modeller, ENTRO

Dr. Joel Nobert	Water Resources Consultant, Tanzania
Dr. Khalid Biro Turk	Hydro- Climatologist, Sudan
Mr. Benjamin Ssekamuli	Hydro Climatologist, Uganda
Eng. Emmanuel Olet	Consulting Civil and Hydraulic Engineer, Kampala, Uganda

OTHER CONTRIBUTORS

Dr. Hellen Natu	Executive Director, Nile Basin Discourse
Dr. Wubalem Fekade	Head, Communication and Social Development Unit, Eastern Nile Technical Regional Office (ENTRO)
Ms. Jane Baitwa	Regional Communication Specialist, NBI Secretariat

ACRONYMS

BCM	Billion Cubic Meters
CRU	Climate Research Unit
DRC	Democratic Republic of Congo
EAC	East African Community
ENSAP	Eastern Nile Subsidiary Action Program
ENTRO	Eastern Nile Technical Regional Office
ESA	European Space Agency
ET	Evapotranspiration
FAO	Food and Agriculture Organisation
FAOSTAT	Food and Agriculture Organisation Statistical Databases
FDFC	Flood Diagnostics and Forecasting Center, Kenya
GCM	Global circulation Model
GDP	Gross Domestic Product
GIS	Geographic Information System
GNI	Gross National Income
GW	Gigawatt
GWh	Gigawatt Hour
Ha	Hectare
HDI	Human Development Index
HDR	Human Development Report
HYDROMET	Hydro-meteorological survey of the Equatorial Lakes
IGAD	Intergovernmental Authority on Development
IGAD-HYCOS	IGAD- Hydrological Cycle Observation System
IGEBU	Institut Géographique du Burundi
IGRAC	International Groundwater Resources Assessment Center
ITCZ	Intertropical Convergence Zone
IWRM	Integrated Water Resources Management
Km	Kilometers
Km2	Square Kilometers
KV	Kilovolts
KWh	Kilowatt hour
L	Litres
LVBC	Lake Victoria Basin Commision
LVEMP	Lake Victoria Environmental Management Program
M	Meters
METTELSAT	Agence Nationale de Meteorologgie et de Teledetection par Satellite
MERIS	Medium Resolution Imaging Spectrometer
NBI	Nile Basin Initiative
NELSAP	Nile Equatorial Lakes Subsidiary Action Program
Nile-COM	Nile Council of Water Ministers
Nile-SEC	Nile Basin Initiative Secretariat
Nile-TAC	Nile Technical Advisory Committee
NTEAP	Nile Transboundary Environmental Action Program
PET	Potential Evapotranspiration
PPP	Purchasing Power Parity
SADC	Southern Africa Development Community
TECCONILE	Technical Cooperation for the Promotion of the Development and Environmental Protection of the Nile Basin
TRMM	Tropical Rainfall Measuring Mission
UNDP	United Nations Development Program

TABLE OF CONTENTS

CHAPTER ONE - PAGE 13
INTRODUCTION

CHAPTER TWO - PAGE 21
NILE BASIN PHYSIOGRAPHY

CHAPTER THREE - PAGE 49
THE SOCIO-ECONOMIC PROFILES OF THE NILE BASIN COUNTRIES

CHAPTER FOUR - PAGE 75
BASIN MONITORING

CHAPTER FIVE – PAGE 95
NILE BASIN CLIMATE

CHAPTER SIX – PAGE 133
HYDROLOGY OF THE NILE

CHAPTER SEVEN – PAGE 169
WATER DEMAND, USE AND HYDRAULIC INFRASTRUCTURE

PAGE 198
OVERALL CONCLUSION

EXECUTIVE SUMMARY

The Nile Basin Water Resources Atlas has been prepared to support stakeholder dialogues and inform decision-making by the Nile Basin riparian states in order to achieve the shared vision of “sustainable socio-economic development through the equitable utilization and, benefit from, the common Nile Basin water resources”.

The basin is home to more than 257 million people or around 20% of the population of the African continent. The water resources of the Nile Basin are of paramount importance for the socio-economy and sectors such as agriculture, power, navigation, fisheries and water supply, sanitation and health and the environment.

The upper parts of the Nile Basin is characterized by mountain ranges and steep slopes. In the middle reaches there are large plateau regions, while the lower parts have wide flood plains and ultimately the huge Nile Delta. The population’s settlement patterns are heavily influenced by the availability of water and the infrastructure. In the downstream countries, population is concentrated along the course of the River Nile and in the Delta. The highest population densities in the upstream countries are found in the Ethiopian Highlands and in the Nile Equatorial Lakes Region. The rural population of the basin countries increased between 1.5% and 3.0% (2005 – 2015) while the urban population increased between 4.4% and 7.0% in the same period. Poverty is widespread and by income, around 40% of the population of the basin countries live below a poverty line of USD 1.25 per day.

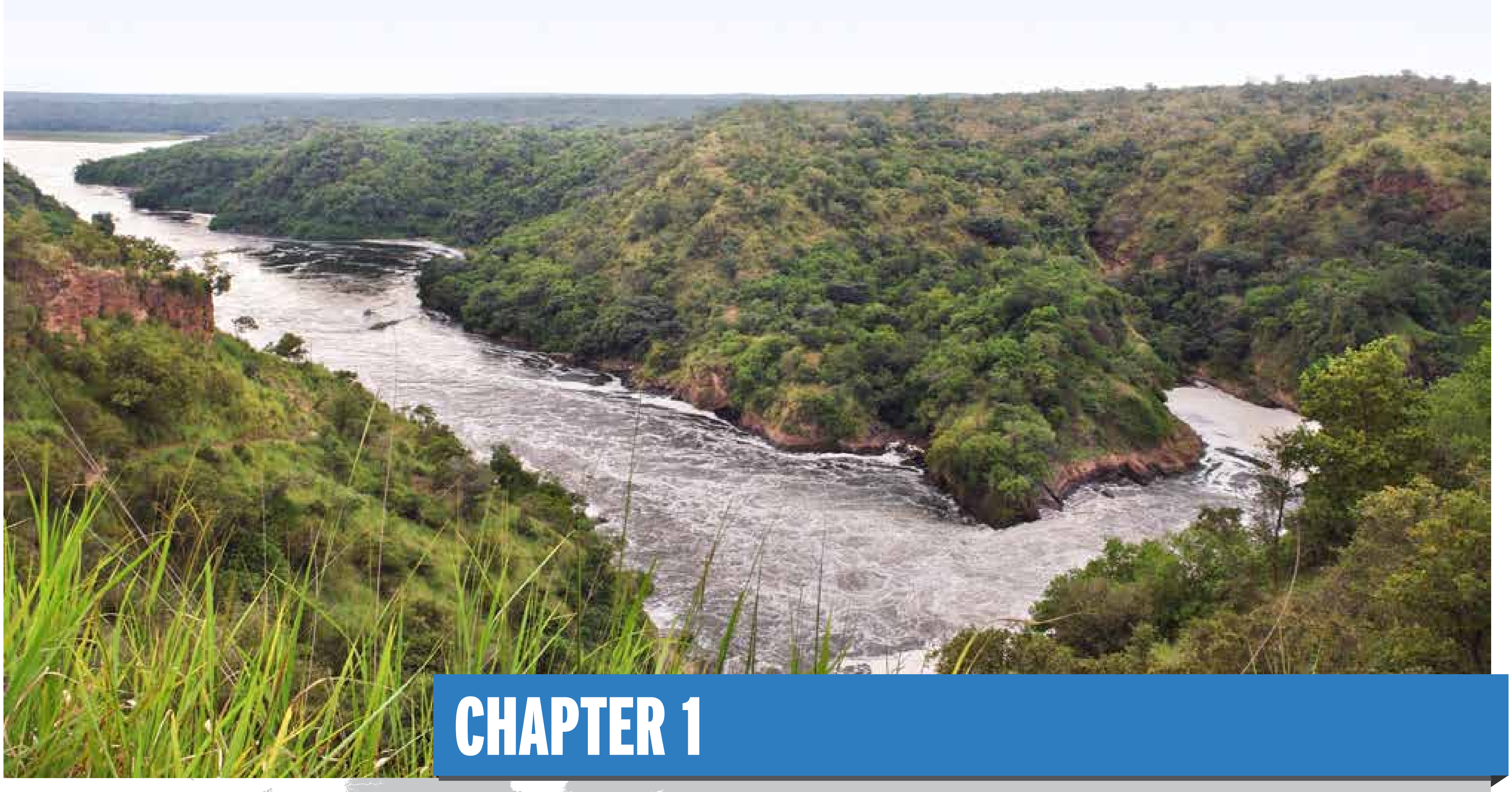
The high dependence on shared basin water resources, which in large areas are scarce, makes a fact-based management essential. Monitoring of water resources is therefore done by all countries and there exist close to 1,000 rainfall stations and close to 450 streamflow gauging stations across the basin countries. Technical and financial resources are needed to operate the stations and get reliable data. In many countries the number of stations decreases and the quality of the data is variable. The need for improvements have been recognized by the Nile Basin Initiative, which has completed a design of a Nile Basin Regional Hydromet System based on upgrading of existing stations adding water quality monitoring and laboratory strengthening. Groundwater monitoring is generally very sparse.

Climatically, the Nile Basin has large variations ranging from the tropical climate in the equatorial region to the Mediterranean climate of the delta. The variations reflect the latitude range, 4° S to 32° N and the altitude range; from sea level to more than 3,000 m. The equatorial lakes region and southwestern Ethiopia have well distributed rainfall with an average annual rainfall of more than 1000 mm while Sudan and Egypt have negligible rainfall, with an average annual rainfall below 50 mm. Combined with temperature ranges of 10 – 45°C, very little surface runoff is generated here. Global warming is bringing about changes in climate around the world. Trends and statistics have to be reviewed as even small changes in temperature averages or extremes can have serious consequences for water resources and supplies, agriculture, power and transportation systems, the natural environment, and even health and safety.

The Nile Basin streamflow patterns are influenced by the variations in climate and topography/altitude. The Blue Nile is highly seasonal with most of its flow occurring between July and September, while the White Nile flow is stable over the year. On the average, the Blue Nile contributes almost twice the volume of water (roughly 1600 m^3/s) of the White Nile. Groundwater is another, though small part of the water resources of the basin. The most significant aquifer is the Nubian Sandstone. Sediment production takes place in upland areas with the Ethiopian Highlands as the main source compared to other parts of the basin. Water quality is generally influenced by human activities and urban areas and industrial activities are the main influencing factors.

The water resources in the basin are essential for sustaining life, the economy and a healthy environment. Water is used off-stream (withdrawn e.g. for agriculture or domestic use), in-stream (e.g. hydropower, fisheries, environment) or on-stream (e.g. transport, tourism). By far, the largest consumptive use is for irrigation (roughly 2600 m^3/s) with Egypt and Sudan as the largest users. Water demand for municipal and industrial use is rapidly increasing from the present estimates of roughly 400 m^3/s. Water demands for all sectors is expected to increase substantially and there is a risk that the aggregate water demand basin-wide can surpass available water will become unable to meet the water demand. A high degree of trust, collaboration and sharing of water and benefits between the Nile riparian nations becomes imperative and the Nile Basin Initiative has a strategic mission to facilitate the cooperation.

Photo: istock



CHAPTER 1

INTRODUCTION


Photo: Vivek Bahukhandi

Albert Nile just before Murchison Falls

The Nile Basin

The Nile is the world's longest river and has a drainage area of about 3.2 million km² which is nearly 10% of the landmass of the African continent. Running through 11 countries from south to north, the river flows over 35 degrees of latitude, traversing highly diverse landscapes and climatic zones. The Nile has two main tributaries; the White Nile with its upstream catchments fed by rivers originating in Burundi and in Rwanda and the Blue Nile originating in Ethiopia, both of which have very distinct hydrologic regimes. Other tributaries of the Nile are the Sobat river draining parts of the south-west Ethiopia, and eastern parts of South Sudan the Atbara river passing through Sudan and the Bahr el Ghazal draining the western part of South Sudan.

The Nile Basin is home to over 257 million people which is about 54% of the total population of the 11 countries that share the Nile. The Nile Basin has hugely diverse ecosystems with a significant part classified as arid and semi-arid. These diverse ecosystems coupled with the diverse climatic zones have been observed to determine the distribution of the population within the basin. The riparian communities are very heavily dependent on exploitation of the environment and water resource for their livelihoods.

The large number of countries that share the Nile Basin, combined with the uneven distribution of the water resources among the countries, population pressure, urbanization and complex hydrology of the Nile System coupled with climate change pose significant challenges for the sustainable management of the shared waters.

Over a period of several years, riparian countries of the Nile have come together to try to address challenges within the basin so as to harness the resource for sustainable development. The first international technical cooperation (1967-1992) was the Hydro meteorological Surveys Project of the Upper Nile (Equatorial Lakes) Catchments (HYDROMET) which was followed by the Technical Cooperation Committee for the Promotion of the Development and Environmental Protection of the Nile (TECCONILE:1993-1999). The Nile Basin Initiative (NBI) was launched on 22 February 1999. The launching of the NBI as an all-inclusive platform ushered a new era in the history of the Nile cooperation.


Photo: istock

Food sharing


Photo: The World Bank

Dry river bed, South Sudan


Photo: istock

Ngorongoro Conservation Area - Tanzania

RIVER LENGTH
6,695 km

AREA OF THE NILE BASIN
3,176,541 km^2

POPULATION
257 million

THE NILE BASIN INITIATIVE

The Nile Basin Initiative (NBI) is an inter-governmental partnership of 10 Nile Basin countries namely; Burundi, DR Congo, Egypt, Ethiopia, Kenya, Rwanda, South Sudan, The Sudan, Tanzania and Uganda, established on 22nd February, 1999. Eritrea participates as an observer.

For the first time in the Basin's history, an all-inclusive basin-wide institution was established, to provide Basin States with a forum to discuss with trust and confidence the sustainable management and development of the shared Nile Basin water and related resources for win-win benefits.

The partnership is guided by a Shared Vision Objective: *'To achieve sustainable socio-economic development through equitable utilization of, and benefit from, the common Nile Basin water resources'.* The shared belief is that countries can achieve better outcomes for all the people of the basin through cooperation.

The highest political and decision making body is the NBI is the Nile Council of Ministers (Nile-COM), comprised of Ministers in charge of Water Affairs in the NBI Member States. The Nile-COM is supported by a Technical Advisory Committee (Nile-TAC), comprised of 20 senior government officials, two from each of the partner states. The NBI is one institution with three centers; the Secretariat (Nile-SEC) based in Entebbe, Uganda is responsible for the overall basin wide perspective, corporate direction of the institution and leads implementation of the 'Basin Cooperation' and 'Water Resource Management' programs. The Eastern Nile Technical Regional Office (ENTRO) based in Addis Ababa, Ethiopia, leads implementation of the Water Resources Development Program in the Eastern Nile sub-basin comprising of Egypt, Ethiopia, South Sudan and The Sudan. The Nile Equatorial Lakes Subsidiary Action Program Coordination Unit (NELSAP-CU) based in Kigali, Rwanda, leads implementation of the Water Resources Development Program in the Nile Equatorial Lakes sub-basin comprising Burundi, DR Congo, Egypt, Ethiopia, Kenya, Rwanda, South Sudan, The Sudan, Tanzania and Uganda.

In each Member State there is an NBI national office, which coordinates and ensures regional NBI interventions are embedded in national development planning.


Photo: Dr. Nicholas Azza

NILE BASIN INITIATIVE
INITIATIVE DU BASSIN DU NIL

SHARED VISION OBJECTIVE: 'to achieve sustainable socio-economic development through the equitable utilization of, and benefit from, the common Nile Basin water resources'.

What NBI does

The Basin Cooperation Program actively provides the only all-inclusive regional platform for multi stakeholder dialogue, for sharing information, joint planning management and development of the shared water and related resources in the Nile Basin. The platform further creates opportunities for learning, networking and sharing experiences across Basin States.

The objective of the water resources program is to assess, manage, and safeguard the water resources base that supports the peoples of the Nile Basin. Under this program, NBI undertakes water resources analysis to to inform riparian dialogue, strengthens Member States' analytic capacities, formulates transboundary policies and promotes collaborative monitoring of the Nile Basin.

The Water Resources Development Program assists Member States to identify and prepare investment projects of regional significance, which are economically viable, environmentally friendly and socially acceptable as well as mobilize financial and technical resources for their implementation by the Member States.

NILE BASIN WATER RESOURCES ATLAS

Without synthesized information, identifying and devising mitigation measures for the critical threats to the sustainability of the water and related natural resources of the basin becomes a challenge.

As much as certain aspects of our environment such as topography do not change, most aspects of our physical environment change. As populations grow, effective planning for sustainable development requires dependable information about the trends in our changing environment.

In order to develop the Nile Basin resources to address urgent social and economic needs of the people while ensuring equity in sharing of the benefits, decision makers need evidence based information to enable them to make evidence based decisions.

As part of expanding the knowledge base, the NBI has developed a Water Resources Atlas for the Nile Basin to provide synthesized, interpreted information to the stakeholders and thereby promote evidence based decision making.

The Nile Basin Water Resources Atlas provides a visual account of the status of the resources, present observed trends, vital statistics and the biophysical status of the basin.

The Atlas will inform the second Edition of the State of River Nile Basin Report and will provide a platform for viewing the spatial and temporal distribution of resources within the basin especially hot and hope spots and their environmental, economic and social significance.

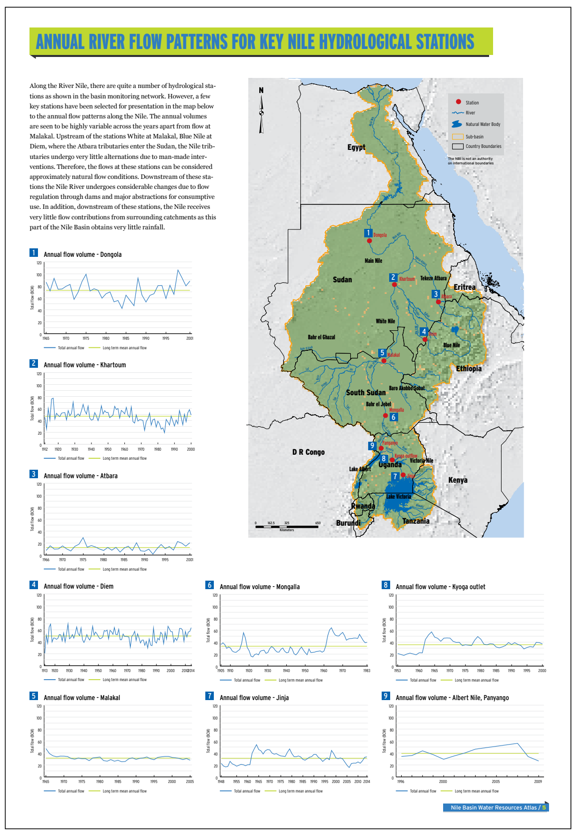
By guiding and informing basin-wide planning, the Nile Basin Water Resources Atlas together with the State of River Nile Basin Report will significantly contribute to achievement of the NBI goals of equitable benefit sharing and win-win outcomes, that are at the heart of cooperation on the Nile.

Objectives

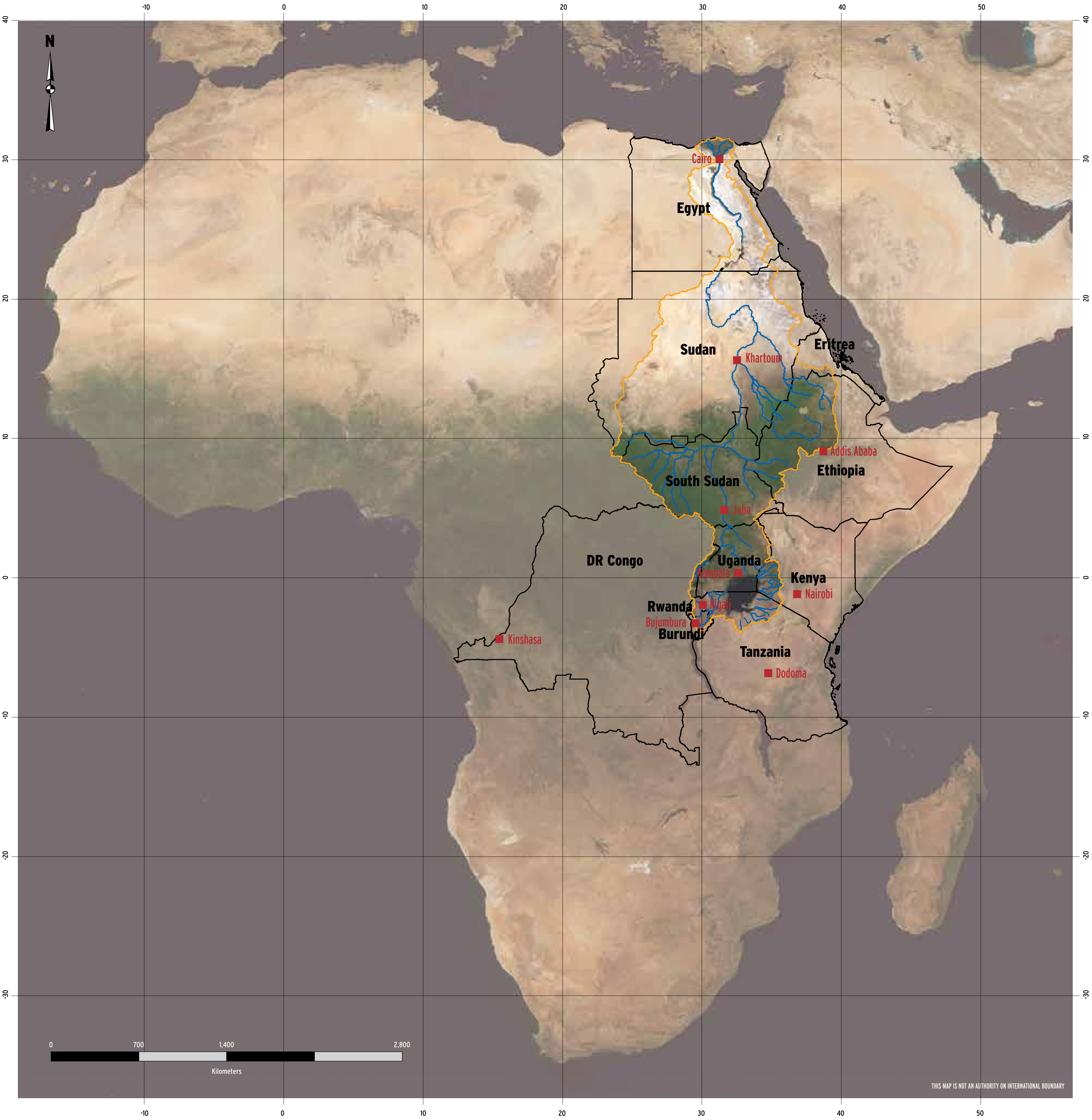
The primary objective of the Nile Basin Water Resources Atlas is to present factual information on water resources of the Nile Basin, its spatial and temporal distribution and uses. The Atlas makes extensive use of illustrations to present facts, characteristics and trends with respect to the water resources of the Nile Basin and serves as shared knowledge base on Nile.

Approach

The Nile Water Resources Atlas was developed by a team of NBI staff in collaboration with experts from NBI member states (members of the Regional Working Group). Three consultants supported the development of illustrations with a professional firm taking care of the graphic design and editorial process. The data and statistics used have been validated and sometimes provided by representatives from each Member State.


ANNUAL RIVER FLOW PATTERNS FOR KEY NILE HYDROLOGICAL STATIONS

LOCATION OF THE NILE BASIN IN AFRICA

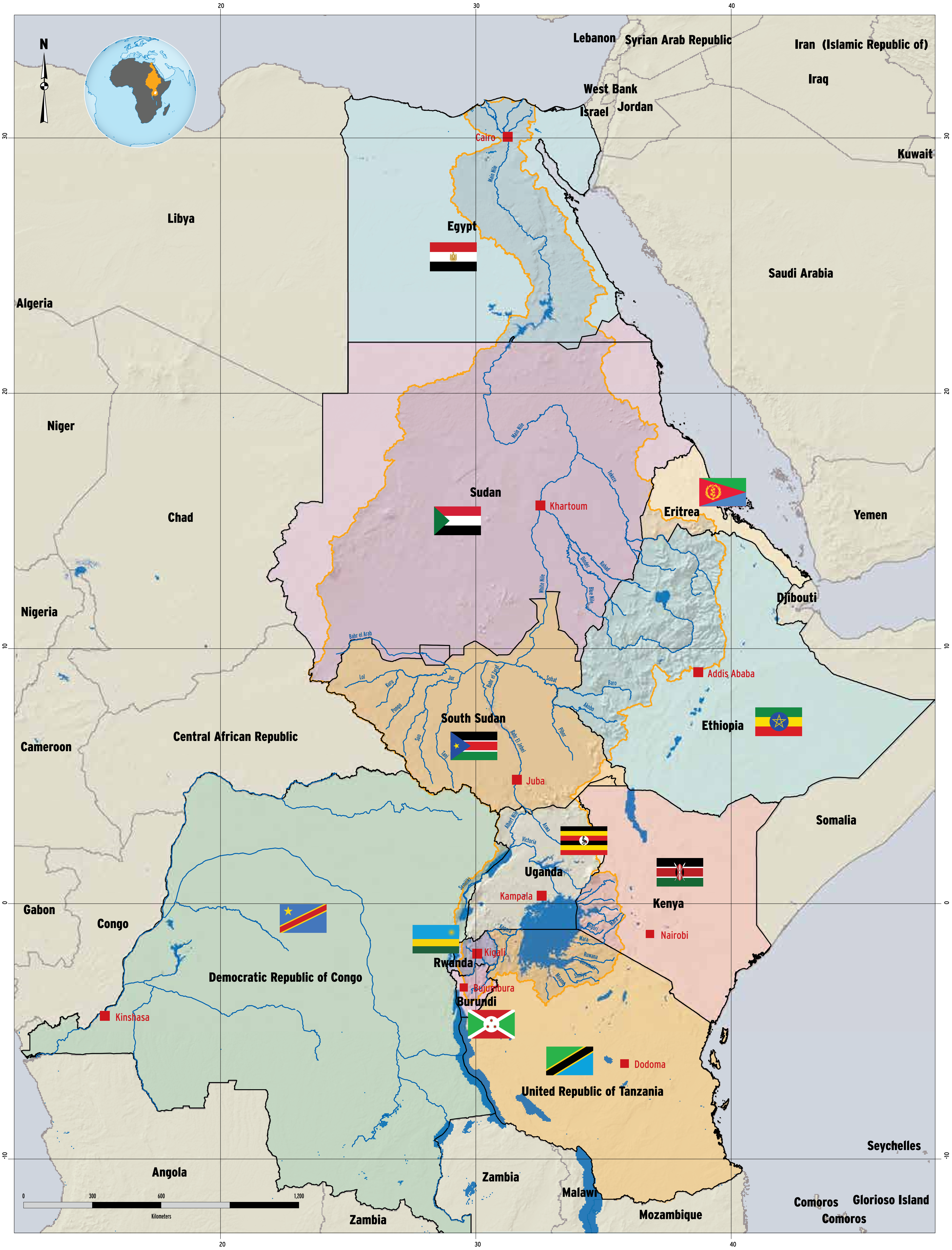


The Nile Basin covers an area of about 3.2 million km^2, which represents some 10 percent of the African continent and hosts nearly 20 percent of the African population. The basin extends from 4° south to 31° north latitude.

The Nile is the longest river in the world with a length of 6,695 km. It has two main tributaries: 1) the White Nile, originating from the Equatorial Plateau of East Africa, the headstreams of which flows into Lake Victoria, and 2) the Blue Nile, with its source in the Ethiopian highlands. Other significant tributaries are the Tekeze-Atbara and the Baro-Akobbo-Sobat, both originating in the Ethiopian highlands. Lake Victoria with the surface area of 66,700 square kilometres is the world's second largest freshwater lake after Lake Superior in North America.

Eleven countries share the river: Burundi, the Democratic Republic of the Congo, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, the Sudan, South Sudan, the United Republic of Tanzania and Uganda. The Nile Basin is home to approximately 257 million people, while some 487 million live within the eleven riparian states. The Nile waters play a vital role in the socio-economic development of the Nile Basin States. Agriculture is the dominant economic sector in most Nile riparians. The Nile also has huge potential for hydropower production.

THE NILE BASIN COUNTRIES



THIS MAP IS NOT AN AUTHORITY ON INTERNATIONAL BOUNDARIES
Data Source: The Global Administrative Unit Layers (GAUL) dataset, FAO - 2014

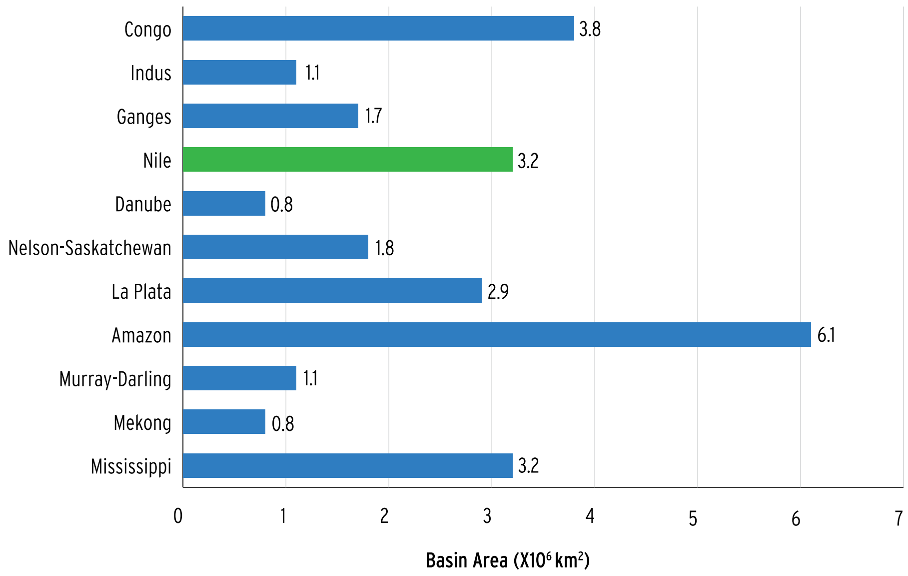
The designations employed and the presentation of material in the maps do not imply the expression of any opinion whatsoever on the part of FAO and NBI concerning the legal or constitutional status of any country, territory or sea area, or concerning the delimitation of frontiers

QUICK STATISTICS ABOUT THE NILE

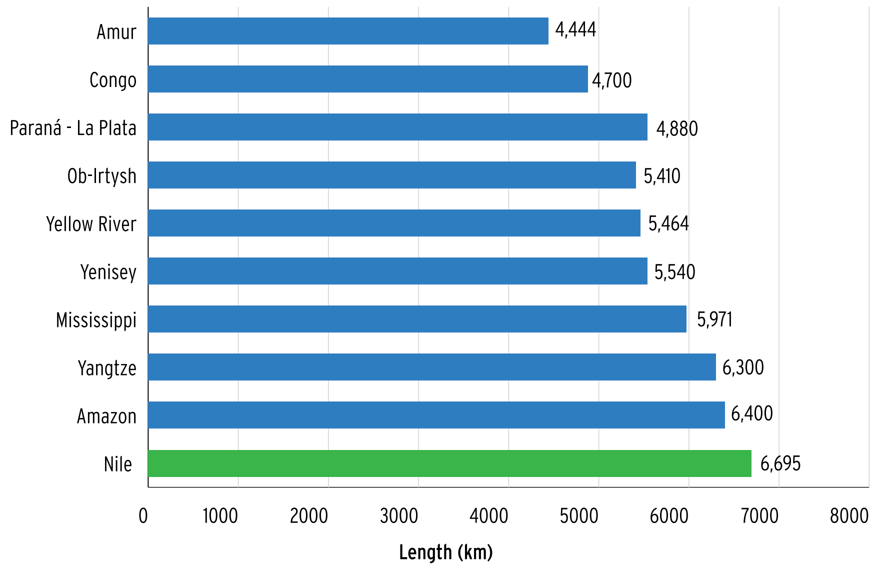
AREAS OF COUNTRY WITHIN THE NILE BASIN

Country	Estimated Total Area (km²)	Area in the Nile Basin (km²)	Area in the Nile Basin (% of total basin Area)	Area in the Nile Basin % of total country area)
Burundi	27,834	13,860	0.44	49.39
DR Congo	2,345,410	21,796	0.69	0.91
Egypt	996,960	302,452	9.52	30.34
Eritrea	121,722	25,697	0.81	21.11
Ethiopia	1,144,035	365,318	11.50	31.93
Kenya	593,116	51,363	1.62	8.66
Rwanda	26,338	20,625	0.65	84.01
South Sudan	644,329	620,626	19.54	97.71
Sudan	1,864,049	1,396,230	43.95	74.90
Tanzania	945,000	118,507	3.73	12.69
Uganda	241,248	240,067	7.56	99.51
Total		3,176,541		

Basin Area: Comparision of the Nile Basin area to other river basins of the world

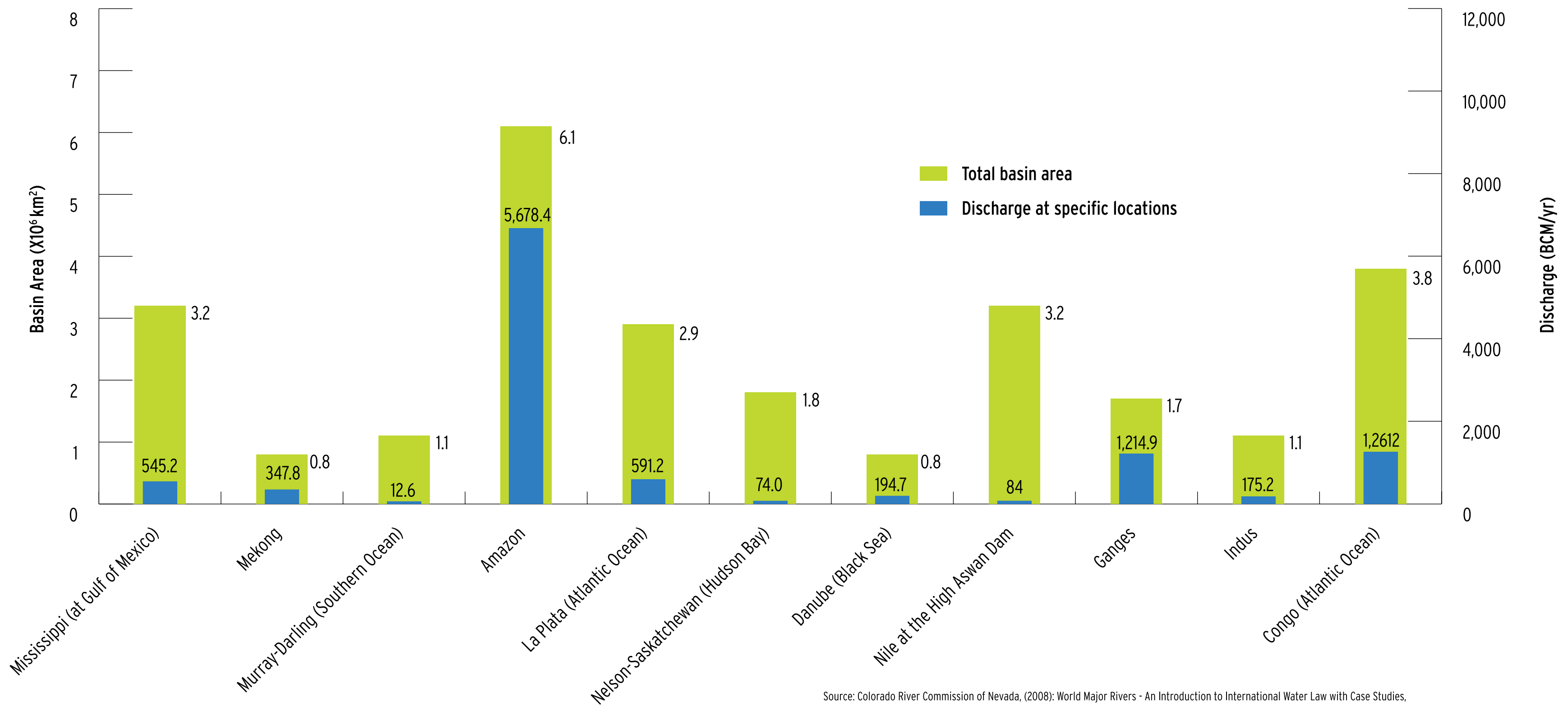


River Length: The length of the Nile in comparison to other rivers of the world



Source: World Major Rivers - An Introduction to International Water Law with Case Studies, Ministry of Environment, DR Congo, River regulation authority - RVI, DR Congo.

Discharge of the main selected rivers in the world



Source: Colorado River Commission of Nevada, (2008): World Major Rivers - An Introduction to International Water Law with Case Studies, The Water Encyclopedia (Lewis Publishers, 1990); Ministry of Environment, DR Congo, River regulation authority - RVI, DR Congo, and NBI database.

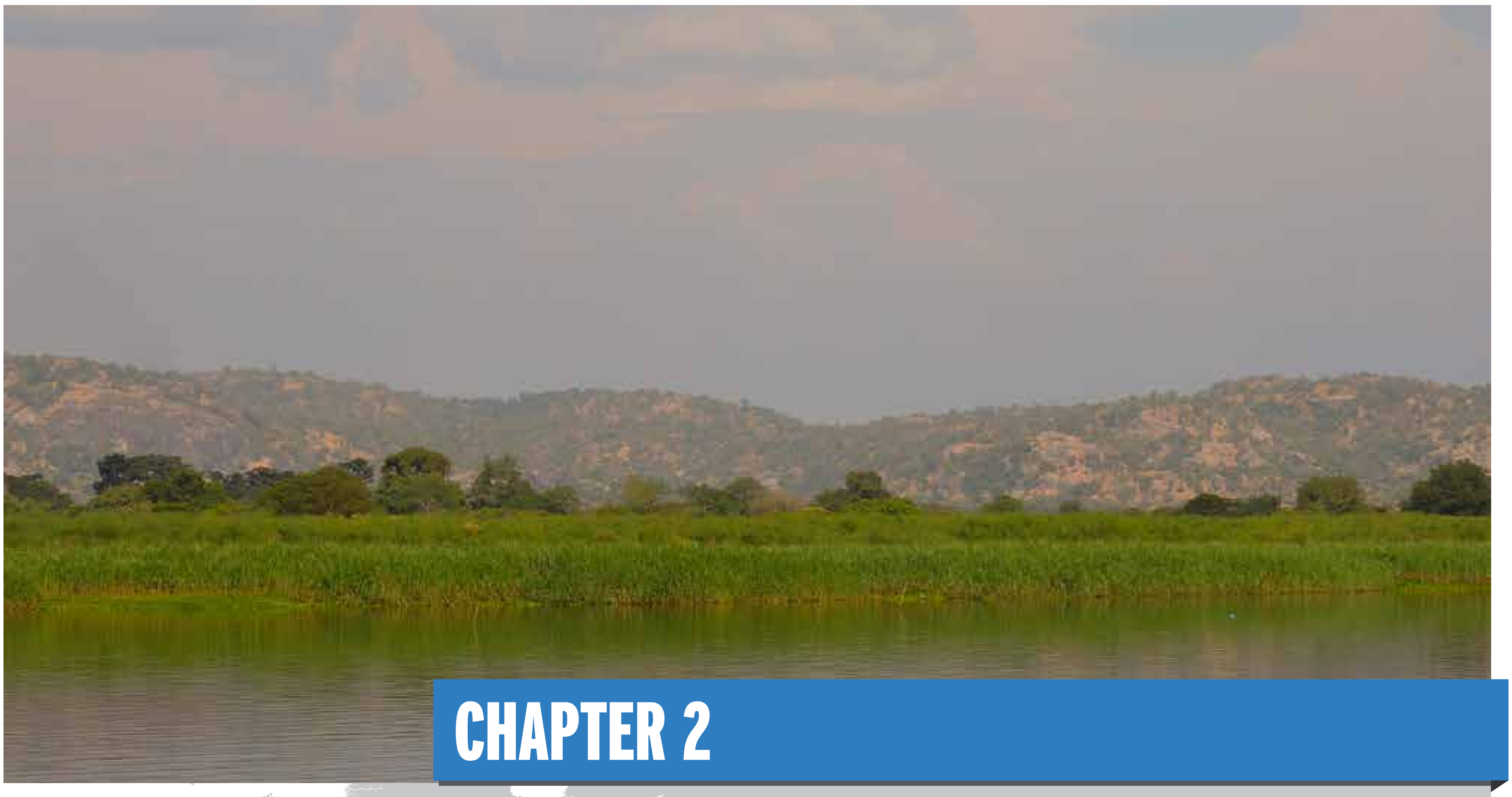


Photo: Dr. Nicholas Azza

CHAPTER 2

NILE BASIN PHYSIOGRAPHY

KEY MESSAGES

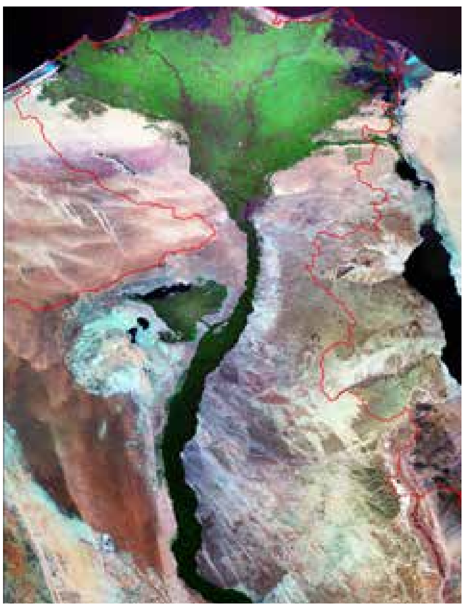


Photo: istock

Nile Delta

The Nile River basin is rich with variety of natural resources (lakes, wetlands, highlands, ecosystem, biodiversity, etc.). In the basin a large population depends on the biodiversity and flood plains for their livelihoods. However, these natural resources are under pressure and degradation from various natural forces (climate change) and human interventions. Collective actions at regional level are needed to protect, sustain resources and generate benefits.

Photo: Jørn Eriksson/flickr.com

Rwenzori mountains, Uganda

Each physiographic region in the Nile basin has a more or less unique combination of surface, slope, soils, topography and vegetation. It is rarely in the world to identify river basins with such rich diversity. Potentials of such rich diversity could be utilized to benefit its population and sustain its environment.

The topography of the Nile basin includes mountain ranges of the upper Kagera, White Nile, Blue Nile and Tekeze-Atbara rivers – to wide flood plains from the lower reaches to the delta. The patterns of topographic variables (altitude, slope and aspect) bring about the patterns, the heterogeneity and the complexity of climate, soil, vegetation, fauna, land cover and land use in connection with socio-economic interactions.

Photo: istock

Birds at Kazinga chanel, Uganda

Beside its length (the longest worldwide), the Nile River basin has many other unique features among the world large river basins, i.e. the Sudd wetland, the largest freshwater wetland in the Nile Basin; Lake Victoria is the second largest natural open surface water body; 17 wetlands sites registered by Ramsar; diverse species of flora and fauna.

Photo: A'Melody Lee; World Bank

Kitabi tea estate, Rwanda

The Nile basin is divided into sixteen terrestrial ecoregions, reflecting the great expanse of the basin. Moving through the basin from south to north, there is a gradual change in elevation and climatic conditions, producing a striking latitudinal gradation in vegetation and fauna. This gradation in ecoregions is accompanied by a marked decrease in the diversity of plant and animal species.

Land cover change by sub-basins indicates the decline of forest areas and increase of cultivated land in almost all the sub-basins.

INTRODUCTION

Photo: Vivek Bahukhandi

Albert Nile, Uganda

The Nile River flows through eleven countries (Burundi, DR Congo, Egypt, Ethiopia, Eritrea, Kenya, Rwanda, South Sudan, Sudan, Tanzania, and Uganda). The Nile basin comprises two broad sub-systems, these are the Eastern Nile sub-system and the Equatorial Nile sub-system. The basin was delineated into ten sub-basins (Main Nile, Atbara, Blue Nile, White Nile, Baro-Akobo-Sobat, Bahr El Jebel, Bahr El Ghazal, Lake Albert, Victoria Nile, Lake Victoria). These sub-basins featured five broad physiographic regions with diverse topography, drainage patterns and geomorphology.

These physiographic regions include (1) highlands - plateaus and mountains; (2) open water surfaces (lakes – both natural and man-made); (3) wetlands and swamps; (4) flat lands; and (5) deserts. Each physiographic region has a more or less unique combination of surface, slope, soils, topography and vegetation. The first two physiographic regions mainly in the upper sub-basin, and the later three regions covers mostly the mid and lower sub- basins.

The Nile River is the longest river in the world at 6,695 km, flowing northward through the tropics and the highlands of eastern Africa and drains into the Mediterranean Sea. The basin covers about one-tenth of the area of the continent, drains a total land area of 3,200,000 km^2. Beside its length, the Nile River basin contains other unique features among the world large river basins, e.g. the Sudd wetland, Lake Victoria; 17 wetlands sites registered by Ramsar and diverse species of flora and fauna.

Moving through the basin from south to north, there is a gradual change in elevation and slope (ranges 0 to 33 degrees) and climatic conditions, producing a striking latitudinal gradation in vegetation and fauna. The Nile River basin supports a range of wetland ecosystems and protected areas distributed across the entire length of the basin (national parks, wilderness areas, community conserved areas, nature reserves, and privately owned reserves). This gradation in ecoregions is accompanied by a marked decrease in the diversity of plant and animal species in northward direction. The hydrological cycle of the Nile basin supports and maintains high productivity of biodiversity within the lakes and in the wetlands and swamps - particularly of fish, plant communities and wildlife. In the basin a large population depends on the biodiversity and flood plains for their livelihoods.

The topography of the Nile basin includes mountain ranges of the upper Kagera, White Nile, Blue Nile and Tekeze-Atbara rivers. The upper parts of the basin have a ridged topography and steep slopes. Most rivers in the Eastern Nile exhibit much steeper slope in their upper reaches compared to the rivers that originate in the Equatorial Lakes region. These steeper slopes, beside high contribution of flow, also contribute to erosion, land degradation of watersheds and downstream sediment transport.

Changes in land cover are determined by a complex set of interactions between environmental and socio-economic factors. Land cover change in sub-basins indicates the decline of forest areas and increase of cultivated land in almost all the sub-basins, indicative of increasing human activity in the basin. The Nile basin has 17 soil groups, the dominant soil group in the basin is vertisols (18.5% of basin area), followed by yermosols (16.7%). Bare areas are dominant in low lying areas, mainly desert area of the Main Nile but there are also significant bare areas in steep slopes. Soil moisture is highest in the three upper southern sub-basins (the lakes area) and lowest in the Main Nile and Tekeze-Atbara sub-basins. Agriculture is found in all categories of elevations but mainly in low lying areas (less than 502 m) and medium elevation areas (890 – 1,454 m) and also practiced in some steep slope areas. Forest is dominant in the elevation range between 500 m and 2,159 m and shrub-land is dominant in the elevation range between -47 and 1,454 m and in steep slope areas (30 – 33 degrees).

RELIEF CHARACTERISTICS

Topography

The topography of the Nile Basin includes mountain ranges of the Upper Kagera, White Nile, Blue Nile and Tekeze-Atbara rivers. The upper parts of the basin have a ridged topography and steep slopes. There are large plateau regions along the middle reaches of the basin and wide flood plains from the lower reaches to the delta.

Photo: Lars Nilse/Flickr.com

Crater lake in western Uganda

Photo: The World Bank

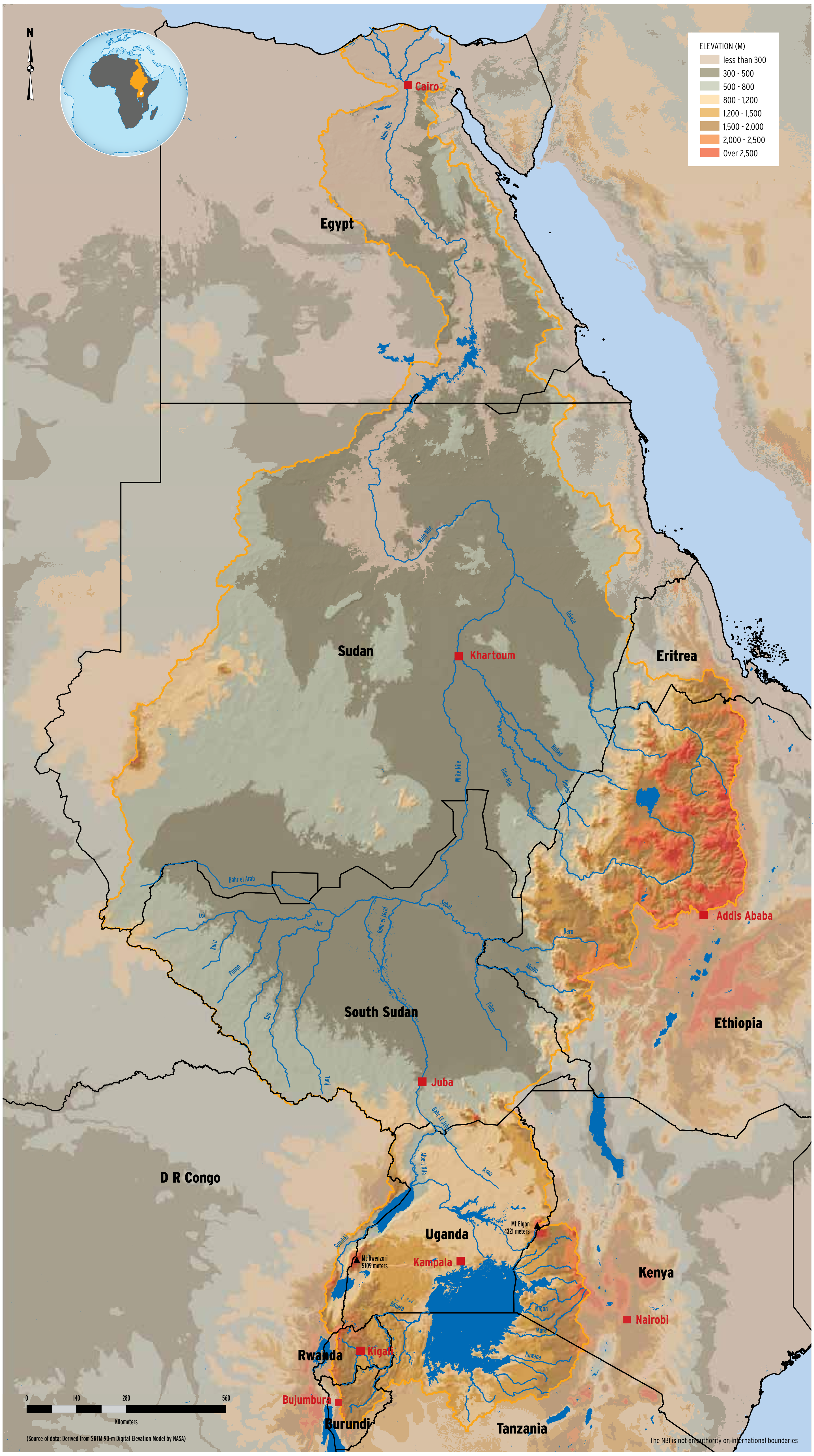
Kenyan grasslands

Photo: John Eriksson/flickr.com

Rwenzori mountain ranges

Photo: John Eriksson/flickr.com

Rwenzori mountains, Uganda



(Source of data: Derived from SRTM 90-m Digital Elevation Model by NASA)

The NBI is not an authority on international boundaries

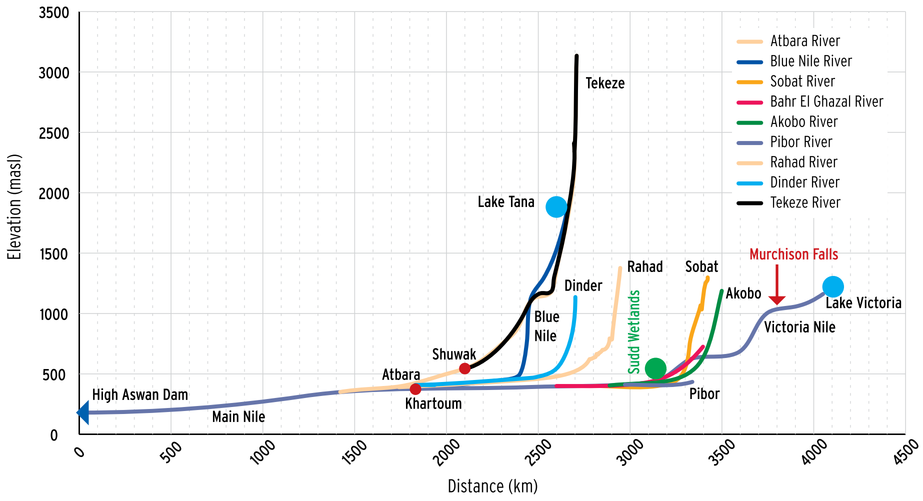
Slope range in the Nile Basin

The slope gradient is one of the most important factors affecting soil erosion by the surface runoff. Under the same rainfall condition, the surface runoff velocity could be drastically different on different slopes, and thus the amount of eroded soil could also be very different. The slope in the basin varies between 0 and 33 degrees.

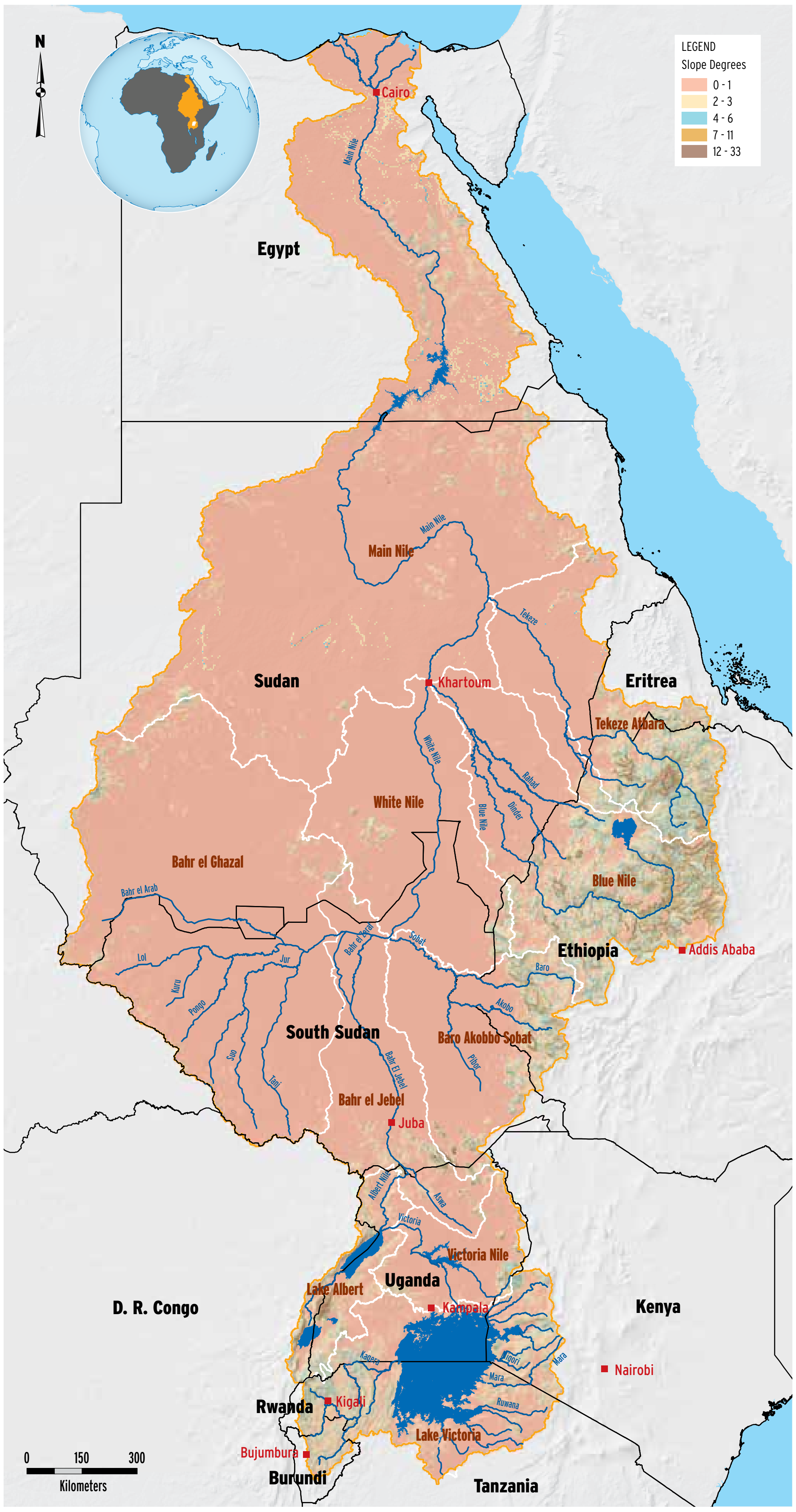

Photo: Adam Cohn/ Flickr.com

A valley in Rwanda with tea plants

Longitudinal profiles of major tributaries on the Nile



The longitudinal bed profiles of main rivers are shown in the adjacent figure. The graph shows elevation (metres above sea level, masl) of river bed as a function of distance from a selected common downstream point, in this case, the High Aswan Dam. Most rivers in the Eastern Nile exhibit much steeper slope in their upper reaches compared to the rivers that originate in the Equatorial Lakes region. The rivers in their steep slope reaches have high energy gradients and are capable of transporting high sediment loads, as observed in the rivers originating in the Ethiopian highlands. In contrast, the rivers originating from the Equatorial Lakes region (Victoria Nile, Albert Nile and Bahr El-Jebel) show breaks in the slopes of the river bed, which are points where the river passes through lakes and swamp areas.



(Source of data: SRTM 90-m Digital Elevation Model by NASA)

The NBI is not an authority on international boundaries


Photo: The Minister of Information/flickr

Simien mountain range in northern Ethiopia

GEOLOGICAL FORMATION OF THE NILE BASIN

Geology of the Nile Basin

Crystalline basement rocks, which comprise of crystalline igneous and metamorphic rocks of the Precambrian age are present across the area, but mainly in the upstream parts of the basin. With the exception of metamorphic rocks the parent material is essentially impermeable, and productive aquifers occur where weathered overburden and extensive fracturing are present.


Photo: Milly Mbuliro

Hills in Ethiopian highlands


Photo: Thomas Favre-Bulle/flickr.com

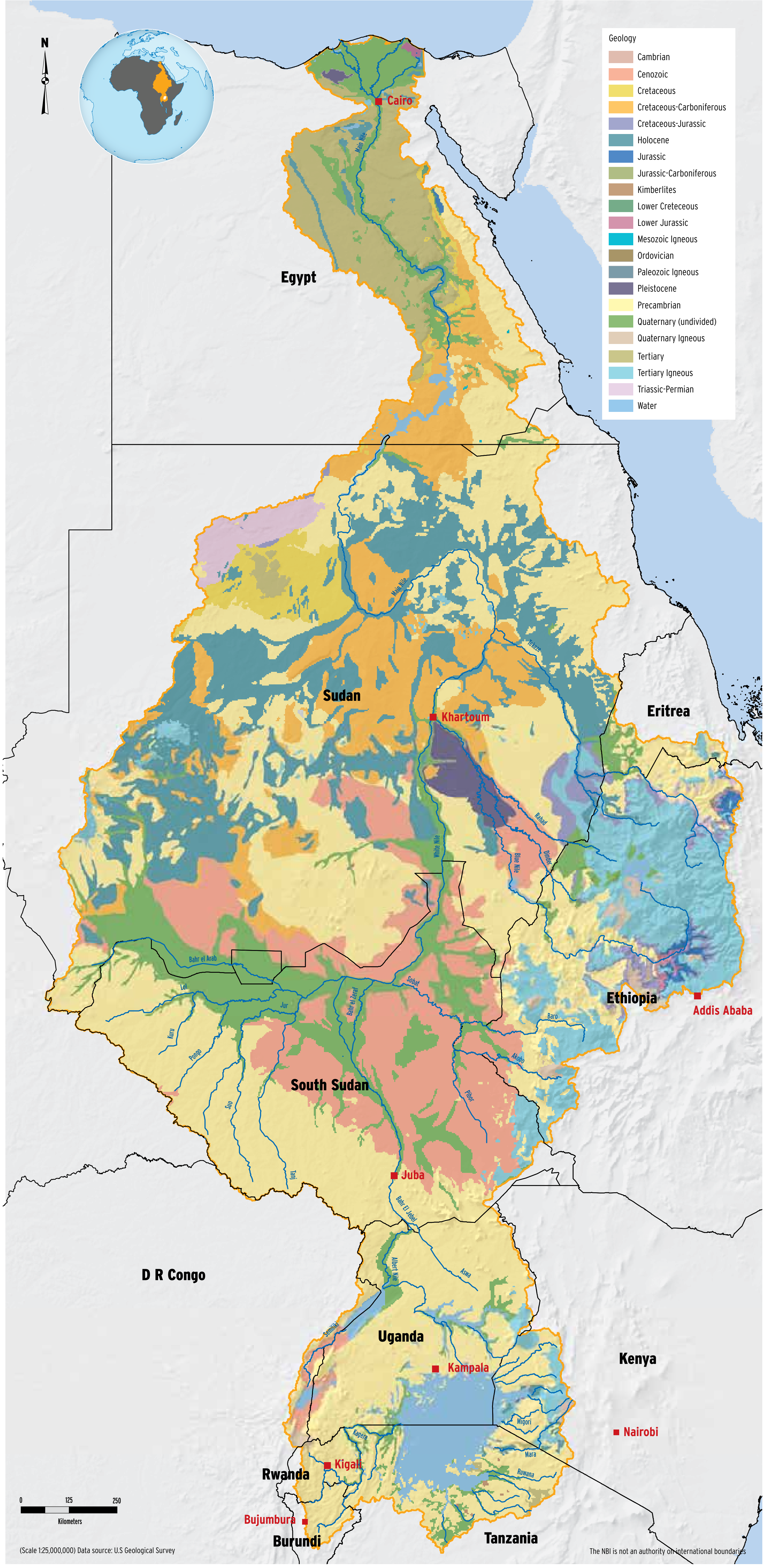
Egyptian desert

The crystalline basement upper and middle catchment watercourses collectively considered as making up the Bahr el Ghazal system.

The Muglad cretaceous rift basin underlies the very subdued topography of the Sudd and the lower reaches of the Bahr el Ghazal.

Tertiary and Pleistocene sedimentary infill dominates the lower parts of the basin. Consolidated sedimentary rocks are highly variable and can comprise low permeability mudstone and shale, as well as more permeable sandstones, lime stones and dolomites, forming some of the most extensive and productive aquifers.

Unconsolidated sedimentary aquifers are present in many river valleys. Volcanic rocks occupy the uplands (mainly the Ethiopian highlands), where they form highly variable, and usually highly important, productive aquifers.



(Scale 1:25,000,000) Data source: U.S Geological Survey

The NBI is not an authority on international boundaries

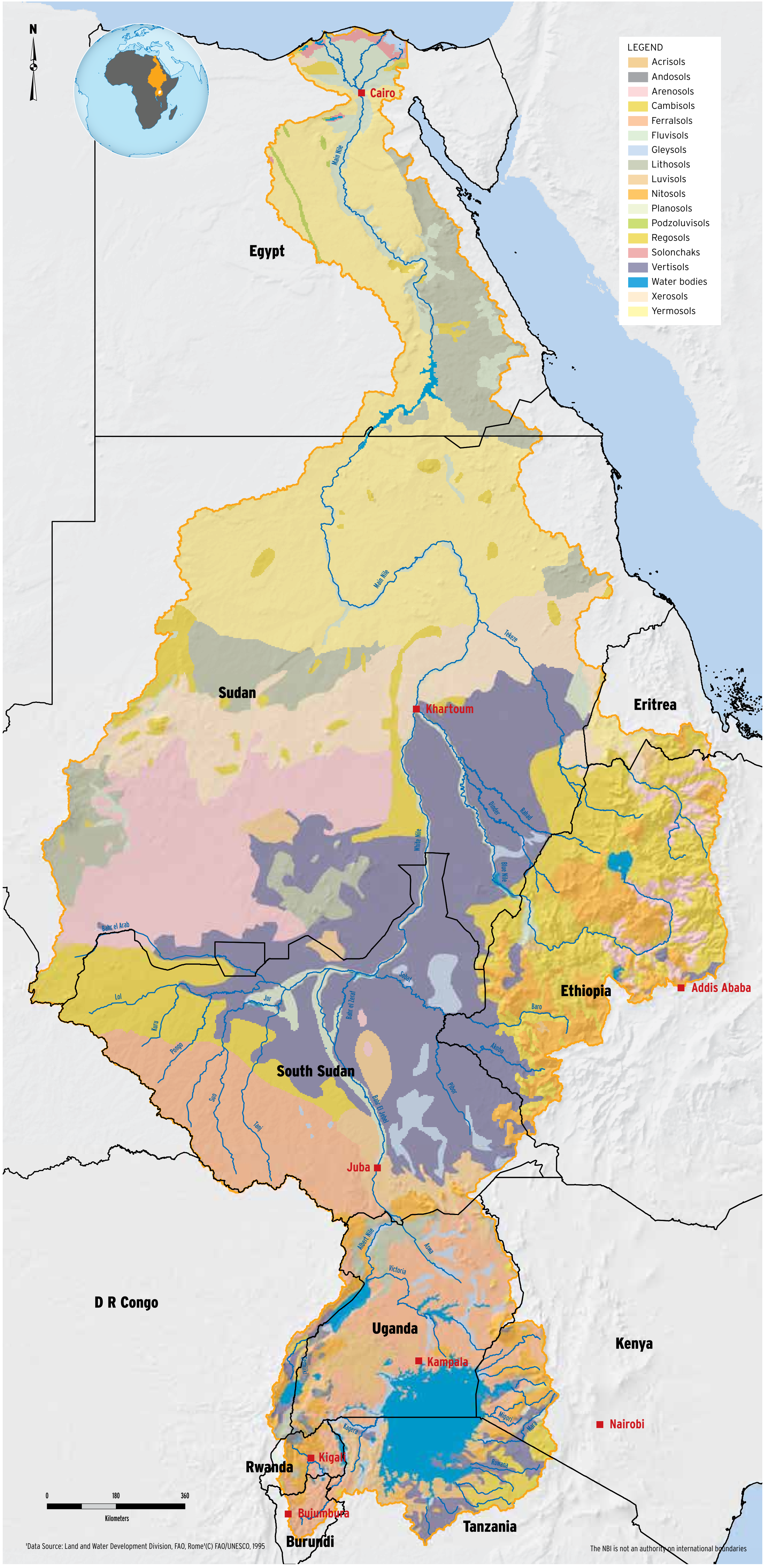
Soil types in the basin

According to the World Reference Base for Soil Resources (WRB), which is the international taxonomic soil classification system, Nile Basin has 17 dominant soil groups.

The characteristics of the soil groups are as tabulated in Annex A

The dominant soil group in the basin is vertisols (18.5% of the total basin area), followed by yermosols (16.7%).

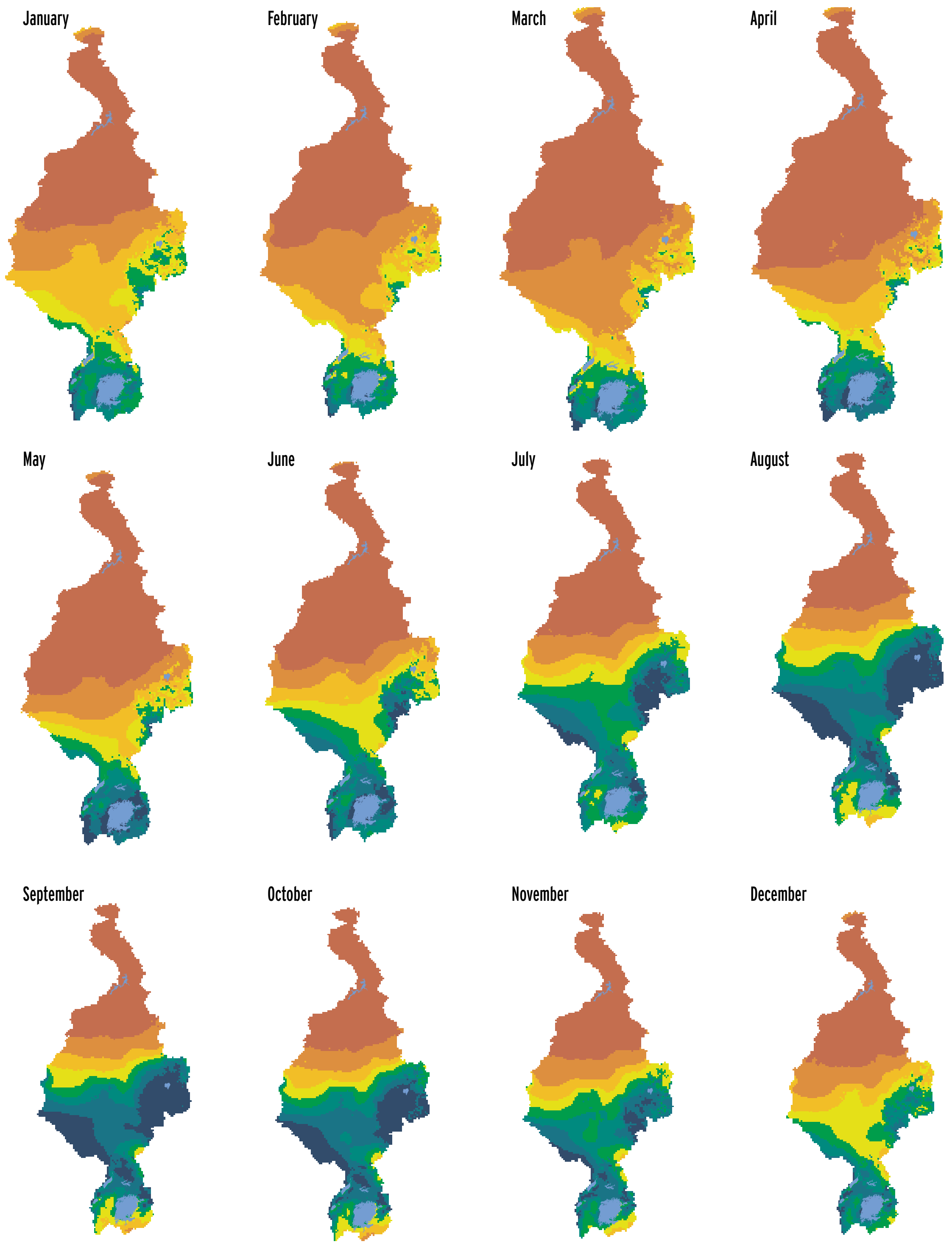
Dominant Soil	Area (km^2)	Percentage of Area
Acrisols	44,985	1.4
Andosols	7,267	0.2
Arenosols	284,955	9.0
Cambisols	224,354	7.1
Ferralsols	314,978	9.9
Fluvisols	115,040	3.6
Gleysols	55,855	1.8
Lithosols	235,957	7.4
Luvisols	73,978	2.3
Nitosols	159,521	5.0
Planosols	860	0.0
Podzoluvisols	3,930	0.1
Regosols	210,591	6.6
Solonchaks	5,330	0.2
Vertisols	587,655	18.5
Water bodies	91,303	2.9
Xerosols	228,120	7.2
Yermosols	530,263	16.7



¹Data Source: Land and Water Development Division, FAO, Rome¹(C) FAO/UNESCO, 1995

The NBI is not an authority on international boundaries

Spatial temporal variation of soil moisture in the basin



Data source: This dataset is based on modeling and analyses by Antonio Trabucco (Forest Ecology and Management Research Group, K.U. Leuven) with the support of the IWMI and ICIMOD and provided online by CGIAR-CSI


Photo: Vivek Bahukhandi

Fringing swamp

Soil moisture is defined as the ratio of water content in the soil in percentage of volume or weight. It is the measure of the amount of water in the vadose zone (unsaturated zone). Soil moisture is a key variable for understanding hydrological processes in the unsaturated zone. It plays an important role in weather and climate predictions from the regional to the global scale by controlling the exchange and partitioning of water and energy fluxes at the land surface. Agricultural and irrigation management practices, especially in semi-arid and arid regions, largely depend on timely and accurate characterization of temporal and spatial soil moisture dynamics in the root zone because of the impact of soil moisture on the production and health status of crops and salinization (Vereecken et al, 2008).

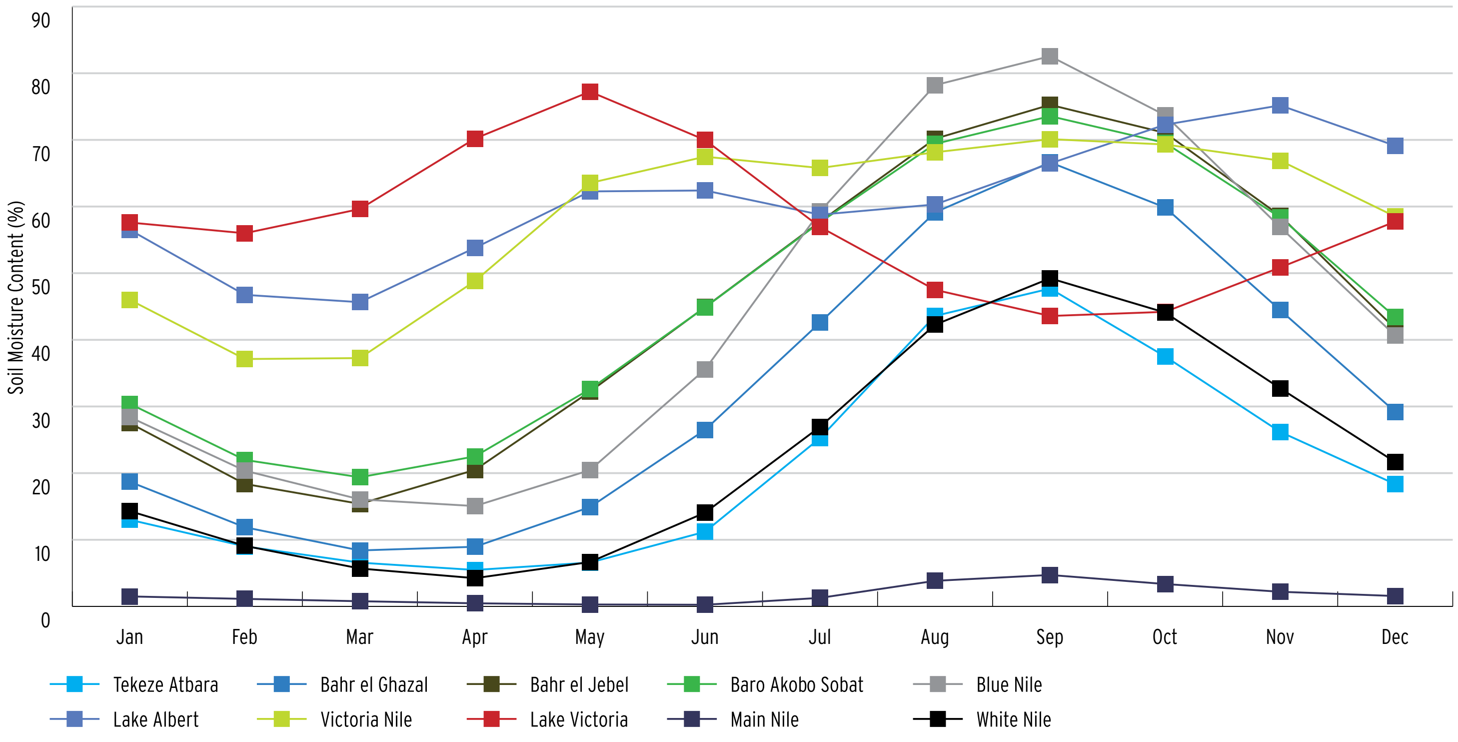
SOIL MOISTURE CONTENT (PERCENT)

🟫 0 - 6	🟩 40 - 51
🟧 7 - 17	🟩 52 - 64
🟨 18 - 28	🟦 65 - 80
🟨 29 - 39	🟦 81 - 100

Average monthly soil moisture variation per sub-basin

Soil moisture variation is determined as the percentage of the maximum amount of soil moisture available for Evapotranspiration (ET) processes within the plant rooting depth which is equal to soil water content at field capacity minus soil water content at wilting point times the rooting depth.

The monthly variation of soil moisture shown in the maps track the rainfall season, as observed clearly in the eastern Nile, where high soil moisture content starts in June and continue in rise through October and in decrease in November and lowest in February – March. The soil moisture is highest in the three upper southern sub-basins and lowest in the Main Nile and Tekeze-Atbara sub-basins.



ECO-REGIONS IN THE NILE BASIN

An ecoregion is defined as a geographically dinstict assemblage of plants and animals that share similar environmental conditions and interact in such ways as to enhance their collective long term survival.

The Nile Basin is divided into sixteen terrestrial ecoregions, reflecting the great expanse of the basin. These are Victoria Basin forest savannah mosaic, Miombo woodlands, Acacia –Commiphora bushlands and thickets, the Ethiopian montane grasslands and woodlands, Sudanian savannah, Sahelian Acacia savannah, saharah desert and the Saharan woodlands and steppe.

Moving through the basin from south to north, there is a gradual change in elevation and climatic conditions, producing a striking latitudinal gradation in vegetation and fauna. This gradation in ecoregions is accompanied by a marked decrease in the diversity of plant and animal species.

Photo: istock

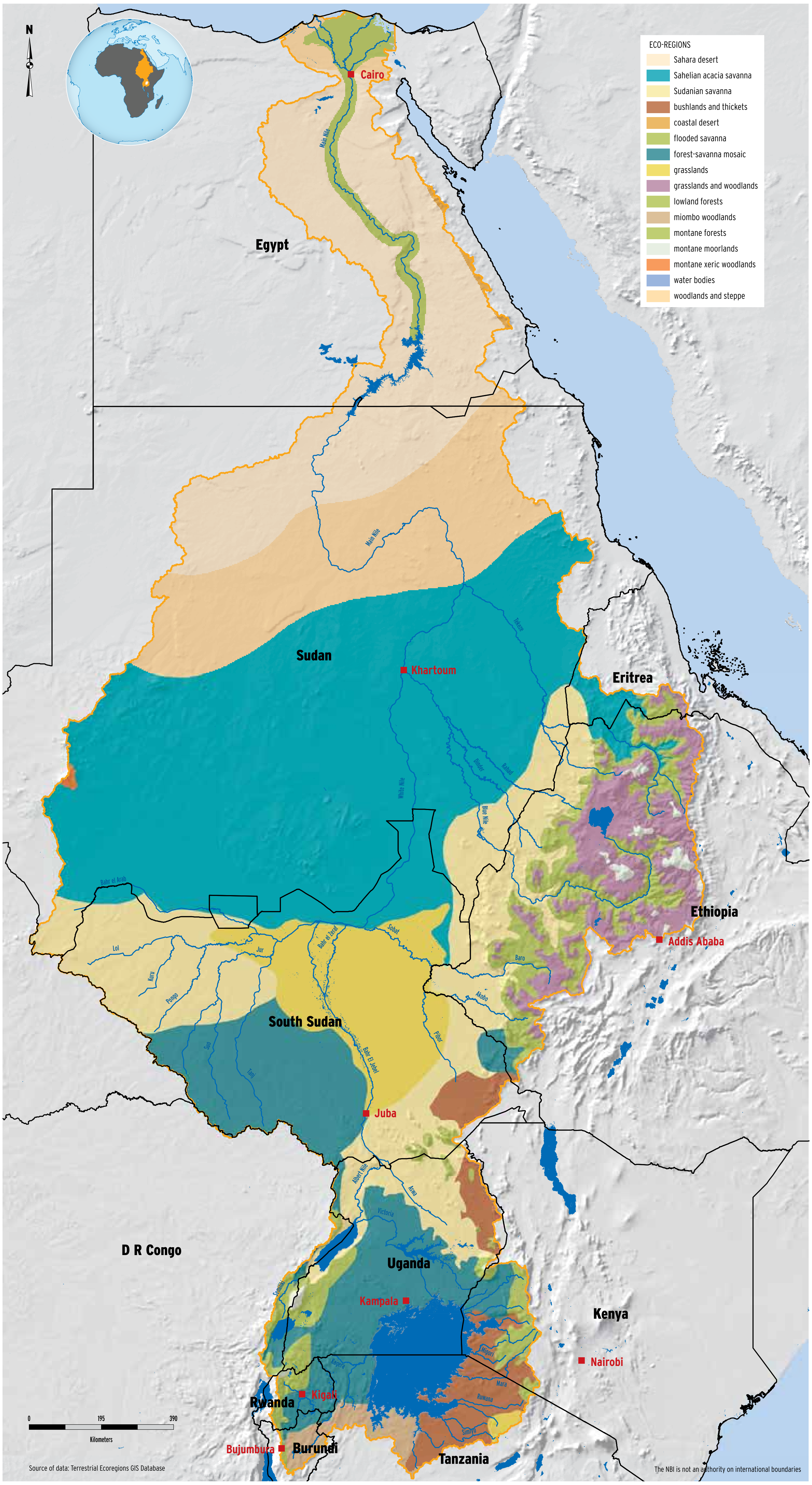
Mara River

Photo: Milly Mbuliro

Invasive cactus species in a woodland

Photo: Bernard Dupont/flickr.com

Mabira forest undergrowth



Source of data: Terrestrial Ecoregions GIS Database

The NBI is not an authority on international boundaries

LAND COVER IN THE NILE BASIN

Land use/cover in the Nile Basin

According to ESA GlobCover project, 2009, the main land use/cover in the basin are bare areas (31%), shrublands (29%), cultivated land (23%), forest (7%) and grassland (6%).

Among the environmental variables, topography is of special importance. Topographic variables comprise altitude, slope and aspect. The patterns of altitude, slope and aspect bring about the patterns, the heterogeneity and the complexity of climate, soil, vegetation, fauna, land cover and land use in connection with socio-economic interactions. In Nile Basin, agriculture is found in all categories of elevations but mainly in low lying areas (less than 502 m) and medium elevation areas (890 – 1,454 m) and also practiced in some steep slope areas. Forest is dominant in the elevation range between 500m and 2,159 m and shrubland is dominant in the elevation range between -47 and 1,454 m and in steep slope areas (30 – 33 degrees). Bare areas are dominant in low lying areas, mainly desert area of the Main Nile but there are also significant bare areas in steep slopes.


Photo: FAO/ Matthias Mugisha

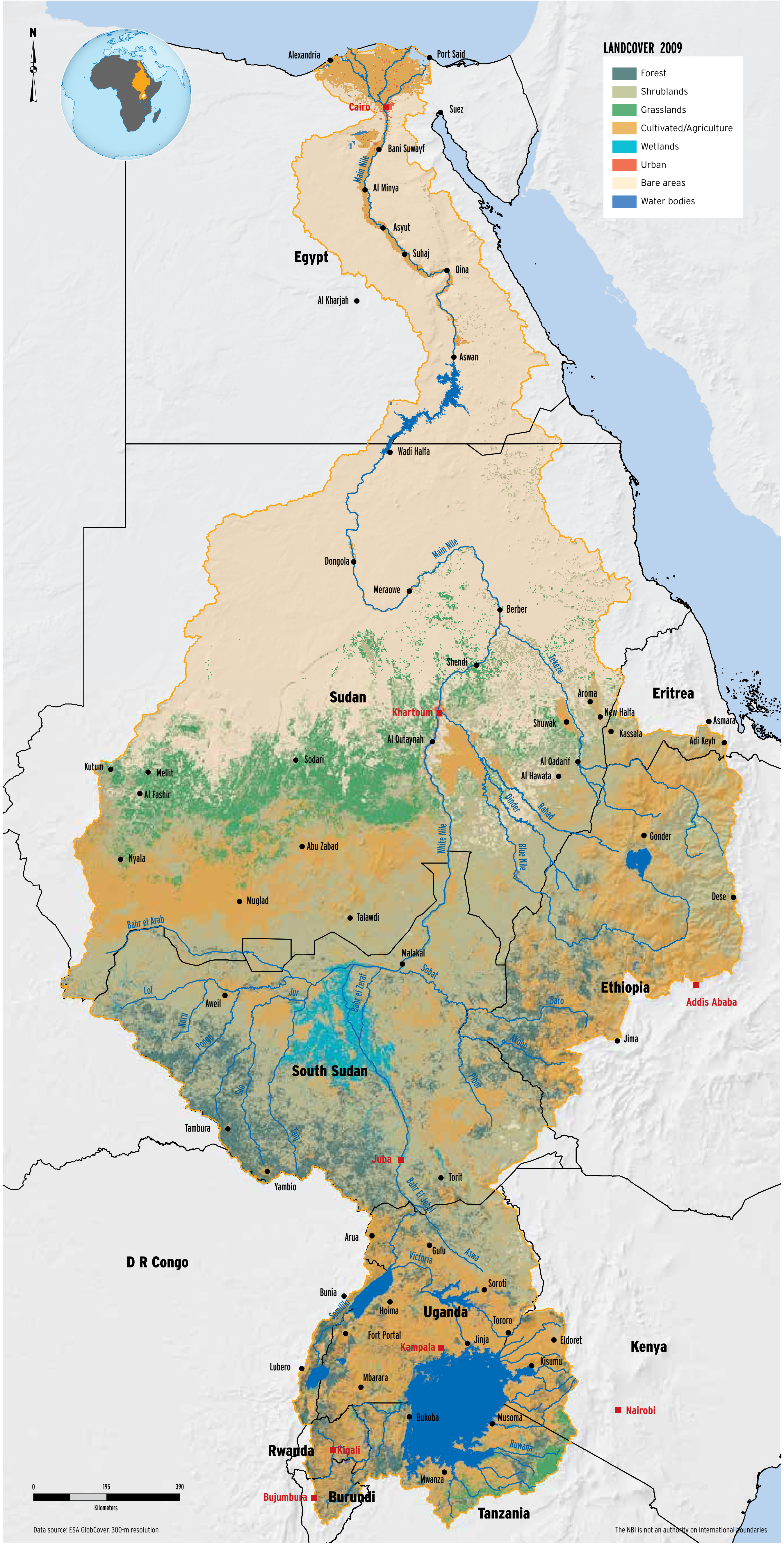
Kapchorwa, Uganda


Photo: istock

Cassava field


Photo: Vivek Bahukhandi

Bwindi Impenetrable Forest. Uganda



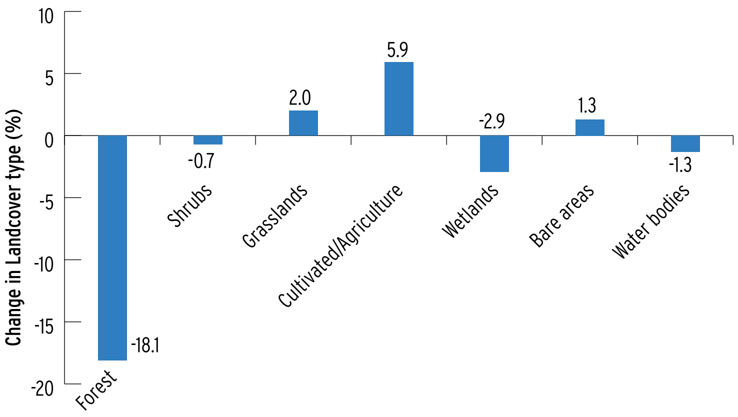
Change in land cover between 2005 and 2009

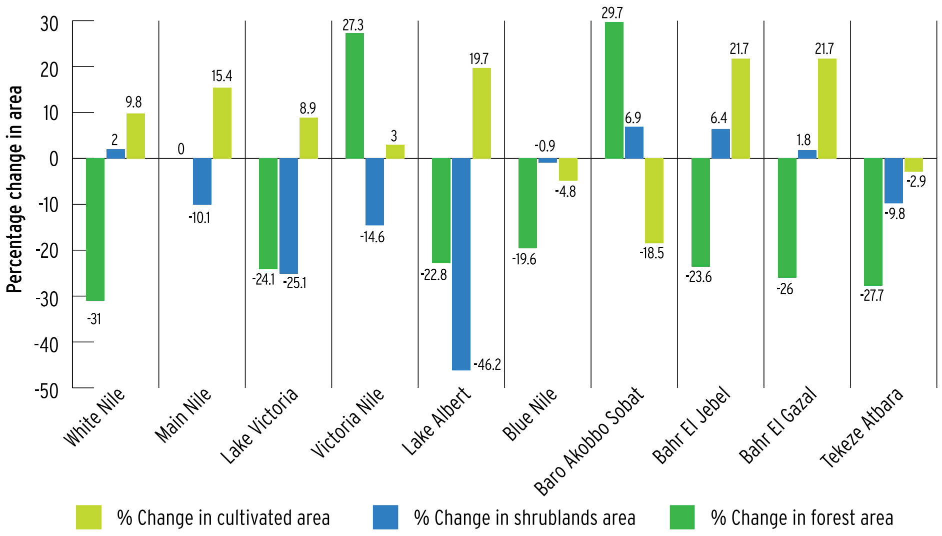
Changes in the land cover are determined by a complex set of interactions between environmental and socio-economic factors. Classified satellite images for the years 2005 and 2009 show substantial changes in different land covers. These changes are considered to reflect natural expansion and contraction in the area of vegetation types, as well as human induced land use changes. Major changes have been observed in the Mau Complex due to human encroachment. Other critical watersheds affected are the montane ecosystem of Mt. Elgon, Mt. Rwenzori and the Ethiopian Highlands.

Land cover change by sub-basins indicates the decline of forest areas and increase of cultivated land in almost all the sub-basins.


Photo: istock

Tea plantations at Gikongoro, Rwanda





Name	Class	% change 2005 - 2009	Change (km²) 2005 - 2009
Forest	4	-18.1	-46803.29
Shrubs	6	-0.7	-6605.15
Grasslands	7	2.0	3609.61
Cultivated/Agriculture	8	5.9	40239.18
Wetlands	9	-2.9	-1458.22
Bare areas	12	1.3	12517.51
Water bodies	13	-1.3	-1261.41


Photo: A'Melody Lee/World Bank

Terrace farming in Rwanda

PROTECTED AREAS IN NILE BASIN

A protected area is defined as a geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long term conservation of nature with associated ecosystem services and cultural values.

Protected areas can take on many different forms, such as national parks, wilderness areas, community conserved areas, nature reserves and privately owned reserves.

The Serengeti and Masai Mara national parks feature the world famous annual migration of wildebeest, zebra and buffalo.

The Sudd in South Sudan features equally impressive mass migrations of large mammals. Other Transboundary conservation areas of considerable significance are the three connected national parks of the Virunga Mountain chain (Virunga National Park, Karisimbi National Park and Bwindi National Park), home to the world's only remaining population of mountain gorilla.

The Boma National Park, sometimes called - the Boma Jonglei National Park, is home to a variety of animals: elephants, giraffe and buffalo. It has numerous types of antelopes like: white-eared kob, common eland, lesser kudu, Bohor reedbuck, gazelles, tiang, Lelwel hartebeest, Beisa oryx and roan. And an impressive diversity and variety of birds; most of which are migratory.

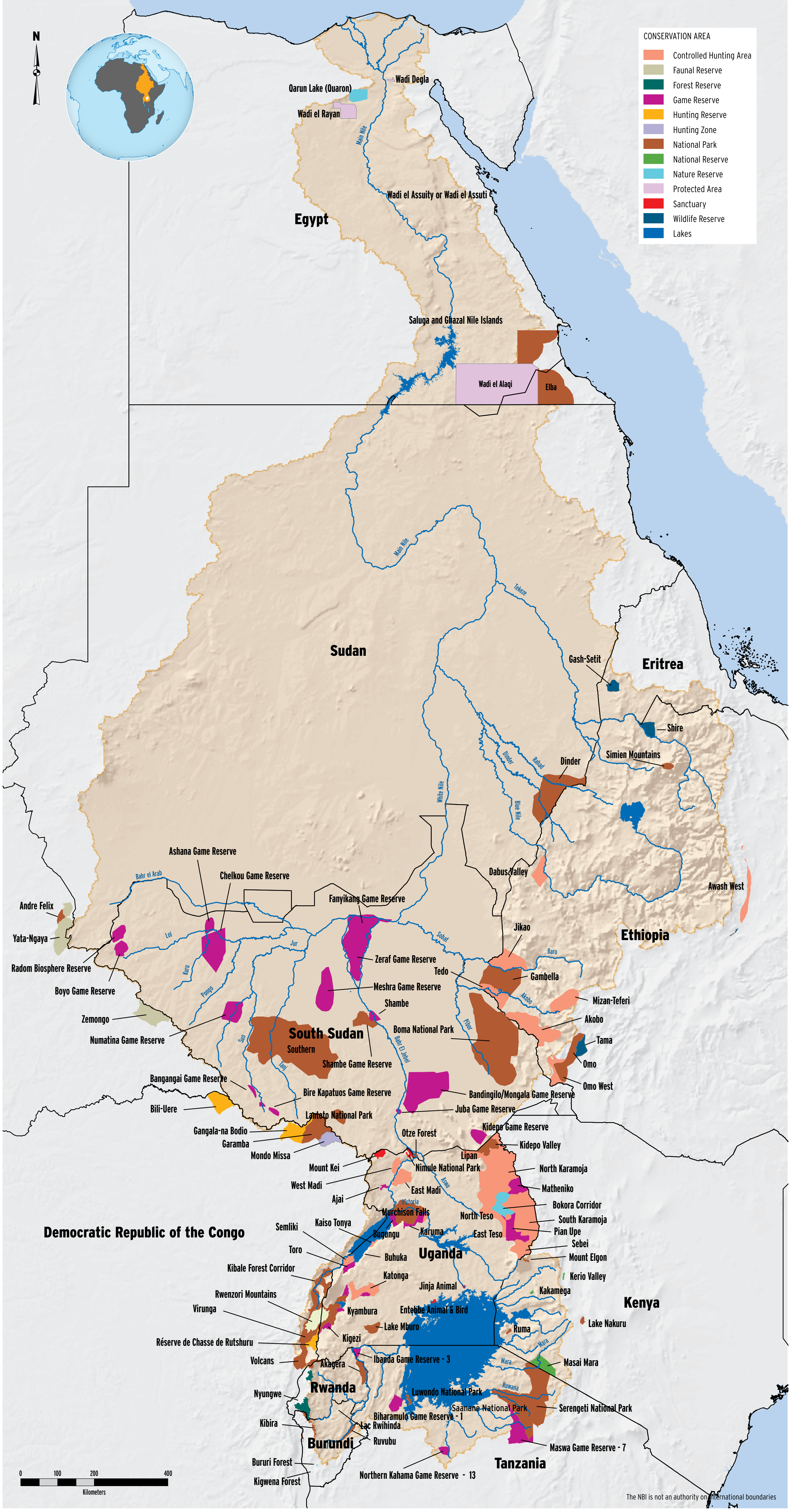
Gambela National Park is located on the Akobo river system, it hosts several wildlife not found elsewhere in Ethiopia. Originally the park was created for protection of extensive swamp habitat and wildlife species.

Photo: Vivek Bahukhandi

Kobus kob thomasi in Queen Elisabeth National Park, Uganda

Photo: Vivek Bahukhandi

Mountain gorilla at Bwindi Impenetrable Forest, Uganda



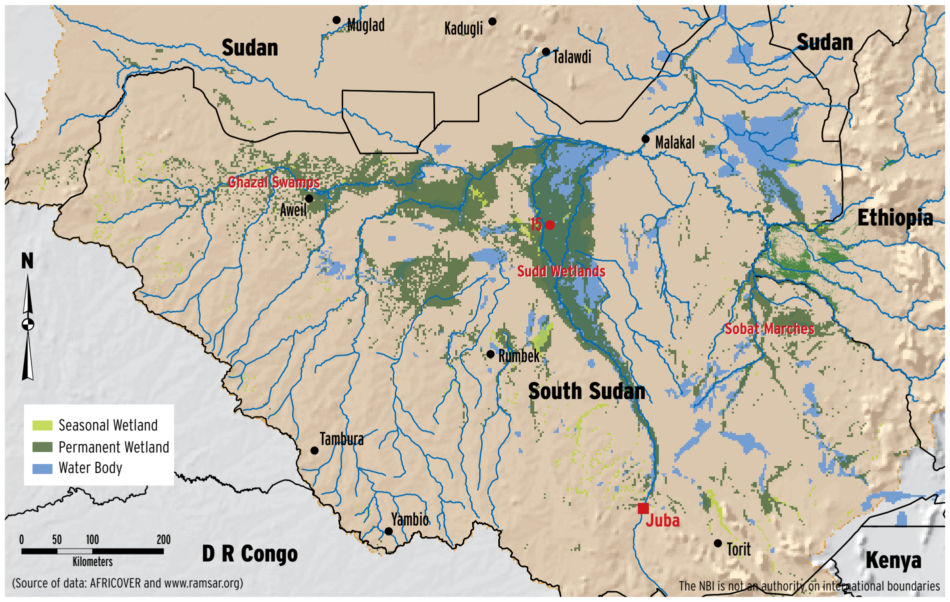
WETLANDS IN THE NILE BASIN

Wetlands are valuable ecosystems that play an important role in maintaining environmental quality, sustaining livelihoods and supporting biodiversity. The wide range of animal and plant species wetlands support provide ecosystem that services in the form of fisheries, fuel-wood, timber, medicines, and the local and global biodiversity, providing high ecological, cultural and economic value through recreation and tourism. Wetlands also exert significant influence on the hydrological cycle, altering flood flows, maintaining low flows and groundwater recharge. Wetlands that are registered by Ramsar as wetlands of international importance in the Nile Basin are presented below.

Photo: Dr. Nicholas Azza

Papyrus on River Nile, Uganda

Wetlands of Bahr El Ghazal and Bahr El Jebel sub-basin



- 🟩 Seasonal Wetland
- 🟩 Permanent Wetland
- 🟦 Water Body

(Source of data: AFRICOVER and www.ramsar.org)

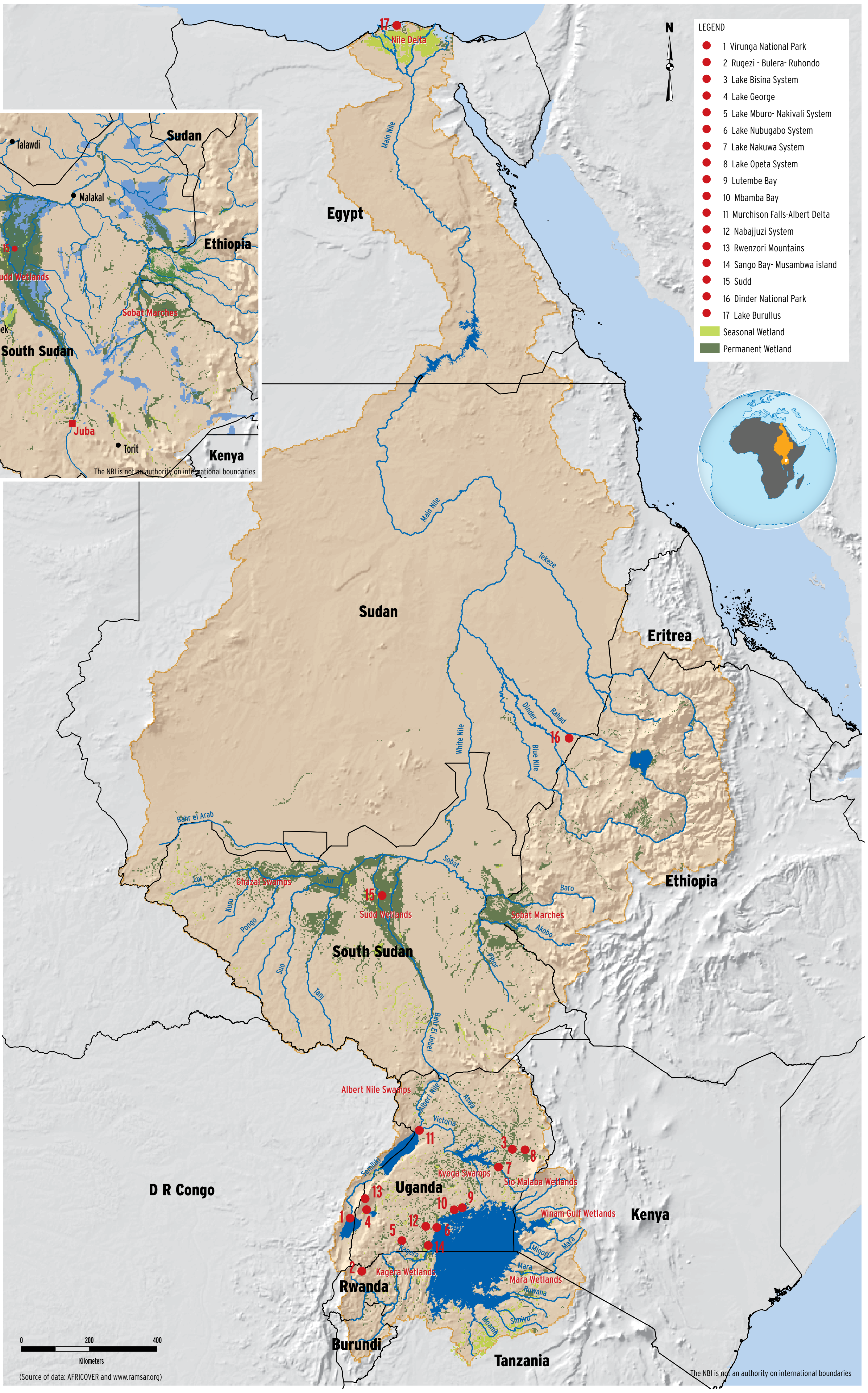
The NBI is not an authority on international boundaries

The Sudd wetland is one of the largest wetland areas worldwide and is located along the Nile in southern Sudan between Mongalla in the south and Malakal in the north, covering an area between 57,000km^2 - 130,000km^2. The size of the wetland is variable, consisting of permanent swamps during the dry season (November until March) and seasonal swamps, created by flooding of the Nile (Bahr el Jebel), in the wet season (April until October).

Photo: istock

Papyrus plant, common in Nile basin wetlands

Wetland and Ramsar sites in Nile Basin



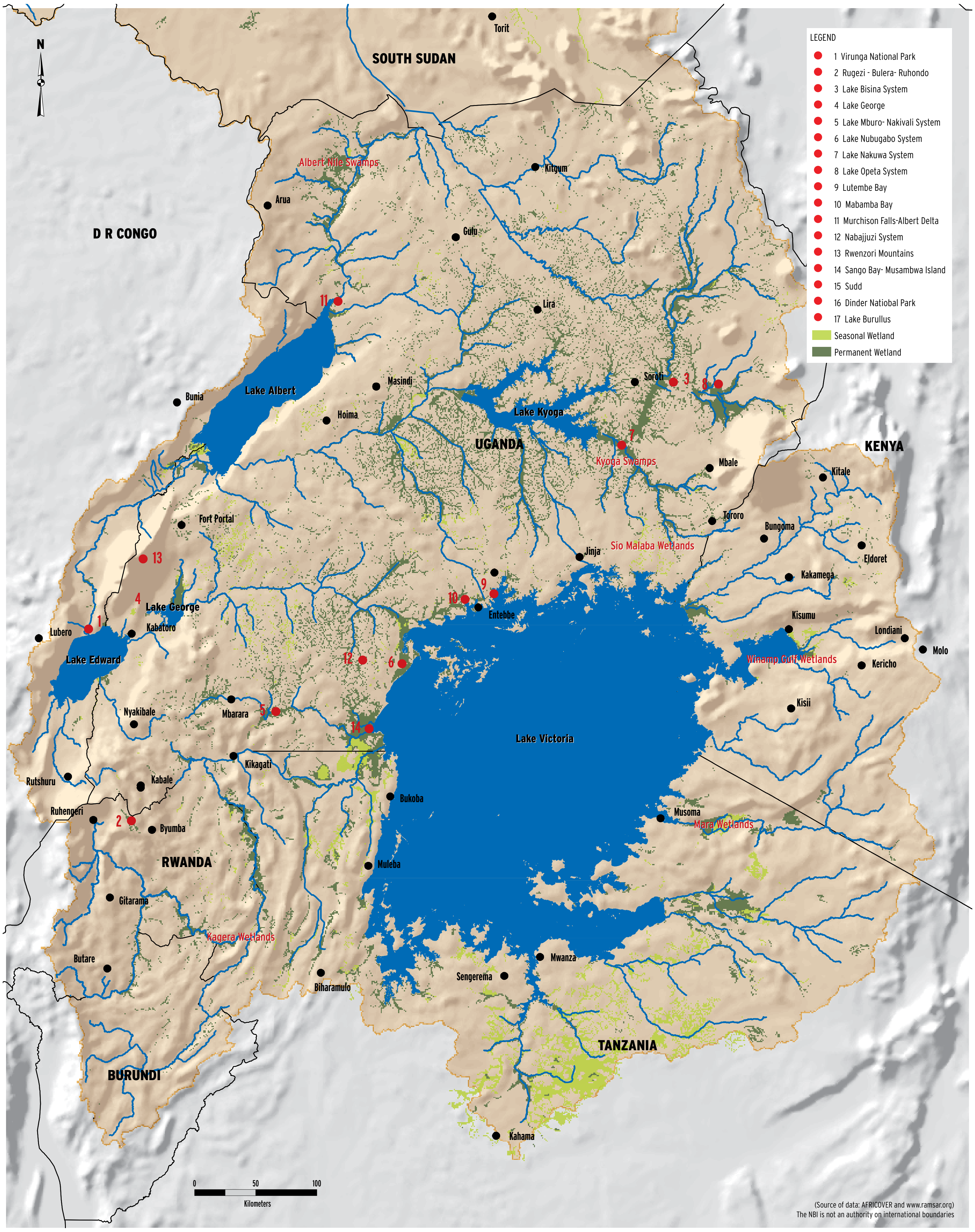
LEGEND

- ● 1 Virunga National Park
- ● 2 Rugezi - Bulera- Ruhondo
- ● 3 Lake Bisina System
- ● 4 Lake George
- ● 5 Lake Mburo- Nakivali System
- ● 6 Lake Nubugabo System
- ● 7 Lake Nakuwa System
- ● 8 Lake Opeta System
- ● 9 Lutembe Bay
- ● 10 Mbamba Bay
- ● 11 Murchison Falls-Albert Delta
- ● 12 Nabajjuzi System
- ● 13 Rwenzori Mountains
- ● 14 Sango Bay- Musambwa island
- ● 15 Sudd
- ● 16 Dinder National Park
- ● 17 Lake Burullus
- 🟩 Seasonal Wetland
- 🟩 Permanent Wetland

(Source of data: AFRICOVER and www.ramsar.org)

The NBI is not an authority on international boundaries

Wetlands in the Nile Equatorial Lakes Region



(Source of data: AFRICOVER and www.ramsar.org)
The NBI is not an authority on international boundaries

Name	Country	Sub-basin	Area (km^2)	Dominant Type
Virunga National Park	DRC	Lake Albert	8,000	Permanent freshwater lakes
Rugezi- Bulera Ruhondo	Rwanda	Lake Victoria	85	Permanent freshwater marshes
Lake Bisina Wetland System	Uganda	Victoria Nile	542	Permanent freshwater lakes
Lake George	Uganda	Lake Albert	150	Permanent freshwater lakes
Lake Mburo- Nakivali Wetland System	Uganda	Lake Victoria	268 - 837	Permanent freshwater lakes
Lake Nabugabo	Uganda	Lake Victoria	220	Permanent freshwater lakes
Lake Nakuwa	Uganda	Victoria Nile	911	Permanent freshwater marshes or pools
Lake Opeta	Uganda	Victoria Nile	689	Permanent freshwater marshes or pools
Mbamba Bay	Uganda	Lake Victoria	24	Permanent freshwater marshes or pools
Murchison Falls-Albert Delta	Uganda	Victoria Nile	172	Permanent freshwater marshes or pools
Nabajjuzi	Uganda	Lake Albert	17	Permanent freshwater marshes or pools
Rwenzori Mountains	Uganda	Lake Victoria	995	Seasonal/intermittent freshwater lakes/rivers
Sango Bay- Musambwa island	Uganda	Lake Albert	551	Seasonal/intermittent freshwater lakes
Sudd	South Sudan	Bahr El Jebel	57,000	Permanent/seasonal rivers
Dinder National Park	Sudan	Blue Nile	10,846	Seasonal/intermittent freshwater lakes/rivers
Lake Burullus	Egypt	Main Nile	426	Permanent freshwater marshes or pools
Bahr El Ghazal swamps	South Sudan	Bahr El Ghazal		Permanent/seasonal rivers
Sobat/Machar Marches	South Sudan	Baro Akobbo Sobat	4,041	Permanent/seasonal rivers

Hydrological functions of major wetlands in the Nile Basin

Wetland	Hydrological functions
Wetlands of Uganda	Most of the individual wetlands link to other wetlands through a complex network of permanent and seasonal streams, rivers. and lakes, making them an essential Part of the entire drainage system of the country (UN-WWAP and DWD,2005)
Headwater wetlands of the Baro Akobo	Regulate flow in the Baro Akobo River while believed to play an important role in maintaining downstream dry-season river flows
Lake Albert	Critical link between the White Nile and its headwaters; without the flow regulation of this lake the White Nile would be reduced to a seasonal stream and could play no significant role in maintaining the base flow of the main Nile (Talbot and Williams, 2009)
Sudd, Machar Marshes and wetlands of the Bahr Ghazal	Significantly attenuate flows of the White Nile and its tributaries reducing flood peaks and supporting dry-season river flows, thereby minimizing the seasonal variation in the flow of the White Nile (Sutcliffe and Widgery, 1997; Sutcliffe and Parks, 1999)
Nile Delta	Limits saline intrusion from the Mediterranean Sea, thereby protecting coastal freshwater sources (Baha El Din, 1999)

(Source: IWMI, 2012)

MAJOR SUB-BASINS OF THE NILE

The Nile Basin covers an area of about 3,176,541 km^2 in eleven countries. The Nile Basin Comprises two broad sub systems. These are the Eastern Nile sub system and the Equatorial Nile sub system. The basin is further divided into ten Major sub-basins. The Eastern Nile sub sytem comprises the Main Nile Sub-basin, Tekeze-Atbara Sub-basin, Blue Nile Sub-basin and the Baro- Akobo-Sobat Sub-basin. The Equatorial Nile sub system comprises of Lake Victoria sub-basin, Albert Nile Sub-basin, Victoria Nile Sub-basin, Bahr el Jebel Sub-basin, White Nile Sub-basin and Bahr el Ghazal Sub-basin.


Photo: istock

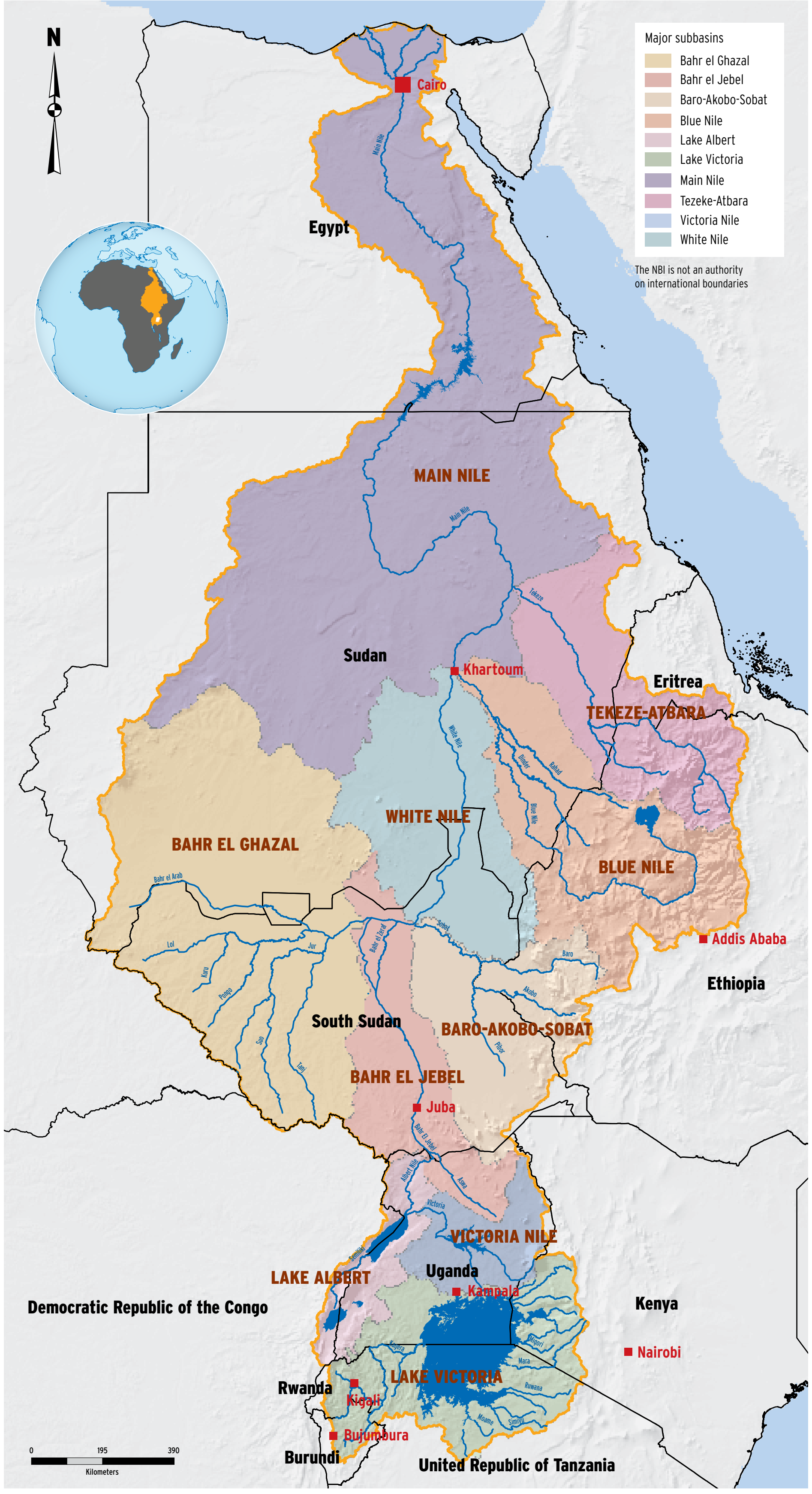
Landscape in Ethiopia near Ali Doro


Photo: istock

Lake Kivu Rwanda


Photo: istock

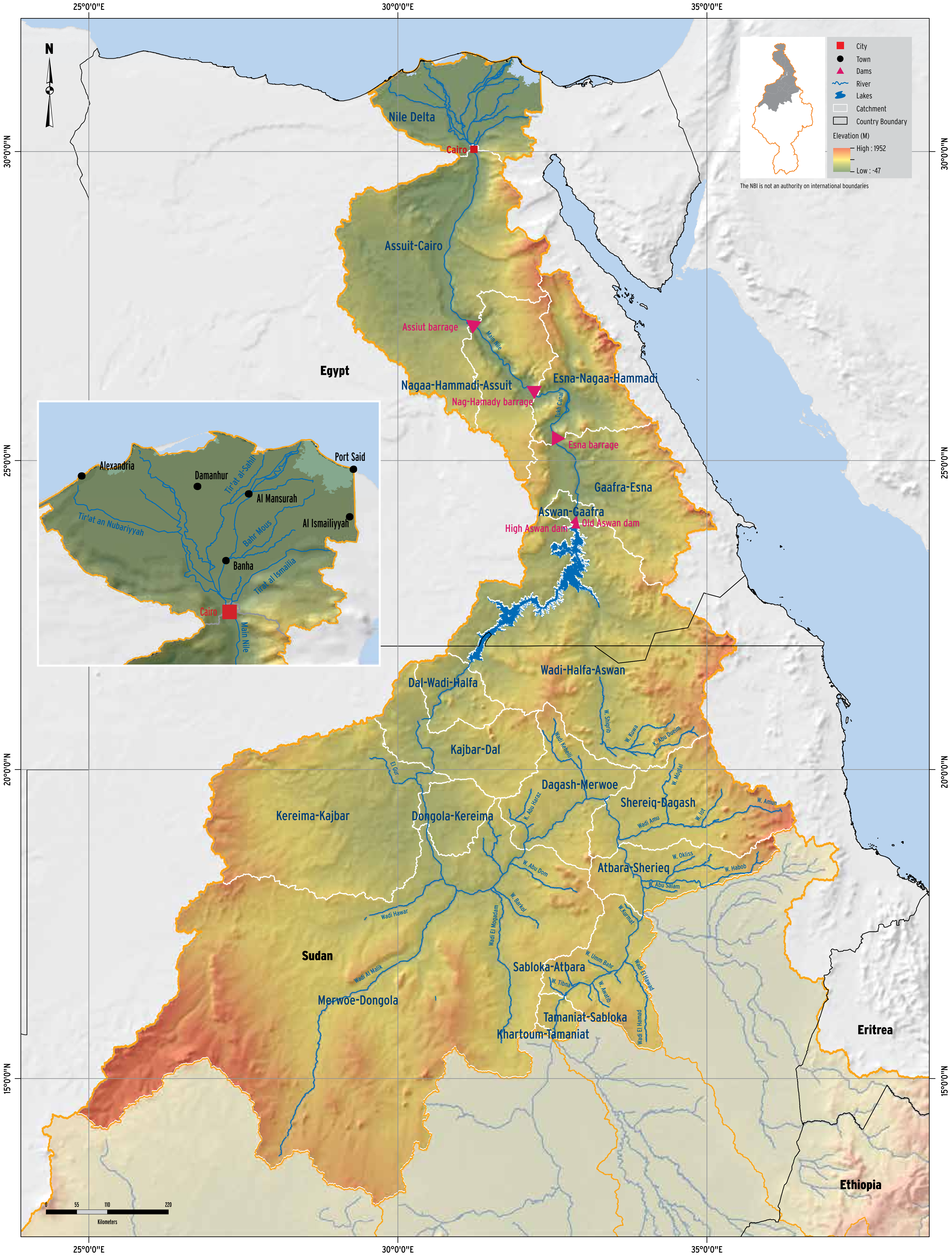
Aswan view



Sub-basin	Area (Km^2)
Lake Victoria	241,893
Lake Albert	96,807
Victoria Nile	85,521
Bahr el Jebel	185,364
Bahr el Ghazal	604,746
Baro-Akobo-Sobat	204,288
White Nile	258,803
Blue Nile	304,656
Tekeze-Atbara	232,374
Main Nile	958,872

The Main Nile Sub-basin

The Main Nile encompasses the downstream river reach, starting at the Blue–White Nile confluence at Khartoum. The Main Nile system, divided into two distinct sections – Main Nile in Sudan upstream of the High Aswan Dam; and Egyptian Nile below Aswan, including the Nile Valley and Delta. This large area generates virtually no runoff, and in-stream evaporation results in a net loss. The average annual precipitation in the sub-basin is 198mm and average annual potential evapotranspiration is 2,206mm. River flow in the lower reaches is controlled by Lake Nasser, which is subject to considerable evaporation losses. Most river flow is diverted to the irrigation schemes in the north of Sudan and in Egypt, and very often most of the river discharge into the Mediterranean is drainage and re-used water.



The Tekeze-Atbara Sub-basin

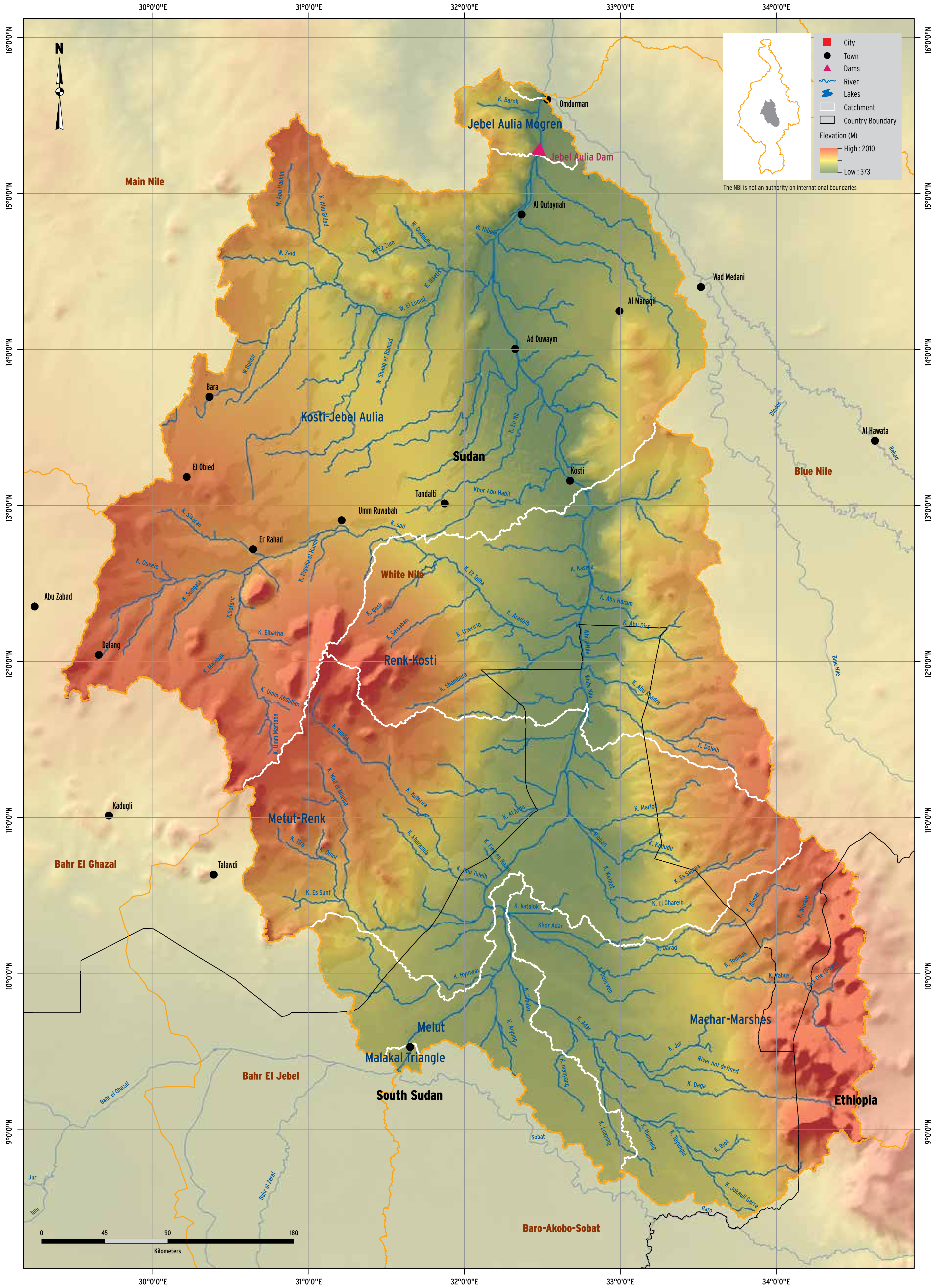
The Tekeze (Setit in Sudan) River originates from the highlands of Ethiopia as the Goang (Atbara in Sudan) and Angereb Rivers. Flows are highly variable with very little retention in wetlands or floodplains anywhere in the basin and the sediment flows are very high. The rainfall is uni-modal concentrated in August and September with mean annual rainfall 900mm. The average annual potential evapotranspiration in the sub-basin is 1,778mm.

The Blue Nile Sub-basin

The source of the Blue Nile is the Little Abbay River in the Ethiopian Highlands. The Little Abbay flows into Lake Tana, which discharges into the Blue Nile and runs 900 km down through the highlands into Sudan (Roskar, 2000). Other rivers which flow into Lake Tana. Blue Nile contributes about 60% of the flow of Main Nile (Sutcliffe and Parks, 1999). From the Sudanese-Ethiopian border the Blue Nile flows north from humid to semi-arid conditions and there is usually little additional runoff north of Roseires. The exceptions are the two tributaries, the Ayma-Dinder and the Rahad. This part of the sub-basin is characterized by a highly seasonal rainfall pattern, most of the rain falling in four months (June to September), with a peak in July or August. The precipitation over the Blue Nile sub-basin (in Ethiopia) varies from 1000mm in the north-eastern part to 1450-2100 mm over the south-western part of the sub basin. The average annual potential evapotranspiration over the sub-basin is 1,765mm. Soil erosion is a major threat in the Blue Nile Basin (Conway and Hulme, 1993).

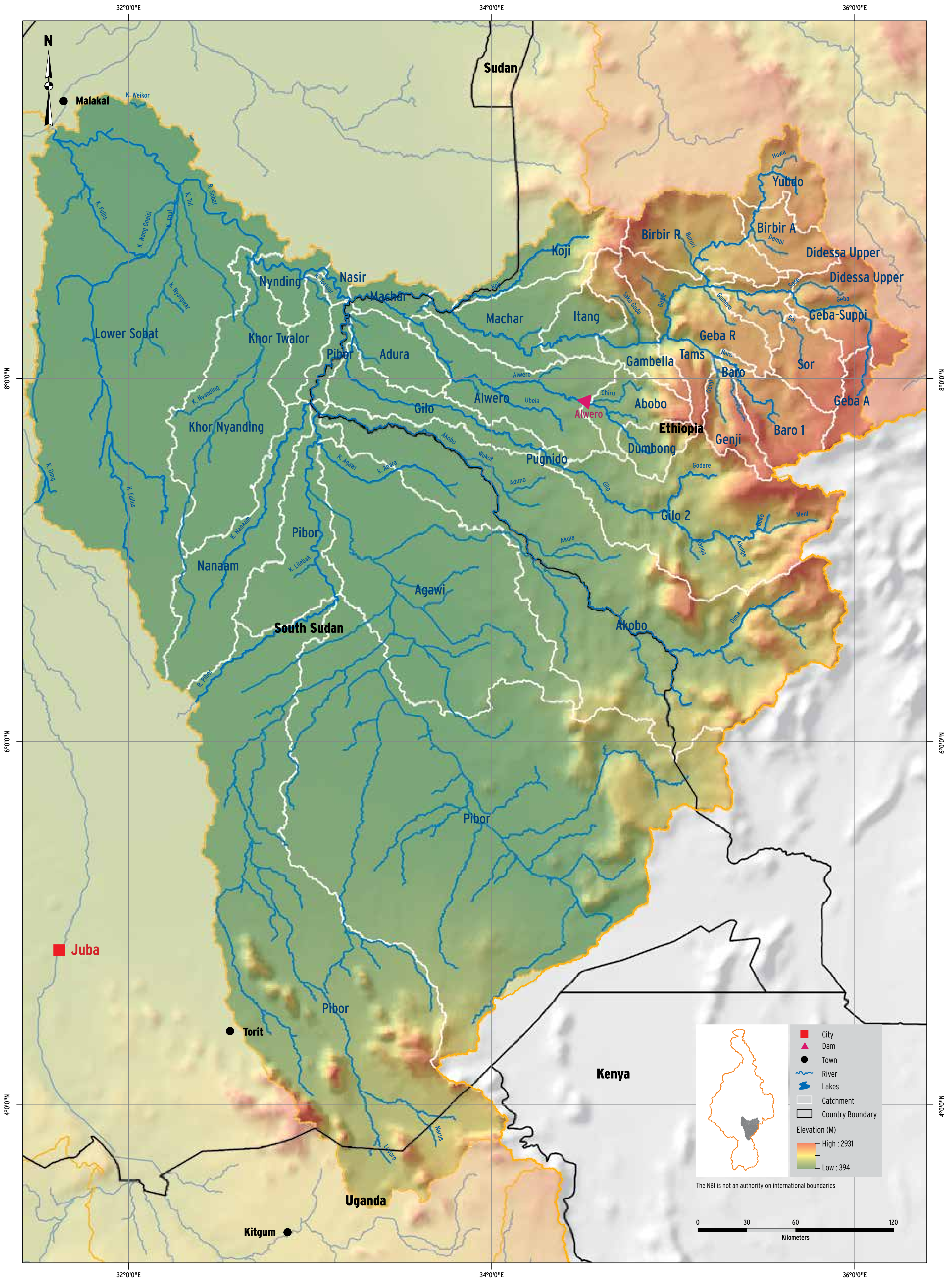
The White Nile Sub-basin

The White Nile Sub-basin originates at the confluence of Bahr el Jebel River and Baro-Akobo-Sobat River above Malakal. The sub-basin is shared by South Sudan, Ethiopia and Sudan. Tributary inflows are sporadic and small and flood plain storage results in delay of outflow and increased loss to evaporation. The average annual rainfall in the sub-basin is 754mm and the average annual potential evapotranspiration over the sub-basin is 1983 mm. The Sudd wetland provides the base flow component and the Baro-Akobo-Sobat basin contributes the seasonal component.



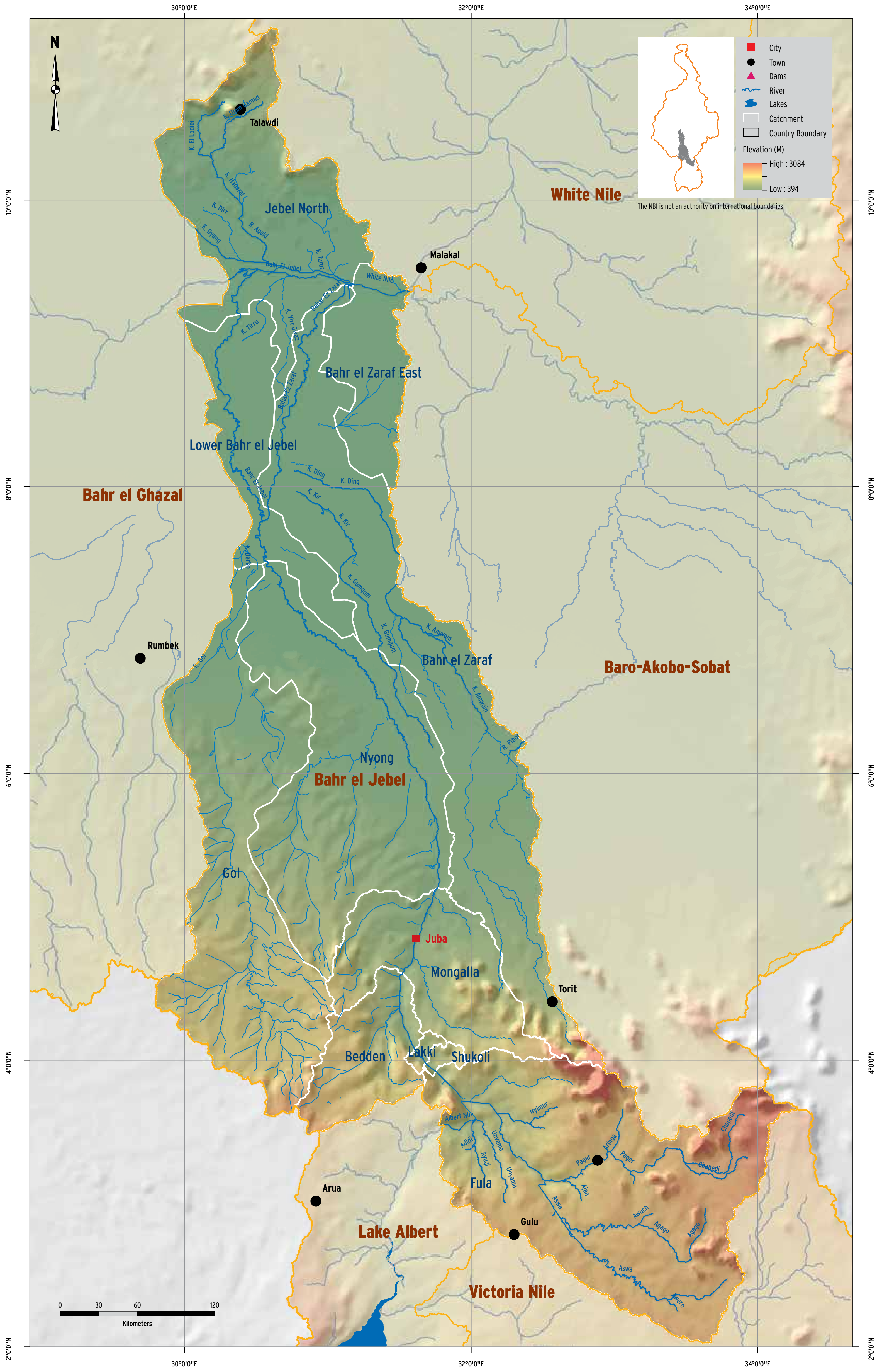
The Baro-Akobo-Sobat Sub-basin

The Baro-Akobo-Sobat River includes the discharge from two tributaries: the Baro River from the Ethiopian Highlands and the Pibor River from southern Sudan and northern Uganda. Most of the runoff develops in the mountains and foothills of Ethiopia. Portions of the Baro flow spill through a series of channels to large wetlands known as the Machar Marshes. Pibor drains a wide area of plains, but only contributes significantly in times of high rainfall. The highest rainfall is over the Baro basin in the east of the sub-basin where the average annual precipitation almost reaches 2,000mm. The lowest is over the southeast over a tributary of the Pibor River with an annual precipitation only slightly over 300mm. The average annual precipitation over the entire sub-basin amounts to 1,338 mm and the average annual potential evapotranspiration is 1,592 mm.



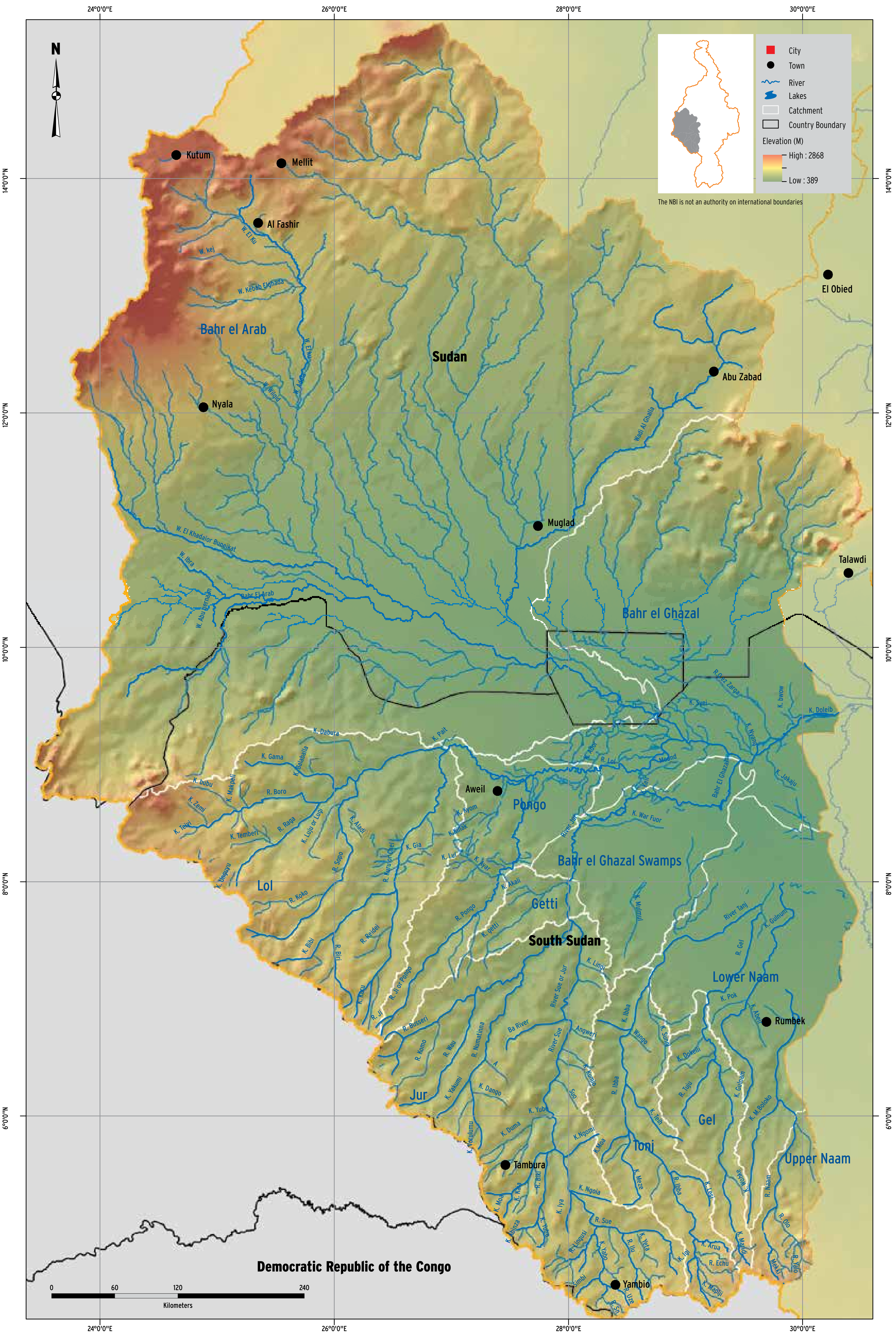
The Bahr el Jebel Sub-basin

Exiting Lake Albert, the river flows north into Sudan and is known as the Bahr el Jebel. The Bahr El Jebel Sub-basin is the most complex of the Nile reaches due to having many seasonal inflows. Below the Sudan-Uganda border, the river receives seasonal flow from torrential streams before entering the Sudd, south of Mongalla. The Sudd is a region of permanent swamps and seasonal wetlands, within which approximately half of the Bahr el Jebel flow is lost to evaporation. The average precipitation over the area is 1067 mm and the average annual potential evapotranspiration is 1,694 mm. Rainfall intensity decreases to the north where the annual average does not exceed 760 mm. Precipitation falls mostly in one season from April to October. This coincides roughly with the river flood period when the area is permanently flooded. Swamps expand in proportion to the magnitude of the inflow from the Mongalla and from local precipitation.



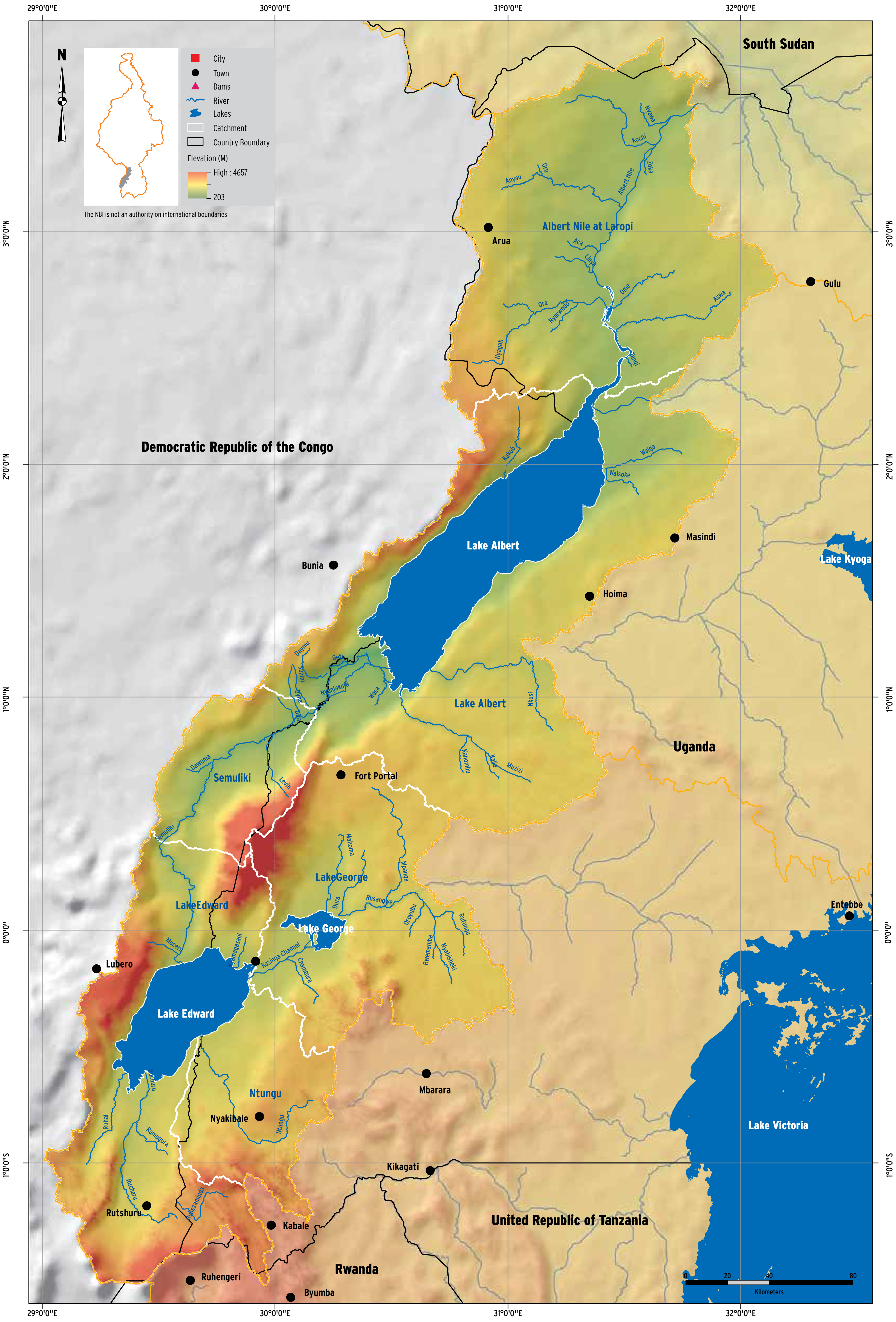
The Bahr el Ghazal Sub-basin

The Bahr El Ghazal Sub-basin consists of a number of tributaries that run from the border of the Congo Basin to the Nile. The sub-basin is shared by Sudan and South Sudan. The peak of rainfall in the south-western part produces over 1,550mm of average annual rainfall, which decreases toward the northeast where the annual precipitation does not exceed 500 mm. The average annual precipitation over the entire area is 826 mm and the average annual potential evapotranspiration over the sub-basin is 1,807 mm. The sub-basin is divided into many tributaries with bank overflow and flooding. In this large area of very low slope, nearly all the basin runoff and precipitation evaporates.



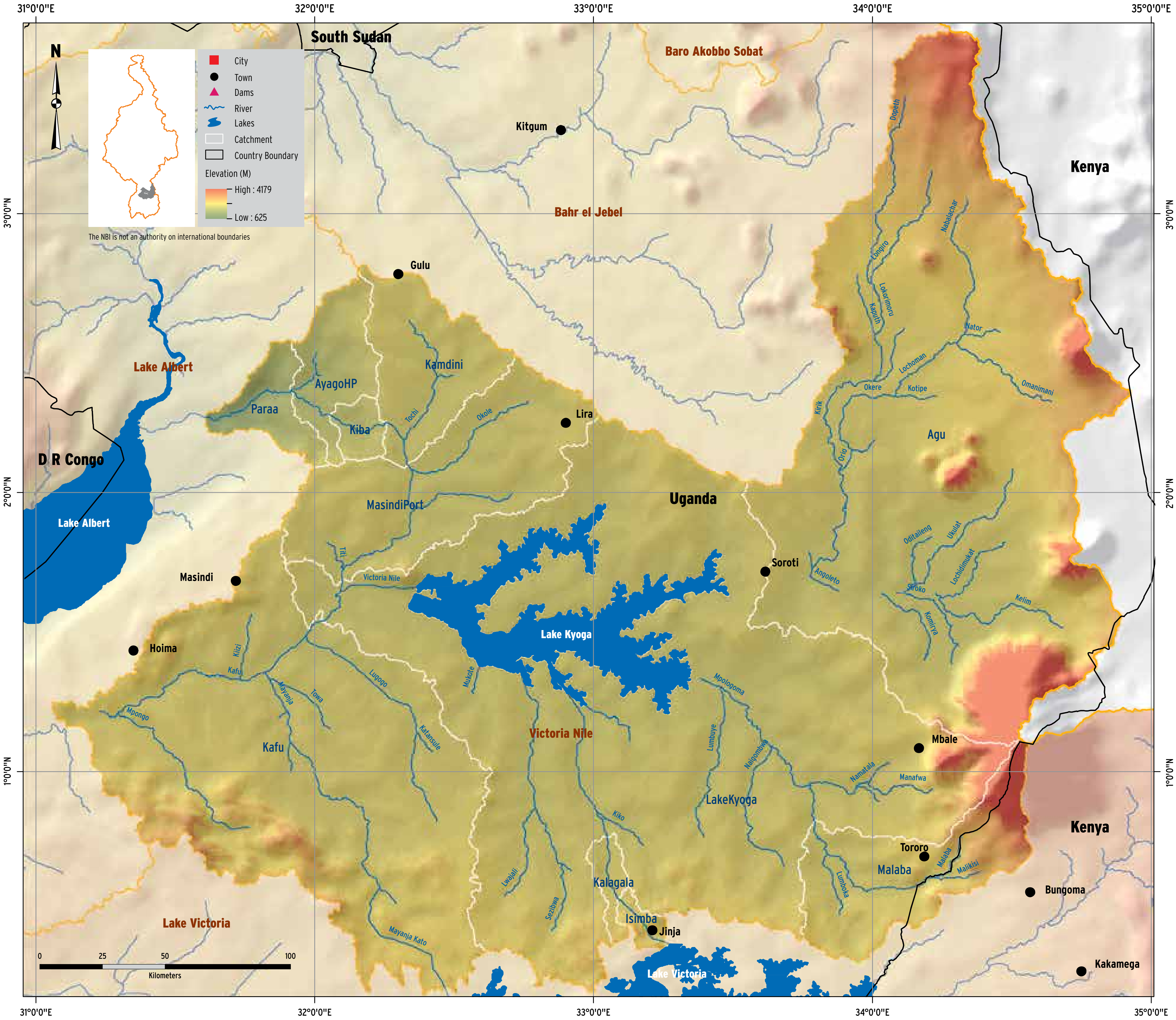
Albert Nile Sub-basin

In addition to the Victoria Nile, the lake also receives inflow from the Semliki River in the south, which drains an additional area that includes Lakes Edward and George. The direct rainfall and inflow from Albert's immediate basin is thought to be offset by evaporation over the lake surface. Therefore, the net contribution of Lake Albert to the main Nile flows is believed to be a result of the Semliki inflow (Shahin, 1985). The river leaves the northern end of Lake Albert as the Albert Nile, flows through northern Uganda, and at the Sudan border becomes the Bahr el Jebel. The average annual precipitation over the sub-basin is 1,179 mm and the average annual potential evapotranspiration is 1,544 mm.



The Victoria Nile Sub-basin

From the outlet of Lake Kyoga, the Lower Victoria Nile flows north and west, passing through a series of rapids and dropping 415 m along its course toward Lake Albert. The average annual basin rainfall is nearly 1,300 mm and the average annual potential evapotranspiration is 1,544 mm. The net water contribution of Lake Kyoga to Victoria Nile flows has historically been very low and often negative due to evaporative losses over the lake and wetlands (Sutcliffe and Parks 1999; Shahin 1985).



River Nile in northern Uganda

The Lake Victoria Sub-basin

The Lake Victoria sub-basin is the area covering the lake surface itself and the catchment areas of all its tributaries. The outlet hydrological station is at Jinja. The most distant source of the Nile is the Ruvyironza River, which flows into Lake Victoria through the Ruvubu and Kagera rivers. Other rivers converging into Lake Victoria – the largest of the Nile Equatorial Lakes – include the Simiyu-Duma, Grumeti-Rwana, Mara, Gucha-Migori, Sondu, Yala, Nzoia, Sio, Katonga and Ruizi. The lake's surface area is about 66,700km^2 and occupies a large proportion of the entire sub-basin. Three countries Kenya (6%), Tanzania (51 %) and Uganda (43%) share the lake shoreline, and six countries share the basin: Burundi, DRC, Kenya, Rwanda, Tanzania and Uganda. The area around Lake Victoria has the fastest-growing population in East Africa, estimated to be more than 40 million in 2015. Lake Victoria is important for agriculture, industry, domestic water supplies, hydropower, fisheries, travel, tourism, and environment. The average annual precipitation over the sub-basin is 1368mm and the average annual potential evapotranspiration is 1486mm.

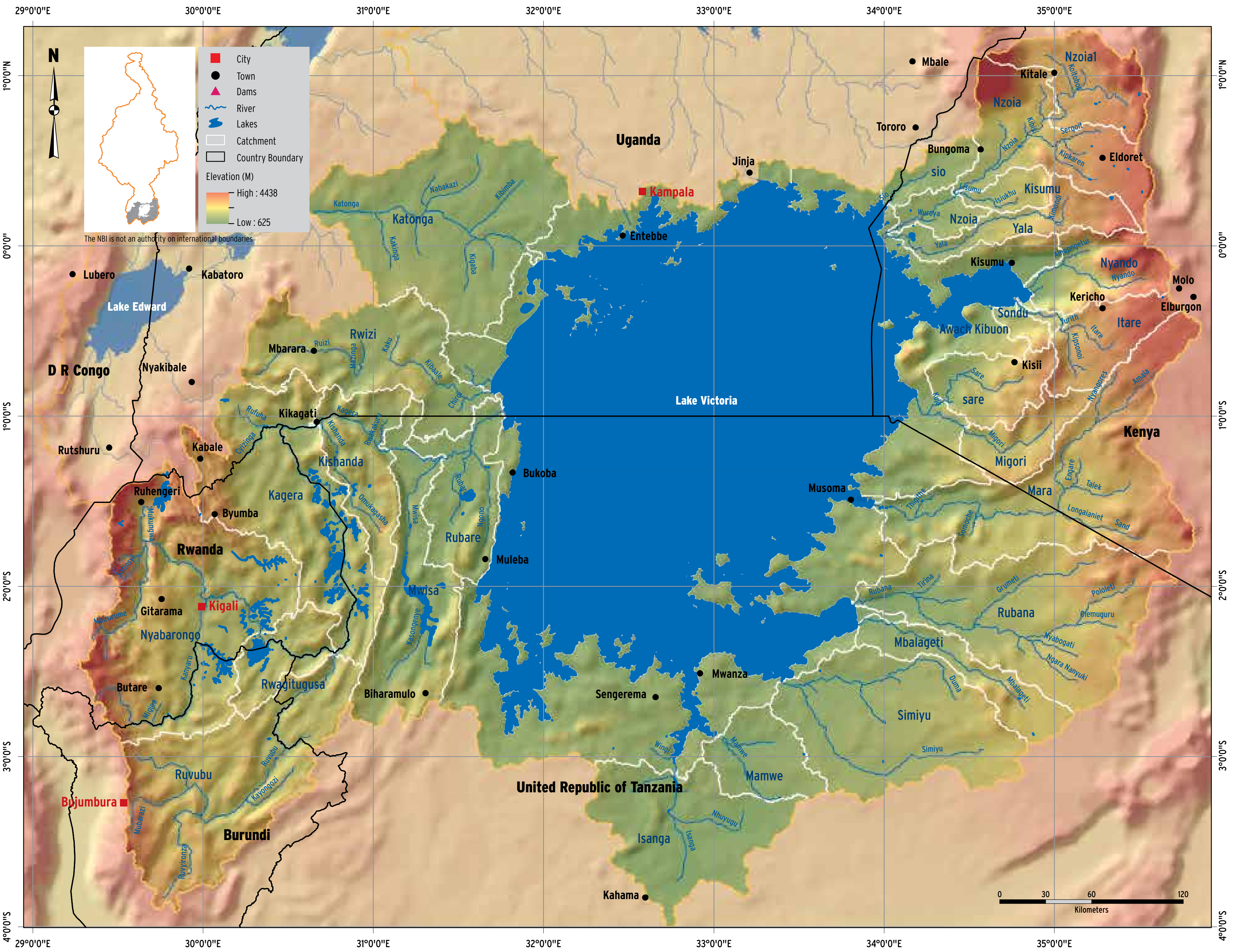


Photo: vivek Bahukhandi

Lake Bunyoni, Uganda

ANNEX A

The characteristics of the soil groups

Code	Soil type	Drief description
AC	Acrisols	These are soils that are characterized by low activity clay. Most extensive on acid rock weathering, notably in strongly weathered clays, which are undergoing further degradation. Low-input farming on Acrisols is not very rewarding. Undemanding, acidity-tolerant cash crops such as pineapple, cashew or rubber can be grown with some success.
AN	Andosols	These are black soils of volcanic landscapes. Parent material is mainly volcanic ash. Andosols have a high potential for agricultural production
AR	Arenosols	Soils having a texture, which is loamy sand or coarser to a depth of at least 100 cm from the soil surface. Arenosols occur in vastly different environments and possibilities to use them for agriculture vary accordingly. All Arenosols have a coarse texture, accountable for the generally high permeability and low water and nutrient storage capacity. Arenosols are further marked by ease of cultivation, rooting and harvesting of root and tuber crops.
CM	Cambisols	Medium and fine-textured materials derived from a wide range of rocks, mostly in colluvial, alluvial or aeolian deposits. Cambisols make good agricultural land and are intensively used. The Eutric Cambisols are among the most productive soils on earth. Cambisols on steep slopes are best kept under forest; this is particularly true for Cambisols in highlands.
FR	Ferralsols	Red and yellow tropical soils. Parent material: strongly weathered material on old, stable geomorphic surfaces; more in weathering material from basic rock than in siliceous material. Have low water holding capacity. The chemical fertility of Ferralsols is poor; weatherable minerals are absent and cation retention by the mineral soil fraction is weak.
FL	Fluvisols	Soils developed in alluvial deposits. Environment: periodically flooded areas alluvial plains, river fans, valleys and (tidal) marshes. Fluvisols are normally planted annual crops and orchards and many are used for grazing. Flood control, drainage and/or irrigation are normally required.
GL	Gleysols	Gleysols holds wetland soils that, unless drained, are saturated with groundwater for long enough periods to develop a characteristic "gleyic colour pattern". Parent material consists of a wide range of unconsolidated materials, mainly fluvial, marine and lacustrine sediments of Pleistocene or Holocene age, with basic to acidic mineralogy. Adequately drained Gleysols can be used for arable cropping, dairy farming or horticulture.
LT	Lithosols	Lithosols, which are found in all the agroecological zones of Africa, are very shallow, occurring mainly on steep slopes often with exposed rock debris. These soils are at risk of very severe erosion.
LV	Luvisols	Soils in which clay is washed down from the surface soil to an accumulation horizon at some depth. Parent material is a wide variety of unconsolidated materials including glacial till, and aeolian, alluvial and colluvial deposits. Luvisols are fertile soils and suitable for a wide range of agricultural uses.
NT	Nitosols	Nitisols accommodates deep, well-drained, red, tropical soils with diffuse horizon boundaries and a subsurface horizon with more than 30 percent clay and moderate to strong angular blocky structure elements. Nitisols are predominantly found in level to hilly land under tropical rain forest or savannah vegetation. Nitisols permit deep rooting and make these soils quite resistant to erosion. The good workability of Nitisols, their good internal drainage and fair water holding properties are complemented by chemical (fertility) properties that compare favourably to those of most other tropical soils.
PL	Planosols	Planosols holds soils with bleached, light-coloured, eluvial surface horizon that shows signs of periodic water stagnation with abrupt textural discontinuity. Many planosols areas are not used for agriculture.
PZ	Podzoluvisols	Podzol has an ash-grey, strongly leached eluvial horizon under a dark surface horizon with organic matter, and above a brown to very dark brown. The low nutrient status, low level of available moisture and low soil-pH make Podzols unattractive soils for arable farming. Podzols have some potential for forestry and extensive grazing.
RG	Regosols	Soils with no significant profile development. Regosols are extensive in eroding lands, in particular in arid and semi-arid areas and in mountain regions. They are not used for cultivation but mainly serve as source of murram for various civil works.
SC	Solonchaks	The most extensive occurrences of Solonchaks are in inland areas where evapotranspiration is considerably greater than precipitation, at least during a greater part of the year. Salts dissolved in the soil moisture remain behind after evaporation/transpiration of the water and accumulate at the surface of the soil or at some depth. Excessive accumulation of salts in solonchaks affects plant growth.
VR	Vertisols	Vertisols are heavy clay soils with a high proportion of swelling. These soils form deep wide cracks from the surface downward when they dry out, which happens in most years. Vertisols become very hard in the dry season and are sticky in the wet season. Vertisols are productive soils if properly managed.
X	Xerosols	Aridic (dry) soils. A horizon and an aridic moisture regime; lacking permafrost within 200 cm of the surface.
Y	Yermosols	Aridic (dry) soils, soil horizon that is typical of deserts. A horizon and an aridic moisture regime; lacking permafrost within 200 cm of the surface.

References

- Conway, D. and Hulme, M. (1993). Recent fluctuations in precipitation and runoff over the Nile sub-basins and their impact on main Nile discharge, Climatic change, 25, 127-151.
- Hydrosult Inc., Tecsult, DHV and their Associates Nile Consult, Comatex Nilotica and T&A Consulting (2006). Transboundary Analysis: Abbay –Blue Nile sub-basin, NBI-ENTRO, Addis Ababa
- IWMI (2012). The Nile River Basin: Water, agriculture, governance and livelihoods.
- Kagera Monograph, (2008). Kagera Basin Transboundary Integrated Water Resources Management and Development
- Roskar, J., (2000). Assessing the water resources potential of the Nile River based on data
- Shahin, M., (1985). Hydrology of the Nile basin. Developments in water science, Elsevier, Amsterdam, 1985, XV + 575 pp.
- Sutcliffe, J.V, and Parks, Y.P. (1999). The Hydrology of the Nile, IAHS Special publication 5, IAHS Press, Wallingford, UK.
- Vereecken, H., Huisman, J.A., Bogena, H., Vanderborght, J., Vrugt, J. A., and Hopmans, J. W. (2008). On the value of soil moisture measurements in vadose zone hydrology: A review. Water Resources Research, VOL. 44, W00D06, doi: 10.1029/2008WR006829, 2008

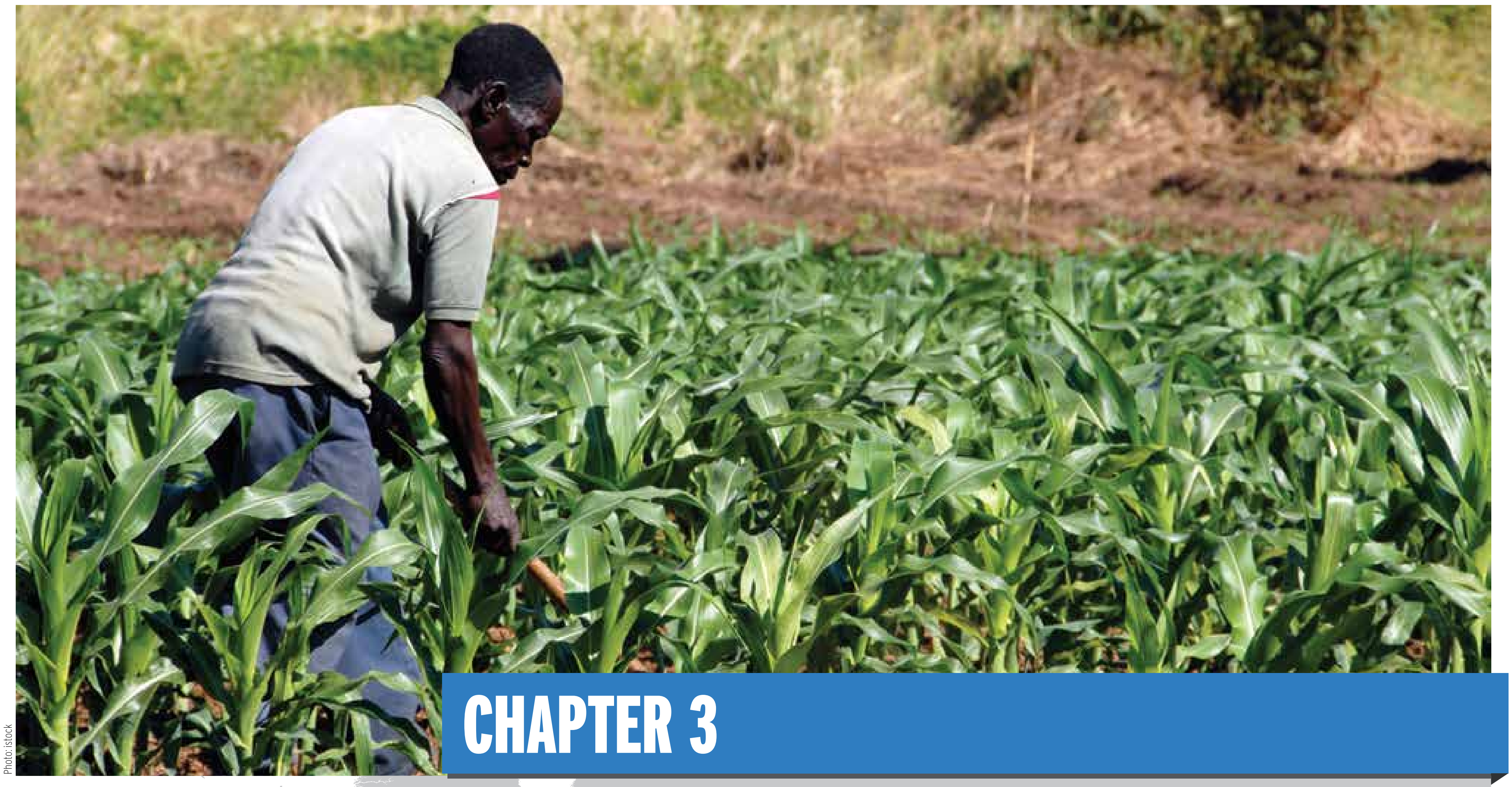


Photo: istock

Maize farm

CHAPTER 3

THE SOCIO-ECONOMIC PROFILES OF THE NILE BASIN COUNTRIES

KEY MESSAGES

Population is increasing; Almost all Nile Basin countries sustain significant deficits in providing basic needs;

Population has been growing in all basin countries

As of 2012, Nile Basin countries' total population is estimated at over 480 million, which means Nile Basin countries are home to over 40 percent of the African population. Some 257 million people live within the Nile Basin boundary.

In all countries, urban population is expected to continue growing accompanied by a relative shrinking of rural population.

The population of Nile Basin countries grew by over four fold in 50 years between 1960 and 2010. As a result, the demand for food, energy and water has been escalating. Per capita water availability has been declining as the population has grown exponentially.

There is considerable unmet demand for basic needs

Almost all countries have made progress in terms of increasing the proportion of population with access to clean drinking water. However, overall, the proportion of the population with access to basic needs (health, education, sanitation, electricity) is still very low by average global standards. With the exception of Egypt, the percentage of population with access to clean water is quite low by world standards. In 8 countries, the percentage of urban population with access to sanitation is less than 50 per cent. For rural areas, the figure is less than 30 percent.

Per capita electricity consumption for all countries except Egypt is less than 200 kWh per year. This is very low compared to average world consumption.

Nile Basin countries are facing formidable challenges to provide the basic needs of their population. Cooperative management and development of the common Nile resources promises to make significant contribution toward meeting these deficits.

The GDP of nearly all Nile Basin countries has been growing steadily

The GDP of nearly all basin countries is increasing, indicating expanding economies. Countries that showed relatively high GDP growth rates are Ethiopia, with average of 7.7 percent per annum for the period 2005 – 2011, and Tanzania, with average of 5.2 per cent for the same period. Five other countries recorded average GDP growth rate of about 3.5 per cent per annum.

There is significant disparity in GDP per capita among Nile Basin countries. Egypt's estimated per capita GDP of over 10,500 USD is more than five-fold the GDP per capita of any of the other Nile Basin countries.

Expanding economies and rapidly growing population bring about opportunities as well as challenges. With growing economies, foreign investment is growing and living standards of the population increasing. However, expanding economies also mean increasing demand for energy, water supply and food. Further, growing urbanization is contributing to increasing demand for energy, food, water and services.

INTRODUCTION

Photo: istock

Girl planting mango tree

This chapter describes the main socio-economic indicators for Nile Basin countries. The objective is to enable better understanding of socio-economic development of riparian countries; and the development challenges they face in meeting the basic needs of their citizens and the opportunities the common Nile Basin water resources offer to address these challenges.

The indicators selected for this chapter provide an overview of the basin in terms of: population its distribution and growth; health related indicators, such as child mortality rates; access to basic services, such as drinking water and electricity; and economic status of the basin countries, such as GDP, poverty level and income distribution. Data used to generate the indicators have been pooled from Nile Basin countries, UN agencies and other global data portals.

DEMOGRAPHY

Population distribution In Nile Basin Countries

Photo: Istock

Group of children, East Africa

The spatial distribution of population in the basin is influenced by a number of factors among which are climate, rainfall, soil fertility, mineral resources, and social and economic infrastructure (transport, education, health, telecommunications, and hospitality sector facilities). The influence of water availability (in the form of large water bodies or rainfall) appears to overshadow other factors.

In the most downstream countries - Egypt and Sudan - human settlement is mainly concentrated along the course of the River Nile. For example, population density is very high in the Nile Delta and Nile Valley in Egypt, yet these areas represent only five per cent of the country's land area.

In the upstream parts of the basin, the pattern of human settlement mainly follows that of rainfall. The highest population densities in the upstream countries are in the Ethiopian Highlands and the Nile Equatorial Lakes Plateau – both regions of high rainfall. Whereas large parts of DR Congo, Eritrea, Kenya, and Tanzania are sparsely populated, there are parts of these countries within the Nile Basin that are densely populated as they fall in the high rainfall belt.

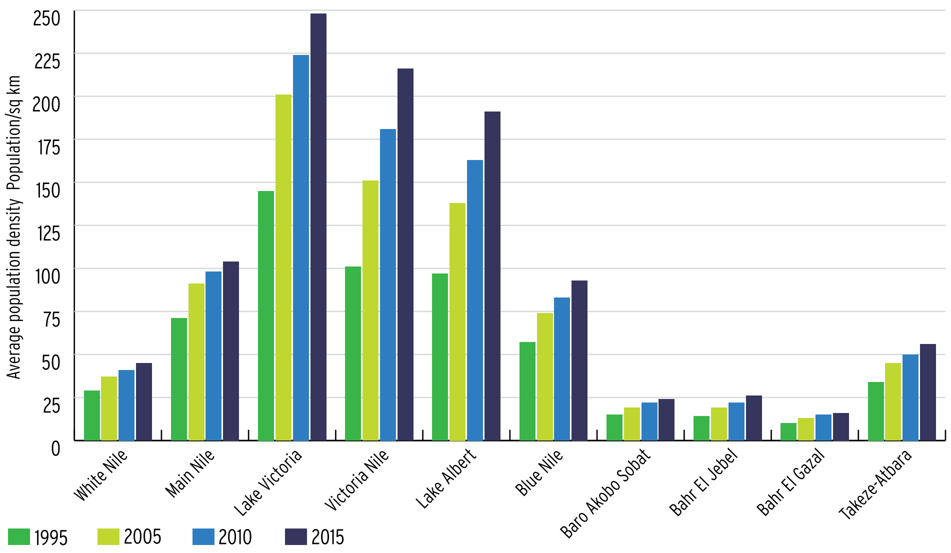
Photo: Nile-SEC

Expanding cities, Cairo, Egypt

Spatial Population Distribution In The Nile Basin

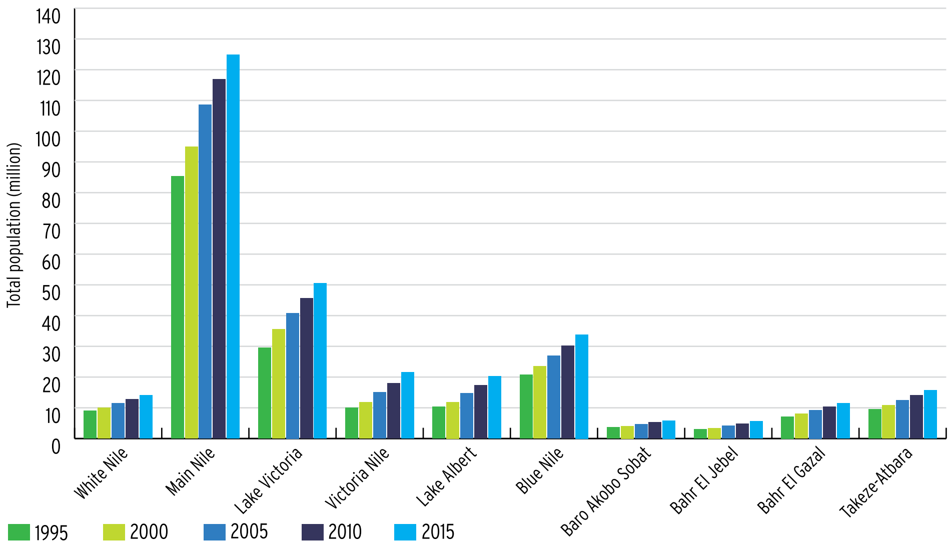
Source of data: A data centre in NASA's Earth Observing System Data and Information System (EOSDIS), Hosted by CIESIN at Columbia University

Average population density trends for the sub-basins in the Nile Basin (1995 – 2015)



Source of data: A data centre in NASA's Earth Observing System Data and Information System (EOSDIS), Hosted by CIESIN at Columbia University

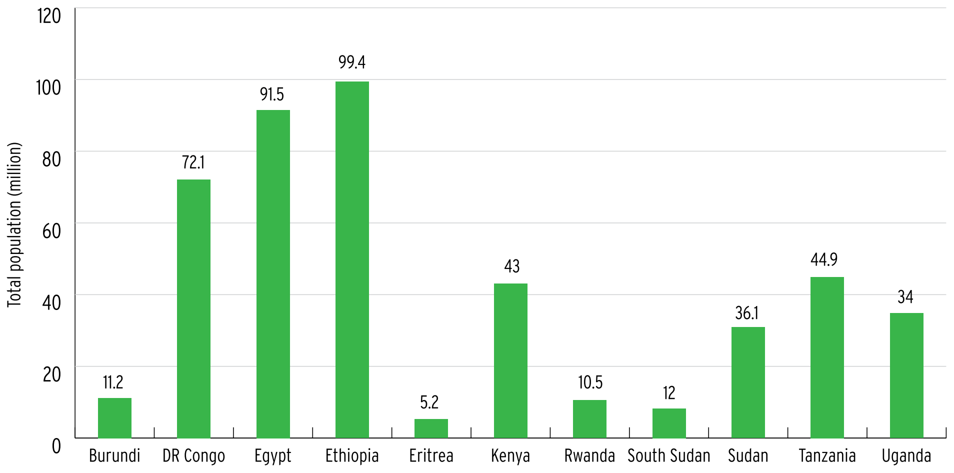
Total population trends for the sub-basins in the Nile Basin from 1995 - 2015



Source of data: A data centre in NASA's Earth Observing System Data and Information System (EOSDIS), Hosted by CIESIN at Columbia University

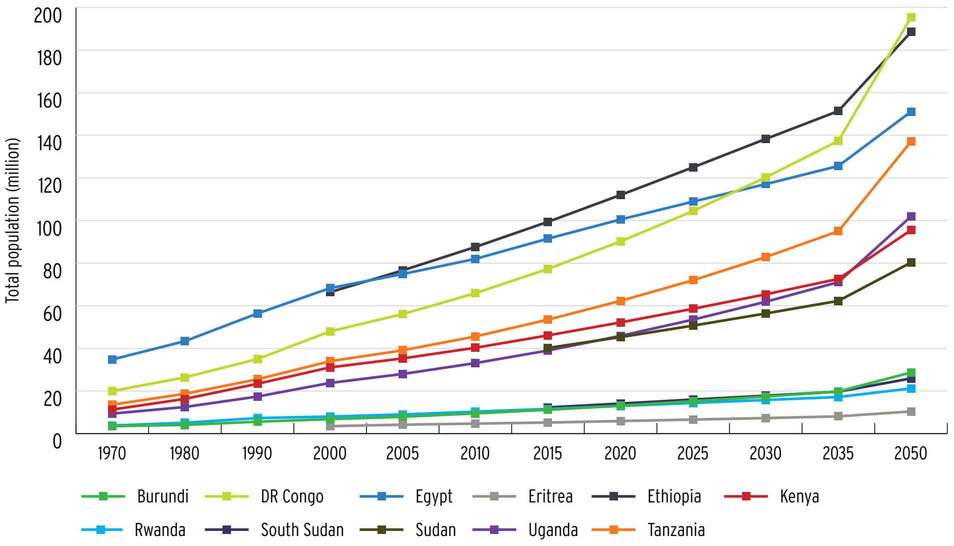
Estimated and projected total population in Nile Basin Countries

Total population in Nile Basin Countries



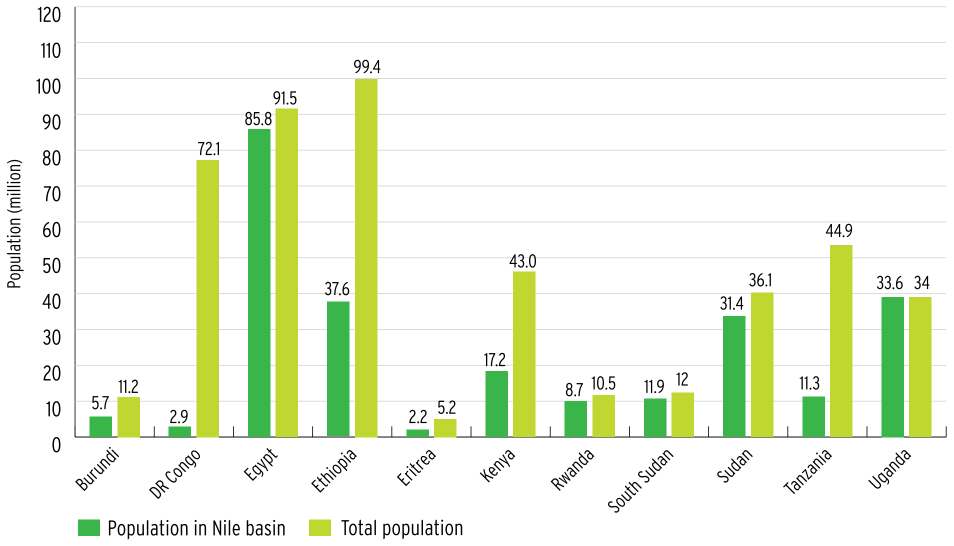
Source of data: National census (Estimated based on census data for DRC, 1984 with estimates for 2013, Kenya, (2014), Tanzania, (2012), Sudan (2014), South Sudan (2014), Uganda (2014), Rwanda, (2012); Burundi, Eritrea, Ethiopia and Egypt - World Population Prospects, UN Population Division, 2012.

Population projection in Nile Basin Countries



Source of data: World Population Prospects: The 2012 Revision from the UN Population Division and projection to 2050
Rwanda National Population projection, 2007 -2022, Uganda National Population and Housing Census, DRC Population census, 1984 and projections to 2050.

Population living in the Nile Basin, 2015

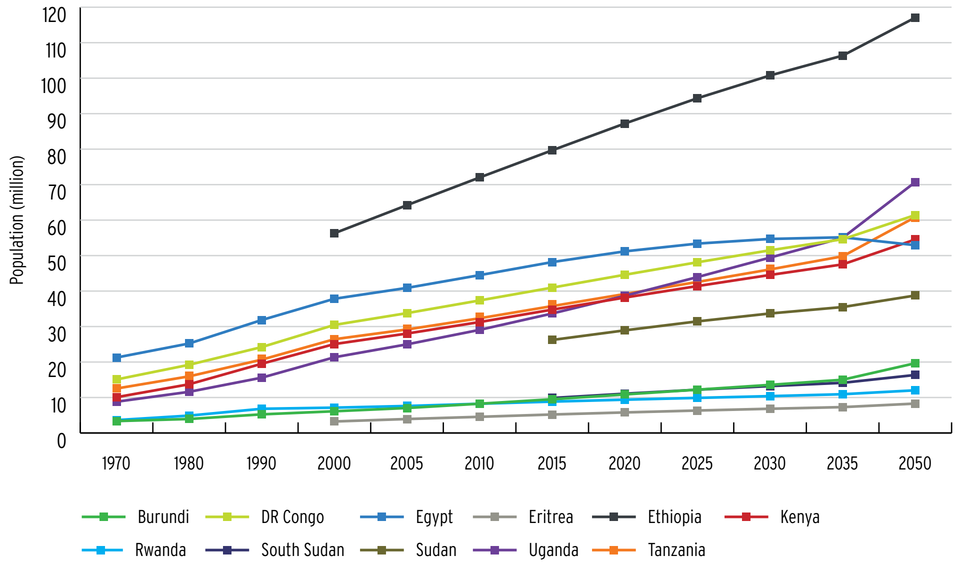


(Source of data: Nile Basin Country, World Population Prospects 2010, LandScan 2009)

The current total population of Nile Basin countries is estimated at 487.3 million. Ethiopia has the highest population (99.4 million) closely followed by Egypt (91.5 million) and DR Congo (72.1 million). Eritrea (5.2 million), Burundi (11.2 million) and Rwanda (11.7 million) have the smallest populations.

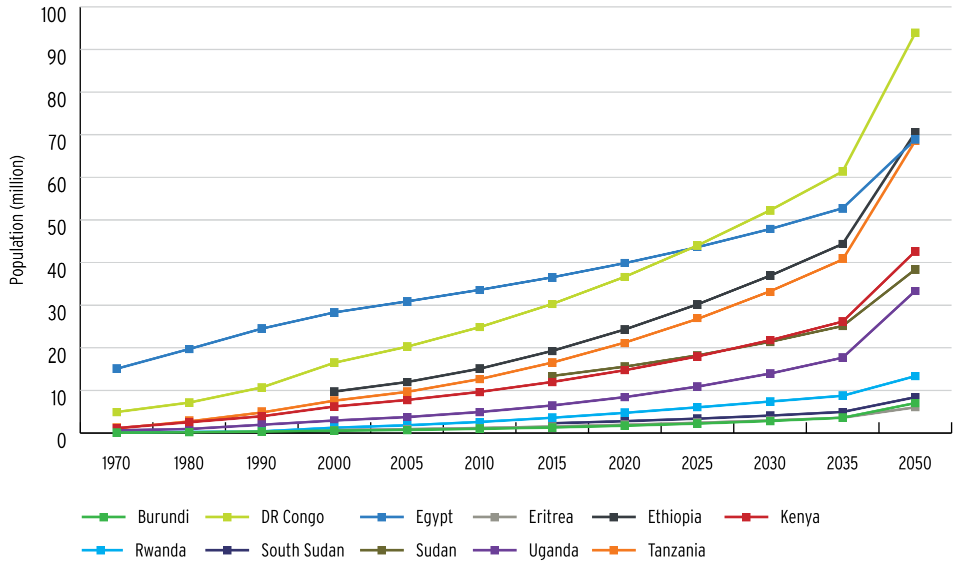
The combined population living within the Nile Basin is estimated at 257 million (or 53% of the total population of Nile Basin countries). Egypt has the highest population living within the Nile Basin (85.8 million), followed by Uganda (33.6 million), Ethiopia (37.6 million) and Sudan (31.4 million). Eritrea (2.2 million) and DR Congo (2.9 million) have the smallest populations within the Nile Basin.

Estimated and projected Rural population



Source of data: World Population Prospects: The 2012 Revision from the UN Population Division and projection to 2050
Rwanda National Population projection, 2007 -2022, Uganda National Population and Housing Census, DRC Population census, 1984 and projections to 2050.

Estimated and projected Urban population



Source of data: World Population Prospects: The 2012 Revision from the UN Population Division and projection to 2050
Rwanda National Population projection, 2007 -2022, Uganda National Population and Housing Census, DRC Population census, 1984 and projections to 2050.

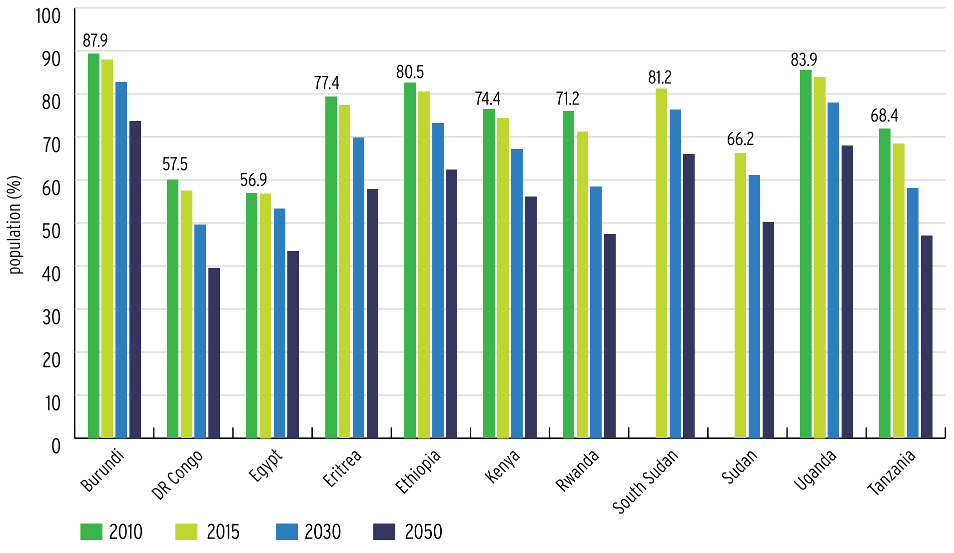
photo: Istock

Women from the Masai tribe of Kenya

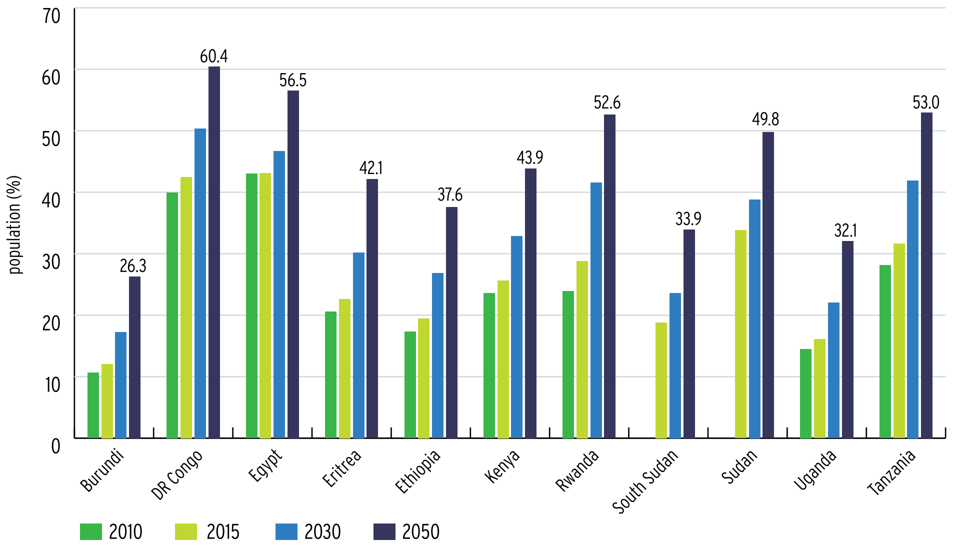
Projections of urban and rural population growth are shown in adjacent charts. The proportion of urban population is expected to rise in all Nile Basin countries. By 2050, the percentage of urban population is expected to reach above 50 percent of the total population in four of the 11 Nile Basin riparian states. In seven countries the urban population makes up more than 40 percent of the total population. In contrast, the rural population is expected to rapidly shrink in all countries.

With increasing urban population, urbanization rate will increase. This, in turn, will result in increased demands for better water supply, sanitation, electricity, communication and other services. Urbanization is expected to increase the pressure on natural resources and the environment as expansion of cities occurs generally at expense of destruction of forests; there is risk of increasing pollution of water resources.

Rural population distribution as a percentage of total population



Urban population distribution as a percentage of total population



The largest share of Nile Basin countries' population is rural. Burundi has the highest proportion of rural population followed by Uganda and South Sudan, while Egypt has the least rural population. Over the next 30 years, however, the proportion of urban population is expected to rise in all Nile Basin countries.

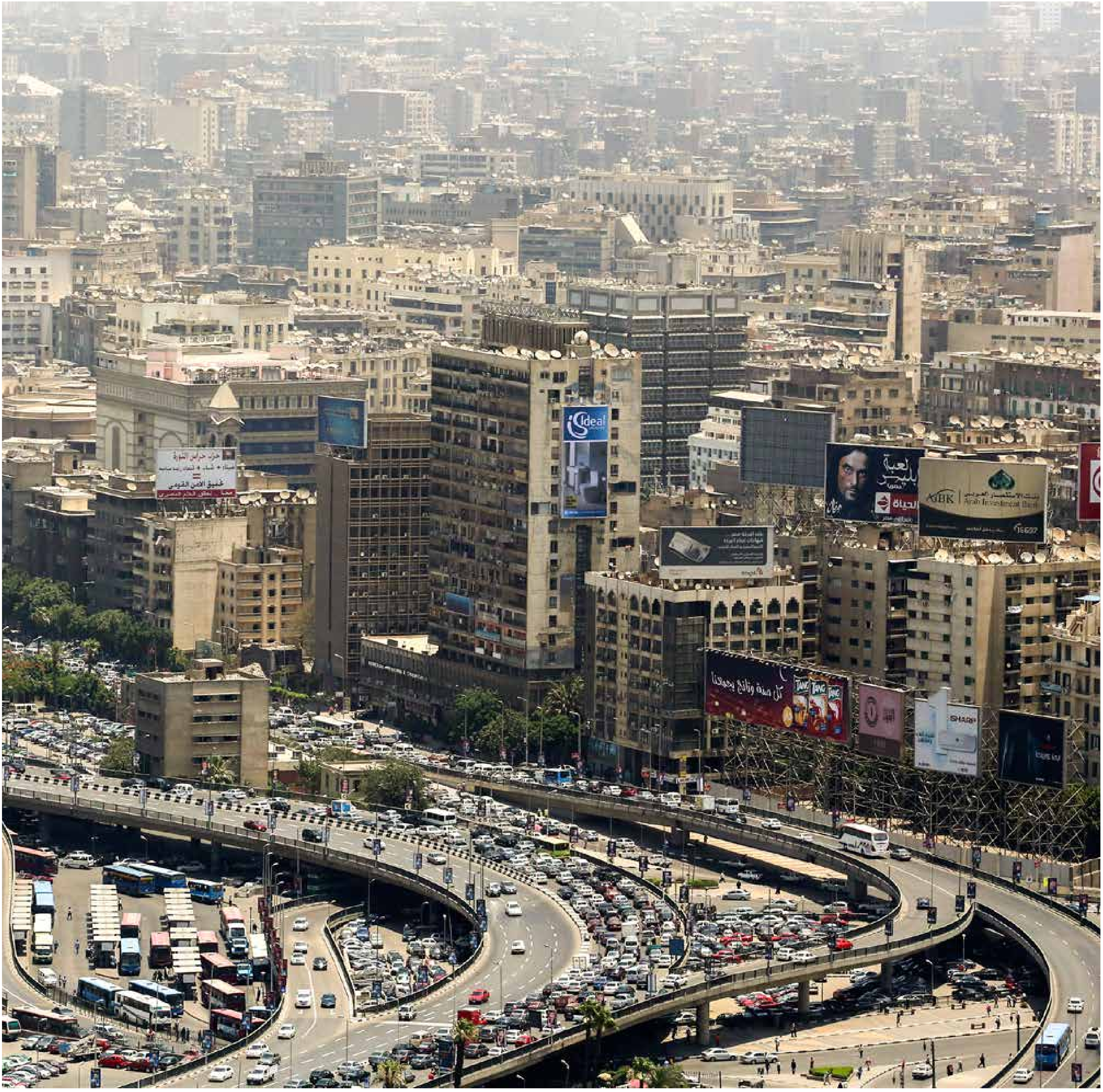
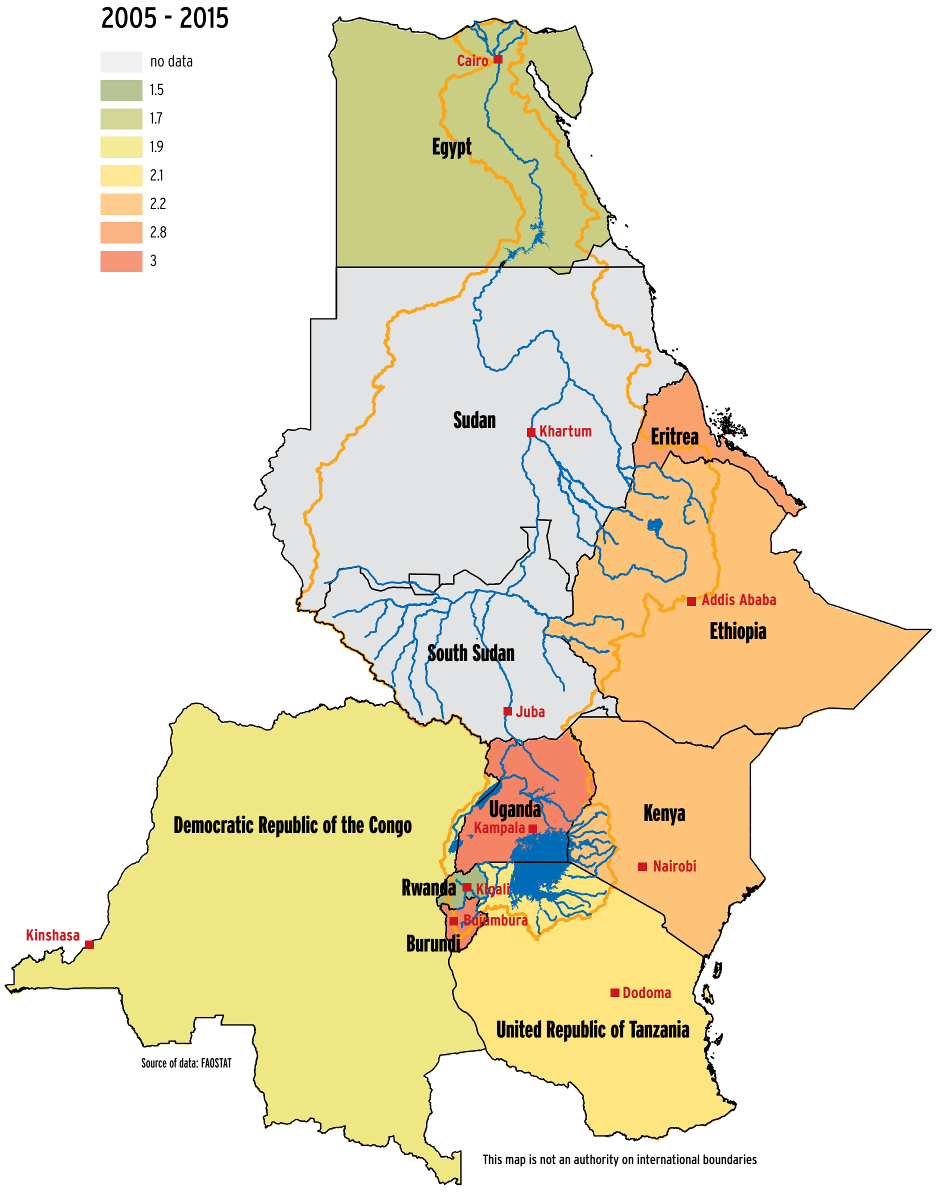


Photo © Dominic Chavez/World Bank

City view of Cairo during mid-morning rush hour

Population growth rates in Nile Basin countries

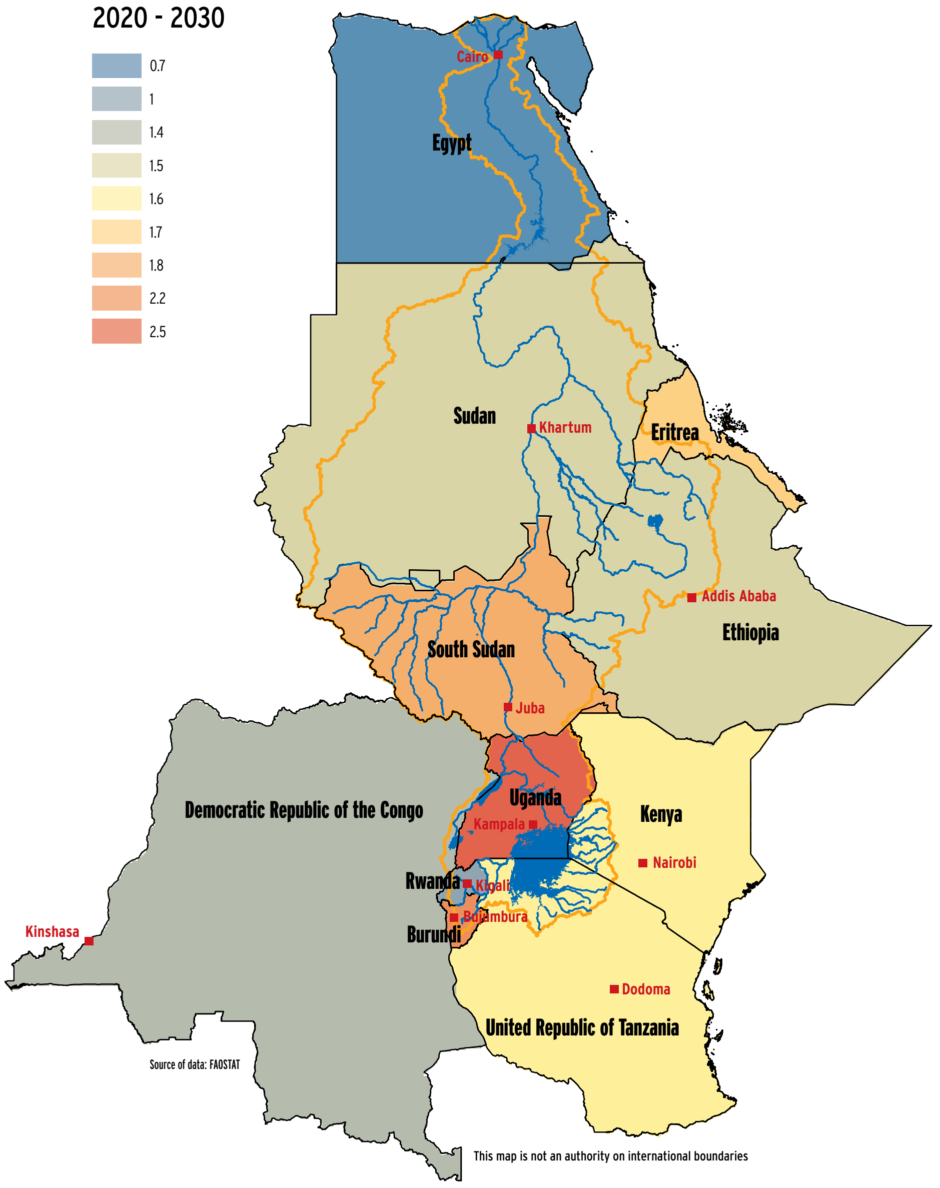
Rural population growth rate (%)
2005 - 2015



Source of data: FAOSTAT

This map is not an authority on international boundaries

Rural population growth rate (%)
2020 - 2030

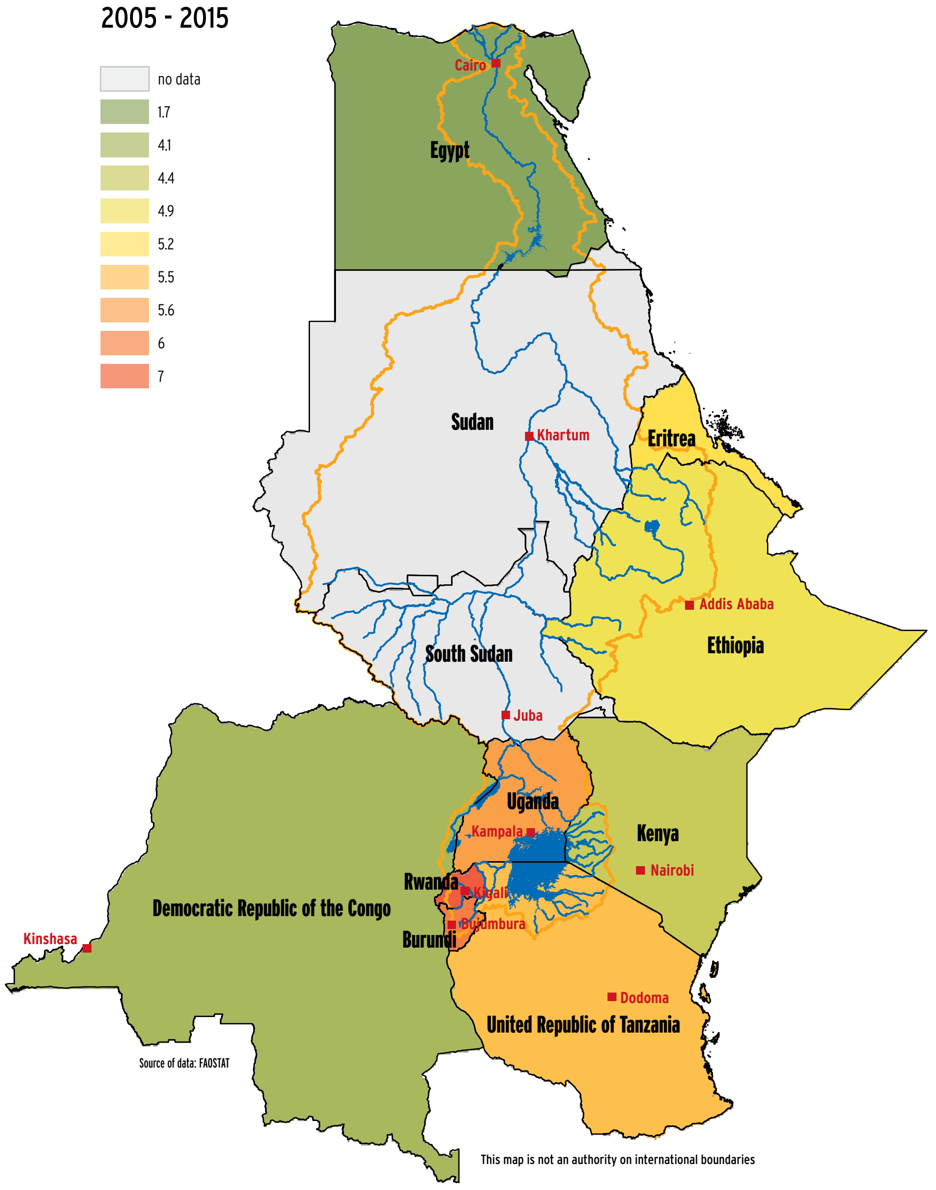


Source of data: FAOSTAT

This map is not an authority on international boundaries

For most countries, the growth rate in rural population is expected to slow down in the period 2020 – 2030 thereby resulting in increasingly smaller proporation of rural population.

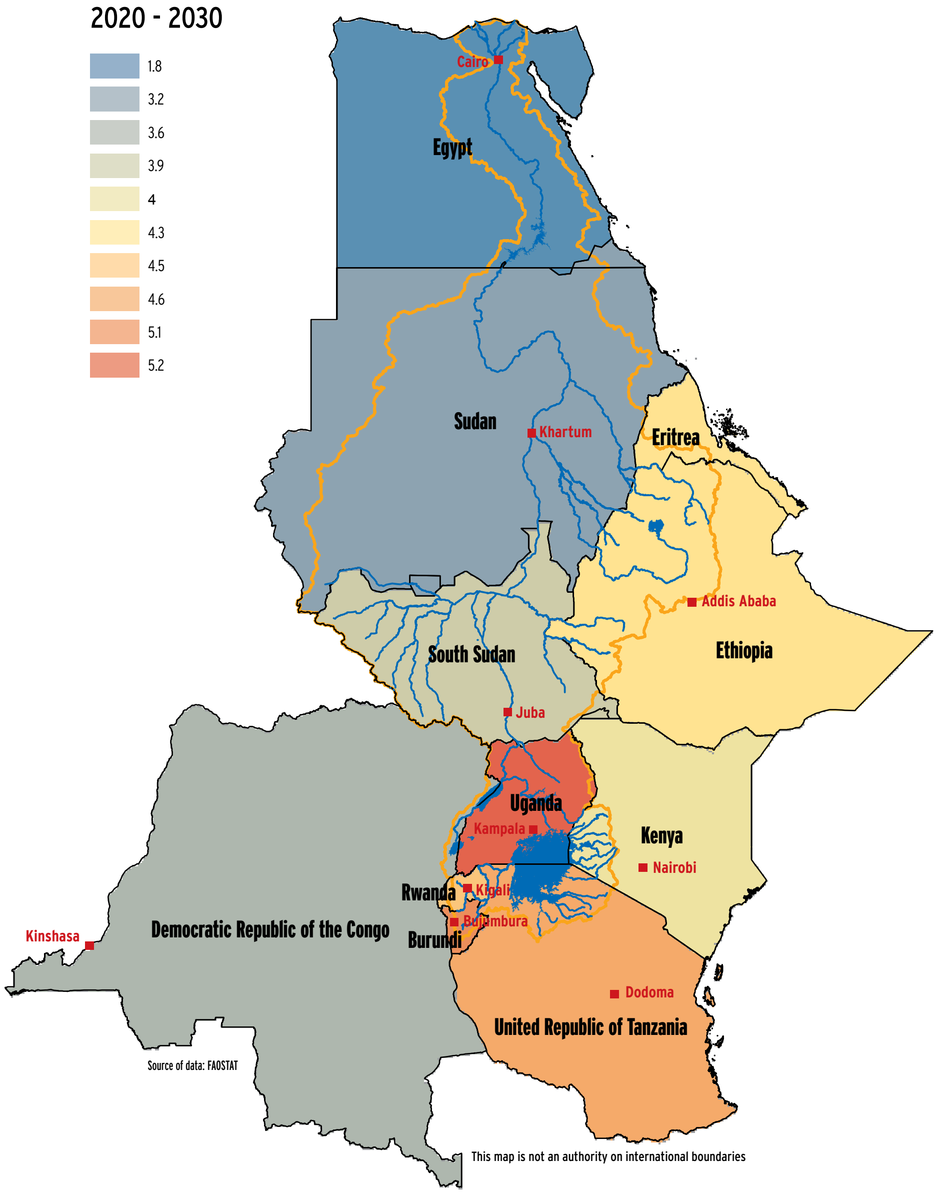
Urban population growth rate (%)
2005 - 2015



Source of data: FAOSTAT

This map is not an authority on international boundaries

Urban population growth rates (%)
2020 - 2030

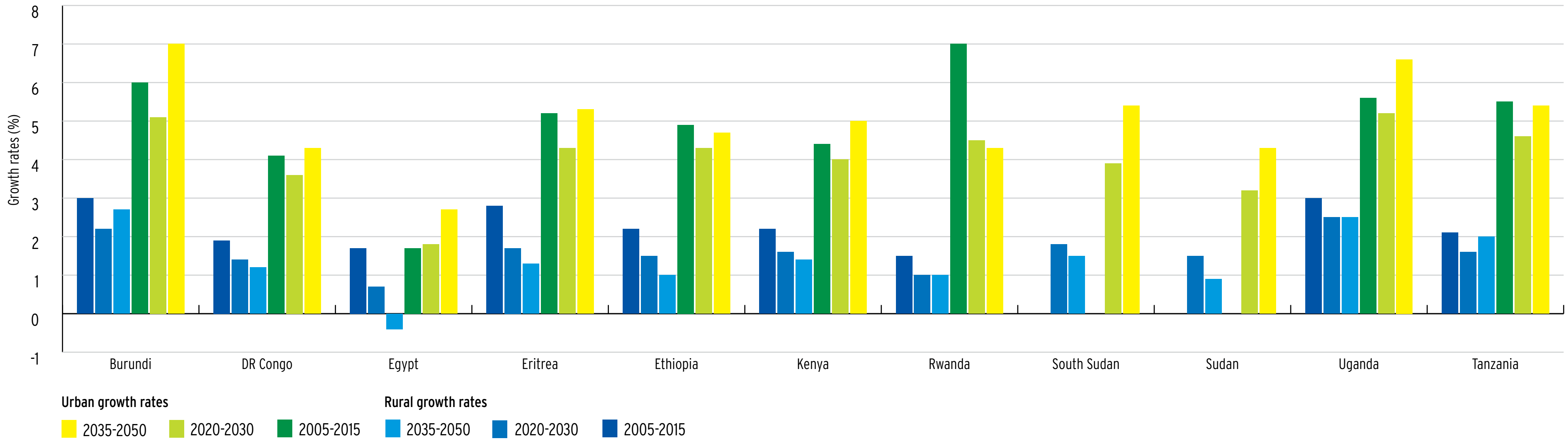


Source of data: FAOSTAT

This map is not an authority on international boundaries

The growth rate of the urban population is expected to slow down in all NIle Basin countries

Current and projected rural and urban population growth rates



Source of data: FAOSTAT

	Rural population growth rates (%)			Urban population growth rates (%)		
Country	2005-2015	2020-2030	2035-2050	2005-2015	2020-2030	2035-2050
Burundi	3.0	2.2	2.7	6.0	5.1	7.0
DR Congo	1.9	1.4	1.2	4.1	3.6	4.3
Egypt	1.7	0.7	-0.4	1.7	1.8	2.7
Eritrea	2.8	1.7	1.3	5.2	4.3	5.3
Ethiopia	2.2	1.5	1.0	4.9	4.3	4.7
Kenya	2.2	1.6	1.4	4.4	4.0	5.0
Rwanda	1.5	1.0	1.0	7.0	4.5	4.3
South Sudan		1.8	1.5		3.9	5.4
Sudan		1.5	0.9		3.2	4.3
Uganda	3.0	2.5	2.5	5.6	5.2	6.6
Tanzania	2.1	1.6	2.0	5.5	4.6	5.4

Highest rural population growth rates in the Nile Basin are observed for the period 2005-2015 at the range of 1.5% to 3.0%. In the future (2020-2030 & 2035-2050) the rural population growth rate is projected to decline and the rate is expected to be negative for Egypt by 2035-2050. In contrast, urban population growth rate is expected to increase significantly in all Nile Basin countries.

- Population data refers to the World Population Prospects: The 2012 Revision from the UN Population Division.
- Urban/rural population data refers to the World Urbanization Prospects: The 2011 Revision from the UN Population Division. Long term series estimates and projections from 1961 to 2050.

The average annual population growth rates between 2010/2015 were 3.2% in Burundi, 2.7% in DRC, 1.6% in Egypt, 2.6% in Ethiopia, 2.7% in Kenya, 2.7% in Rwanda, 2.1% in Sudan and 3.0% in the United Republic of Tanzania. Uganda has the highest population growth rate 3.3% in the basin (HDR Statistics 2015). Population projections indicate continued growth in the basin, which will increase the demand for natural resources in the basin countries. The flipside is that this large population also presents an opportunity in terms of a workforce for economic development and a vibrant market for the diverse goods and services

Photo: Salahaldeen Nadir / World Bank

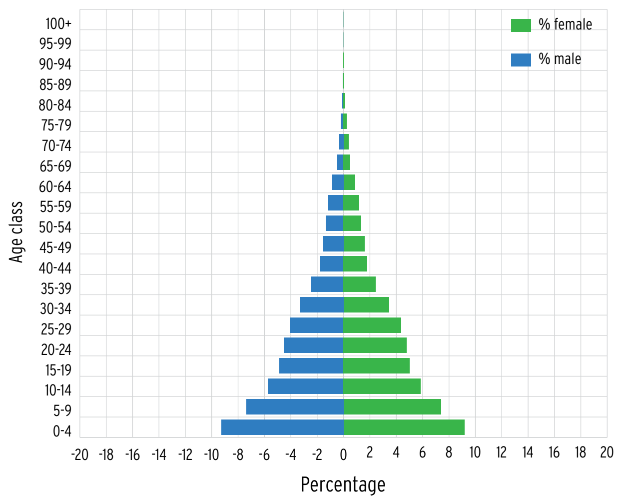
PTA meeting with the new school being built at the background Um Deresayah, North Kordofan, Sudan

GENDER, AGE AND MORTALITY

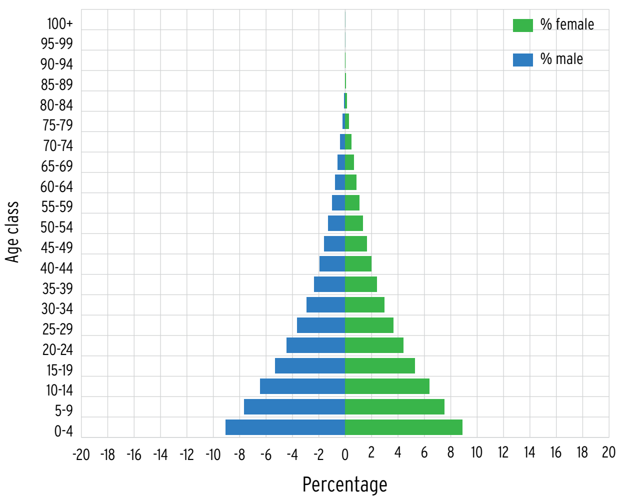
Gender and age distribution in Nile Basin countries

Nile Basin countries feature population pyramids flatter at the bottom, which is characteristic of populations with younger age structure. The broad base and narrow top of the pyramids also indicate low life expectancy. Most basin countries exhibit similar population pyramid structures, with the exception of Egypt, Kenya and Uganda. The population pyramid for Egypt shows a relatively large proportion of the 15 – 34 age group. Kenya, in contrast has the highest proportion of older population (greater than 60 years). Uganda shows a 'denting' in the pyramid, which signifies a relatively small proportion of the 20 – 34 age group. Common to all countries, however, is a high proportion of young population, that age group that is 20 years or under. This could be explained by a change in the dynamics of the demography of the basin, particularly a significant drop in infant mortality rates in all countries (see page 13) accompanied by high fertility rates, though the latter has started to decline.

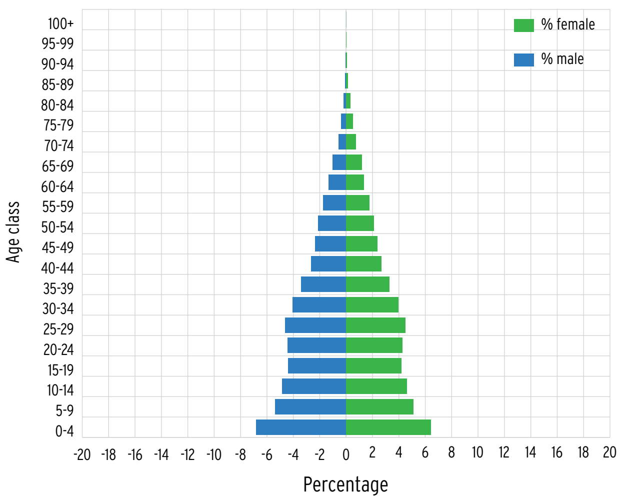
Burundi



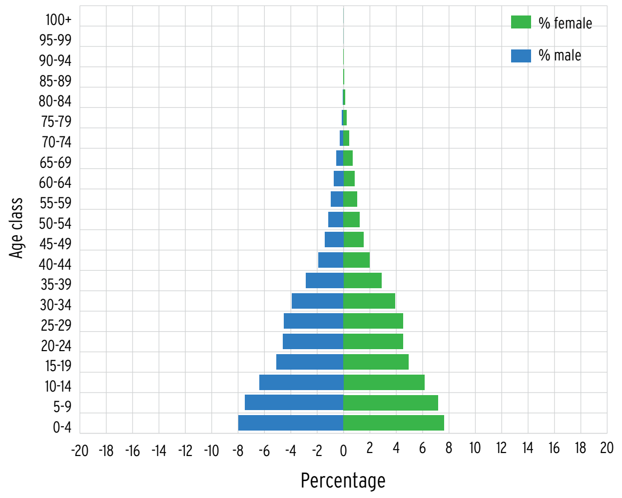
DR Congo



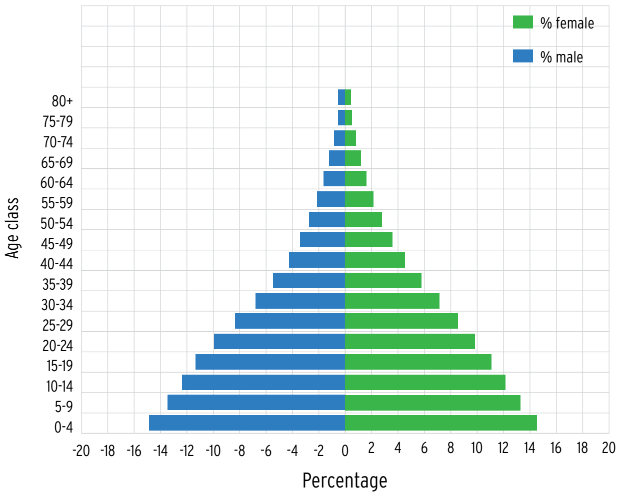
Egypt



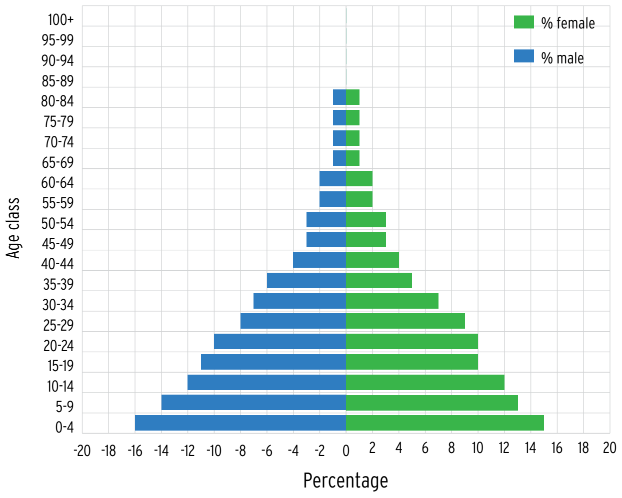
Eritrea



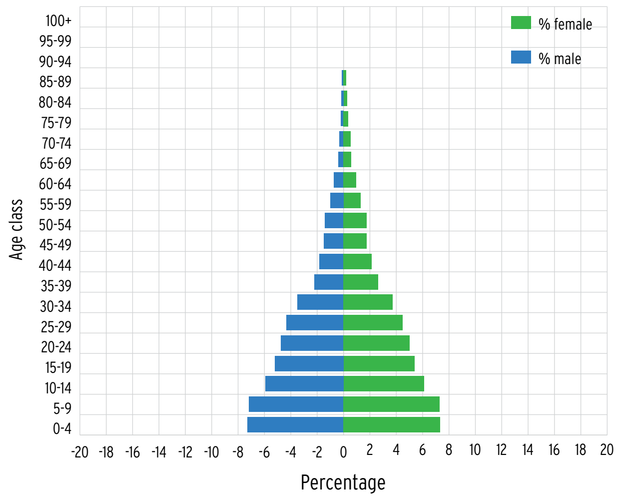
Ethiopia



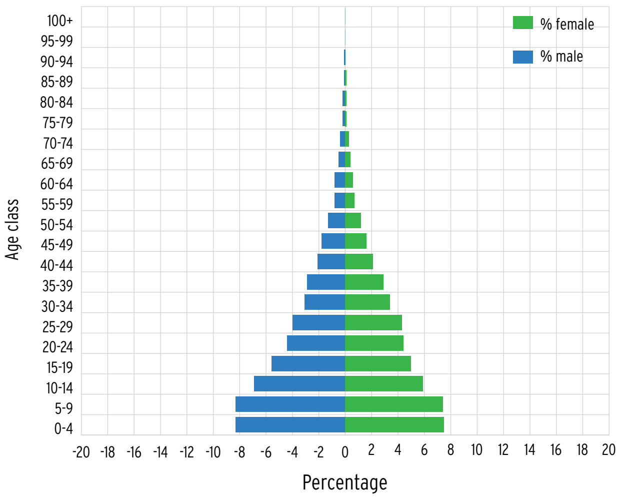
Kenya



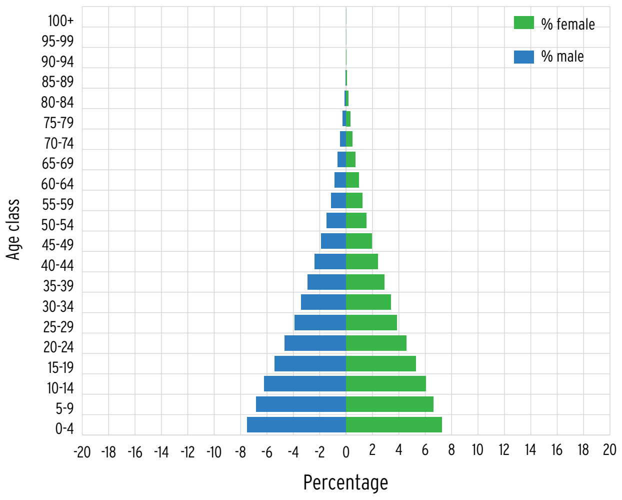
Rwanda



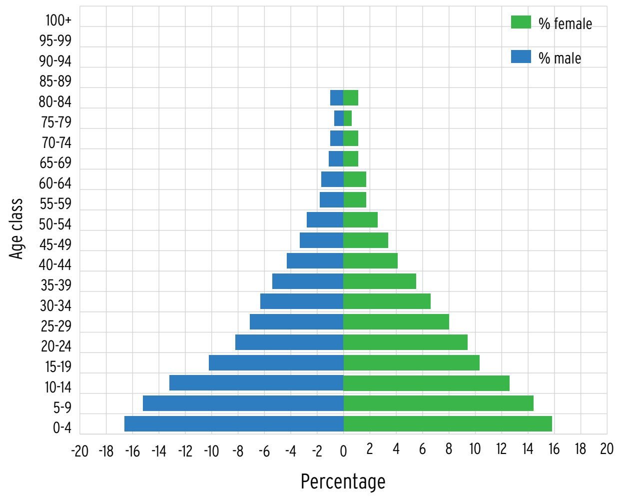
South Sudan



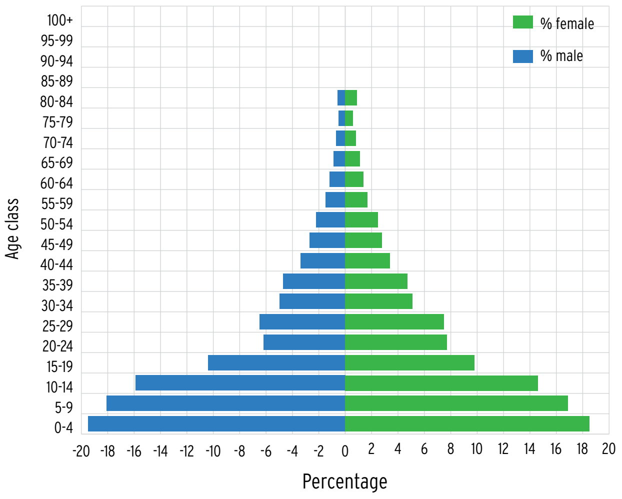
Sudan



Tanzania



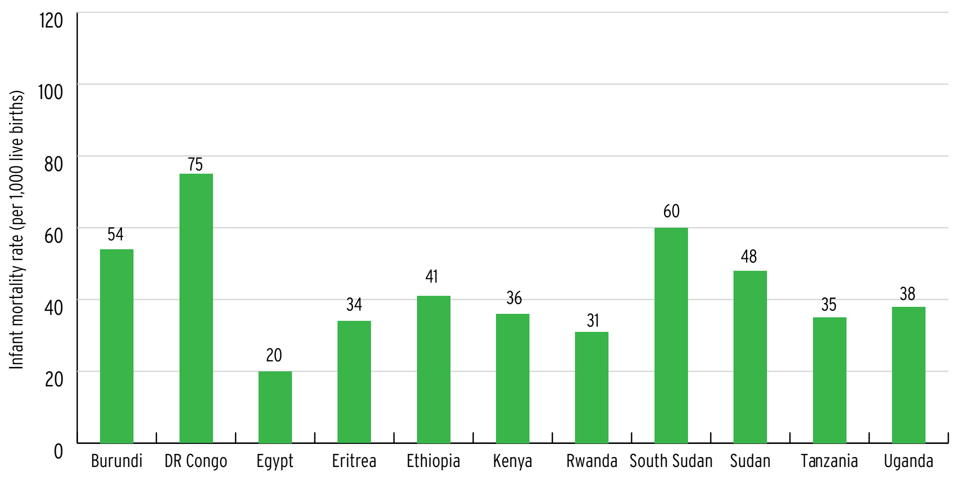
Uganda



Data Source: UN population Division 2010 Revision

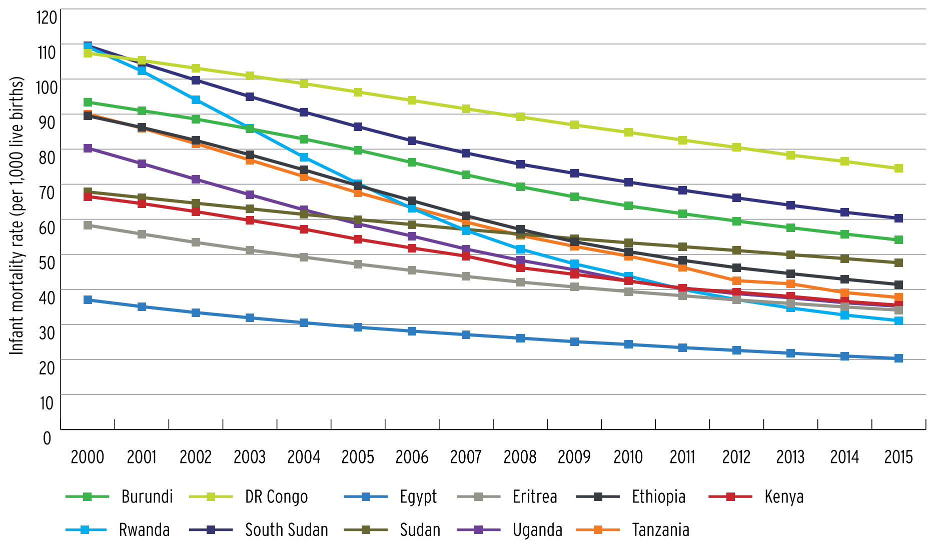
Infant mortality and life expectancy

Infant mortality rate in Nile Basin countries, 2015



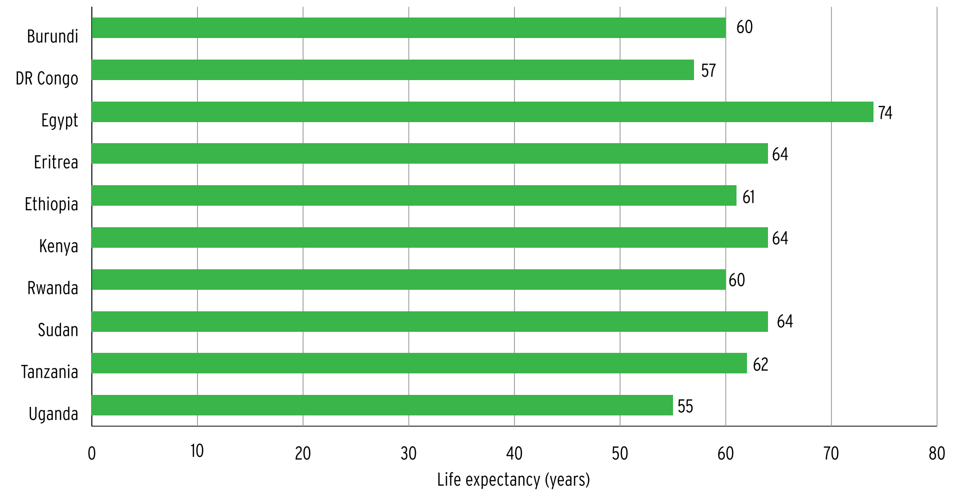
Source of data World Bank, 2015

Infant mortality rates trends in Nile Basin countries



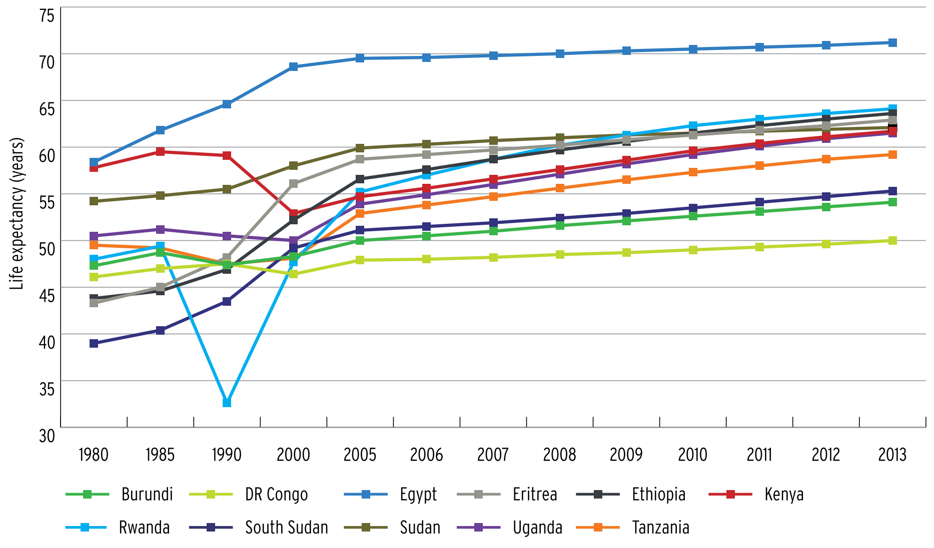
(Source of data: UN Inter-agency Group for Child Mortality Estimation (UNICEF, WHO, World Bank, UN DESA Population Division, 2015); National Institute of Statistics of Rwanda (NISR), Rwanda Poverty Profile Report,2013/14, August 2015

Life expectancy at birth for the Nile Basin countries (2015 estimate)



Source: UNDESA (2013a).2012 Revision. World Population Prospects. Population Division Database

Trends of life expectancy for the countries in Nile Basin



Source of data: CIA World Fact Book), 5th Sudan Population and Housing Census, 2008, NBS projections for 2009-2015; Tanzania National Bureau of Statistics, Tanzania in Figure - 2015

The infant mortality rate (IMR) is the number of deaths of infants under one year per 1,000 live births. This rate is often used as an indicator of the level of health in a country. The global average infant mortality rate is 49.4 according to the United Nations. Infant mortality is a very important indicator of human development - any improvement in the living conditions and poverty status of the population is immediately reflected in a decline in the level of infant mortality.

For the Nile Basin countries, DR Congo has the highest infant mortality rate (75), followed by South Sudan (60) and Burundi (54). Egypt has the lowest infant mortality rate (20), followed by Rwanda (31).

In all basin countries, infant mortality rates have decreased over the past 15 years, which indicates, among others, increase in access to health services. Decreasing infant mortality rates coupled with high fertility rate in all basin countries, however, has led to rapid population growth overall.

Mother with baby in Uganda

photo: istock

Life expectancy at birth compares the average number of years to be lived by a group of people born in the same year, if mortality at each age remains constant in the future. Life expectancy at birth is also a measure of overall quality of life in a country and summarizes the mortality at all ages.

For the Nile Basin countries, Egypt has the highest life expectancy (74 years), the rest of the Nile Basin countries have a life expectancy between 55 and 64 years.

SELECTED COUNTRY DEVELOPMENT INDICATORS

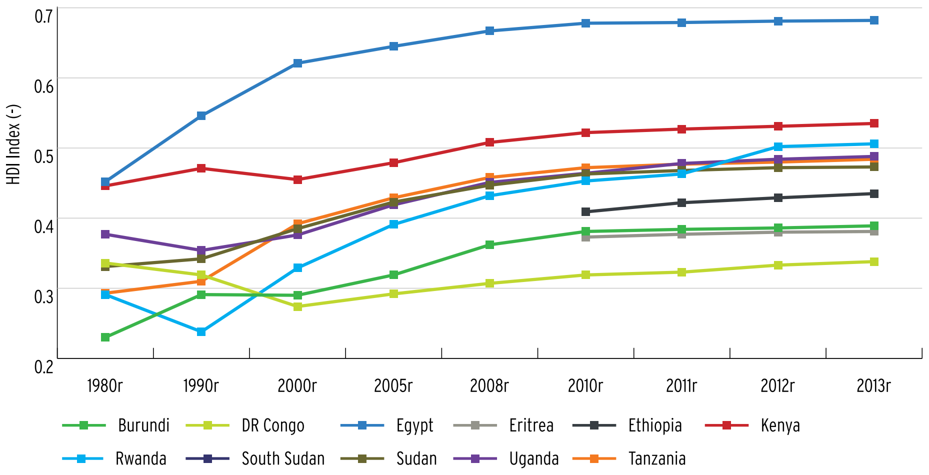
Human Development Index (HDI)

The Human Development Index (HDI) is a summary measure of average achievement in key dimensions of human development: a long and healthy life, being knowledgeable and having a decent standard of living. The HDI is the geometric mean of normalized indices for each of the three dimensions.

All Nile Basin countries are in Low Human Development category with the exception of Egypt which is in Medium Human Development category.

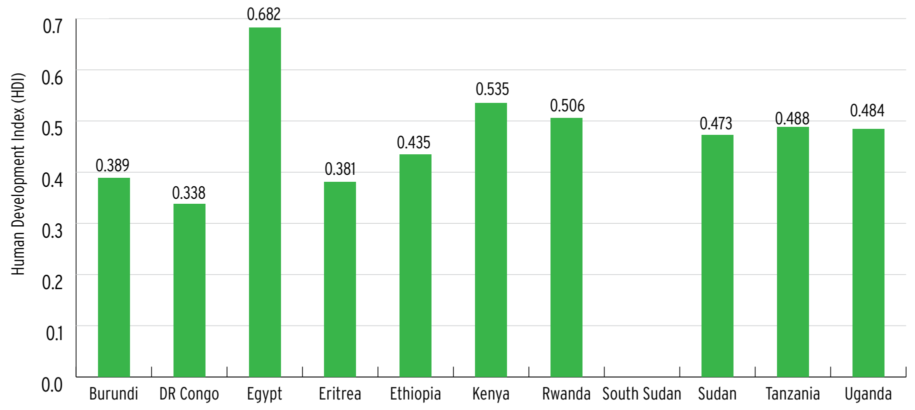
Since 2000, all Nile Basin countries, however, have shown relatively rapid improvement in HDI.

Human Development Index trends, 1980-2013



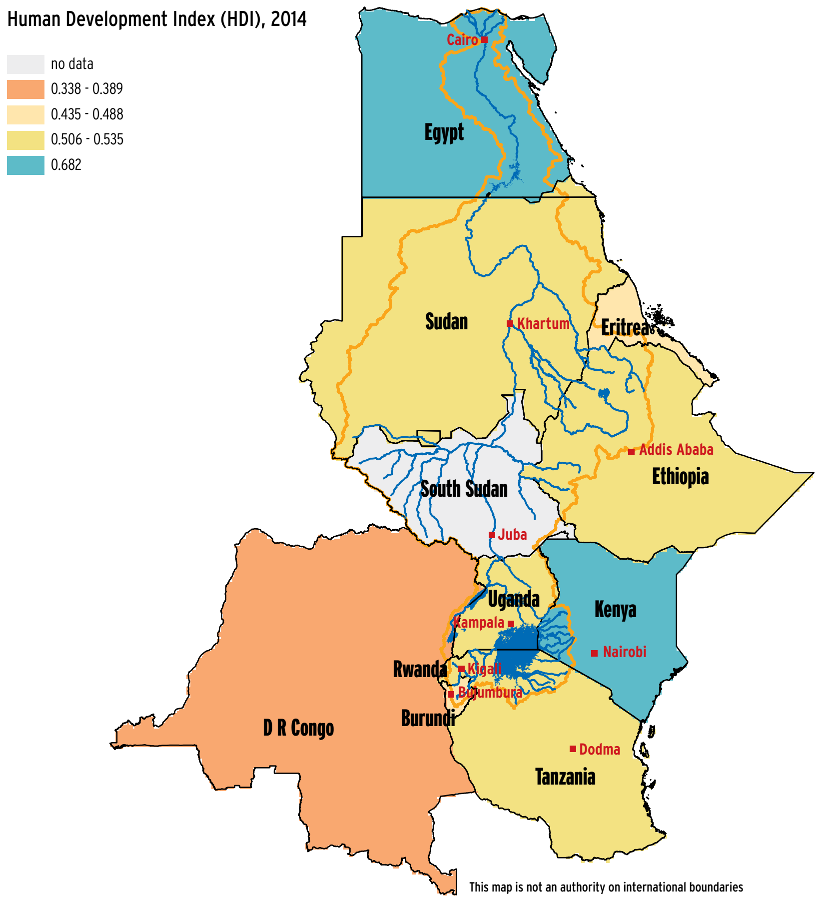
Source of data: HDRO calculations based on data from UNDESA (2013a), Barro and Lee (2013), UNESCO Institute for Statistics (2013), UN Statistics Division(2014), World Bank (2014) and IMF (2014). http://hdr.undp.org/en/content/table-2-human-development-index-trends-1980-2013

Human Development Index (HDI)



Source of data: HDRO calculations based on data from UNDESA (2013a), Barro and Lee (2013), UNESCO Institute for Statistics (2013), UN Statistics Division(2014), World Bank (2014) and IMF (2014). http://hdr.undp.org/en/content/table-2-human-development-index-trends-1980-2013

Human Development Index (HDI), 2014



This map is not an authority on international boundaries

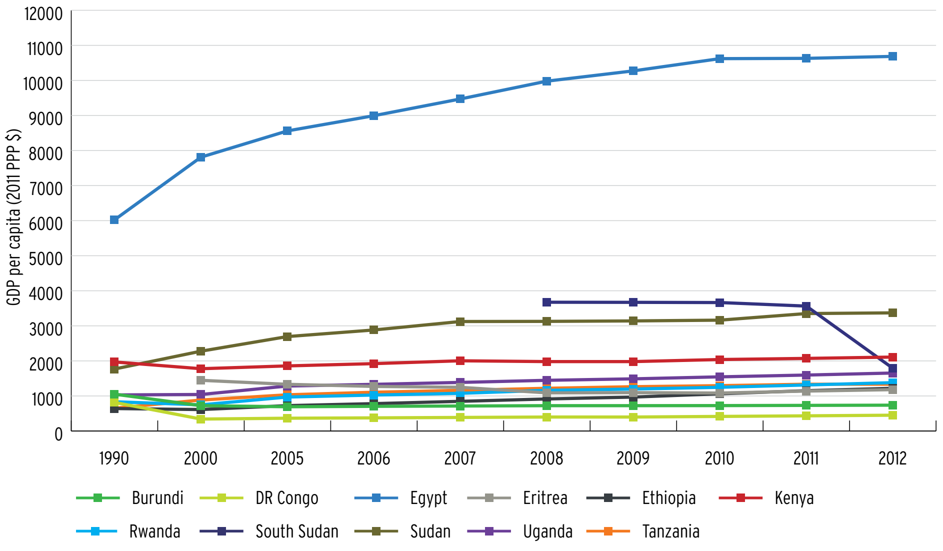
Gross Domestic Product

GDP per capita (PPP based) is gross domestic product converted to international dollars using Purchasing Power Parity (PPP) rates and divided by total population. Among Nile Basin countries, Egypt has the highest GDP per capita, followed by Sudan. DR Congo and Burundi have the lowest Gross National Income (GNI) per capita is defined as the sum of value added by all producers who are residents in a nation, plus any product taxes (minus subsidies) not included in output, plus income received from abroad such as employee compensation and property income divided by the population. In 2014 Egypt and Sudan had the highest GNI per capita.

The data show where production takes place in an economy. The distribution gives the percentage contribution of agriculture, industry, and services to total GDP. Agriculture includes farming, fishing, and forestry. Industry includes mining, manufacturing, energy production, and construction. Services cover government activities, communications, transportation, finance, and all other private economic activities that do not produce material goods.

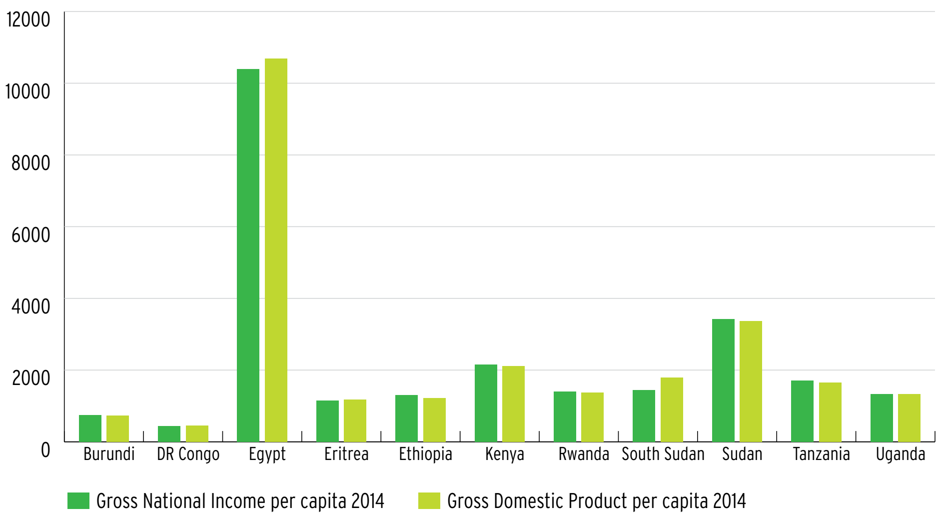
About 20% of Nile Partner states GDP is generated by agriculture. Agriculture still dominates the economy of many countries in the region. With structural transformation and industrialization, this contribution could change. Egypt has the highest per capita income (2011 PPP $ 2013) of US$ 10,733, almost 15 times larger than Burundi which has the lowest at US $747. Ethiopia had the highest real GDP growth rates at 8.5%.

Trends in GDP per capita in Nile Basin countires



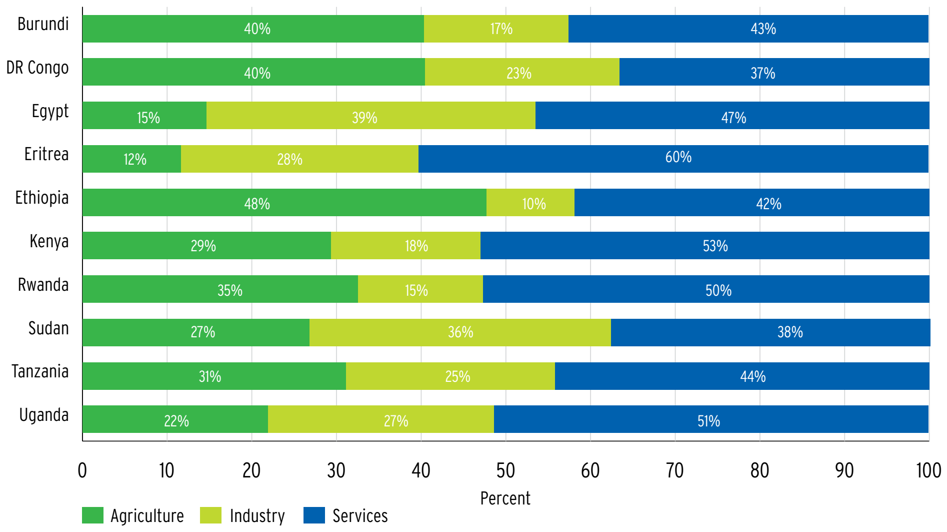
Source: UNDP, World 2014, World Development Indicator database

Gross Domestic Product and Gross National Income per capita (measured in 2011 PPP$)



Source: UNDP, World 2014, World Development Indicator database

Contribution of sectors to total GDP in Nile Basin countries (2014 estimate)



(Source of data: CIA World Fact Book), Tanzania National Bureau of Statistics; National Institute of Statistics of Rwanda (NISR), Rwanda Poverty Profile Report,2013/14, August 2015

Photo: Simone D. McCourtie / World Bank

Laborers from a land husbandry activity on steep hills. About 60% are women; Rwanda

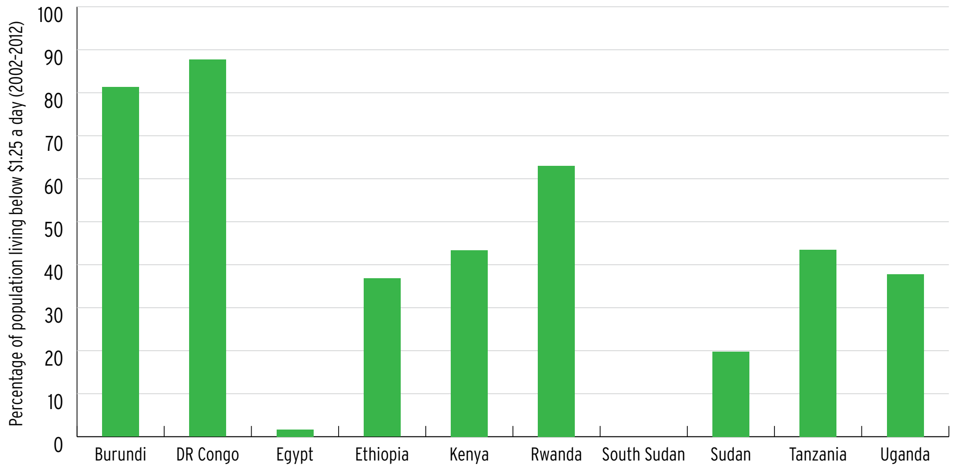
Poverty in the Nile Basin Countries

No matter how it is defined (e.g. lack of adequate income/consumption capacity; lack of wealth/assets including shelter, clothing, production assets; capability deprivation - education, health, skills, information; deprivation of capacity to influence decisions, etc.) poverty is widespread, and socio-economic conditions are difficult for a large majority of the Nile basin population. For example, by income alone, more than 40% of the population of most of the Nile basin countries lives on less than the international poverty line of 1.25 dollar a day (in purchasing power parity terms) PPP.

Population below PPP $1.25 a day shows the percentage of the population living below the international poverty line $1.25 (in purchasing power parity terms) a day. In five of the countries, the percentage of population below the PPP $ 1.25 a day is greater than 40 percent; greater than 60 percent in three countries.

Tackling such extreme levels of poverty is a policy priority of all Nile Basin countries.

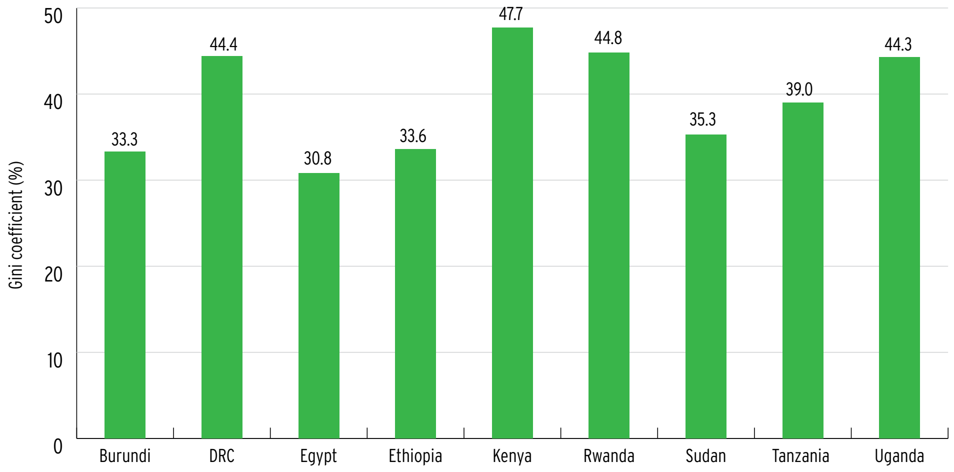
Population living below income poverty line



Source of data: UN, Human Development Report, 2015; no data for South Sudan

Economic Inequality

Gini coefficient of inequality (2003 - 2012) for Nile Basin Countries



Source of data: world Bank (2015); Tanzania National Panel Survey Wave 3, 2012-2013-National Bureau of statistics; National Institute of Statistics of Rwanda (NISR), Rwanda Poverty Profile Report,2013/14, August 2015

Gini coefficient is a measure of inequality. The coefficient varies between 0, which reflects complete equality and 100%, which indicates complete inequality (one person has all the income or consumption, all others have none).

The Gini coefficient is above 40 in four (Kenya, Rwanda, Uganda and DRC) out of nine Nile countries (no data are available for Eritrea, South Sudan), indicating substantial inequalities of income and wealth within these countries.

Where estimates are available, rural poverty incidence exceed urban poverty incidence. In terms of population below international poverty lines, again Burundi and DR Congo are the poorest at 81.3% and 87.7% respectively. Egypt has lowest $1.5 a day poverty incidence (1.7%) and the mean income shortfall is as low as half a percentage point. For $3 a day, poverty rates are understandably higher, although almost similar rankings hold.

Access to Potable Water and Sanitation

Over the last decade, thanks to commitment to the Millennium Development Goals, nearly all Nile Basin countries have made significant progress in providing safe drinking water to their urban population. However, the proportion of rural population with access to safe drinking water is low by international standards. Egypt is an exception where 99 percent of its rural population has access to safe drinking water.

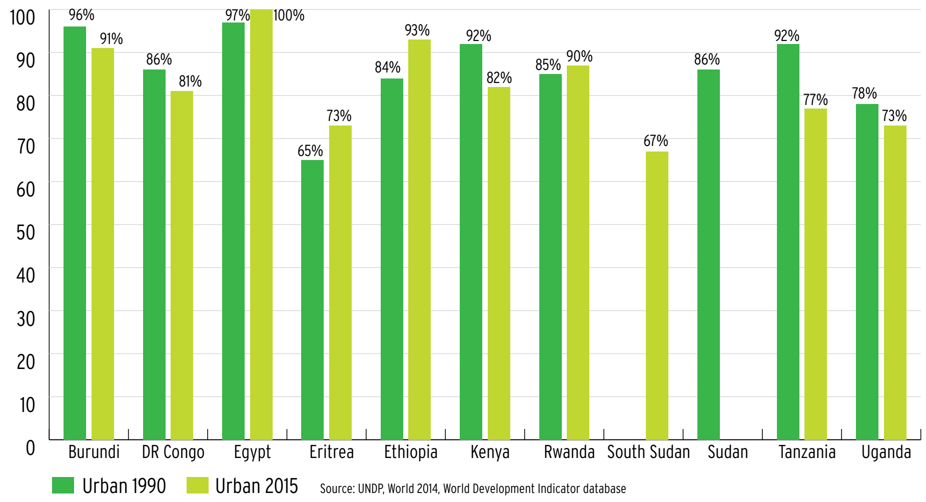
There have been noticeable improvements in providing access to improved sanitation facilities in urban areas. However, still in seven of the basin countries, only less than 50 percent of the urban population has access to improved sanitation services.

Nile Basin countries have made progress in improving access to improved sanitation facilities in rural areas as well. Even so, in seven of the basin countries, onlyless than 30 percent of the rural population has access to improved sanitation services.

Lucia Boki fetches water at a borehole near the village of Bilinyang, near Juba

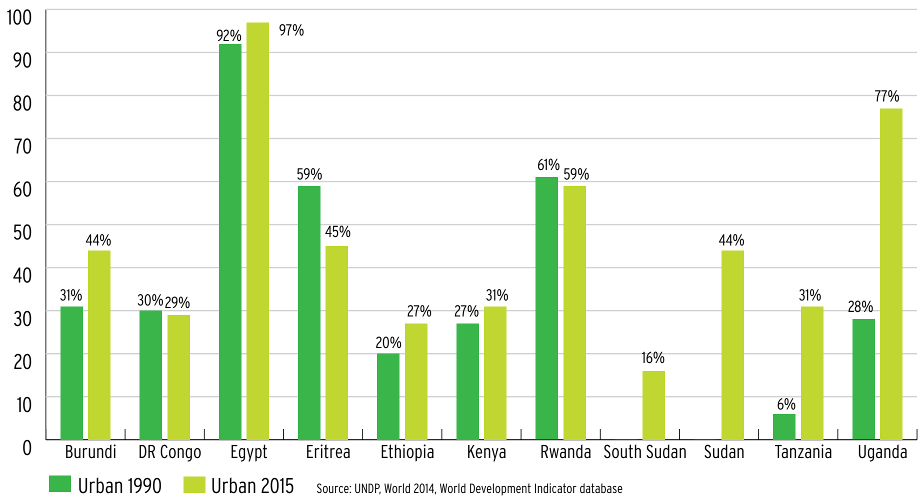
Photo: © Arne Hoel / World Bank

Access to potable water - Estimated percentage of urban population using improved drinking water sources



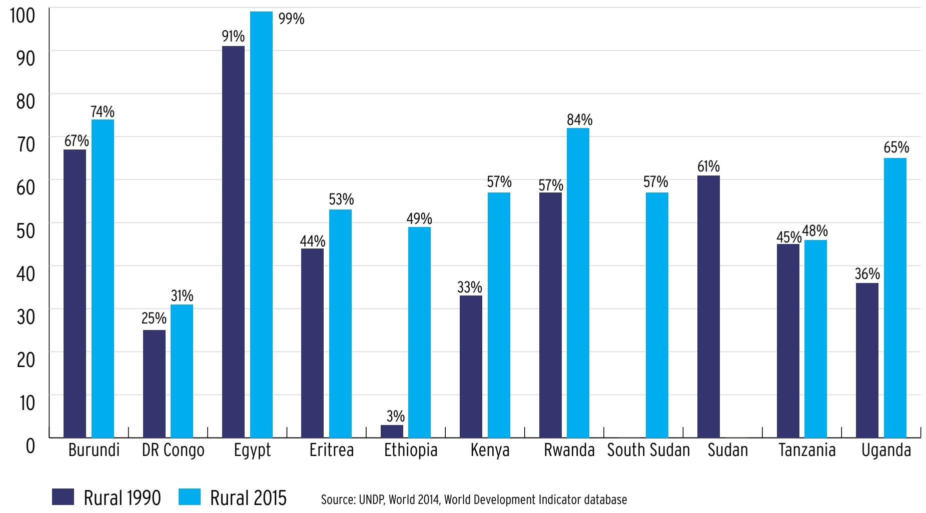
Source: UNDP, World 2014, World Development Indicator database

Access to sanitation - Estimated percentage of urban population using improved sanitation facility



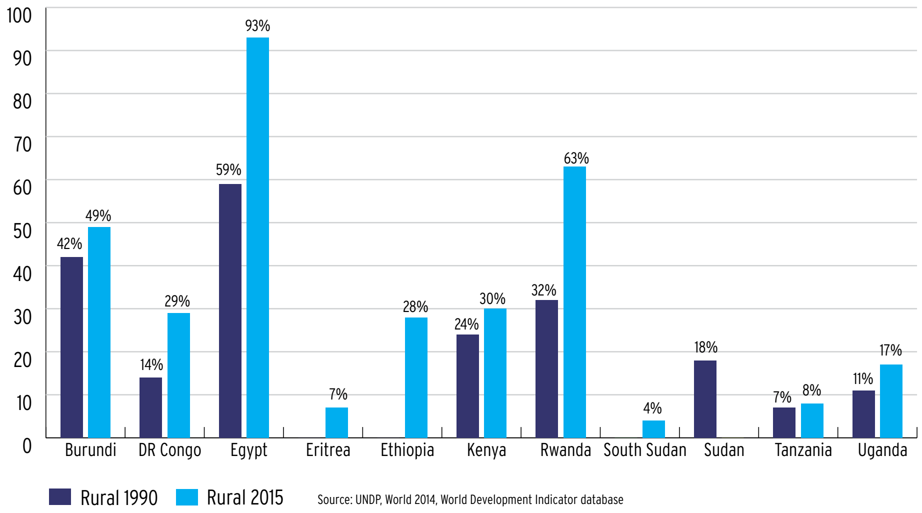
Source: UNDP, World 2014, World Development Indicator database

Access to water - Estimated percentage of rural population with access to improved drinking water facilities



Source: UNDP, World 2014, World Development Indicator database

Access to sanitation - Estimated percentage of rural population using improved sanitation facilities



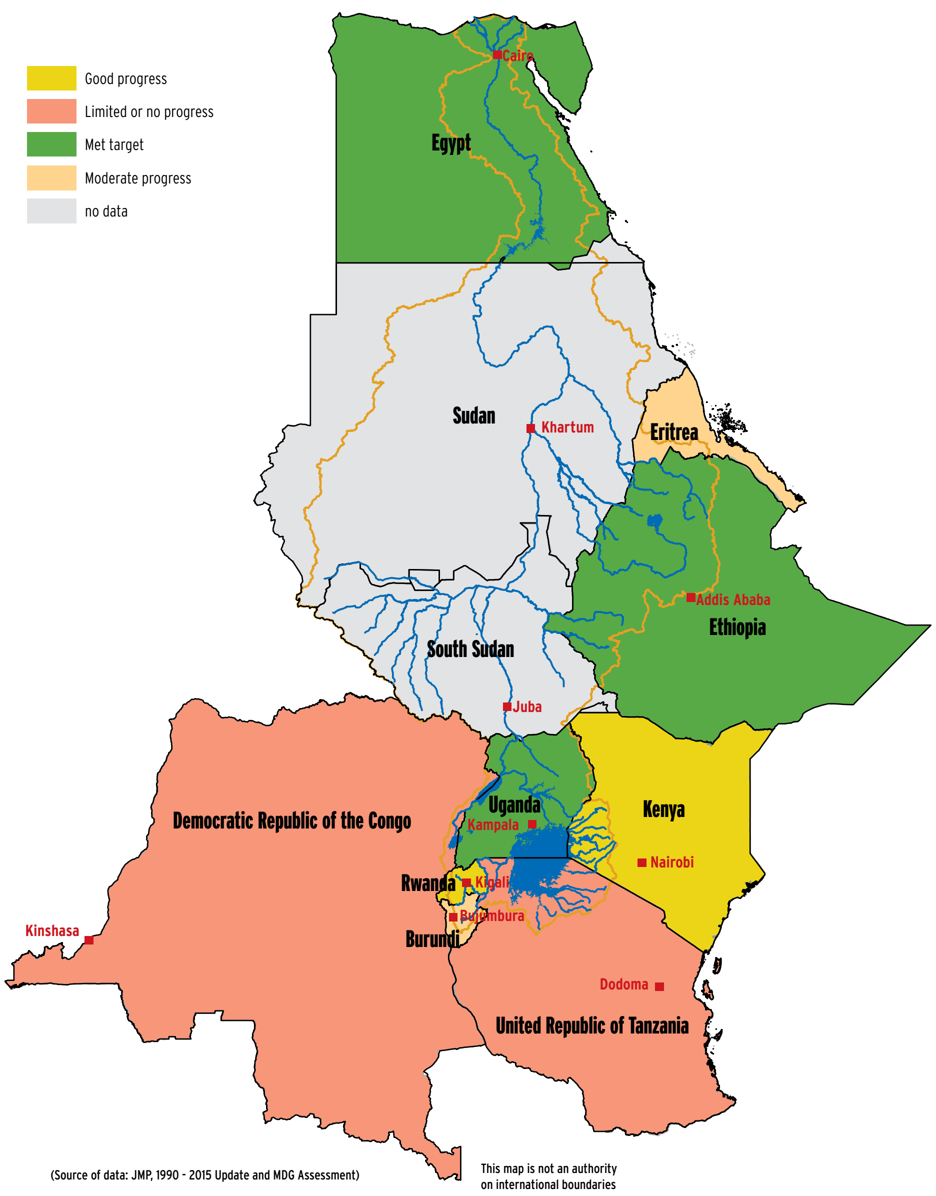
Source: UNDP, World 2014, World Development Indicator database

The renovated water treatment plant in Juba. South Sudan

Photo: © Arne Hoel / World Bank

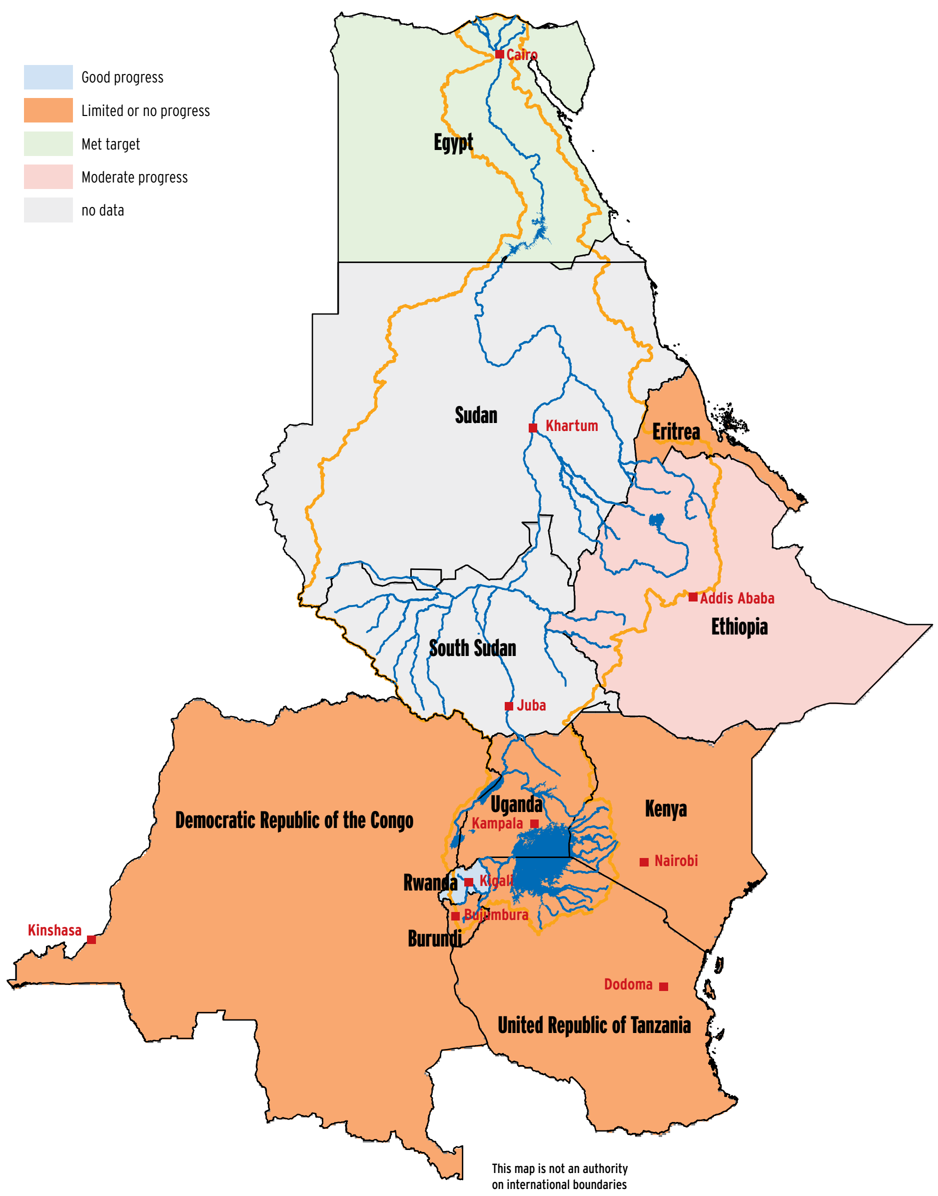
Achievement of MDG targets

Progress towards MDG targets for water supply
25 years progress (1990 - 2015)



(Source of data: JMP, 1990 - 2015 Update and MDG Assessment)

Progress towards MDG targets for sanitation
25 years progress (1990 - 2015)



Level of electrification/access to electricity by country

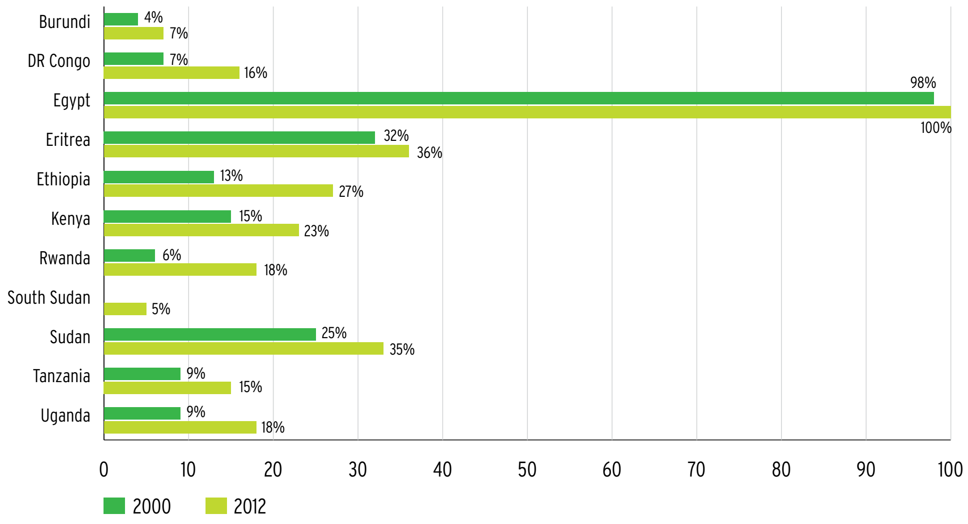
In almost all Nile Basin countries, the percentage of population with access to electricity is very low by world standards. The exception is Egypt where all its population has access to electricity.

Per capita electricity consumption shows stark contrast. Again, Egypt is the exception. Egypt's per capita electricity consumption is more than double the combined per capita electricity consumption of 6 Nile Basin countries.

photo: Istock

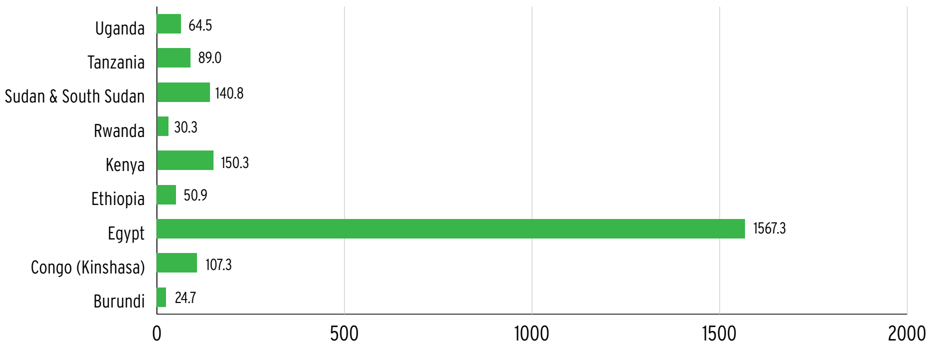
Power distribution

Percentage of population with access to electricity in Nile Basin countries



Source of data: World Bank, Sustainable Energy for All (SE4ALL) database from World Bank, Global Electrification database

Electricity net consumption (KWh/c), 2010



Source: US Energy Information Administration

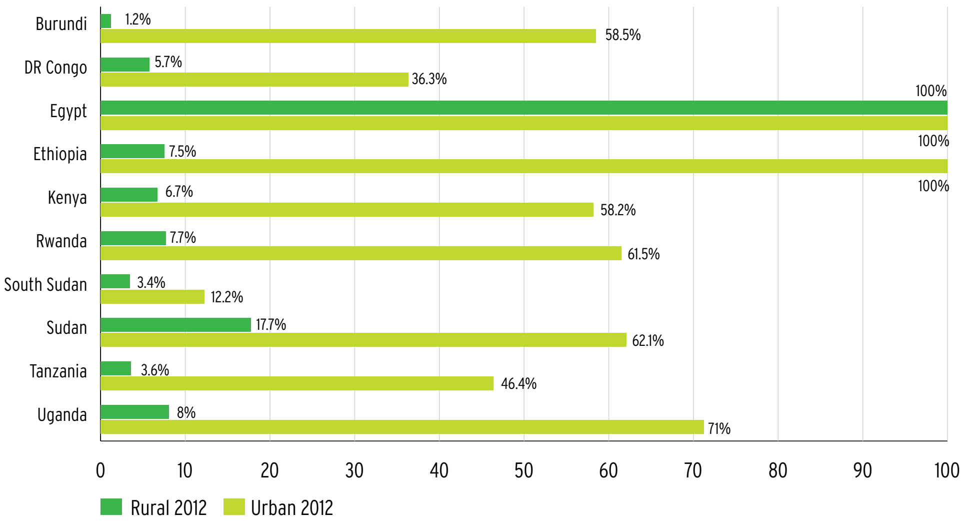
Level of electrification

Access to electricity is the percentage of population with access to electricity. Electrification data are collected from industry, national surveys and international sources.

The DR Congo, where only 16.4% of the population has access to electricity, is an example of the co-existence of huge hydropower potential with extreme energy poverty in the Nile Partner states. Political instability, limited access to investment finance, small market size and weak transmission connections with neighboring countries have all held back exploitation of hydro resources. Ethiopia, Kenya and Uganda are among the most populous countries in the Nile Basin and have the largest populations both with and without access to electricity. Rwanda's electrification rate has increased rapidly in recent years (from 6% in 2008 to 17% in 2012).

Nearly 80% of those lacking access to electricity across Nile Basin are in rural areas, an important distinction when considering appropriate energy access strategies and technical solutions. The problem of inadequate electricity supply is multifaceted: it includes inadequate generating capacity, rundown existing stock and limited transmission and distribution infrastructure. Within the Nile Basin, the number of people living without electricity is increasing, as rapid population growth is outpacing the many positive efforts to provide access.

Access to electricity (% of population)



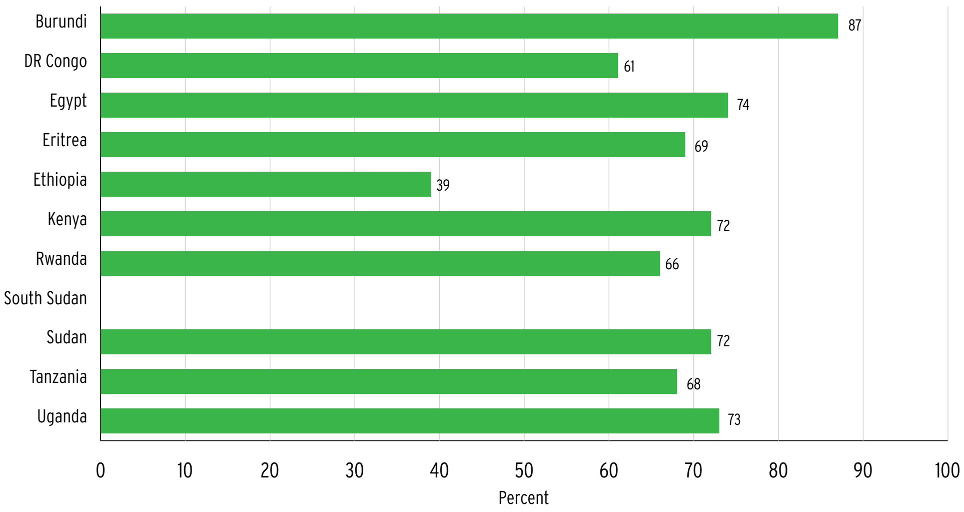
Source of data: WDI 2016

Education and literacy

Youth literacy rate reflects the outcomes of the primary education system over the previous 10 years, and is often seen as a proxy measure of social progress and improving capability for economic achievement. The rate represents the percentage of people aged 15 to 24 years who can both read and write with understanding of simple statements. Generally, 'literacy' also encompasses 'numeracy', the ability to make simple arithmetic calculations.Similar progress has been made in terms of adult literacy in the basin. Adult literacy here encompasses ages 15 and above for both sexes.

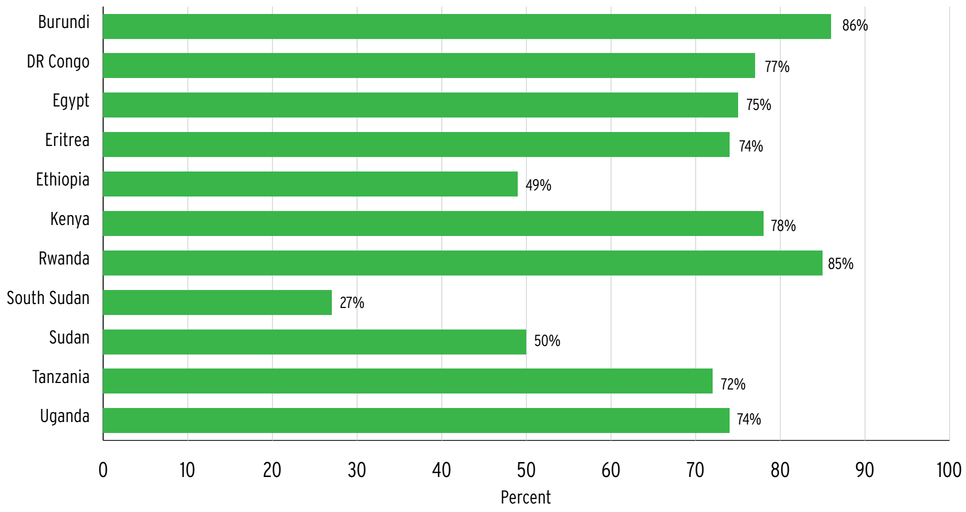
Education and literacy are key indicators of quality of human labor force. Overall, adult female illiteracy rates are higher than adult male illiteracy rates, and this holds for all countries. Again, male youth illiteracy rates are highest in Ethiopia, while Kenya has the lowest youth male and female illiteracy. With the only exception of Kenya, youth female illiteracy rates are higher than youth male illiteracy rates. This implies that females, in general, tend to be more illiterate than their male counter parts in all countries. A gender focused education strategy is therefore highly desirable for effectively engaging female into the socio-economic fabric and address gender inequities.

Adult literacy rate (% ages 15 and older)



Source of data: UNESCO Institute of Statistics database, National Institute of Statistics of Rwanda (NISR), Rwanda Poverty Profile Report,2013/14, August 2015; Tanzania National Bureau of Statistics, Tanzania in Figure, 2015; South Sudan Statistical Year Book, 2011; Sudan Central Bureau of Statistics, 2010

Youth literacy rate, population 15-24 years, both sexes (%)

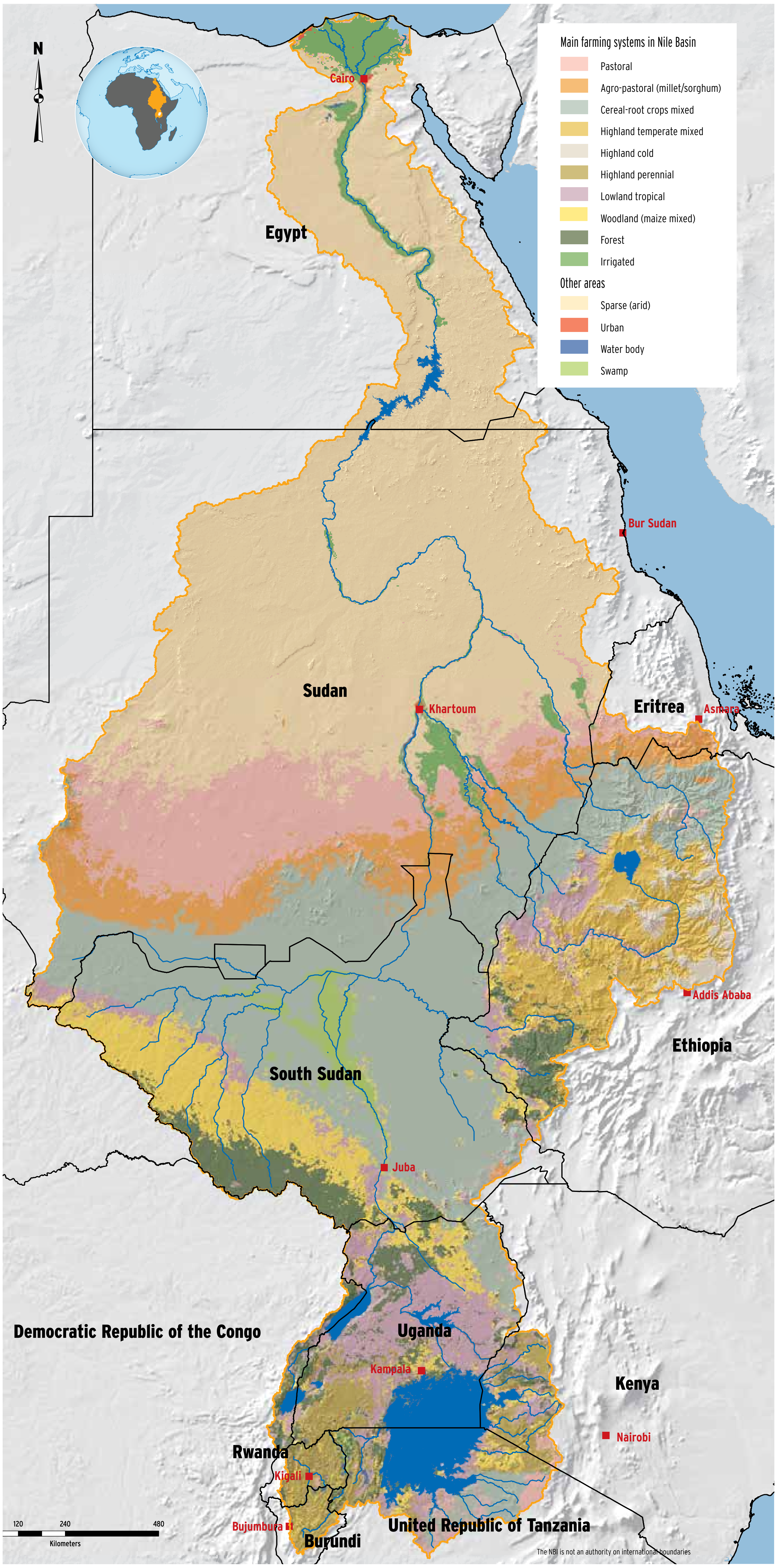


Source of data: UNESCO Institute of Statistics database, National Institute of Statistics of Rwanda (NISR), Rwanda Poverty Profile Report,2013/14, August 2015; Tanzania National Bureau of Statistics, Tanzania in Figure, 2015; South Sudan Statistical Year Book, 2011; Sudan Central Bureau of Statistics, 2010

photo: Istock

School going girls

FARMING SYSTEMS AND PRODUCTION IN NILE BASIN



The entire Nile Basin exhibits a wide spectrum of altitude, temperature, rainfall, humidity and aridity ranges, thus giving rise to diversity of agro-climatic zones and agriculture farming systems and a range of agricultural products thereof.

Farming System	Area Km^2	Percentage
Pastoral	283791.1	8.9
Agro-Pastoral (millet/sorghum)	178584.0	5.6
Cereal -root crops mixed	675250.6	21.3
Highland temperate mixed	136932.2	4.3
Highland cold	38652.9	1.2
Highland perennial	89513.6	2.8
Lowland tropical	190886.3	6.0
Woodland (maize mixed)	203767.5	6.4
Forest	143307.9	4.5
Irrigated	66096.8	2.1
Sparse (Arid)	1033878.0	32.5
Urban	1838.1	0.1
Water Body	94882.1	3.0
Swamp	39072.3	1.2
Total	3176453.3	


Photo: Simone D. McCourtie / World Bank

Impressive land husbandry activity on a steep hills.


Photo: A'Melody Lee; World Bank

The Kitabi Tea processing facility in kitabi, Rwanda


Photo: A'Melody Lee; World Bank

Coffee washing station

Irrigated Farming System

This farming system comprises large scale, traditional, small scale traditional and commercial. In many cases, irrigated cropping is supplemented by rainfed cropping or animal husbandry (the Gezira is one notable exception). Crop failure is generally not a problem, but livelihoods are vulnerable to water shortages, scheme breakdowns and deteriorating input/output price ratios.

Photo: A Melody Lee/World bank

Rice paddies in the swamps and marshes maximise arable land, yielding food and economic security during the growing season

Forest Farming System

Farmers practice shifting cultivation; clearing a new field from the forest every year, cropping it for 2 to 5 years. Cattle and human population density are low. Physical isolation plus lack of roads and markets pose serious problems. Agricultural growth potential is moderate but development requires careful management of environmental risks, including soil fragility and loss of wildlife habitats.

Highland perennial Farming System

This farming system is found in Ethiopia, Uganda, Rwanda and Burundi. The system supports the highest rural population density in the region. The farming system is based on perennial crops such as banana, plantain, and coffee, complemented by cassava, sweet potato, beans and cereals. The main trends are diminishing farm size and declining soil fertility.

Highland temperate mixed Farming System

This farming system is located at altitudes between 1800 and 3000 metres in the highlands and mountains of Ethiopia and smaller areas are found in Eritrea. Small grains such as wheat and barley are the main staples, complemented by peas, lentils, broad beans, rape, teff (in Ethiopia) and Irish potatoes. Typically there is a single cropping season, although some parts of Ethiopia have a second, shorter season. There are major problems in the farming system: for instance, soil fertility is declining because of erosion and a shortage of biomass; and cereal production is suffering from a lack of inputs. There is, however, considerable potential for diversification into higher-value temperate crops.

Photo: A Melody Lee/ World Bank

Rwanda's economic development can be traced to it's innovative landscape reform program. Communities terraced the hills and valleys during the dry season, so that they could retain topsoil, nutrients and water. This meant greater yields and more productive farming.

Cereal-Root Crops Mixed Farming System

This type of farming is found mainly in the dry sub-humid zone. Although the system shares a number of climatic characteristics with the Maize mixed system, other characteristics set it apart, namely; lower altitude, higher temperatures, lower population density, abundant cultivated land, higher livestock numbers per household, and poorer transport and communications infrastructure. Although cereals such as maize, sorghum and millet are widespread, wherever animal traction is absent root crops such as yams and cassava are more important than cereals. Intercropping is common, and a wide range of crops is grown and marketed. The main source of vulnerability is drought but the agricultural growth prospects are excellent.

Maize mixed Farming System

The farming system is the most important food production system in Kenya, Tanzania and Uganda, but also found in Ethiopia and South Sudan. The most typical areas have uni-modal rainfall, but some areas experience bimodal rainfall. The farming system also contains scattered irrigation schemes, but these are mostly small-scale. Where a bimodal rainfall pattern occurs farmers have two cropping seasons, but in drier areas they usually harvest only once a year from a given field. The main staple is maize and the main cash sources are cattle, tobacco, coffee and cotton, plus the sale of food crops such as maize and pulses. The main source of vulnerability is drought.

Agro-Pastoral millet/sorghum Farming System

For the Nile Basin countries, this system of farming is mainly found in Sudan, South Sudan, Ethiopia and Eritrea. Crops and livestock are of similar importance. Rainfed sorghum and pearl millet are the main sources of food and are rarely marketed, whereas sesame and pulses are sometimes sold. Livestock are kept for subsistence (milk and milk products), offspring, transportation (camels, donkeys), land preparation (oxen, camels), sale or exchange, savings, bride wealth and insurance against crop failure. The main source of vulnerability is drought, leading to crop failure, weak animals and the distress sale of assets. Agricultural growth potential is modest and presents important challenges.

Pastoral Farming System

This system is located in the arid and semi-arid zones extending from Sudan, Ethiopia and Eritrea. During the driest period of the year, Sahelian pastoralists move south to the Cereal-Root Crop Mixed System areas and they return north during the rainy season. The main source of vulnerability is the great climatic variability and consequently high incidence of drought.

Sparse (Arid) Farming System

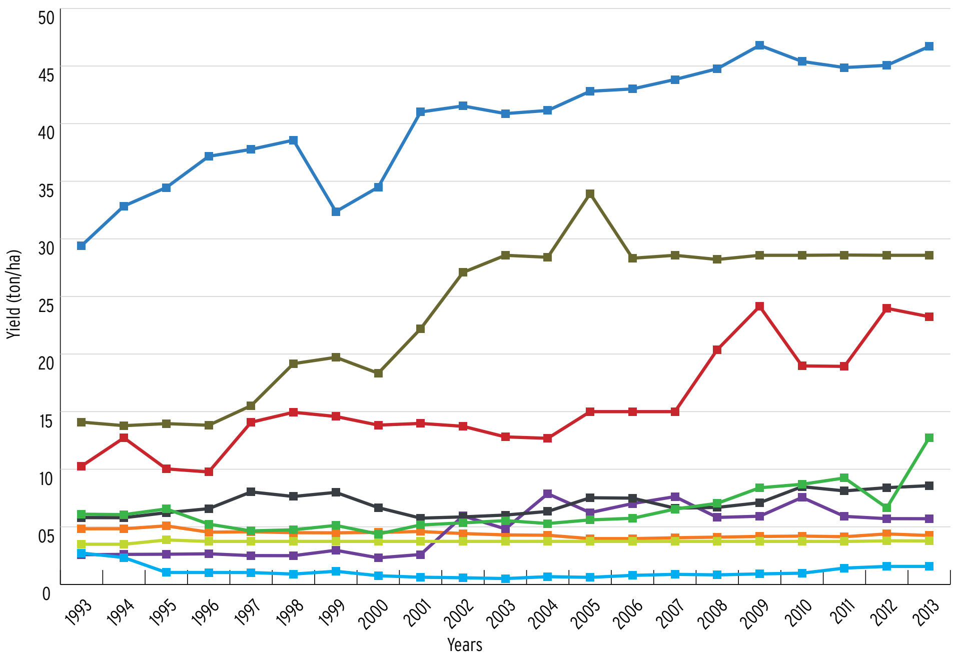
The system is mainly found in Sudan and Egypt. It is of limited significance from the point of view of agriculture. Because the wadis and their surrounding areas are considered part of the Pastoral Farming System, grazing within the actual Sparse (Arid) System is limited. There are some scattered irrigation settlements in these arid areas, in most cases used by pastoralists to supplement their livelihoods.

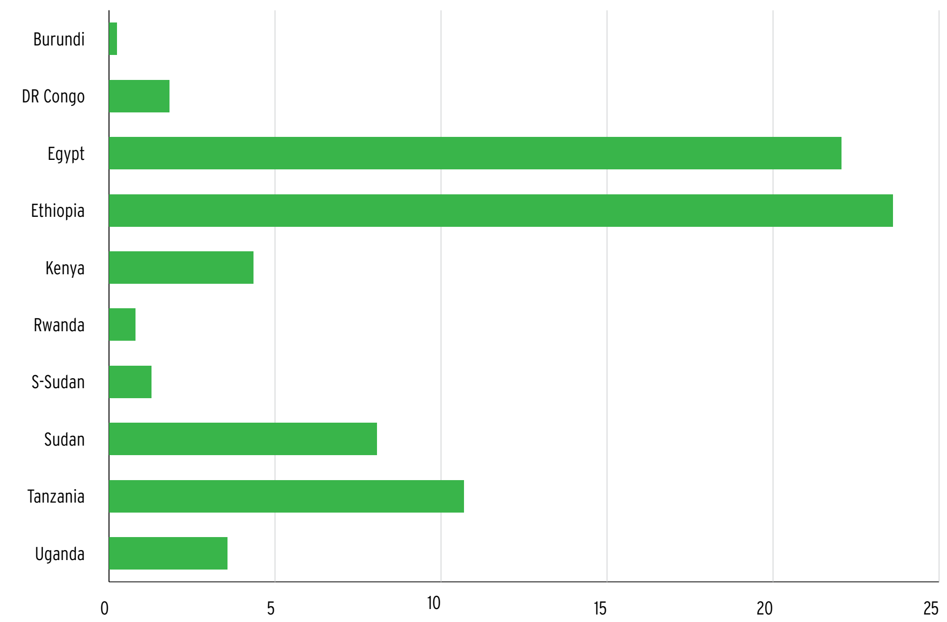
Agriculture Production and Yield

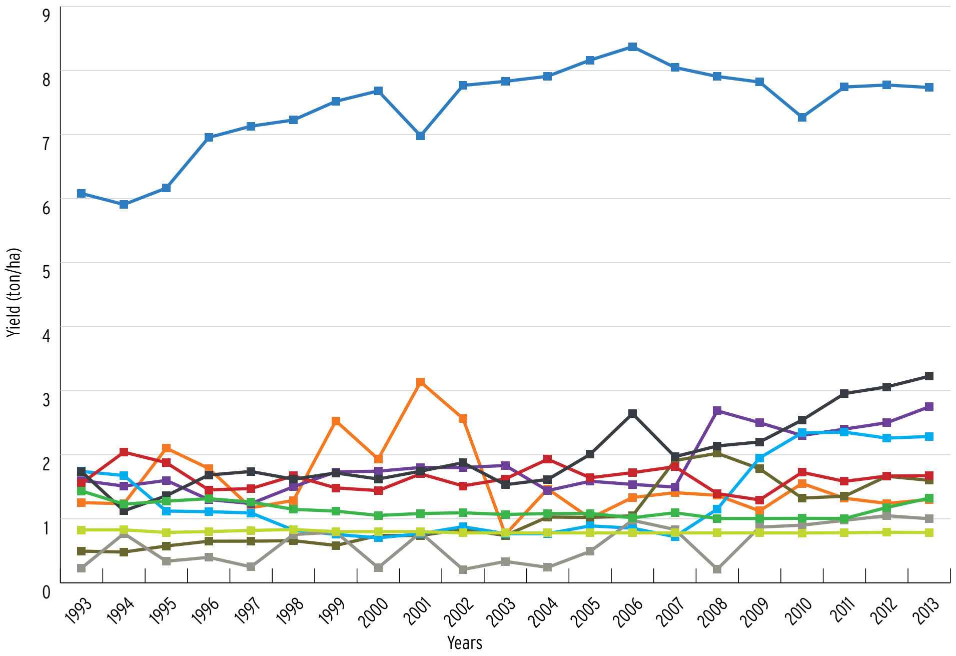
Agriculture is a major livelihood source in the Nile Basin, sustaining tens of millions of people. It provides occupations for more than 75 per cent of the total labour force and contributes to one-third of the GDP in the basin (IWMI, 2012). Enhancing agriculture could directly contribute to poverty alleviation in the region as most of the poor live in agricultural areas, and are therefore largely reliant on agriculture as their primary (and often only) source of income and living. Increased agricultural production can also be effective to reduce the cost of living for both rural and urban poor through reduced food prices (OECD,2006).

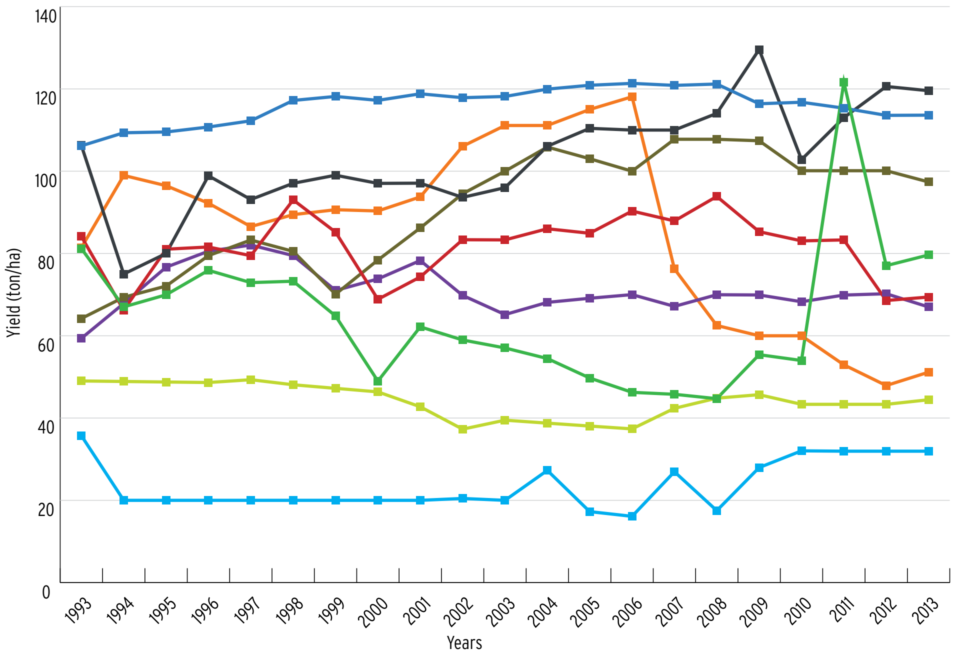
Countries and settings within the Basin exhibit considerable variability in terms of their livelihood sources, though dominant sectors of employment/income remain the same for all countries. For example, agriculture sector contributes over 40% of the value added to GDP in Ethiopia, Sudan, Burundi, Tanzania and Rwanda and in the vicinity of 40% in Kenya, Uganda, and Congo DR and slightly above 10% in Egypt.

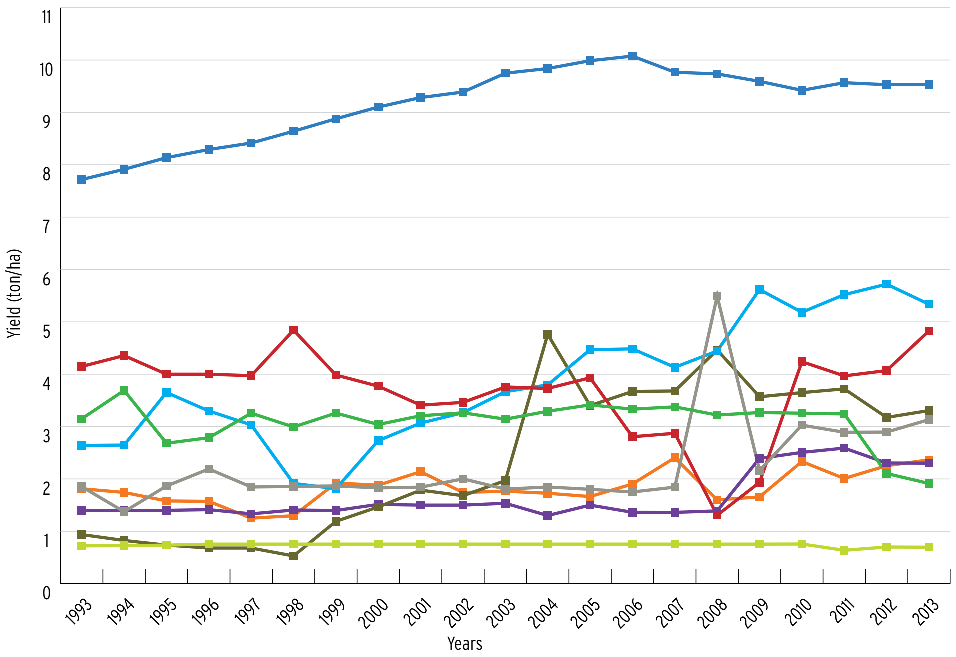
Food production in most of the Nile Basin Partner states have not kept pace with the population increase over the past four decades. As a result, the Nile basin is the one region where per capita food production saves for Egypt is roughly constant at a level that is less than adequate. And much of the agriculture is not commercially oriented and is characterized by small landholdings, low inputs use, and low crop yields. Agricultural support services including input supply, credit, agro-processing, and marketing channels are poorly developed, which along with other multiple market failures, discounts returns to agriculture (value added per worker).

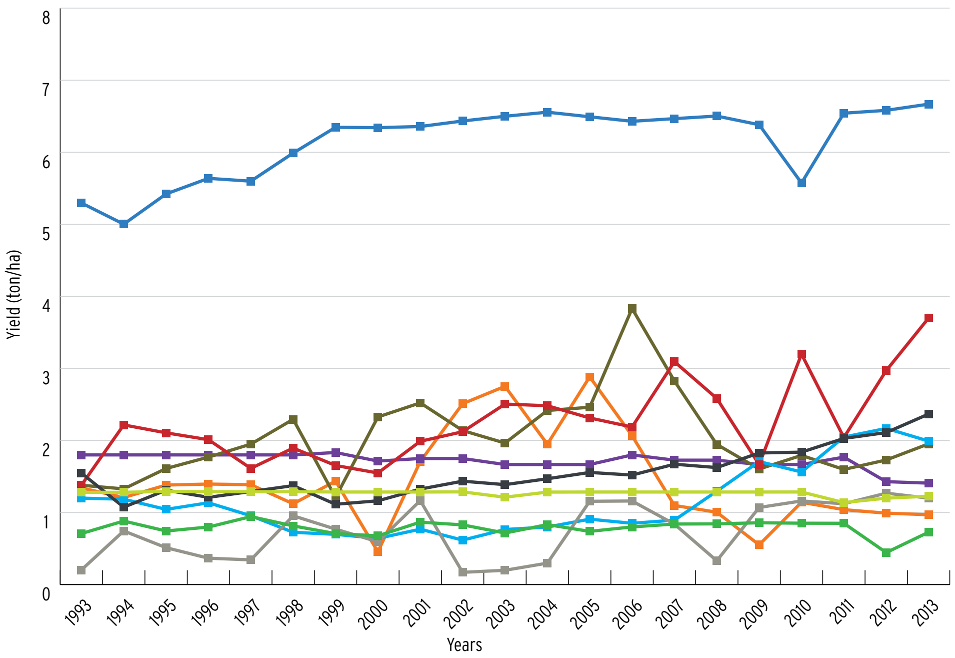

Yield - Bananas


Cereal production (Millions metric tons)


Yield - Maize


Yield - Sugarcane


Yield - Rice (Paddy)


Yield - Wheat

Burundi — DR Congo — Egypt — Eritrea — Ethiopia — Kenya
Rwanda — Sudan — Uganda — Tanzania

Photo: © Arne Hoel / World Bank

Corn after harvest

Production - Bananas

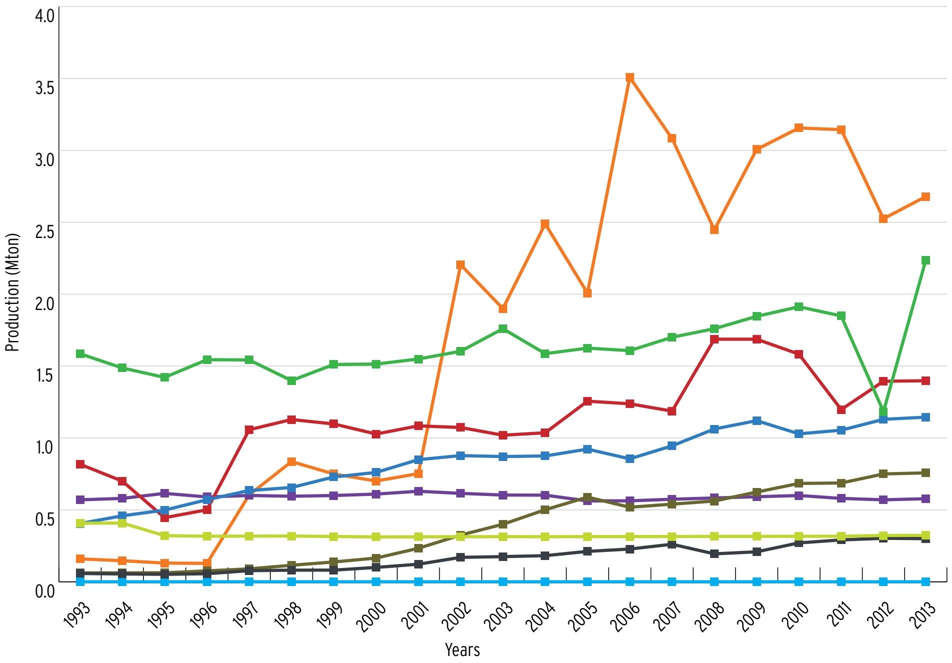
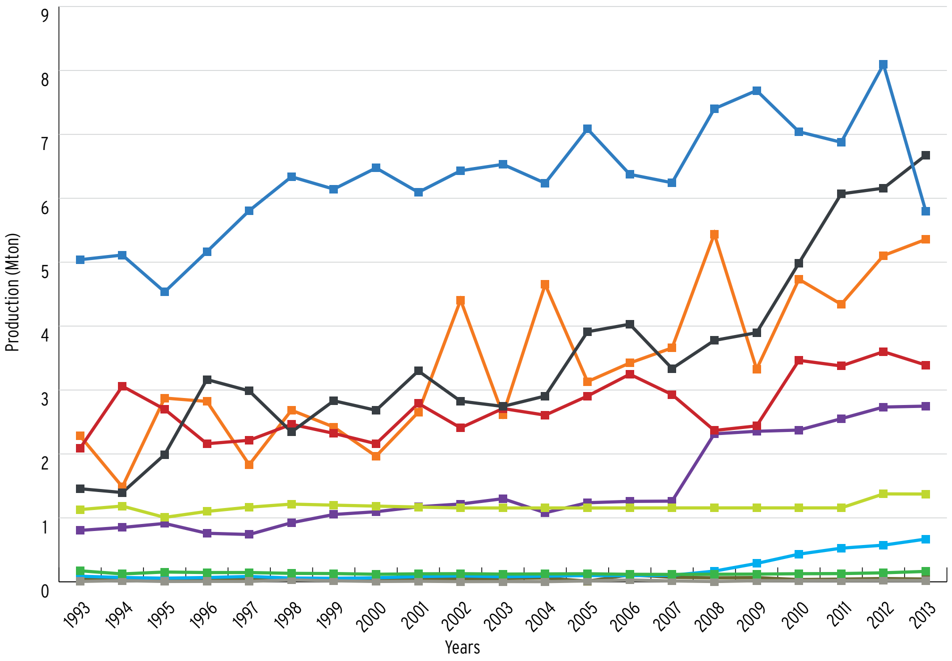


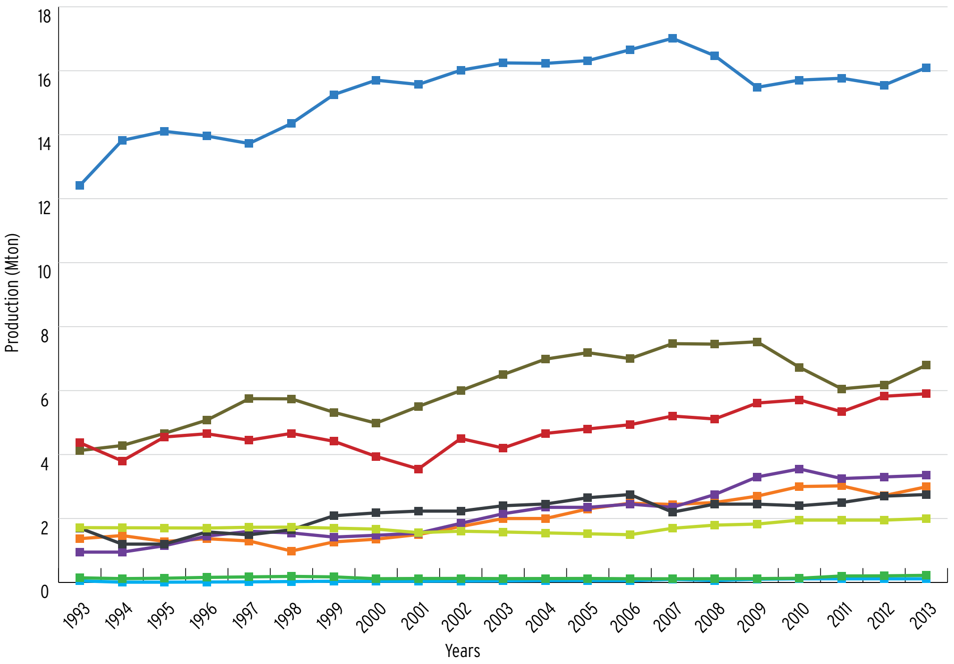
Photo: A Melody Lee; World Bank

Improvements at the Kigali Seed Plant have allowed the plant to meet the increased demand that has resulted from greater productivity on farms in Rwanda.

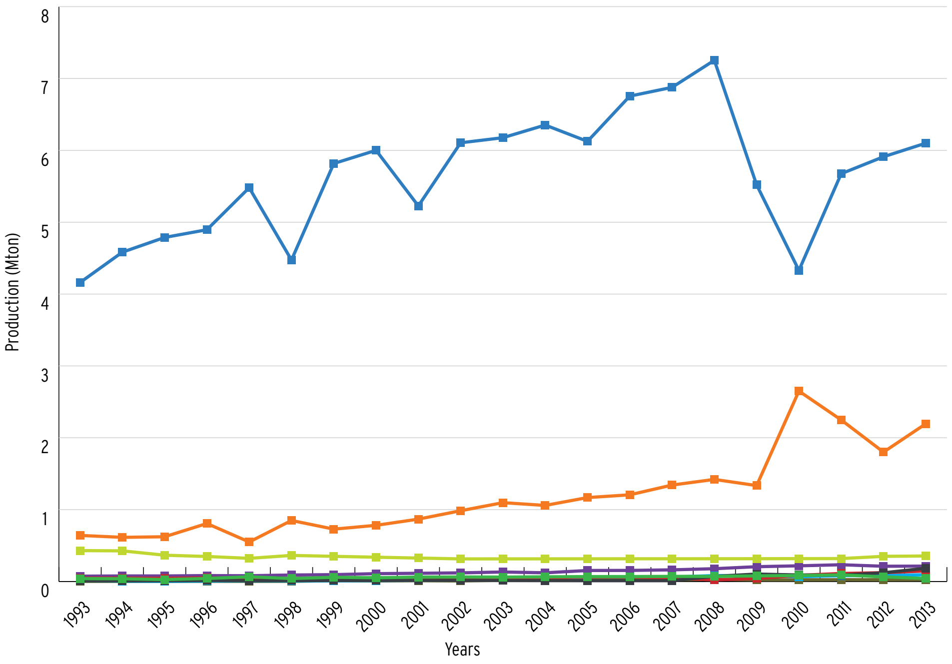
Production - Maize



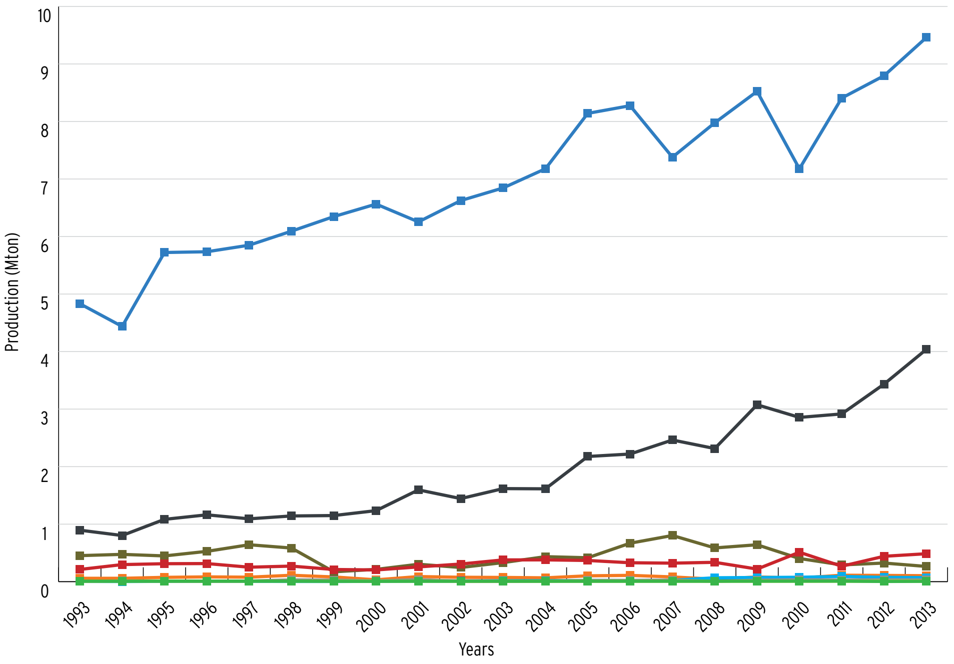
Production - Sugarcane



Production - Rice (Paddy)



Production - Wheat



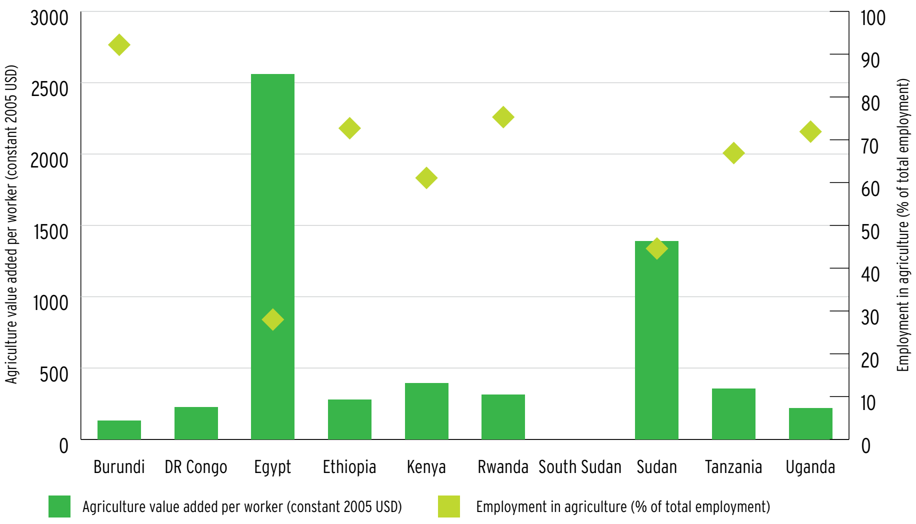
Burundi DR Congo Egypt Eritrea Ethiopia Kenya

Rwanda Sudan Uganda Tanzania

Agricultural labor force and agricultural productivity

Crop production and livestock husbandry account for about half of household income in the Nile basin partner states. Most of the Nile partner states are overwhelmingly rural, and the agriculture sector employs a large proportion of total labor force. As example, the agriculture sector employment accounts for 70 to 90% of total employment in Burundi, Ethiopia, Rwanda, Tanzania, and Uganda. Likewise, agriculture sector employs around 80 to 90% of female labor force in those countries, plus Congo. Also, with the exception of Ethiopia and Kenya, agriculture sector accounts for higher proportion of female employment than male employment, which implies that women are heavily dependent on agriculture sector for their employment security.

The poorest members of society are those who are most dependent on agriculture for jobs and income. Average agricultural value added per worker is low in many of the Nile partner states (lowest in Burundi (US$ 132 and Highest in Egypt (US$ 2561), reflecting a low degree of mechanization and limited penetration of improved seeds and inputs such as fertilizers. As agriculture sector value added per worker is a measure of agriculture sector productivity/efficiency, it implies that agriculture sector in the Nile Partner States is least efficient, which points to capacity constraints, underemployment, low productivity, market distortions, and poor infrastructure in these overwhelmingly drought-prone and water scarce countries. Therefore, agricultural productivity enhancing technologies and interventions are likely to be pro-gender and pro-poor, simultaneously.


Agricultural Labor Force and Agricultural Productivity (2015)

Source of data: WDI 2016

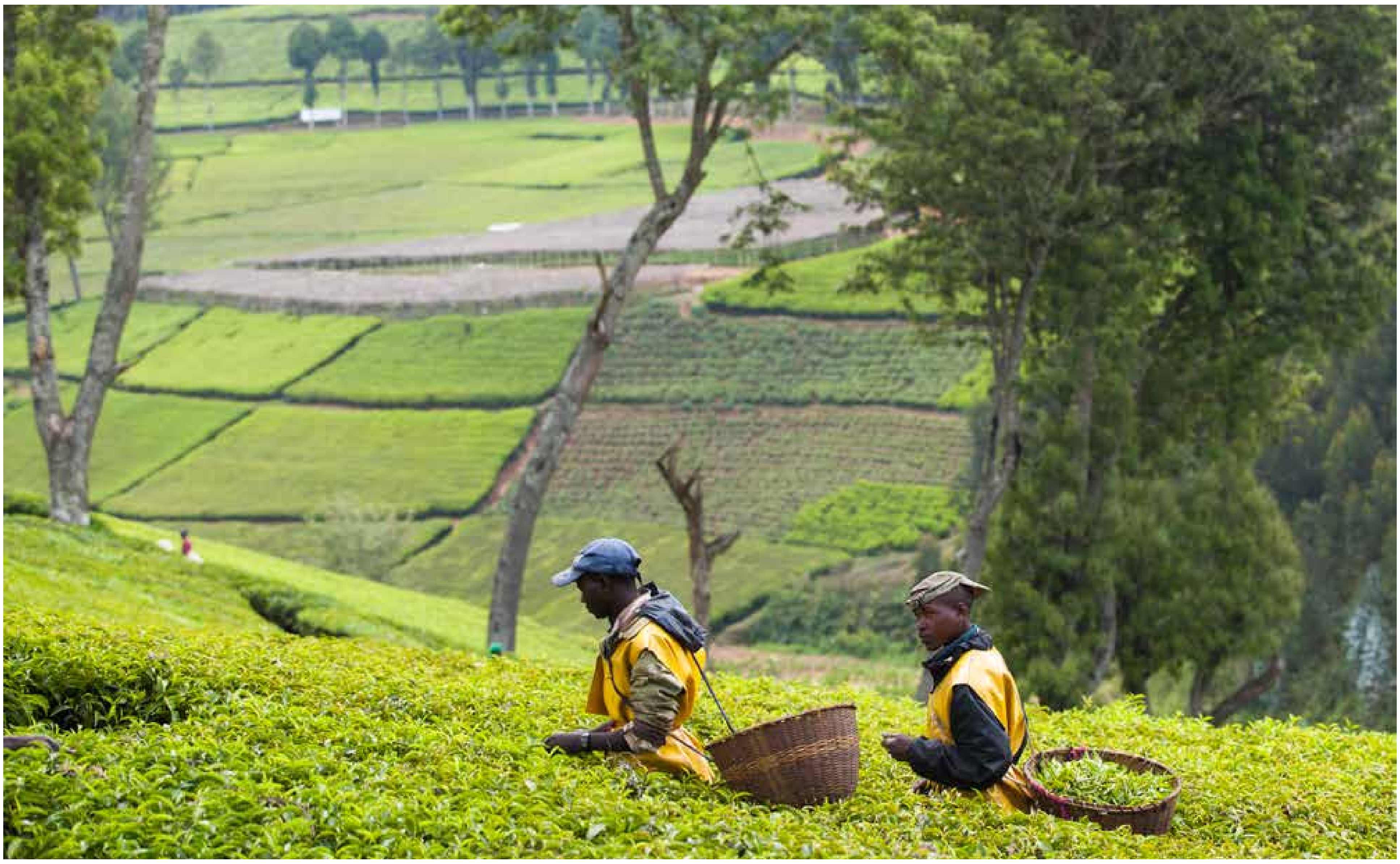


Photo: A'Melody Lee; World Bank

The Kitabi Tea processing facility in kitabi, Rwanda

AGRICULTURAL TRADE


Photo: istock

Fruit and vegetable display outside a shop

The Nile Basin countries including Burundi, DR Congo, Egypt, Ethiopia, Kenya, Rwanda, South Sudan, Sudan, Tanzania and Uganda are endowed and produce agricultural commodities in all categories of (i) Industrial crops such as coffee, tea, sugar cane and perennial nuts such as cashew nuts; (ii) cereals and pulses such as maize, rice, wheat, beans, millet, sorghum, and nuts such as ground nuts, etc (iii) fruits and vegetable such as mangoes, oranges, pineapples and vegetables such as onions, tomatoes etc (iv) livestock and livestock products such as on-hoof cattle, sheep, goats, chicken and animal products of meet, milk, eggs, etc. (v) root tubers such as cassava, yam etc.

Production

The large scale production either rainfed or irrigated are mainly exportables for export earnings, while small scale production that are mainly rain-fed with minimal irrigation are for home consumption and only traded at local markets when there is surplus during seasons of over-production.

Nile Basin countries' policies

Nile Basin countries' policies on trade in agricultural in puts and outputs markets have a direct impact on products and productivity, as well as on the spatial distribution arbitrage from production (surplus) to consumption (deficit) areas. They affect trade at all levels, starting from where production takes place, to the national level, and the inter-regional trade among neighbouring countries, to the international trade in food commodities.

The agricultural trade policies in the Nile Basin region indicate that countries in the region have agricultural trade policies mainstreamed in key policies at the regional level and at national level. At the regional level, the COMESA with 9 Nile basin countries, EAC with 6 Nile Basin counties and SADC with 2 Nile Basin countries, regional policies of liberalization are the main trade policies impacting on intra and extra regional agricultural trade. At the national level, countries have agricultural trade policies mainstreamed in various agricultural policies and strategies. Countries have measures and also take decisions that affect trade in food and agricultural products. The national agricultural policies generally aim at alleviating poverty, promoting food and nutrition security, promoting commercialization of smallholder agriculture, generating foreign exchange, and increasing agricultural production and productivity.

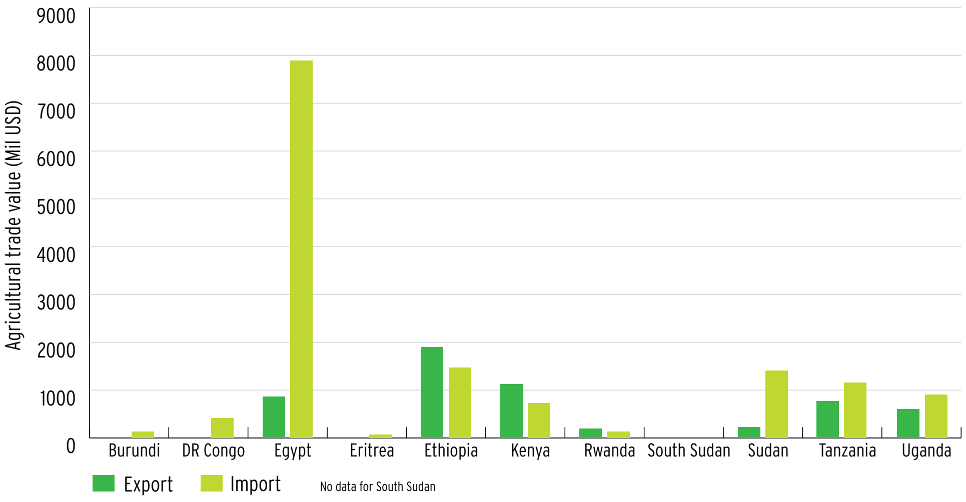
Food security

The 'issue of food security' has remained on the national, regional and global development agenda of our times. Hunger has remained one of the leading causes of death globally, about 925 million people do not have enough food to eat, women although accounting to a slightly over half of the world's population, account for over 60 percent of the worlds hungry and one out of every four children in the world is undernourished. About 13 percent of the world population is undernourished, with the majority of the undernourished persons living in developing countries, some of which are members of the Nile Basin.

Key food export commodities

Among key food export commodities (according to the Common Market for Eastern and Southern Africa (COMESA) COMTrade) from the region are vege-

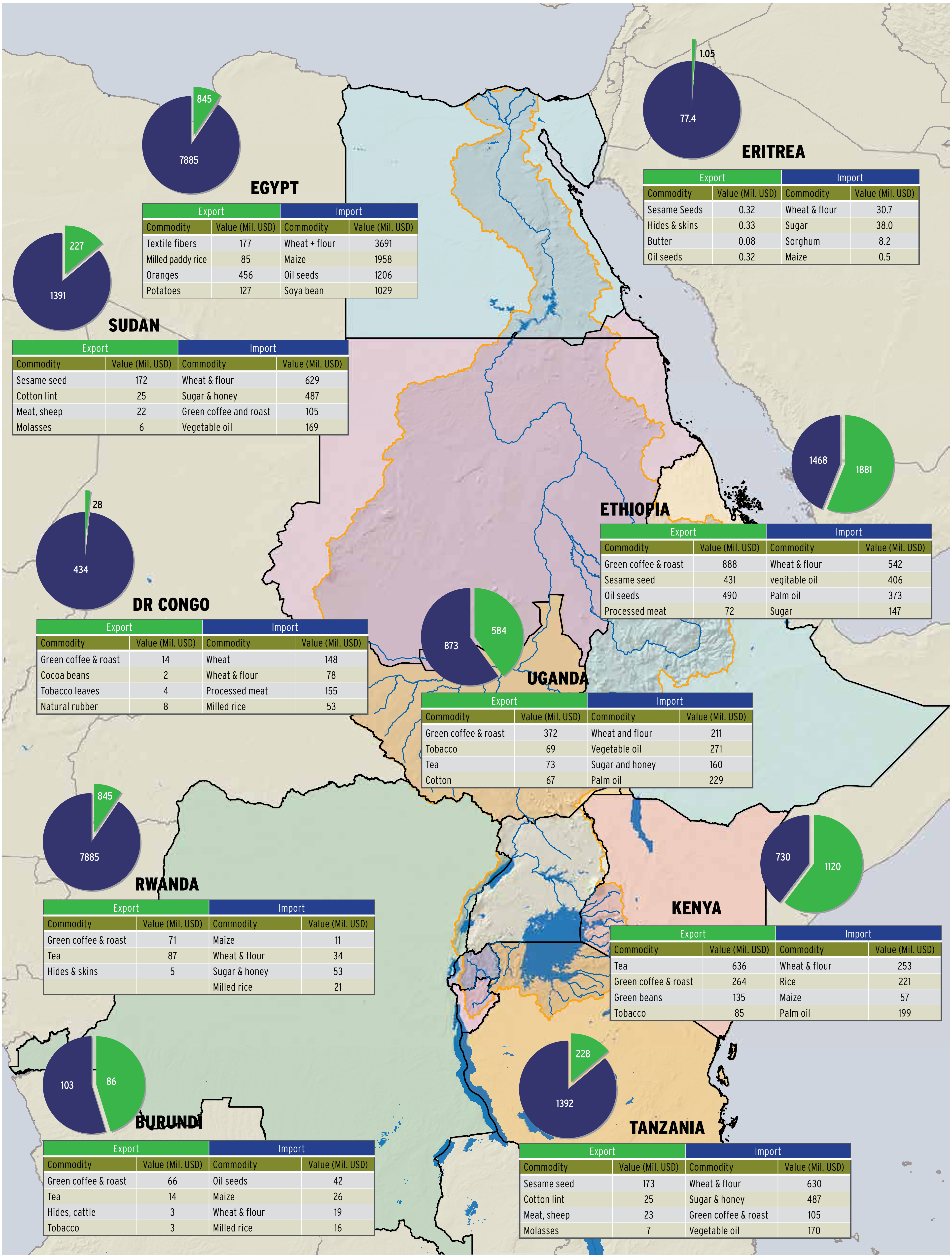
Agricultural trade value



	Exports Agricultural Products Among the Top 5 Exports		IMPORTS Agricultural Products Among the Top 5 Imports		Top 5 Export and Import Partners (Nile Basin Countries Among the top)
Country	Commodity	US$ Thousands	Commodity	US$ Thousands	
BURUNDI (2014)	Coffee, not roasted	51,604	Spelt, common wheat	19,037	DR Congo Kenya
	Black tea (fermented)	13,471			
DR CONGO					
EGYPT (2014)			Maize (excl. seed)	1,942,736	
ETHIOPIA (2014)	Coffee (not roasted)	1,023,583	Palm oil (excl. crud)	447,805	
	Sesamum seeds	714,545			
	Fresh cut flowers	610,431			
	Other vegetables	567,521			
KENYA (2013)	Black tea (fermented)	1,202,918	Crude palm oil	496,464	Uganda, Tanzania
	Fresh cut flowers	477,889			
	Coffee (not roasted)	189,568			
RWANDA (2013)	Coffee (not roasted)	58,341			Tanzania, DR Congo, Uganda, Kenya
	Black tea (fermented)	37,946			
SOUTH SUDAN					
SUDAN (2012)	Live sheep	283,035	Cane or beet sugar	276,822	Egypt Arab Rep.
	Sesamum seeds	187,171			
TANZANIA (2013)	Cashew nuts	188,173	Spelt, common wheat	305,168	DR Congo
	Coffee (not roasted)	160,405			
UGANDA	Coffee, not roasted ...	424,456	Cane or beet sugar	115,436	Kenya, DR Congo, Sudan Rwanda, South Sudan
	Fresh or chilled fish ...	95,614	Palm oil (excl. crud)	110,910	
	Tobacco, partly or w ...	84,113			

Source: UN COMTRADE

Agricultural Trade for the Main Crops



EGYPT

Export		Import	
Commodity	Value (Mil. USD)	Commodity	Value (Mil. USD)
Textile fibers	177	Wheat + flour	3691
Milled paddy rice	85	Maize	1958
Oranges	456	Oil seeds	1206
Potatoes	127	Soya bean	1029

ERITREA

Export		Import	
Commodity	Value (Mil. USD)	Commodity	Value (Mil. USD)
Sesame Seeds	0.32	Wheat & flour	30.7
Hides & skins	0.33	Sugar	38.0
Butter	0.08	Sorghum	8.2
Oil seeds	0.32	Maize	0.5

SUDAN

Export		Import	
Commodity	Value (Mil. USD)	Commodity	Value (Mil. USD)
Sesame seed	172	Wheat & flour	629
Cotton lint	25	Sugar & honey	487
Meat, sheep	22	Green coffee and roast	105
Molasses	6	Vegetable oil	169

ETHIOPIA

Export		Import	
Commodity	Value (Mil. USD)	Commodity	Value (Mil. USD)
Green coffee & roast	888	Wheat & flour	542
Sesame seed	431	vegitable oil	406
Oil seeds	490	Palm oil	373
Processed meat	72	Sugar	147

DR CONGO

Export		Import	
Commodity	Value (Mil. USD)	Commodity	Value (Mil. USD)
Green coffee & roast	14	Wheat	148
Cocoa beans	2	Wheat & flour	78
Tobacco leaves	4	Processed meat	155
Natural rubber	8	Milled rice	53

UGANDA

Export		Import	
Commodity	Value (Mil. USD)	Commodity	Value (Mil. USD)
Green coffee & roast	372	Wheat and flour	211
Tobacco	69	Vegetable oil	271
Tea	73	Sugar and honey	160
Cotton	67	Palm oil	229

RWANDA

Export		Import	
Commodity	Value (Mil. USD)	Commodity	Value (Mil. USD)
Green coffee & roast	71	Maize	11
Tea	87	Wheat & flour	34
Hides & skins	5	Sugar & honey	53
		Milled rice	21

KENYA

Export		Import	
Commodity	Value (Mil. USD)	Commodity	Value (Mil. USD)
Tea	636	Wheat & flour	253
Green coffee & roast	264	Rice	221
Green beans	135	Maize	57
Tobacco	85	Palm oil	199

BURUNDI

Export		Import	
Commodity	Value (Mil. USD)	Commodity	Value (Mil. USD)
Green coffee & roast	66	Oil seeds	42
Tea	14	Maize	26
Hides, cattle	3	Wheat & flour	19
Tobacco	3	Milled rice	16

TANZANIA

Export		Import	
Commodity	Value (Mil. USD)	Commodity	Value (Mil. USD)
Sesame seed	173	Wheat & flour	630
Cotton lint	25	Sugar & honey	487
Meat, sheep	23	Green coffee & roast	105
Molasses	7	Vegetable oil	170

THIS MAP IS NOT AN AUTHORITY ON INTERNATIONAL BOUNDARIES

Source of data: FAO, 2012

tables, fruits and nuts, tea and coffee. Major exporters of vegetables and fruits from the region in 2012 were Egypt with 70.3%, Kenya with 14.5%, and Ethiopia with 6.9%, of the total in the region. Coffee exporting countries are mainly Ethiopia, Uganda and Kenya. Whereas coffee produced in Burundi and Ethiopia is mainly Arabica, Robusta accounts for over 85 % of Uganda's coffee output. In 2012, coffee earnings in Ethiopia, Africa's biggest producer, were worth US$ 825 million, a slight drop from the 2011 level of US$ 834 million. Ethiopian coffee exports were mainly destined to markets outside the Nile basin, in fact outside Africa such as Germany, Saudi Arabia, Belgium, USA and a number of other countries within the EU. On the other hand, Uganda's exports of coffee during the same period were worth over US$ 371 million, down from US$ 435 million earned the previous year and this coffee was mainly exported to Sudan within the Nile Basin and outside the basin to Switzerland and Germany. Generally, most of the exports are to destinations outside the Nile Basin region.

Kenyan Fair Trade coffee Farmer

Photo: istock

In the case of tea, major exporters of this produce from the Nile Basin region are Kenya, and Uganda. Kenya's exports of tea in 2012 were worth almost US$ 1.2 billion, mainly to the export markets of Egypt in the Nile Basin and to Pakistan the United Kingdom and Afghanistan markets outside the Nile Basin. Uganda exported tea worth US$ 50 million in 2012.

Local trade

The Nile Basin region grows staple crops, such as oilseeds, groundnuts, beans, cassava, sesame, maize, and rice, in addition to fruits and vegetables such okra, tomatoes, onions, and cabbages. Much of the production is for home consumption, although there are both local markets and cross border trade takes place. Much of the trade is informal or un-recorded between the communities in the countries. Trade is mainly women traders selling agricultural products in markets; however, only few of these women market their own produce, much of the produce is bought across the borders from other countries. However, according to FAO/WFP Crop and Food Security Assessment Mission (2014), countries or parts of countries of the Nile Basin register food deficits. Much cross border trade both formal and informal is of cereals moving through grain corridors to fill-in deficits. The food and livestock markets in the countries are highly fragmented as a consequence of the poorly developed road network. Livestock such as cattle and small ruminants (sheep and goats) are thriving in the region and form part of the livelihood enhancement. Marketing of small ruminants in the countries and informally across the boarder represents one of the sources of income that largely determine pastoralists' capacity to purchase food items. Another traded commodity is fish. In its fresh form, it is marketed on the local markets or large quantities that are processed, refrigerated and exported. In its smoked form fish is another commodity on both the local and the trans-boundary markets.

Agricultural imports

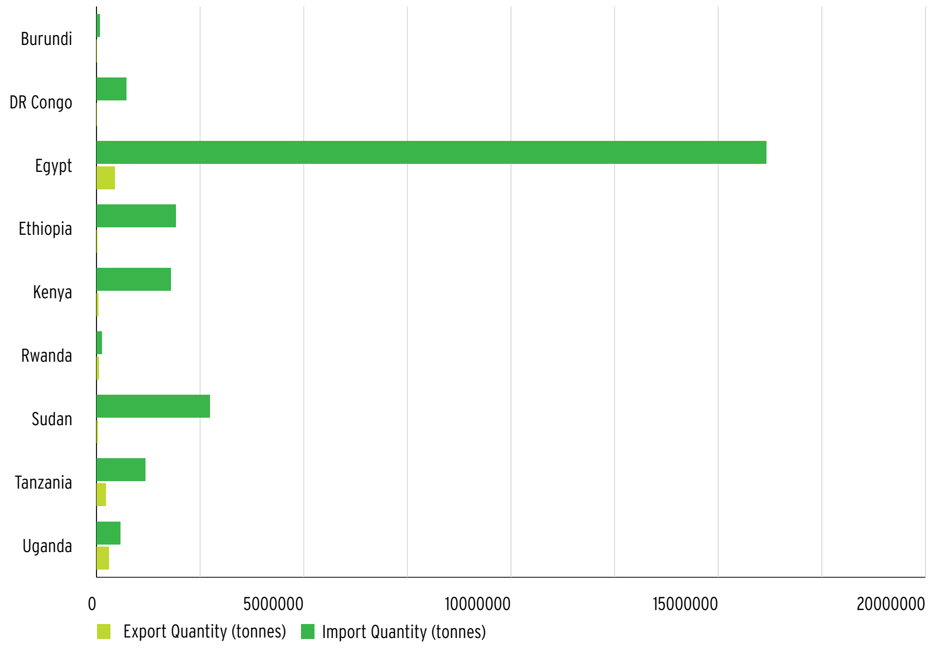
The share of agricultural imports in total imports in the countries is higher than the share of agricultural exports in total exports. This shows an increasing reliance on food imports in the region to fill the deficit that is much influenced by the high population. Much of the imports are food commodities of cereals such as wheat due to the increasing consumer taste for the product and Maize.

Food prices of food commodities

Food prices of food commodities in the Nile basin have remained persistently volatile and have affected countries, households and individuals. The region also faces increasing population, rapid urbanization, changing diets and demand for bio fuel products. These factors increase the demand for food commodities vis-à-vis a challenged food commodity supply due to high prices of fertilizers and fuel, climatic shocks, reduced food stocks, reduced exports and the imposition of food trade restrictions. The restrictions include export bans which increase the uncertainties of food movements between markets in the region, in some cases due to border conflicts. The food price situation therefore poses a significant challenge to the reduction of poverty and hunger.

Generally most countries in the region export industrial crop commodities such as tea and coffee for export earnings and put their import expenditures to importing wheat or food crop commodities in global trade. Intra Nile Basin regional trade is mainly in cereals and pulses, livestock on hooves, and fruits and vegetables

Cereal Trade in the Nile Basin Partner States



Source: FAO 2013

Co-operation between the basin states could be very valuable in the development of the agricultural potential, leading to increased incomes and food security. Greater volumes of trade in agricultural production, combined with the increased use of optimal geographical growing zones for crops (while still securing local basic supplies) could improve efficiency and provide associated increases in economic returns.

CONCLUSION

Photo: istock

Combined with forecast higher living standards and GDP growth, population growth will be the major driver for future food and water requirements in the Nile. Population growth coupled with the current risks, vulnerabilities and challenges posed by poverty, hunger, disease, production and consumption patterns, and climate change, will place increased pressure on the basins natural (forests, wetlands and biodiversity) resources that sustain human life.

The Nile Basin Partner states projected demographic structure, population and urbanization growth present enormous implications and opportunities for human development, structural transformation and sustained economic growth. Demography remains the single most important driver of sustainable development affecting both production and consumption through increased demand for goods and services as well as social amenities, but at the same time poses threats to the sustainable exploitation of the common Nile river basin resources

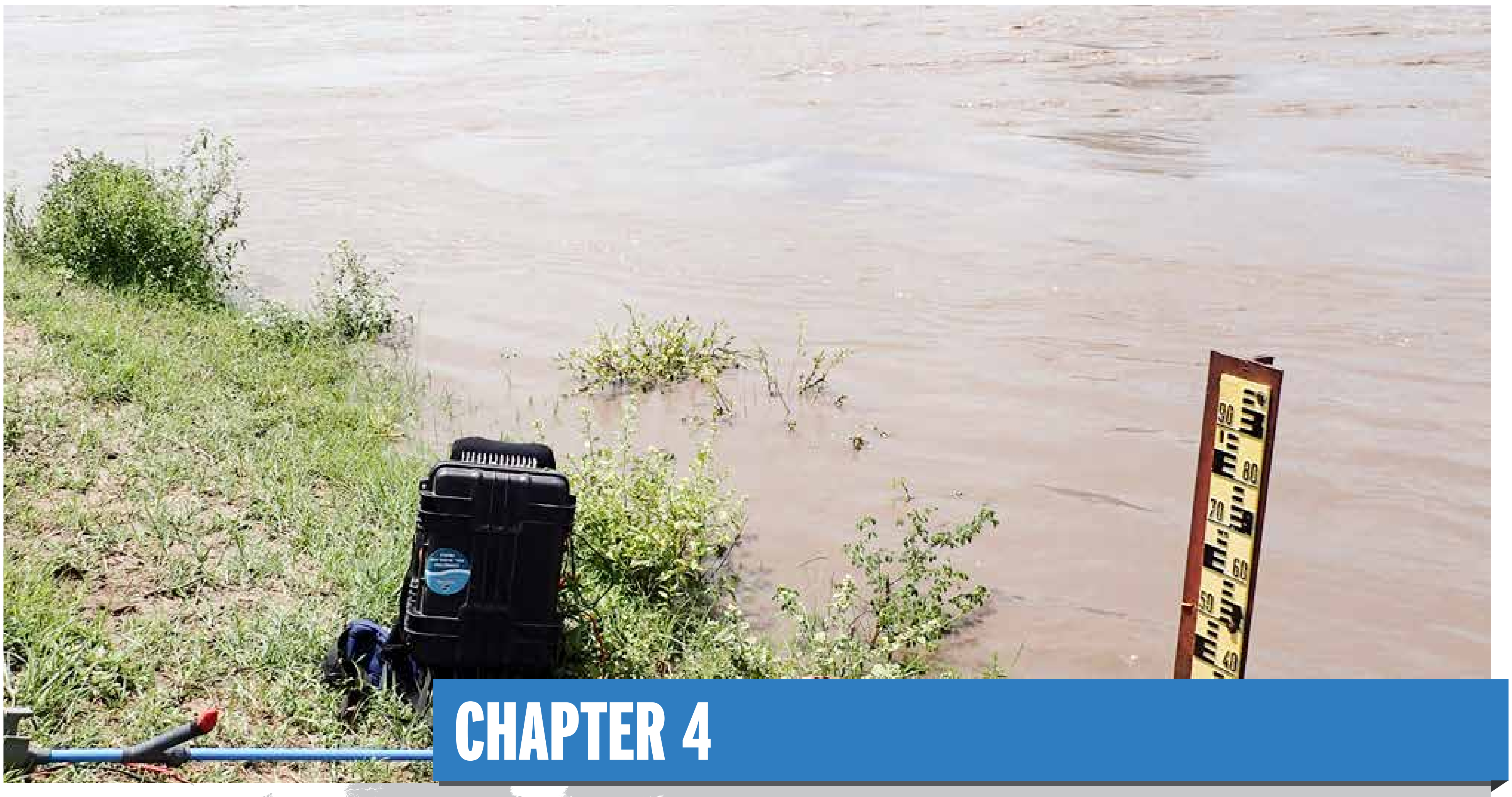
An estimated 30% of the present Nile basin partner states population currently lives in urban areas. This proportion is expected to grow to 37% by 2030 and 47% by 2050. Cairo, which was the most populous city in the basin by 2010, is expected to grow by 23% to 13.5m people. The challenges of food and water shortages, poor infrastructure and housing remain major concerns as the regions cities burgeon in population, with specific attention needed to reducing the proportion of slum dwellers, who currently account for 70% of urban inhabitants in Africa (UN habitat 2011).

Cross-border agricultural trade in the Nile Basin is hampered by logistic and institutional constraints, and by the low level of agro-processing in most Nile countries. Poor infrastructure in rural areas, absence of infrastructure for bulk cargo transport between the upper and lower riparian zones, very high transport costs, lack of storage facilities, custom procedures and non-tariff barriers, and health regulations and standards that are difficult to meet for individual producers are among the factors that make intra-basin trade of agricultural produce a difficult undertaking.

Trade volumes among the Nile countries are indeed small. Some trade occurs among the East African countries, where Uganda is the largest exporter. Intra-basin agricultural trade between the upper and lower Nile regions is virtually non-existent, apart from export of tea from Kenya to Egypt.

References

- Democratic Republic of Congo, Enquête Démographique et de Santé RDC (EDS-RDC), 2013-2014.
- International Water Management Institute, (2012): The Nile River Basin Water, Agriculture, Governance and Livelihoods.
- Kenya Bureau of Statistics (2015): Facts and Figures 2015.
- National Institute of Statistics of Rwanda (NISR), 2015: Rwanda Poverty Profile Report,2013/14
- National Institute of Statistics of Rwanda, (2009): National Population Projection 2007 - 2022
- OECD (Organisation for Economic Co-operation and Development) (2006) Promoting Pro-poor Growth Agriculture, DAC Guidelines and Reference Series, OECD. Paris, France.
- Rwanda Poverty Profile Report, 2013/14, August 2015
- Statistical Year Book, South Sudan, 2011
- Sudan, Central Bureau of Statistics, (2010): Sudan in Figures 2005-2009
- Tanzania Bureau of Statistics, (2015): National Panel Survey Wave, 2012-2013
- Tanzania Bureau of Statistics, (2015): Tanzania in Figure 2014
- Uganda Bureau of Statistics (2014): National Population and Housing Census 2014, Provisional Results
- Uganda Bureau of Statistics, Demographic and Healthy Survey, 2011
- Uganda Water and Environment Sector Performance Report 2015
- UNESCO Institute of Statistics database, National Institute of Statistics of Rwanda (NISR)
- UNEP. (2013). "Adaptation to Climate-change Induced Water Stress in the Nile Basin: A Vulnerability Assessment Report". Division of Early Warning and Assessment (DEWA). United Nations Environment Programme (UNEP). Nairobi, Kenya.
- United Nations, Department of Economic and Social Affairs, Population Division (2014). World Urbanization Prospects: The 2014 Revision, CD-ROM Edition.
- NELSAP / NBI, December 2012. Nile Equatorial Lakes Multi Sector Investment Opportunity Analysis (NEL MSIOA). NEL indicative Investment strategy and action plan. Draft version. Report prepared by BRL Ingénierie. 111 pages



CHAPTER 4

BASIN MONITORING

KEY MESSAGES

There are approximately 928 meteorological and 423 hydrometric stations in the Nile Basin. Over 70 percent of the meteorological stations measure either just daily rainfall totals or rainfall and temperature. Most hydrometric stations measure river or lake water levels. Monitoring of water quality, sediment transport in rivers, and groundwater are at their early stages in most countries. Data transmission from the stations to central data repository in most countries is manual.

The current total number of national monitoring stations in the Nile Basin countries is well below its historical maximum. Staff and financial resources to operate and maintain the complete national network of stations are limited in all countries. Automated data transmission using modern technology is being newly introduced in many countries. In all countries the potential use of data for real-time water resources management is not realized because of a lack of telemetry and data processing and management systems.

There have been national as well as regional initiatives to improve river basin monitoring in the Nile Basin. The Nile Basin Initiative has recently completed the design of a Nile Basin regional Hydromet system. This system will comprise a set of 323 meteorological and 79 hydrometric stations, groundwater and water quality laboratory strengthening and monitoring use of remote sensing for monitoring river basin processes. The system relies on existing monitoring stations to be upgraded to meet the requirements as a regional monitoring network with few new stations added where no current monitoring stations exist. The IGAD-HYCOS is another regional initiative that has supported member countries of the IGAD to upgrade their hydrological monitoring network; some of these stations are in the Nile Basin.

INTRODUCTION

Overview

This chapter presents the current state of water resources monitoring in the Nile Basin. The focus of the chapter is primarily on hydro-meteorological monitoring with additional information provided on monitoring of water quality and groundwater. The information in this chapter is based on data compiled by NBI from the riparian countries. No information was available for part of the Nile Basin that lies in Egypt and Eritrea. The monitoring network presented in this chapter includes only those networks that are operated by national agencies for hydrological and meteorological monitoring services. It doesn't include those monitoring stations that are established and operated by specialized agencies for specific purposes.

Meteorological monitoring

There were 928 meteorological stations in the Nile Basin in the countries surveyed in 2014. Most (674) of these stations measure rainfall only or rainfall and temperature while the rest measure fuller set of meteorological parameters. In addition to the stations that are established and maintained by National Meteorological Services agencies, there are other networks that have been put in place for specific purposes. An example of such special purpose networks is the 19 hydro-meteorological stations that are operated by the Kenyan Flood Diagnostics and Forecasting Centre (FDFC) in the Nzoia and Tana River basins. Such networks are not included in the Atlas.

Overall, basic meteorological variables of precipitation, temperature, relative humidity and evaporation are measured in all countries. Automated weather stations have been introduced in all countries though the distribution and area coverage greatly vary between countries.

Data transmission from the stations in most countries is manual. As can be seen from the table, telemetry is introduced in only five countries, namely, DRC, Ethiopia and Kenya. The telemetry system in DR Congo is part of the SADC- HYCOS.

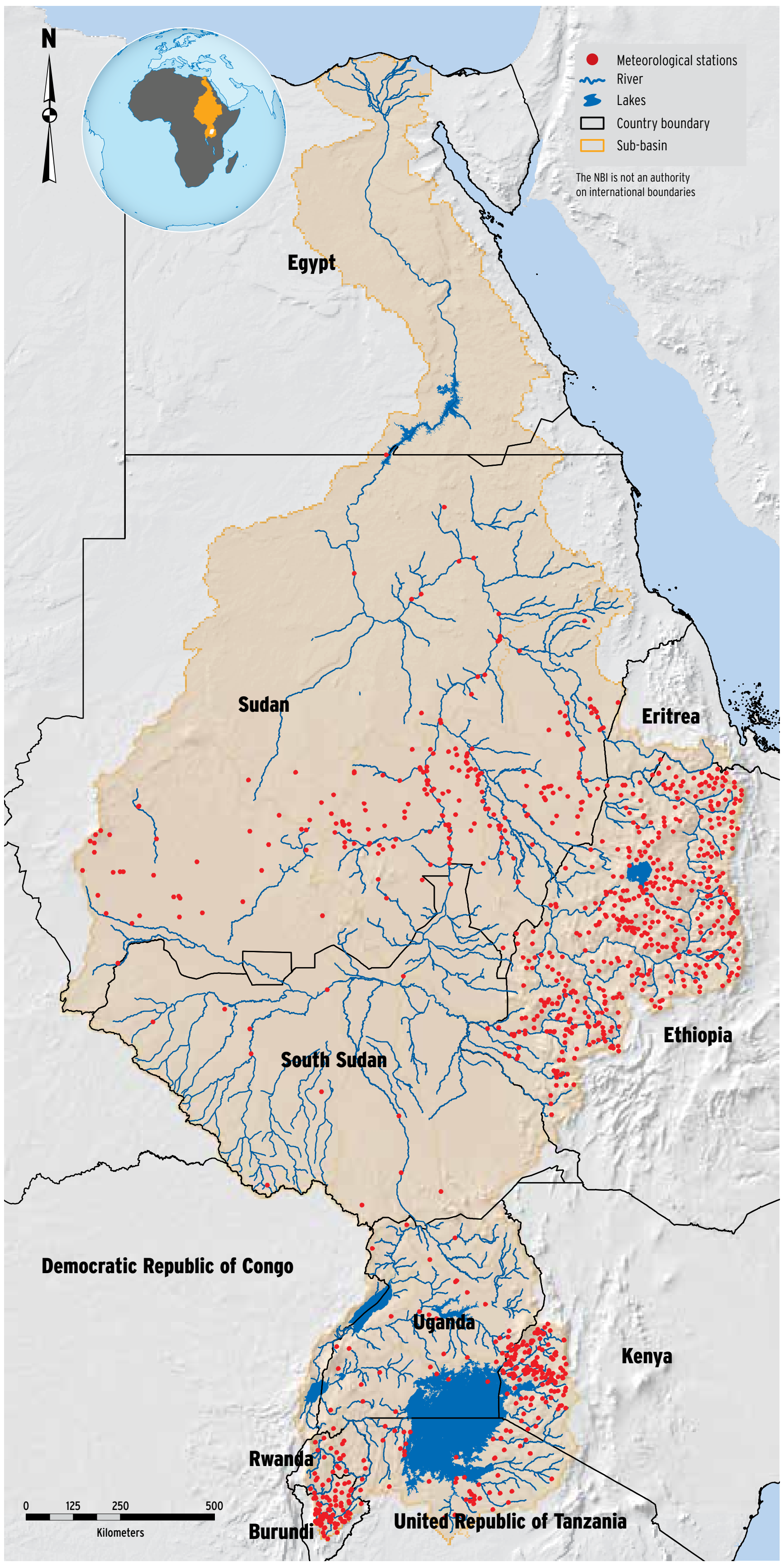


photo: Vivian Nabyonga

Meteorological station at Entebbe, Uganda

NBI countries, met stations summary

Country	Full Met Stations	Rainfall or rainfall and temperature measuring stations
Burundi	10	21
DR Congo	3	0
Ethiopia	99	397
Kenya	27	104
Rwanda	24	11
South Sudan	5	0
Sudan	38	48
Tanzania	17	25
Uganda	31	68
	254	674
Total	928	

National institutions responsible for meteorological monitoring

Country	Institution	Institution full name
Burundi	IGEBU	Institut Géographic of Burundi
DR Congo	METTELSAT	Agence Nationale de Meteorologie et de Teledetection par Satellite
Ethiopia	MOWR	Ministry of Water, Irrigation and Electricity, National Meteorological Services Authority
Kenya	MEWNR	Ministry of Environment, Water and Natural Resources
Rwanda	MINIRENA	Ministry of Natural Resources
South Sudan	MEDIWR	Ministry of Electricity, Dams, Irrigation and Water Resources
Sudan	MWRE	Ministry of Water Resources and Electricity
Tanzania	TMA	Tanzania Meteorological Agency
Uganda	UNMA	Uganda National Meteorological Authority

Existing meteorological monitoring capabilities

Country	Burundi	DR Congo	Ethiopia	Kenya	Rwanda	South Sudan	Sudan	Tanzania	Uganda
Meteorological									
Automated stations	Y	N	Y*	Y	Y	Y	Y	Y	Y
Telemetry	N	Y	Y	Y	N	N	N	Y	N
Precipitation	Y	Y	Y	Y	Y	Y	Y	Y	Y
Temperature	Y	Y	Y	Y	Y	Y	Y	Y	Y
Relative humidity	Y	Y	Y	Y	Y	Y	Y	Y	Y
Evaporation	Y	Y	Y	Y	Y	Y	Y	Y	Y

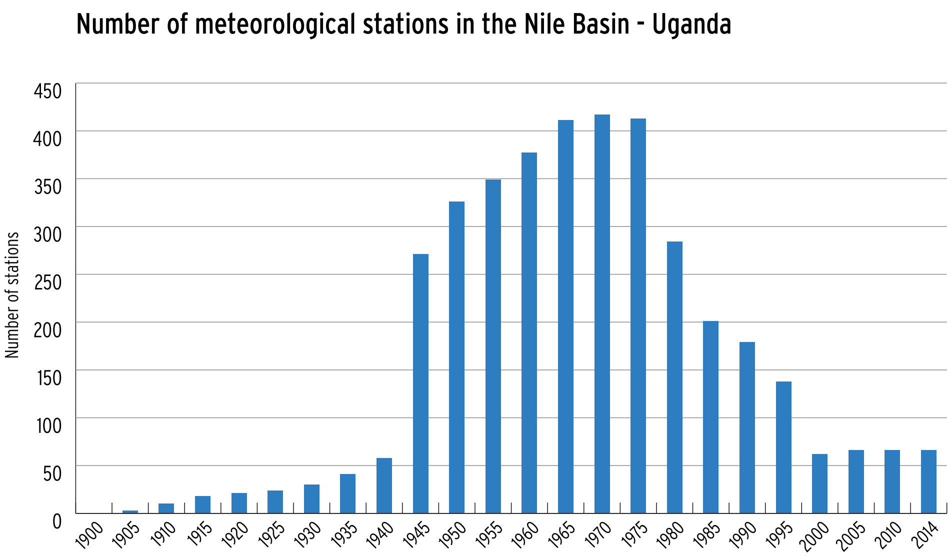
"* Capability recently introduced
Note: the Survey didn't include Egypt"

Historical evolution of meteorological stations

In most countries, meteorological monitoring started in 1900's. The Hydromet Project (1967 – 1992) boosted river basin monitoring in the participating countries, namely, Egypt, DR Congo, Sudan, Uganda, Burundi, and Rwanda. Over the years, however, the number of monitoring stations declined in some of the countries. Charts are provided for Burundi and Uganda to indicate the historical growth and decline in number of meteorological stations for which data was available.


Evaporation pan


Wind vane



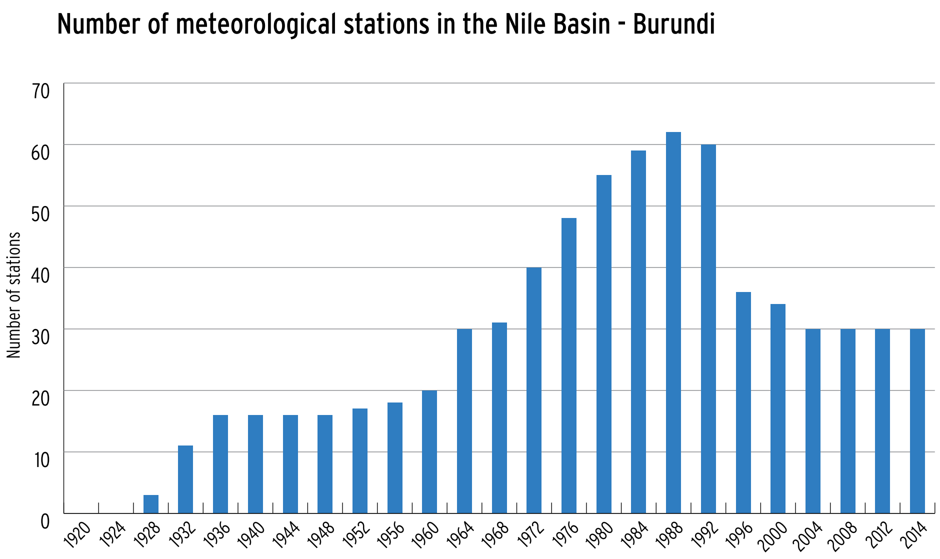



Photo: Nile-SEC

Meteoroligical station at Entebbe, Uganda

Hydrometric monitoring

Hydrometric monitoring networks are defined as observations networks that primarily measure stream flow related parameters (primarily river/lake water levels and river discharge).

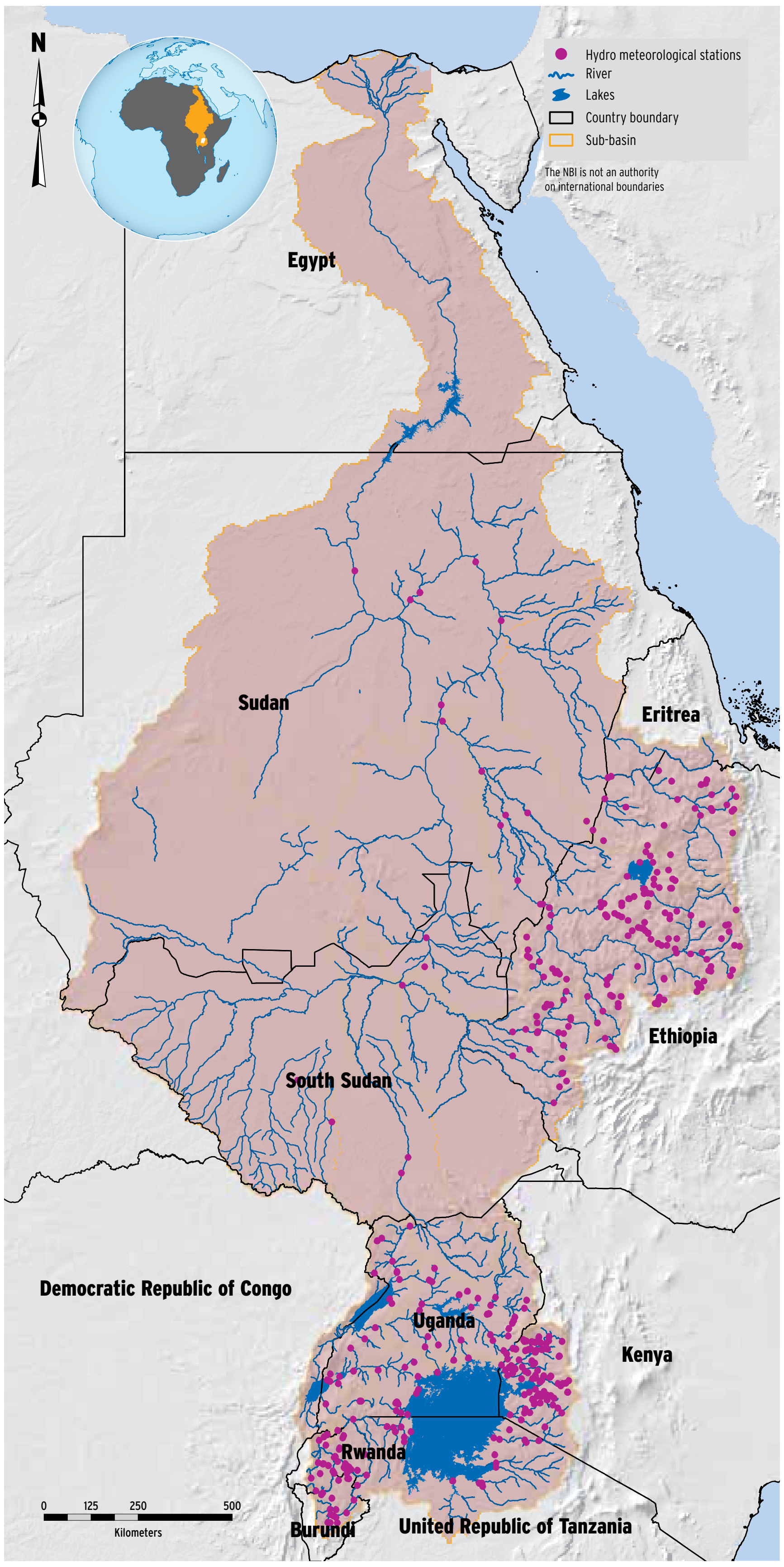
In 2014, there were 427 hydrometric stations in the countries included in the survey. These registered stations primarily measure river/lake water levels and river discharge. In very few stations, suspended sediment load at rivers are measured.

NBI countries, hydrometric stations summary

Country	Hydrometric stations	Country	Hydrometric stations
Burundi	15	Sudan	18
Kagera	15	Blue Nile - Lower	7
DR Congo	0	Main Nile	8
Lake Albert	0	Tekeze-Atbara	3
Ethiopia	176	White Nile	0
Baro-Akobo-Sobat	27	Tanzania	19
Blue-Nile	126	Lake Victoria - Kagera	7
Tekeze-Atbara	23	Lake Victoria - Tanzania	12
Kenya	93	Uganda	66
Lake Victoria	87	Bahr el Jebel	1
Victoria Nile	6	Lake Albert	19
Rwanda	36	Lake Victoria -Kagera	2
Lake Victoria - Kagera	36	Lake Victoria -Uganda	14
South Sudan	5	Victoria Nile	30
Bahr el Ghazal	1		
Bahr el Jebel	2		
Baro-Akobo-Sobat	1		
White Nile	1	Total	428

photo: Kiwalbye

River Nyamugasani at Lake Victoria inlet



Most of the gauging stations employ staff gauges as the only instrument for water level measurement. The available capabilities of the countries with respect to hydrometric monitoring are shown in the adjacent table.

Telemetry for automated data transmission has been introduced in Ethiopia, Uganda and Tanzania recently.

Water quality and sediment monitoring is practiced in very few countries, which is clearly a major gap in current monitoring networks in the Nile Basin. In most countries there is not sufficient capability (laboratories, mobile calibration labs, field sampling kits).

In most countries, groundwater monitoring is virtually non-existent. Comparatively, Uganda has the largest groundwater observation network that includes 30 groundwater monitoring stations.

Existing hydrometric capabilities

Hydrometric	Burundi	DR Congo	Ethiopia	Kenya	Rwanda	South Sudan	Sudan	Tanzania	Uganda
Automated stations	Y	N	Y	Y	Y	N	Y	Y	Y
Telemetry	N	N	Y*	N	N	N	N	Y*	Y
Water level	Y	Y	Y	Y	Y	Y	Y	Y	Y
Discharge	Y	N	Y	Y	Y	Y	Y	Y	Y
Reservoir/Lake level	Y	Y	Y	Y	Y	Y	Y	Y	Y

"* Capability recently indtroduced
Note: the Survey didn't include Egypt"

Existing water quality monitoring capabilities

Water quality/sediment	Burundi	DR Congo	Ethiopia	Kenya	Rwanda	South Sudan	Sudan	Tanzania	Uganda
Basic water quality	Y	N	Y*	Y	Y	N	Y	Y	Y
Special water quality	N	N	N	Y	N	N	Y	N	N
Sediment sampling	Y	N	Y	N	N	N	Y	Y	Y

"* Capability recently indtroduced
Note: the Survey didn't include Egypt"

Existing groundwater monitoring capabilities

Groundwater	Burundi	DR Congo	Ethiopia	Kenya	Rwanda	South Sudan	Sudan	Tanzania	Uganda
Water level	Y	N	Y*	Y	N	N	N	N	Y
Water quality	Y	N	Y*	N	Y	N	N	N	N

"* Capability recently indtroduced
Note: the Survey didn't include Egypt"

The situation with respect to data management and data communication capabilities is shown in adjacent table. None of the countries with the exception of Kenya, Uganda and Tanzania employ systematic data storage and management tools for managing the hydro-meteorological data. Only in few countries, for example in Ethiopia, Uganda, Tanzania telemetry system has been introduced to support near-real time data transmission.

Existing data management and communication capabilities

Data Management / Communication	Burundi	DR Congo	Ethiopia	Kenya	Rwanda	South Sudan	Sudan	Tanzania	Uganda
Coop-data systems	N	N	N	Y	N	N	N	N	N
Auto-access	N	N	N	N	N	N	N	N	N

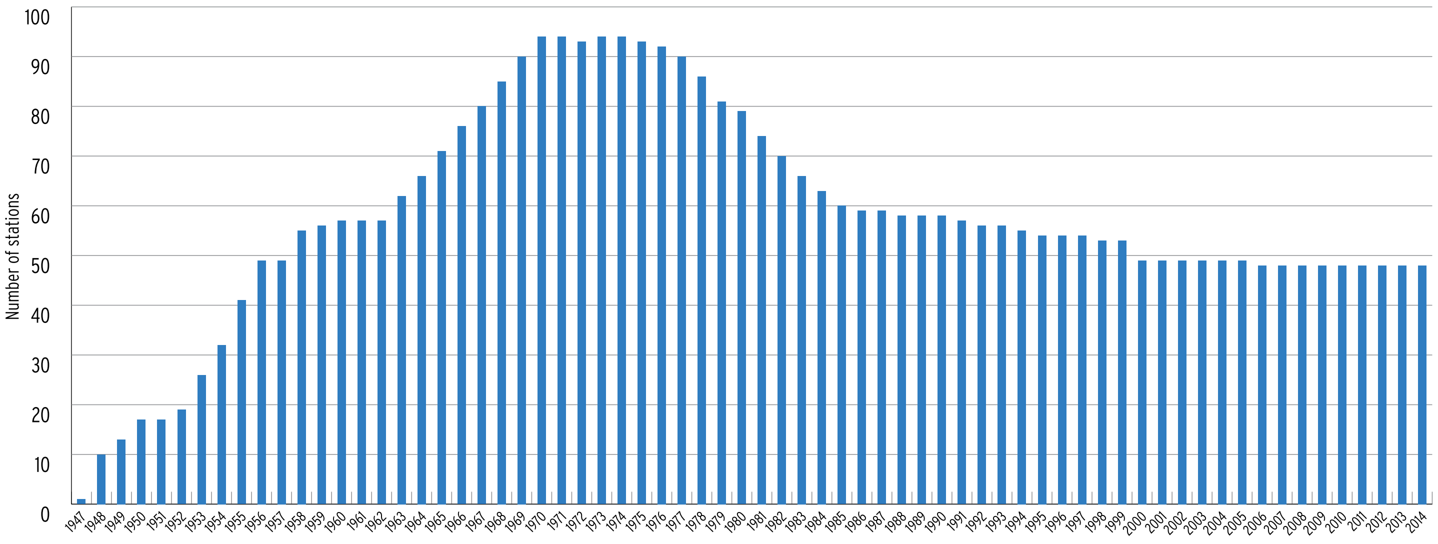
Note: the Survey didn't include Egypt"

History of hydrometric monitoring stations

Uganda is a typical example of the development in national hydrometric monitorng stations. Expansion took place in the 1950's and lasted up to 1970's after which a decline took place. Presently the numbers seem rather stable, but this does not necessarily reflect an output in terms of a steady flow of reliable data.

The exception is Sudan, where measurement of river flow started as early as 1902. Over the years, there has been a general decline in the number of stations that are kept operational or added to the network. Graphs that show how the number of stations evolved in the last several decades are provided here for those countries for which reliable data have been obtained. It can be observed that the early 1950's and 60's exhibited expansion of the monitoring network as more and more stations were added. The late 1960's and early 1970's showed considerable increase in number of stations due to partly the implementation of the Hydromet project that was a collaboration project between countries: Egypt, DRC, Sudan, Uganda, Burundi, Rwanda.

Number of hydrometric stations - Uganda



CURRENT MONITORING NETWORK

The Main Nile Sub-basin

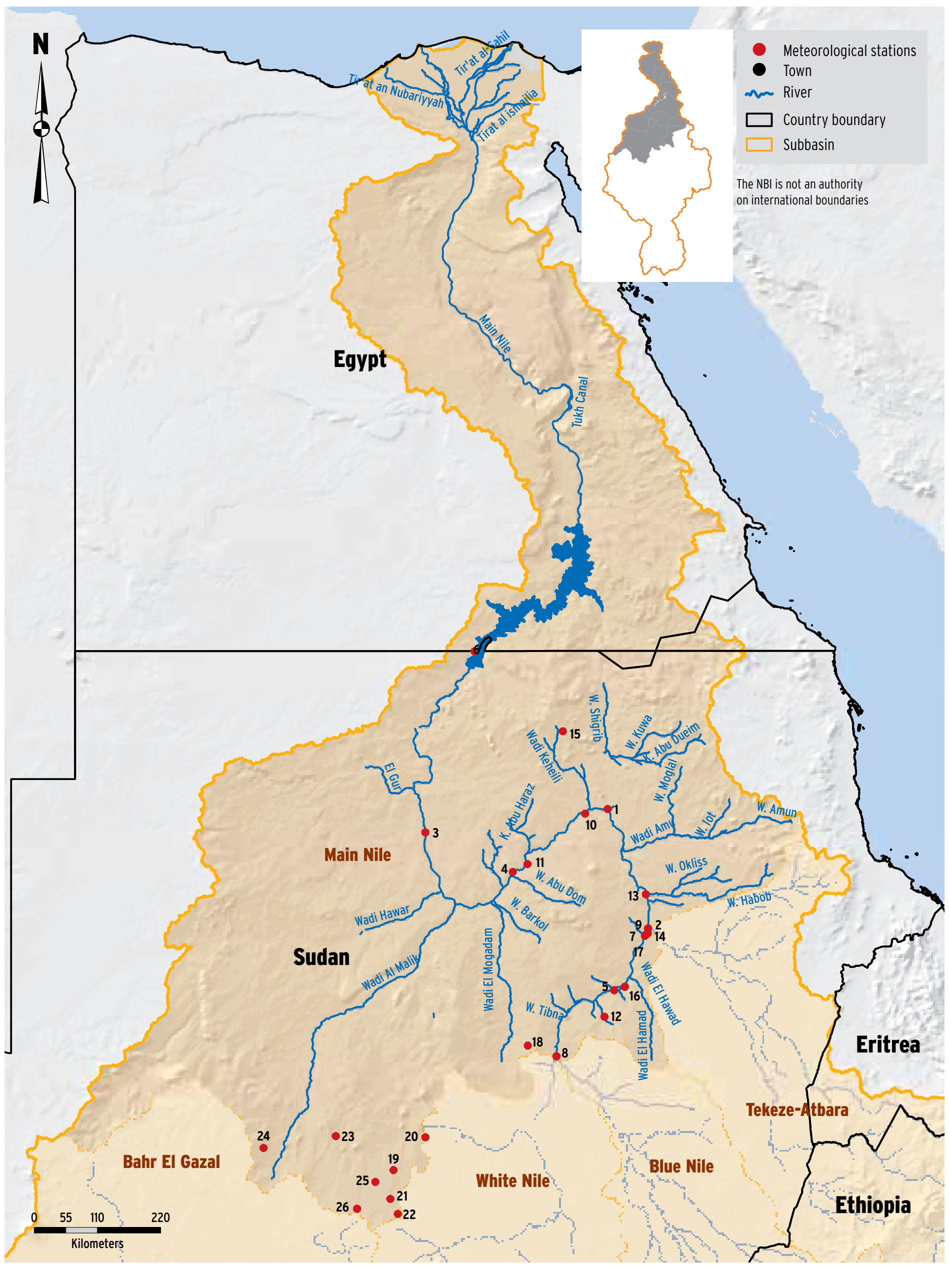
The Main Nile Sub-basin: this sub-basin includes parts of Sudan and Egypt and includes, the Nile Delta, which is one of the most intensively cultivated lands in the world since millennia. The Main Nile sub-basin is the part of the Nile Basin, which receives least amount of rainfall. However, on the other hand, this is the part of Nile Basin which exhibits most of the consumptive water use. It accounts for approximately 80 percent of the total estimated water abstraction from the Nile system for irrigation. In addition, evaporation from the High Aswan and Merowe dams account for about 13 – 14 $10^9 m^3$ of water per year that is approximately 78 percent of all the evaporation from man-made reservoirs basin-wide. With increasing water demands under increased climatic variability, it is crucial to strengthen monitoring of water use patterns and evapo-transpiration in this part of the Nile Basin.


photo: Vivian Nabyonga

Stream gauge

Meteorological monitoring network

There are 26 meteorological stations in Sudan within the Main Nile sub-basin. The distribution of the stations is shown in the map below. 11 stations are reported to measure the full range of meteorological parameters and the rest 7 measure daily rainfall totals only.

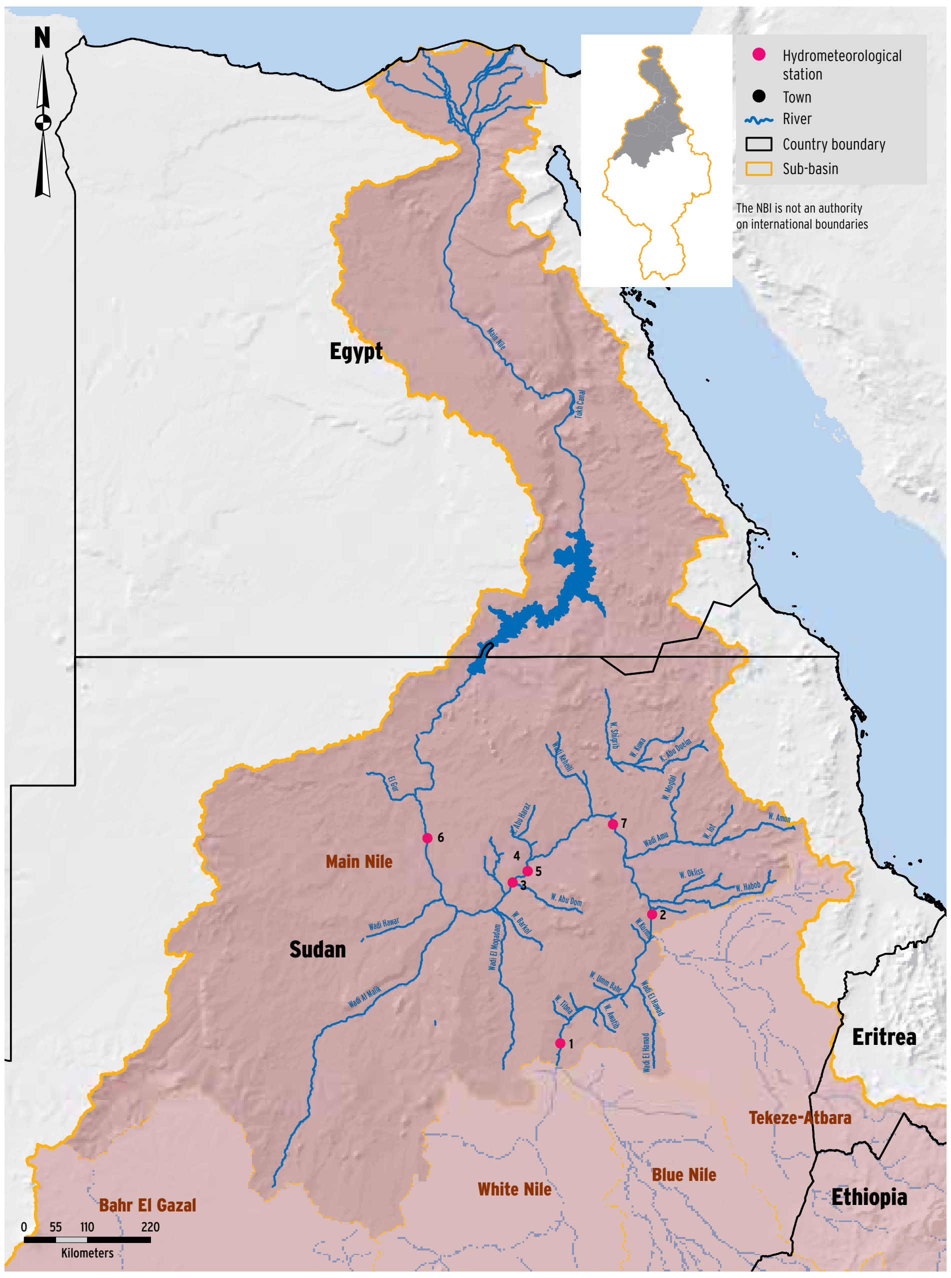


No	Name of Station
1	Abu Hammad
2	El Showak
3	Dongola
4	Karima
5	Shendi
6	Wadi Halfa
7	El Hudeiba
8	Shambat
9	Eldamer
10	Gumaiza
11	Merowe Dam Axis Left Bank
12	Algoz
13	Bauga
14	Damer
15	Station no.6
16	Turagma
17	Zeidab
18	Abu hamra
19	Hamrat Alsheikh
20	Kogmer
21	Rabwa Station
22	Shaboola
23	Sodari
24	Um bader
25	Um Karoam
26	Goz Ashger

Hydrometric stations

There are 8 hydrometric stations in the sub-basin in Sudan. The number of stations in Egypt, i.e. downstream of the High Aswan Dam is not included in the survey results. The oldest station, Main Nile at Thamaniat was established in 1912 and, hence, has over 100 years of records. The ultimate downstream station before the Nile enters the High Aswan Dam is at Dongola, which was established in 1923. Three stations, namely, Tamaniat, Dongola, measure sediment loads in addition to water level and discharge. A new station has been established recently at Merowe dam (commissioned in 2009).

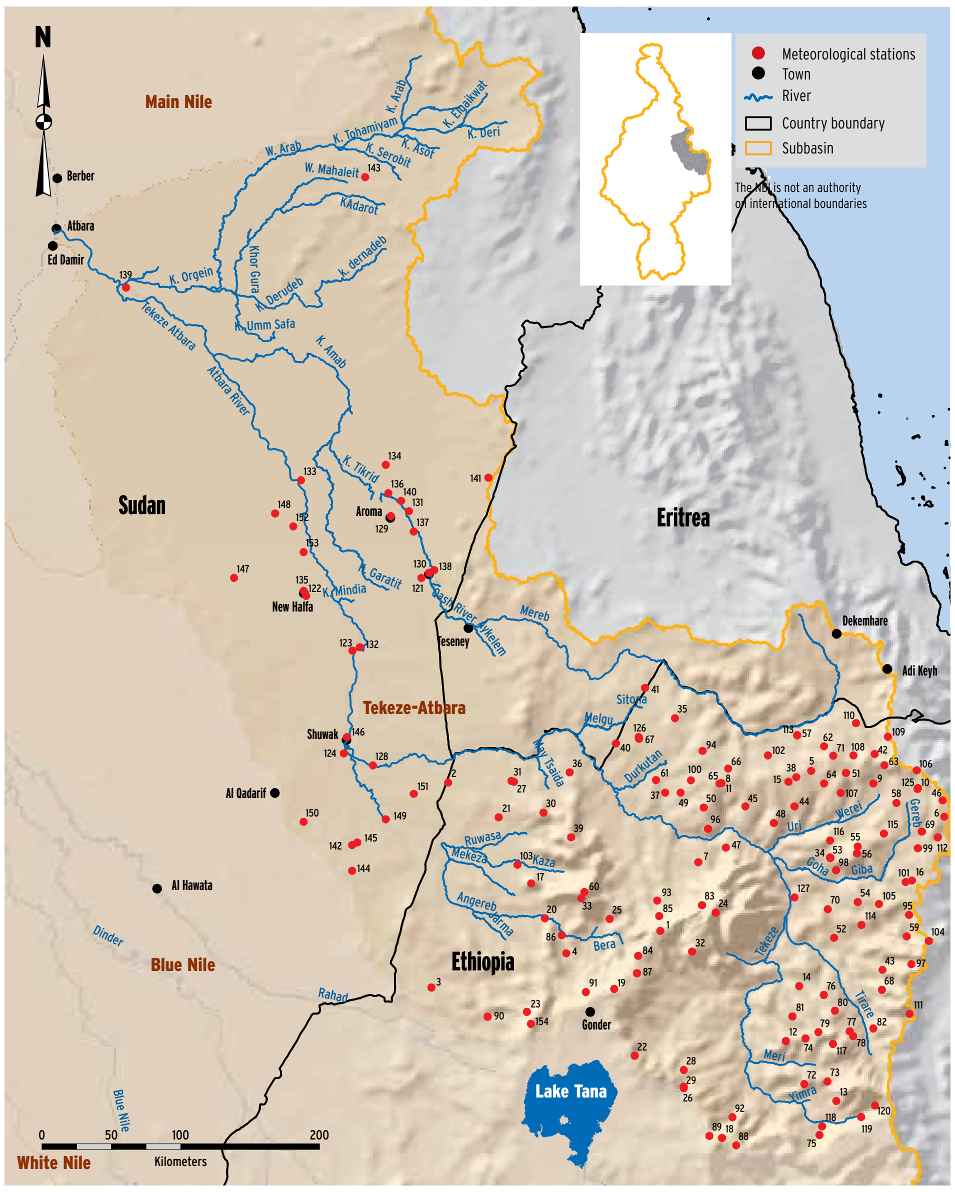
Main issues that require strengthened monitoring in this sub-basin are water quality deterioration, sediment load and sand encroachment and water loss through river bank overflows. Dongola, Tamaniat and Hassanab stations are included in the Nile Basin Regional Hydromet Network with main strengthening required in sediment and water quality monitoring.



1	Tamanyat
2	Barbar
3	Merowe Bridge
4	Merowe Dam Axis Downstream
5	Merowe Dam Axis Upstream
6	Dongola
7	ElKuru

The Tekeze-Atbara Sub-basin

The Tekeze-Atbara Sub-basin: the Tekeze-Atbara drains the highlands of central – north Ethiopia. Its main rivers are the Tekeze (also known as Setit in its lower reaches), Gwang and Atbara, which constitutes the ultimate downstream river reaches. The long-term average annual water yield of the sub-basin is approximately 12 10^9 m^3. The rivers are highly seasonal in their flows. The rivers are used to supply water for hydropower generation and irrigation. There are three dams in the sub-basin, the TK5 in Ethiopia (commissioned in 2009), Khashm el Girba in Sudan (commissioned in 1964) and the Atbara dam complex (also known as Rumela-Burdana dam, not yet operational).



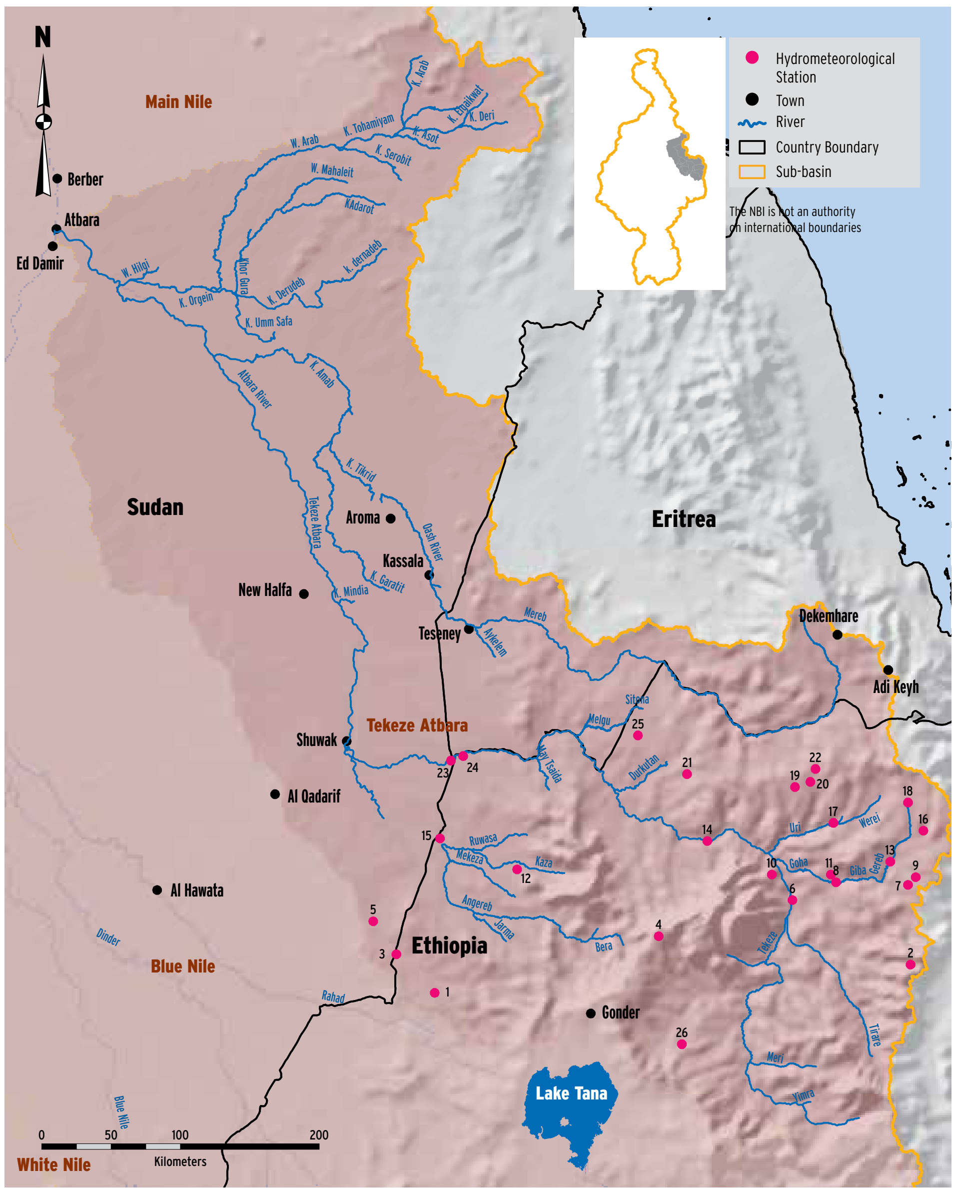
Meteorological monitoring network

There are 136 meteorological stations in the sub-basin, with 128 of them in Ethiopia and 8 in Sudan. The distribution of the stations is shown in the map. 30 stations (26 in Ethiopia and 4 in Sudan) are reported to measure the full range of meteorological parameters and the rest 106 measure daily rainfall totals only.

photo: Nile-SEC

Wind vane

No	Name of Station
1	Debark
2	Humera
3	Metema
4	Sanja
5	Adwa
6	Atsebi
7	May Tsebri
8	Maygaba
9	Nebelet
10	Senkata
11	Shire Endasilasse
12	Amde Work
13	Lalibela
14	Tsitsika
15	Axum Air Port
16	Mekele Air Port
17	Adi Arkay
18	Agere Genet
19	Ambagiorgis
20	Ashere
21	Baeker
22	Belesa (Hamusit)
23	Chanchok
24	Chenek
25	Chew Ber
26	Ebinat
27	Endris
28	Guhala
29	Ibnat
30	Kafta
31	Mykadra
32	Mekane Birhane
33	Tegdie (Kirakir)
34	Abi Adi
35	Adiawala
36	Adigoshu
37	Adikilte
38	Adimehemeday
39	Adiremets
40	Aditsetser
41	Badme
42	Biezet
43	Bora
44	Daro Hafash
45	Debrekerbe
46	Dera
47	Dimma
48	Edaga Selus
49	Edaga Hibret
50	Endabaguna
51	Feresmay
52	Finarawa
53	Gelebeda
54	Gijjet
55	Guroro
56	Hagere Selam
57	Halelo
58	Hawzen
59	Hewane
60	Ketema Negus
61	Mayhanes
62	Merhsenay
63	Muglat
64	Rahya
65	Selehelehe (IV)
66	Semema
67	Shiraro
68	Wedisemro
69	Wukuro
70	Yichila
71	Yiha
72	Ayna Bugna
73	Belebala Giyorgis
74	Chilla
75	Dibiko
76	Esrel (Libanos)
77	Gibana
78	Hamusit
79	Kewzeba
80	Sekota
81	Telajen/Hamusit
82	Zata
83	Adidaro
84	Dabat
85	Dib Bahir
86	Felwuha
87	Gedebeye
88	Gobgob
89	Kimir Dingay
90	Negadebaher
91	Tikil Dengay
92	Welela bahir
93	Zerma
94	Adidaro
95	Adigudom
96	Adigebru
97	Adishehu
98	Agibe
99	Agulai
100	Asegede
101	Aynalem
102	Chila
103	Dansha
104	Debud
105	Dengolet
106	Edaga Hamus
107	Edagaribi
108	Enticho
109	Fatsi
110	Gerehu Srnay
111	Hashenge
112	Haykmshal
113	Rama
114	Samre
115	Tsegereda
116	Workamba
117	Asketema
118	Dabo Ketema
119	Kulmesk
120	Muja
121	Kassala
122	New Halfa
123	Khashm Elgirba
124	Elshwak
125	Fireweini
126	Shiraro
127	Tekeze Hydro power
128	Wad alheleo
129	Aroma
130	Banrt
131	Degen
132	Gashm algerba
133	Goz Ragab
134	Hadalia
135	Halfa Elgadida
136	Matateb
137	Mekali
138	Mokram
139	Sidon
140	Tendalayi
141	Togan
142	Tomorgu
143	Barbar
144	Doka
145	ElGuraish
146	Showak
147	Elazaza North
148	Es salama
149	Hillat Hakuma
150	shasheina
151	Um brakeit
152	Um Grgor
153	Um Rahau
154	Aykel



Hydrometric stations

there are 26 hydrometric stations in the sub-basin; 23 in Ethiopia and the rest 3 in Sudan. The oldest station, Atbara near Kilo 3 was established in 1923. Most stations in Ethiopia were established after the mid 1970's. All stations measure river water level with most stations employing manual staff gauges while 8 stations in the upstream part are equipped with automatic water level recorders. Erosion and sediment transport are key processes in the sub-basin but not adequately monitored.

Strengthening sediment monitoring is one of the key areas for improving the monitoring system in the sub-basin.

The rivers in this sub-basin are highly seasonal and water resources are scarce compared to the current and anticipated future demands. Therefore, coordinated management of storage dams in Ethiopia and Sudan would help in reducing losses, and maximizing water use efficiency. For this purpose, a real-time data collection and communication system is required to support future coordinated management of water storage dams in Ethiopia and Sudan.

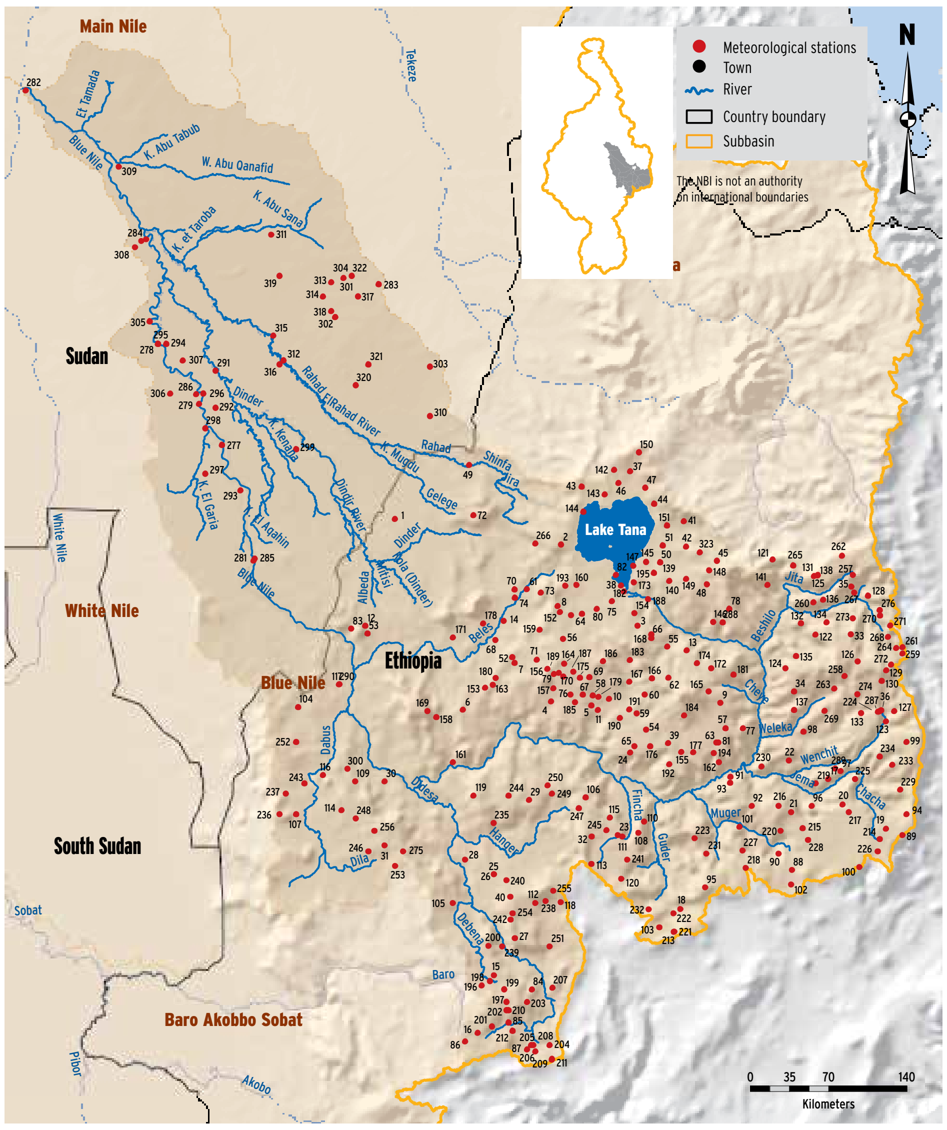
No	Name
1	Gendawoha near Kokit
2	Atsela near Adishihu
3	Goang near Metema
4	Asera near Debark
5	Al Asira
6	Tekeze near Yechila
7	Metere near Ainalem
8	Gheba near Adi Kumsi
9	Dolo near Quiha
10	Buya near Maitsemri
11	Illala near Mekele
12	Mekezo near Dansha
13	Gheba near Mekele
14	Tekeze near Embamadre
15	Angareb near Abdi Rafi
16	Genfel at Wukro
17	Worie near Maikenetal
18	Sulluh near Hawsien
19	Ayehida near Axum
20	Maimidimar near Adwa
21	Sebtta near Adidahiro
22	Maidungur near Adwa
23	Hamdait
24	Tekeze at Humera
25	Molge near Shiraro
26	Zarema at Zarema

The Blue Nile Sub-basin

The Blue Nile river (known as Abbay in Ethiopia) drains the highlands of Ethiopia and contributes about 60 per cent of the annual flow of the Nile measured at Aswan in Egypt. The long-term average annual water yield of the sub-basin is approximately 50 BCM. The Blue Nile is highly seasonal with approximately 70 percent of its annual flow occurring in just 4 months. The Blue Nile is source of water for major irrigation schemes in the Sudan. The Blue Nile causes severe flood damages in Sudan from time to time. The Grand Ethiopian Renaissance Dam (GERD) is under construction on the Blue Nile designed to store some 74 $10^9 m^3$. With the GERD in place, the Blue Nile will be fully regulated and its downstream flow depends on releases from the dam. This is expected to reduce flood damages significantly. There are opportunities for cross border collaboration on the coordinated management of the Blue Nile in which joint monitoring of river flows is an important component.

Meteorological monitoring network

There are 304 meteorological stations in the sub-basin, with 286 of them in Ethiopia and 18 in Sudan. The distribution of the stations is shown in the map below. 64 stations (53 in Ethiopia and 11 in Sudan) are reported to measure the full range of meteorological parameters and the rest 106 measure daily rainfall totals only.



No	Station
1	Quara
2	Shahura
3	Adet
4	Ayehu
5	Birr Sheleko
6	Bullen
7	Chagni
8	Dangila
9	Debre Work
10	Finoteselam
11	Lay Birr
12	Mankush
13	Motta
14	Pawe
15	Bedele
16	Gatira
17	Alem Ketema
18	Ambo Agriculture
19	Debre Berhan
20	Eneware
21	Fiche
22	Gunde Meskel
23	Kachise
24	Mehal Meda
25	Angerguten
26	Anger
27	Arjo
28	Dedessa
29	Gidayana
30	Kamashe
31	Nedjo
32	Shambu
33	Amba Mariam
34	Mekane Selam
35	Wegel Tena
36	Wereilu
37	Gondar A.p.
38	Bahir Dar New
39	Debre Markos
40	Nekemte
41	Addis Zemen
42	Amed Ber
43	Chandiba
44	Enfranz
45	Gassay
46	Kolladiba
47	Maksegnit
48	Mekaneyesus
49	Shinfa
50	Wanzaye
51	Wereta (Add)
52	Addis Kidame
53	Almahal
54	Amanueal
55	Asteriyo
56	Bambudi
57	Bichena
58	Bure
59	Dembecha
60	Dengay Ber
61	Dengel Ber
62	Digua Tsion (Bibugn)
63	Dimma
64	Durbet
65	Elias
66	Fasiledes
67	Finoteselam
68	Gilgelbeles
69	Gundil
70	Jawi
71	Kidamaja
72	Kunzila
73	Liben
74	Mandura
75	Merawi
76	Shandi
77	Shebelberenta (Yeduha)
78	Simada
79	Wegedade
80	Wetet Abay
81	Yetemen
82	Zege
83	Zela (Yarienja)
84	Boreka
85	Dembi
86	Sigmo
87	Agaro
88	Chancho
89	Debele
90	Derba
91	Filiklik
92	Gebere Guracha
93	Gohatsion
94	Gudoberet
95	Jeldu
96	Lemi
97	Meragna
98	Rema
99	Sarmider
100	Sheno
101	Siadebr
102	Sululta
103	Tikur Enchine
104	Abadi
105	Abasina Joger
106	Alibo
107	Bambase
108	Combolcha
109	Dalaty
110	Embabo
111	Fincha
112	Gutten
113	Hareto
114	Mendi
115	Neshi
116	Odda Bildigulu
117	Sherekole
118	Sibusire
119	Uke
120	Wayu
121	Debre Zebit
122	Debre Zeit
123	Degollo
124	Densa
125	Gashena
126	Gimba
127	Gishe Rabel
128	Gishen
129	Guguftu
130	Kabie
131	Kone
132	Koreb
133	Ligwama
134	Masha
135	Saynt Adjibar
136	Shoga
137	Wegidi
138	Kon Abo
139	Ambesame
140	Arb Gebeya (Dera)
141	Arb Gebeya (Gaint)
142	Aymba
143	Chewahit
144	Delgi
145	Dera Hamusite
146	Koma Fasiledos
147	Korata
148	Lewaye
149	Licha
150	Shembekit
151	Yifag
152	Abay Sheleko
153	Addis Alem
154	Andassa
155	Aneded (Amber)
156	Askuna
157	Azana
158	Baruda
159	Chara
160	Chimba
161	Debre Zeit
162	Dejen
163	Dibate
164	Enjabara
165	Felege Berhan
166	Feres Bet
167	Genetabo
168	Geregera
169	Gesengessa
170	Gimijabet Mariam
171	Gulback
172	Gundo Woin
173	Kembaba
174	Keranio
175	Kessa
176	Kuy
177	Lumamme
178	Mambuk
179	Mankusa
180	Menta Wuha
181	Merto Lemariam
182	Meshenti
183	Quarit
184	Rob Gebeya
185	Sebader
186	Sekela
187	Tilili
188	Tis Abay
189	Urana
190	Wadeyesus
191	Yechereka
192	Yejube
193	Yesemala
194	Yetnora
195	Zenzelema
196	Abdela
197	Bido
198	Debena
199	Gechi
200	Kone
201	Setema
202	Yambero
203	Yanfa
204	Babu
205	Boto
206	Choche
207	Dame
208	Gembe
209	Semodo
210	Setema
211	Somodo
212	Toba
213	Arb Bila
214	Chacha
215	Debre Tsige
216	Degem
217	Deneba
218	Enchini
219	Fetra
220	Fital
221	Gimbi Bila
222	Gubre
223	Harodoyo
224	Jara
225	Jihur
226	Kotu
227	Muger
228	Muke Turi
229	Seladingai
230	Serkulla
231	Shekute
232	Toke Erenso
233	Wegere
234	Zemro
235	Agallo Mitti
236	Amba 10
237	Amba 16
238	Arbgebeya
239	Dedessa River
240	Ehud Gebeya
241	Gebete
242	Getema
243	Gizen
244	Haro
245	Homi
246	Jarso
247	Jermet
248	Kiltukara
249	Kiramu
250	Kokeffe
251	Kone
252	Menge
253	Mukelemi
254	Muletadiga
255	Sasiga
256	Werejiru
257	Ajibar (Add)
258	Akesta
259	Ancharo
260	Dawunt (Chet)
261	Dessie Zuria Met
262	Estayish
263	Genete Sch
264	Gerado
265	Geregera
266	Gobiye
267	Gosh-Meda
268	Kelem Meda
269	Kellela
270	Kundi
271	Kutaber
272	Tebasit
273	Tenta Tateke Sch
274	Wein-Amba
275	Hena
276	Teleyayen
277	Abu Naama
278	Sennar
279	Umm Benin
280	Wad Medani
281	Ed Damazine
282	Khartoum
283	El Gadaref
284	Elgezira
285	Roseires
286	Singa
287	Cheffa
288	Simada
289	Yetenora
290	Sher. Gizen (W)
291	Dendar
292	Dender
293	Karkoj
294	Kassab
295	Sennar Town
296	Singa
297	Tozi
298	Ubhugar
299	Wad Alneal
300	Abu Kshma
301	Abu Sharaba
302	Almatna
303	Kagai
304	Leiya
305	Hugerat
306	Rabak
307	Ummsigan
308	Wad En Na'em
309	Wd Alkali
310	Basunda
311	Elfaw
312	Elhawata
313	G.enahal
314	Gadamblyia
315	Mafaza
316	W.eshaair
317	Elhory
318	Elmetna
319	Gadamblyia South
320	Samsam
321	Um Blail
322	Um Leiyon
323	Debre Tabor

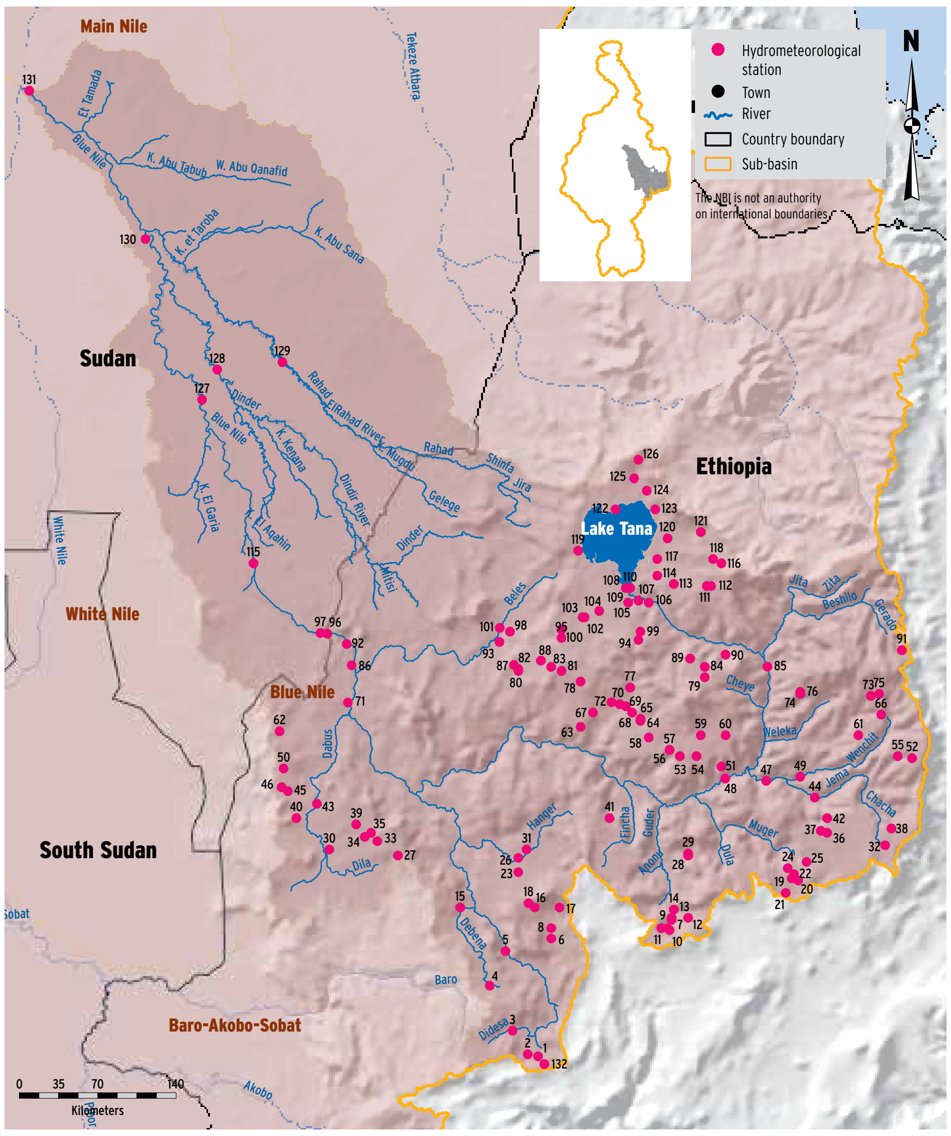
Hydrometric stations

There are 133 hydrometric stations in the sub-basin; 126 in Ethiopia and the remaining seven in Sudan. The station just downstream of Ethiopia – Sudan border, the Diem station, has a record of over 100 years and, therefore, one of the most important. However, is due to the recent heightening of the Roseries Dam in Sudan, the station at times get inundated by the back-water of the dam. Most stations in Ethiopia were established in the early 1960's. Erosion and sediment transport are also key processes in the sub-basin but not adequately monitored.

The Blue Nile sub-basin offers one of the greatest opportunities for hydropower development in the Nile Basin. In addition, providing over 60 percent of the average annual flow of the Nile, the Blue Nile is the major source of water for the Nile. Key focus in strengthening of hydrometric monitoring system shall be on real-time data collection and transmission system, sediment monitoring and monitoring of river morphological changes downstream as a result of anticipated flow regimes in the sub-basin.


Ground water level monitoring station

photo: Nile-SEC



No	Station
1	Urgessa near Gembe
2	Temsa near Agaro
3	Didessa near Dembi
4	Dabana near Bunobedele
5	Didessa near Arjo
6	Wama near Nekemte
7	Melke near Guder
8	Sifa near Nekemte
9	Bello near Guder
10	Fatto near Guder
11	Indris at Guder
12	Guder at Guder
13	Huluka near Ambo
14	Debis nearGuder
15	Dabana near Abasina
16	Tato near Gutie
17	Indris near Sire
18	Adiya near Nekemte
19	Gerbi near Sululta
20	Roba near Chancho
21	Deneba near Chancho
22	Mugher near Chancho
23	Uke near Nekemte
24	Aleltu near Chancho
25	Gorfo near Gorfo
26	Angar near Nekemte
27	Dilla near Nedjo
28	Tinshu Duber near Duber
29	Tilku Duber near Duber
30	Aleltu at Nedjo
31	Little Ang at Angar Gutin
32	Chacha at Chacha
33	Komis near Gori
34	Koriche near Kiltu Kara
35	Hujur near Nedjo
36	Robi Jida near Muka Ture
37	Aleltu near Muka Ture
38	Beressa near Debre Berhan
39	Sechi nearMendi
40	Mutsa near Bambasi
41	Neshi near Shambo
42	Robigumero near Lemi
43	Dabus near Asosa
44	Jemma near Lemi
45	Haffa near Assosa
46	Gambella near Asossa
47	Jemma at Abay Confluence
48	Abay at Kessi Bridge
49	Wenchit near Alem Ketema
50	Hoha near Asossa
51	Muga near Dejen
52	Wizer near Mehal Meda
53	Yeda near Amber
54	Bogena at Lumame
55	Shy near Mehal Meda
56	Chemoga near Debremarkos
57	Abahim at Debremarcos
58	Jedeb near Ama Nuel
59	Teme near Mota
60	Suha near Bichena
61	Gebregura. near Degolo
62	Shelkole near Komosha
63	L. Fettam at Galibed
64	Temcha near Dembecha
65	Gudla at Dembecha
66	Jogola at Wereilu
67	Abbay near Bure
68	Chereka at Yechereka
69	Birr near Jiga
70	Leza near Jiga
71	Abay at Shergole Cableway RGS
72	Lah near Finote Selam
73	Mechela near Kabe
74	Boreda near Mekaneselam
75	Selgi near Kabe
76	Lege Cora near Mekaneselam
77	Talia near Jiga
78	Fettam at Tilile
79	Tigdar nearGunde Woin
80	Dondor near Metekel
81	Missini at Kossober
82	Ardy near Metekel
83	Ayo near Kossober
84	Azuari near Mota
85	Abay at Mekane Selam-Gundewein Br.
86	Abay at Yarenga Bridge
87	Dura near Metekel
88	Buchiksi near Kidamaja
89	Sedie near Mota
90	Abbay near Kessie
91	Gerado near Dessie
92	Abay at El Delm
93	Gilgel Be. near Mandura
94	Tul near Adet
95	Quashini near Addis Kidame
96	Abbay at Sudan Border
97	Eldeim
98	Main Beles at Bridge
99	Shina near Adiet
100	Amen at Dangila
101	Main Bele at Bridge DS of Bagusta
102	Gelgel Abbay near Marawi
103	Koga at Merawi
104	Bered at Merewi
105	Ezana near Bahirdar
106	Mendel near Tis Abbay
107	Andassa near Bahir Dar
108	Lake Tana at Bahir Dar
109	Abbay at Bahir Dar
110	Abbay near Pedagogi
111	Chena near Istay
112	Wenka near Istay
113	Fegoda near Arb Gebeya
114	Gelda near Ambessame
115	Roseries
116	Ribb near Gasai
117	Gumara near Bahir Dar
118	Zufil near Debre Tabor
119	Lake Tana at Kunzila
120	Ribb near Addis Zemen
121	Upper Ribb On DebreTabor Road
122	Lake Tana at Gorgora
123	Garno near Infranz
124	Gemero near Maksegnit
125	Megech near Azezo
126	Angareb near Gonder
127	Wad Eleis
128	Gewesi
129	Hawata
130	Madani
131	Khartoum
132	Yebu at Yebu

The White Nile Sub-basin

The White Nile contributes about 25 – 26 $10^9 m^3$ to the Main Nile measured just upstream of the White – Blue Nile confluence in Khartoum. It receives water from rivers that drain the Equatorial Lakes region of the Nile Basin and which pass through a series of natural lakes and swamps. As a result, the White Nile provides a relatively more uniform seasonal flow compared to the Blue Nile and Tekeze-Atbara rivers. The White Nile provides long navigable reaches due to its flat slope and stable flow.


Acoustic Doppler Current Profiler (ADCP)

Meteorological monitoring network

There are 36 meteorological stations in the sub-basin, with 30 of them in Sudan, four in Ethiopia and two in South Sudan. The distribution of the stations is shown in the map below. 8 stations (five in Sudan and three in Ethiopia) are reported to measure the full range of meteorological parameters and the remaining 22 measure daily rainfall totals only.

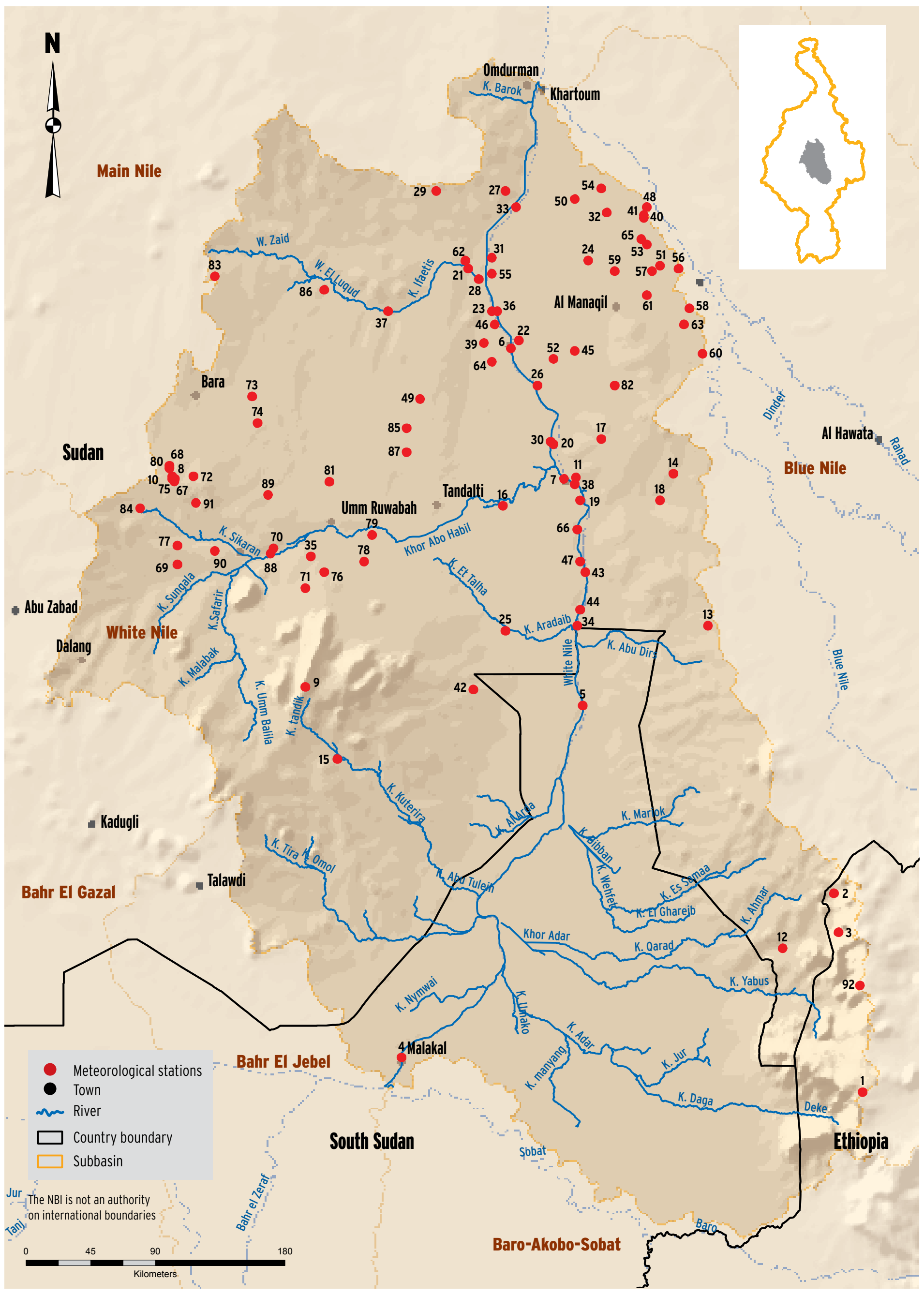

photo:Nile-SEC

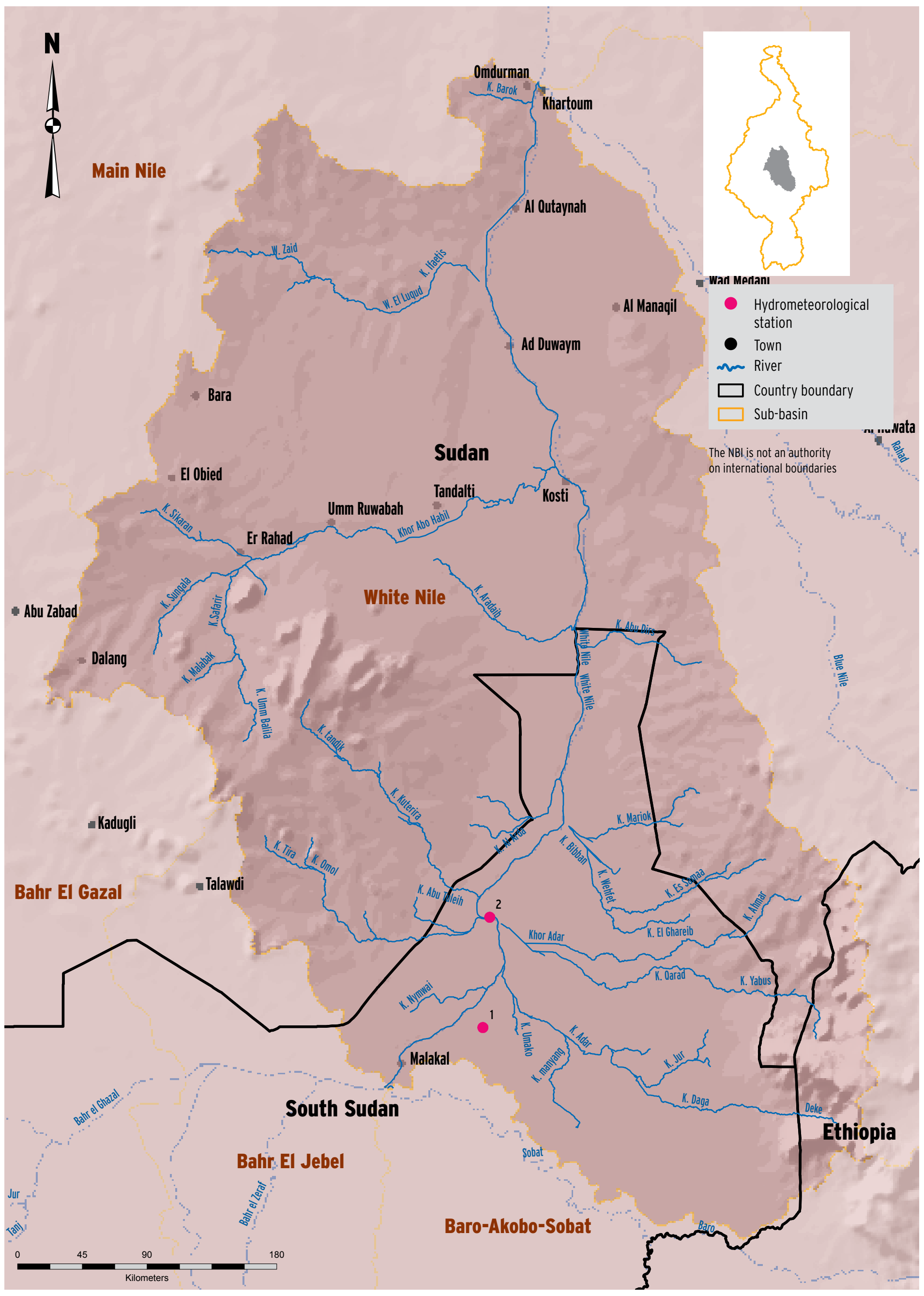
Automatic weather station

Hydrometric stations

The only station that is operational is White Nile at Malakal. The station is close to of Malakal town just downstream of the Sobat – White Nile confluence. Historically, there were four additional stations but they were not operational at the time of the survey conducted in 2014.

The White Nile is an important source of water, especially during the dry season (November – May/June), when the Blue Nile and other tributaries from the Ethiopian highlands are at their lowest levels. Therefore, rehabilitating the non-functioning stations in the sub-basin is urgently required. The Nile Basin regional Hydromet system has included the station at Malakal (Renk) and the station d/s of Jebel Awlia dam as regional stations.





No	Name Of Station
1	Begi
2	Kurmuk
3	Famesetre
4	Malakal
5	Renk
6	Ed Dueim
7	Kosti
8	El Obeid
9	Rashad
10	Elobeid
11	Rabak
12	Aldali
13	J.mazmoum
14	J.sagdi
15	Abu Gubeiha
16	Um Kouka
17	Jabal Biut
18	Jabal Moui
19	Um Hani
20	Aba
21	Abger
22	Abu Harira
23	Dubasi
24	El Neima
25	Elakaf
26	El-Kawa
27	Elsheikh Essaddig
28	Es Sufi
29	Esh Shageig
30	Fashashoya
31	Fatisa
32	Fawar
33	Geteina
34	Goda
35	Goz Khadra
36	Hashaba
37	Helba
38	Hellat Abbas
39	Idd El`Ud
40	Istarahna
41	Istarahna
42	J Megeneis
43	Jebelein
44	Kerikera
45	Rahama
46	Shabasha
47	Showal
48	Toba
49	Tuweimat
50	Ub Guta
51	Umm Dueina
52	Umm Suneint
53	Umm'udam
54	Ureik
55	Wad Alzaki
56	Wad Bashkar
57	Wad El Burr
58	Wad El Umarbi
59	Wad Ezzein
60	Wad Figad
61	Wad Hilal
62	Wad Nimir
63	Wad Nu'man
64	Wakara
65	Zubeir
66	Zuleit (1)
67	Algalah
68	Almashtal
69	Elban Gadid
70	Elsemaih
71	Gabrat Elshaikh
72	Khur Taget
73	Muzdalifa
74	Namlah
75	Obeid Albusta
76	Rifee Um Rawaba
77	Shekan
78	Shirkela
79	Shirkela Um Aush
80	Tareg Almashea
81	Ubo Grain
82	Um Dam Haj Ahmed
83	Um Garfa
84	Um Ramad
85	Um Saigaoon
86	Ummsiyala
87	Wd Ashana
88	Abu Habel
89	Alaen
90	Alrahed
91	Um Kadada
92	Assosa

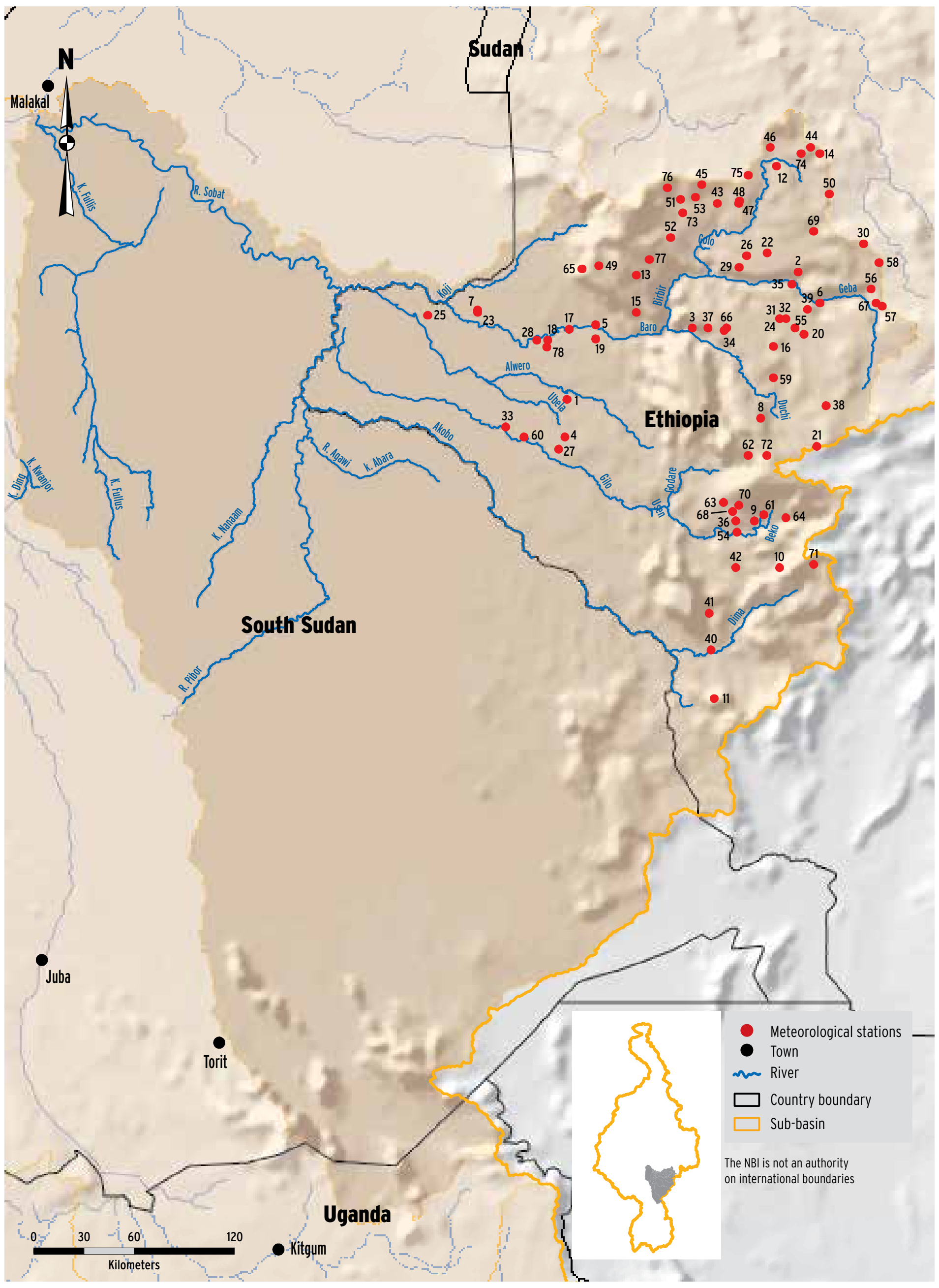
No	Name
1	Khor Adar
2	Melut

The Baro-Akobo-Sobat Nile Sub-basin

The Baro-Akobo-Sobat sub-basin is shared by Ethiopia and South Sudan. Its major rivers are the Baro, Akobo and Pibor. The Baro, after joined by Akobo and Pibor makes the Sobat that flows to the northwest to join the Bahr el Jebel and eventually form the White Nile. The annual water yield of the Sobat is approximately 12- 13 10^9m³. The reach of the Baro and Sobat downstream of Gambella town (in Ethiopia) is navigable. A key feature of the hydrology of the sub-basin is that its rivers (especially in the lower reaches) flow over flat surface with meandering patterns creating complex interactions with surrounding floodplains. The spill from the Baro river into the Machar marshes (in the White Nile Sub-basin) is one of naturally occurring transfer of water into a neighboring catchment.

Meteorological monitoring network

There are 78 meteorological stations in the sub-basin – all in Ethiopia. The distribution of the stations is shown in the map below. 17 stations are reported to measure the full range of meteorological parameters. Most stations are in the highlands with very few of the stations located in the lower plains of the sub-basin in Ethiopia.

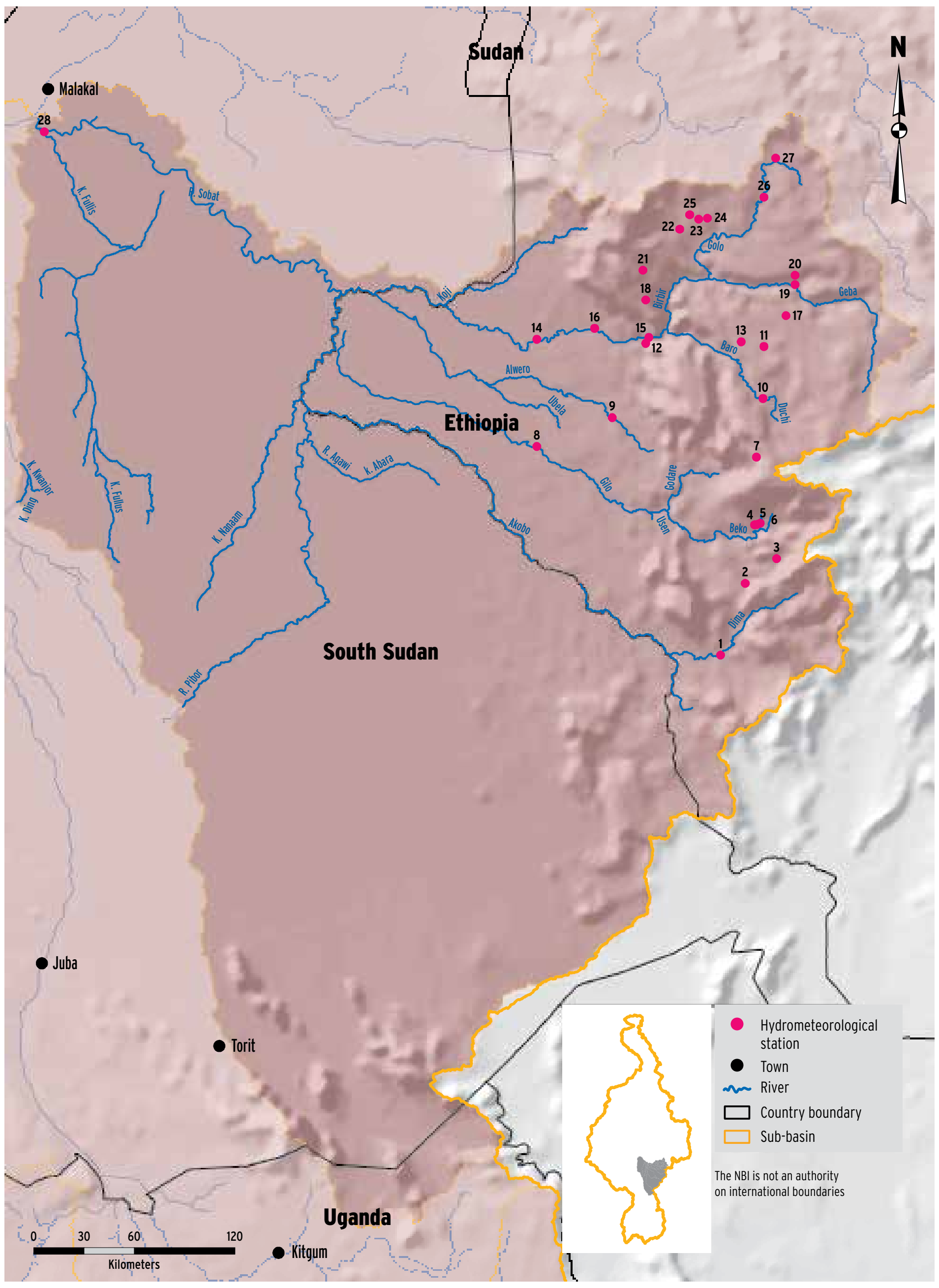


No	Name of Station
1	Abobo
2	Alge
3	Bure
4	Fugnido
5	Gambela
6	Hurumu
7	Jikawo (Lare)
8	Masha
9	Tepi
10	Aman
11	Jeba
12	Ayira
13	Dembidolo
14	Gimbi
15	Shebel
16	Gore
17	Abol
18	Aliyadora
19	Baro Bonga
20	Becho
21	Bitta Genet
22	Darimu (Dopa)
23	Eliadora
24	Fugo Leka
25	Gnignang
26	Gobe
27	Gog
28	Itang
29	Kidame Gebaya
30	Meko
31	Metu Hospital
32	Nopa
33	Puchala
34	Soretefasese
35	Supe
36	Tinishu Miti
37	Uka
38	Yadota
39	Yayo (Dorani)
40	Guraferda (Biftu)
41	Koy
42	Mizan Teferi
43	Alemteferi
44	Dengoro
45	Gidame
46	Guliso
47	Lalo Kelle
48	Mechara
49	Mugi
50	Nolekaba
51	Qaqi
52	Seko Humbi
53	Yubdo
54	Bechi
55	Bilambilo
56	Bontu
57	Chora
58	Dega
59	Didu Gordomo
60	Dippa
61	Fide
62	Gecha
63	Gubete
64	Kura
65	Menko Lencho
66	Sibo
67	Wetete (TP)
68	Yeki
69	Yembo
70	Ermichi
71	Shewa Gimira
72	Yina
73	Chanka
74	Enango
75	Figakobra
76	Kebe
77	Rob Gebeya (Kel)
78	Lare

Hydrometric stations

there are 28 stations in the sub-basin (27 in Ethiopia and 1 in South Sudan). More than half of the stations in Ethiopia were established in 1980's and, therefore, have short records. Breaks in records often pose additional challenges in using such short records.

The hydrometric network of this sub-basin is far from adequate. The sub-basin, especially in its lower reaches exhibit highly complex hydrology in which the rivers at time bifurcate and join back the main stem and floodplains and swamps interact with the river flows. The Hydrometric network in this sub-basin requires strengthening with additional data collection through remote sensing to adequately understand the hydrology of the sub-basin.



No	Name
1	U. Akobo Nr. Dima
2	Berhan Nr. Bebeka Farm
3	Gacheb Nr. Mizan Tefri
4	Begwuha Nr. Tepi
5	Bitinwuha Nr. Tepi
6	Beko(Shoha Nr. Tepi
7	Gengi Nr.Gecha
8	Gilo Nr. Pignudo
9	Awero at Dam/Dumbong Village
10	Upper Baro Nr. Masha
11	Gumero Nr.Gore
12	Bonga Nr. Bonga
13	Uka @ Uka
14	Baro @ Itang
15	Baro @ Bonga
16	Baro @ Gambella
17	Sore Nr. Metu
18	Agami Nr. Ashi
19	Geba Nr. Suppi
20	Eilika Nr. Supe
21	Meti Nr. Dembidolo
22	Keto Nr. Chanka
23	Cherecha Nr. Chanka
24	Merdefa Nr. Alem Teferi
25	Kuni Nr. Chanka
26	Birbir Nr. Yubdo
27	Ouwa Nr. Guliso
28	Hillet Dolieb

The Bahr el Jebel Sub-basin

The Bahr el Jebel sub-basin has one of most complex hydrology in the Nile Basin. The Sudd system of wetlands, the second largest freshwater wetland in the World, is a key feature of the sub-basin. The main river, Bahr el Jebel, has river flow records since the beginning of the 20th century. However, due to conflicts in South Sudan, river gauging was interrupted for more than 20 years.


photo: Nile-SEC

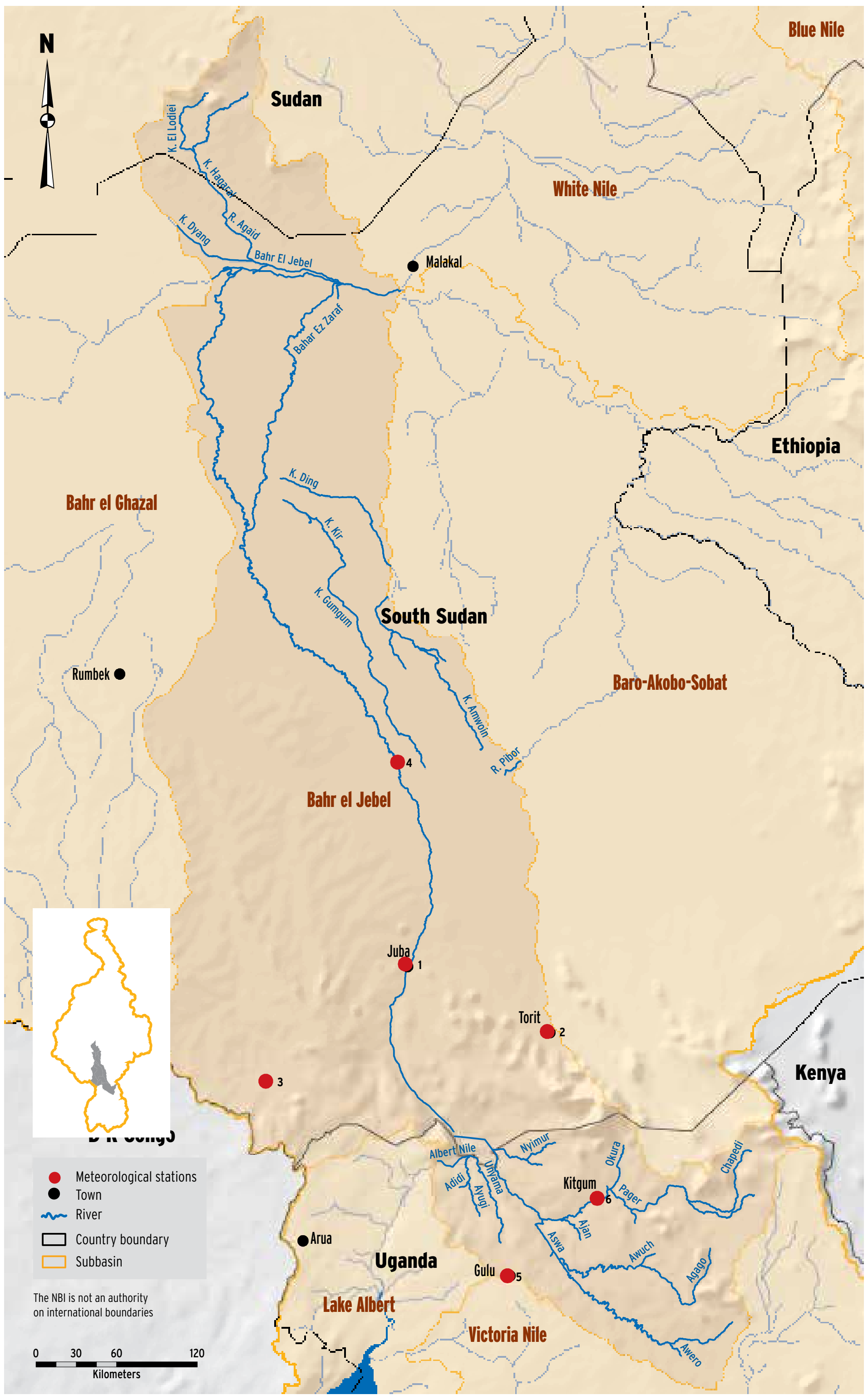
Wind vane


photo: Vivian Nabyonga

Water level reader

Meteorological monitoring network

There are six meteorological stations in the sub-basin; five in Uganda and one in South Sudan. Only three full met stations are available in the entire sub-basin.

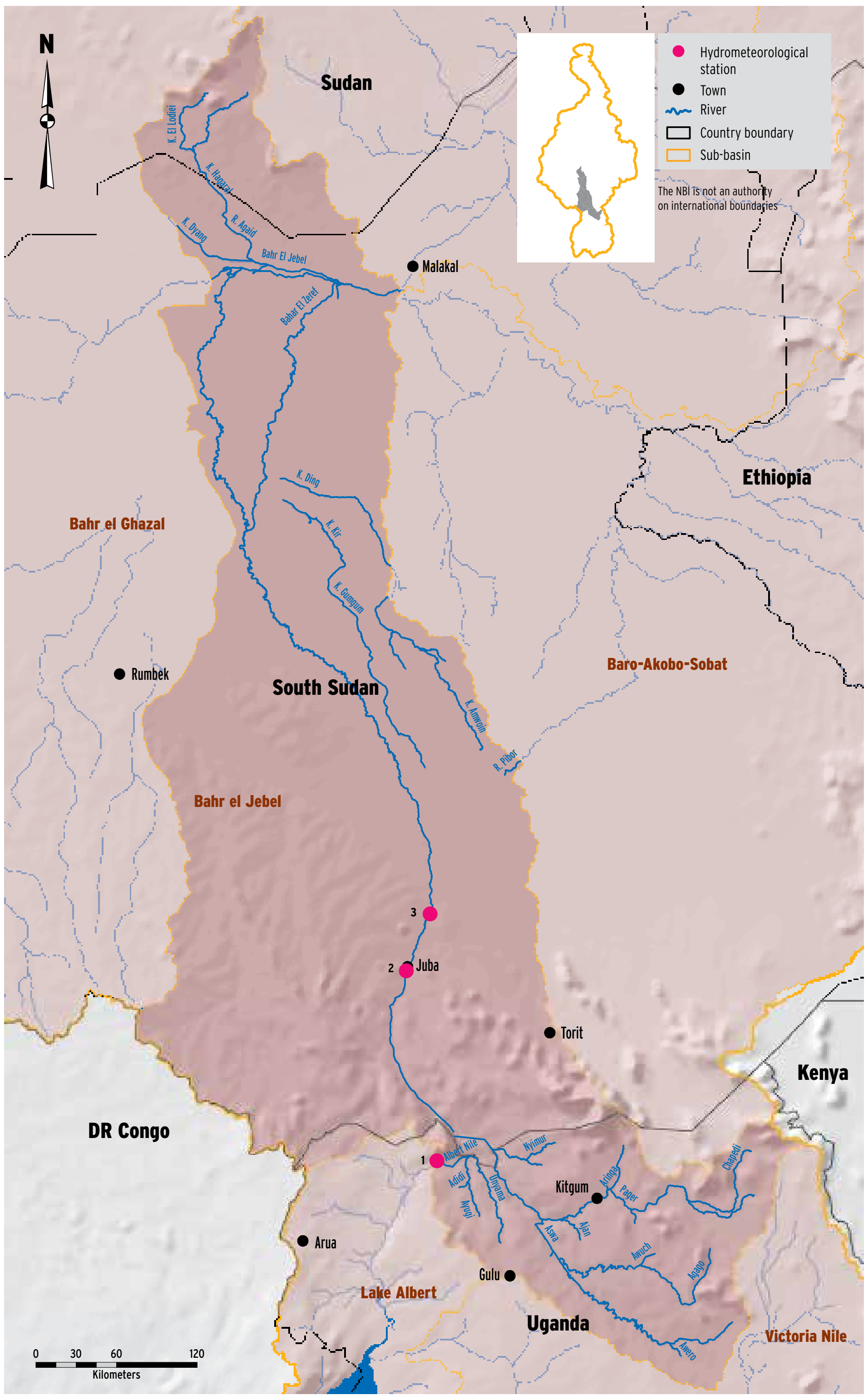


No	Name of Station
1	Juba
2	Torit
3	Yei
4	Bor
5	Gulu met station
6	Kitgum Centre Vt

Hydrometric stations

There are 4 stations in the sub-basin (3 in South Sudan and 1 in Uganda). The stations in South Sudan are Bahr el Jebel at Mongala and Bor while the single station in Uganda is at Laropi. Three stations are not sufficient for this sub-basin.

The hydrology of the Bahr el Jebel sub-basin has been the subject of many investigation in the past. However, there is a gap in the understanding of the interaction between the river system and the system of wetlands in the sub-basin. Severe flooding has caused huge damages in recent years but the monitoring infrastructure is nowhere near adequate. The sub-basin requires a system of monitoring that employs ground-based as well as remote sensing supported data collection and transmission.



No	Name of Staion
1	R. Albert Nile at Laropi
2	Juba
3	Mongalla

The Bahr el Ghazal Sub-basin

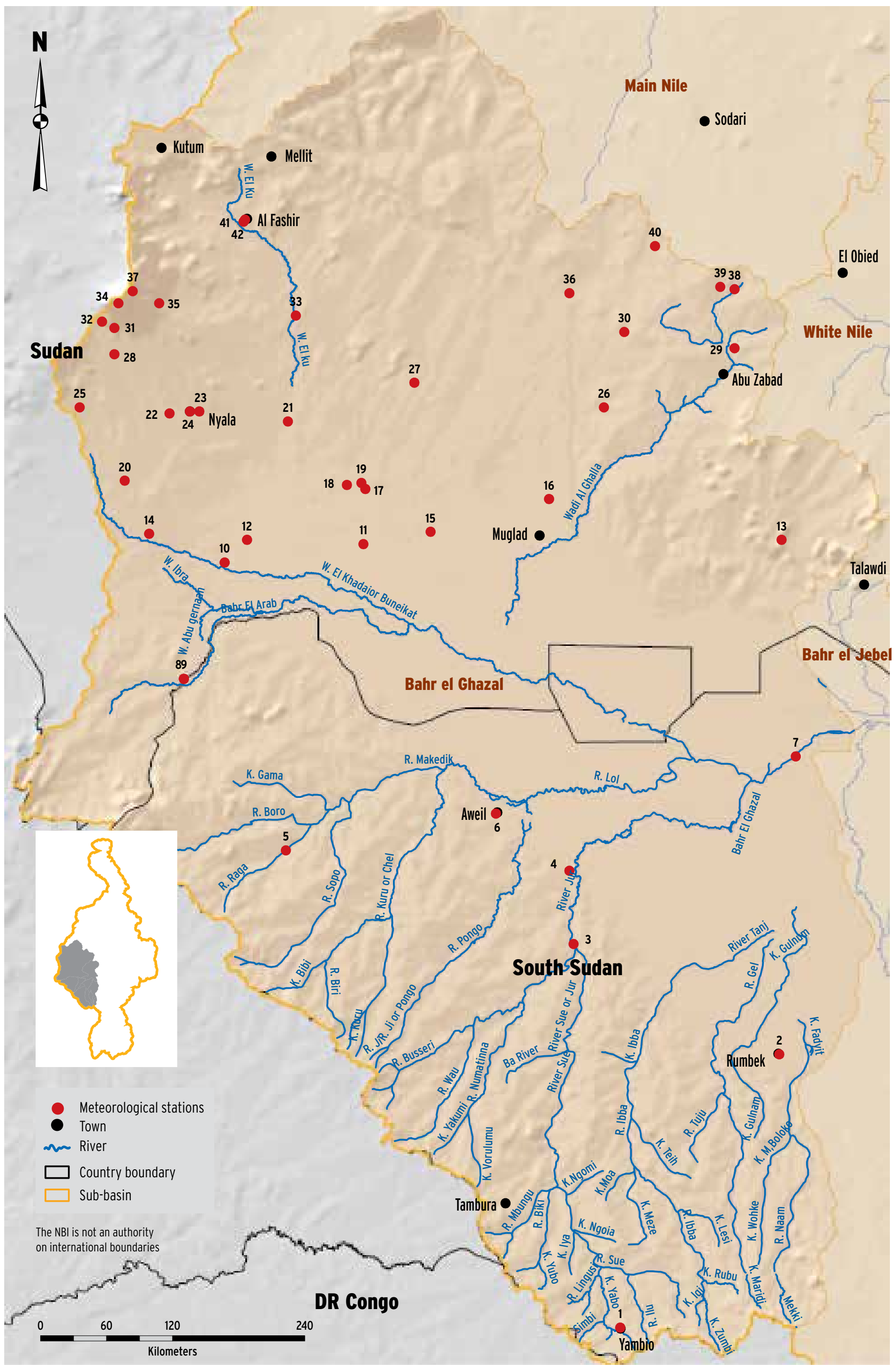
The Bahr el Ghazal Sub-basin drains is shared by South Sudan and Sudan. It has an area comparable to the Blue Nile but with very small outflow. The main river, Bahr el Ghazal, flows and joins the Bahr el Jebel downstream of Lake No.

Dry river bed in South Sudan

photo: Arsenie Coseac/Flickr

Meteorological monitoring network

There are 14 meteorological stations in the sub-basin; two in South Sudan and 12 in Sudan. Nine stations are full met stations.

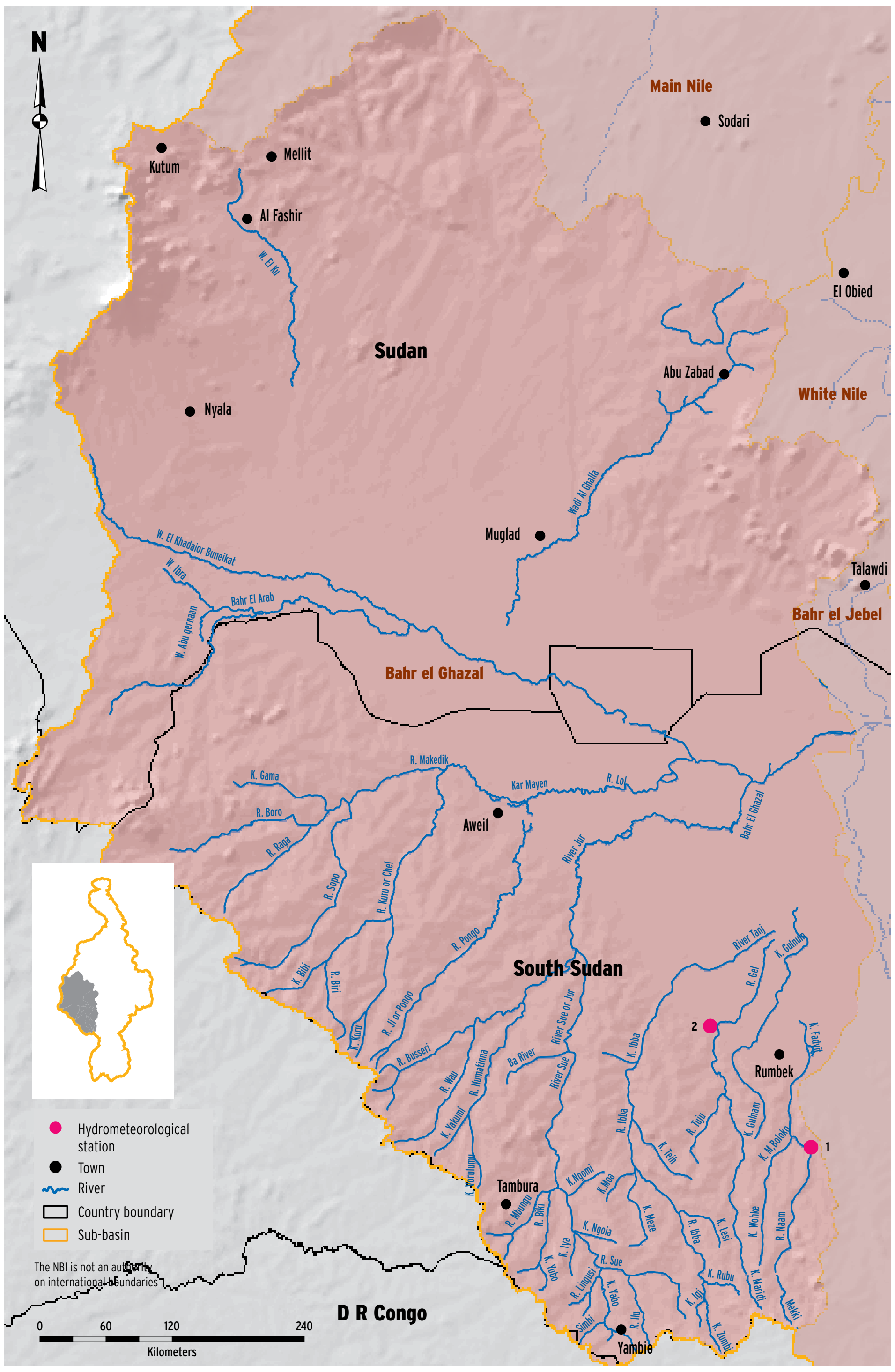


No	Name of Station
1	YAMBIO
2	RUMBEK
3	Wau
4	KUAJOK
5	Raga
6	AWEIL
7	BENTIU
8	Alradoom
9	RADOM
10	BURAM
11	ABU MATARIG
12	UMM SIKEINAT
13	Kadugli
14	tulus
15	ABUGABRA
16	Babanusa
17	ABU HEMEID
18	EL-DEAIN
19	Gazala gawazat
20	EID EL-GANAM
21	MUHAGRIA
22	ET TOMAI
23	Neyala
24	Nyala
25	DANKOG
26	Elodaiah
27	EL-TEWAISHA
28	KAS
29	Giraih Elsarha
30	En Nahud
31	KALOKITING
32	KUNGAR
33	WAFA'A
34	TORA TONGA
35	MALEMM
36	Wd Bunda
37	SUNI
38	Elmazroob
39	Alkhowi
40	Eial Bakhit
41	El Fasher
42	El Fasher

Hydrometric stations

There is only one station in the sub-basin – on a tributary of the river at Wau in South Sudan. The map below shows the location of the station. The table adjacent to the map provides the list of hydrometric stations that were available but not operational and those newly proposed as part of strengthening the monitoring system in South Sudan.

The Bahr el Ghazal is the least monitored sub-basin in the Nile Basin. As a result, the hydrology of the sub-basin is not well understood although indications are that the sub-basin has considerable water resources potential. A combination of ground – and remote sensing based observations of hydro-meteorological parameters are needed for the long-term sustainable management of the water resources of the sub-basin.



Note: All Hydrometric stations in Bahr el Ghazal are not operational

1	Rumbek
2	Gel

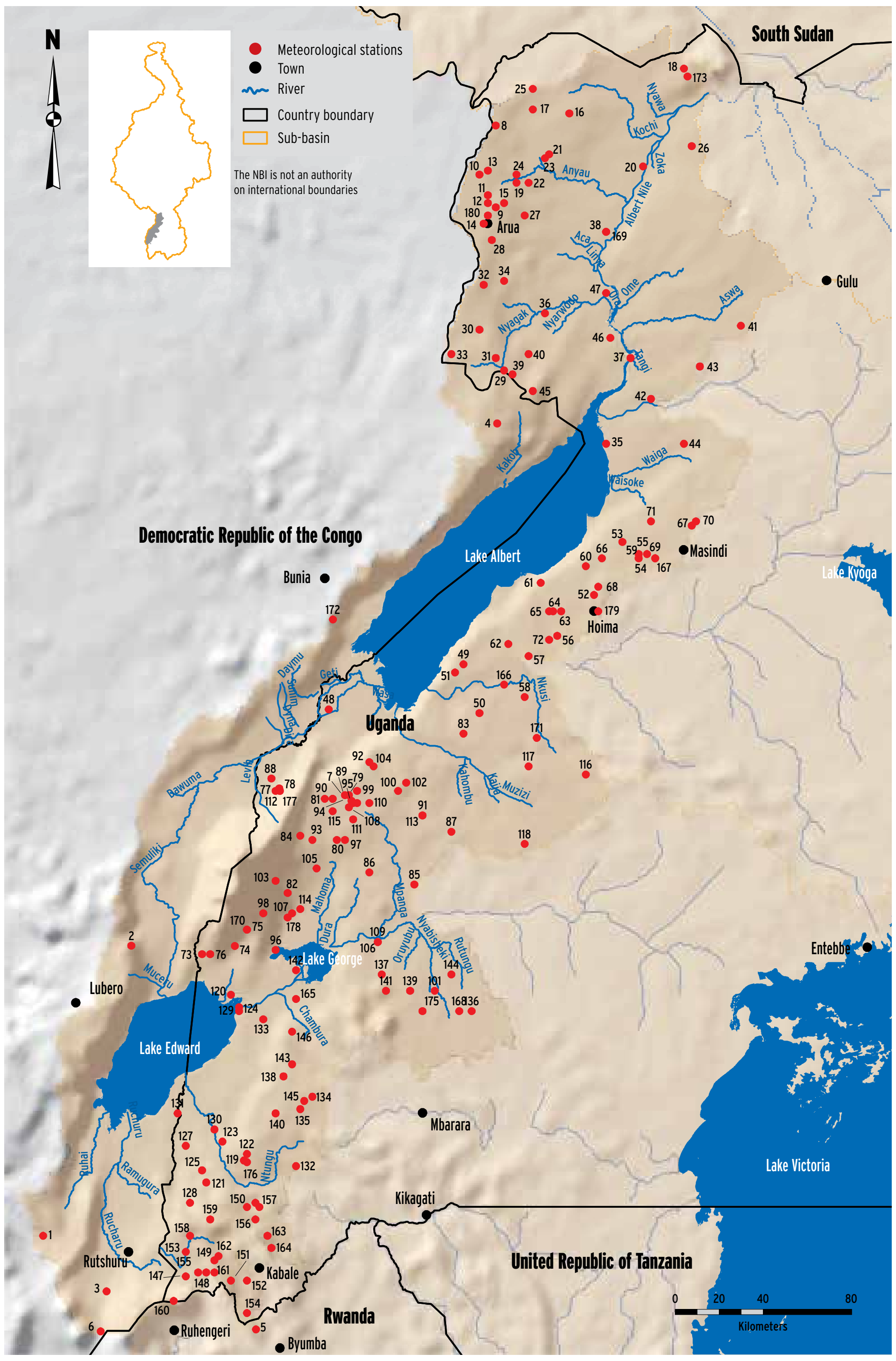
The Lake Albert Sub-basin

The Lake Albert Sub-basin is shared by DR Congo and Uganda. The sub-basin has three main lakes, Edward, Albert and George. Victoria Nile is regulated in part by the outflow from the lake. The sub-basin is an area of oil exploration and, hence, water quality and quantity monitoring is very important for sustainable management of the water resources.

ADCP being lowered into the the stream

Meteorological monitoring network

There are 29 meteorological stations in the sub-basin; all in Uganda.11 stations are full met stations. The distribution of the stations is shown in the map below.



No	Name
1	Bukombo
2	Isale Vuhovi
3	Rumangabo
4	Ugongo
5	BUNGWE-PNILP
6	SHINGIRO
7	Fort Portal
8	Koboko St. Charles L
9	Abi Estate
10	Olovu
11	Lokiragodo
12	Manibe Omuazire
13	Ovujo
14	Arua Central Govt Prison
15	Wandi BAT Uganda Ltd
16	Yumbe Hospital (Aringa)
17	Ladonga VFM
18	Moyo Boma
19	Terego Dispensary
20	Obongi Dispensary
21	Upupe Dispensary - Arua
22	Otrevu
23	Utumbari - Arua
24	Ivu
25	Mount Kei Forest Station
26	Adjumani Prisons Farm
27	Bileafe Tobacco Station
28	Kuluva
29	Payidha
30	Warr Dispensary
31	Nyapea St.Aloysius
32	Usi Forest Station - Nebbi
33	Lendu Forest Station
34	Nyara TWGCS
35	Buliisa Gomborora Hqs
36	Okollo Dispensary
37	Pakwach Dispensary
38	Rhino Camp Dispensary
39	Goli African.Inland.
40	Nebbi UTC
41	Anaka
42	Kabalega Falls
43	Wangkwar Camp
44	Wairingo River Camp
45	Erusi Forest Station
46	Pokwero Group Farm
47	Wadelai WDD
48	Rwebisengo
49	Kyangwali
50	Mugalike WFM
51	Kasonga HM
52	Dwoli Estate
53	Busingiro Forest
54	Nyamageta Estate
55	Kinyala Estate
56	Kizirafumbi
57	Kabwoya
58	Kiryanga Gombolola
59	Nyabyeya
60	Kigorobya
61	Biseruka
62	Bugoma CFR
63	Bugambe Tea Estate
64	Rwabikondo Estate
65	Nyamolobyo Estate
66	Siba
67	Kihonda Estate
68	Wampanga Forest Station
69	Kinyala Sugar Scheme B
70	Kisindi Group Farm
71	Kigumba Farm
72	Muntme Fatima Parish
73	Mpondwe Customs Post
74	Nyabirongo
75	Nyamugasani
76	Bwera
77	Bundibujo
78	Butiti
79	Kahangi Estate
80	Kilchooney Estate
81	Nyakasura School
82	Bugoye
83	Kagadi Gombololo
84	Kisomoro
85	Nkoma
86	Bigodi
87	Matiri
88	Nyaruru
89	Kyembogo Farm
90	Virika School
91	Kyenjojo
92	Kijura Tea Factory
93	Yeriya Estate
94	Mugusu Estate
95	Chakatimba Estate
96	Muhokya Toro Limeco Ltd
97	Isunga Estate
98	Kilembe Mines
99	Sebutole
100	Kyehara II
101	Bulemba
102	Kikumiro V
103	Mobuku HEP
104	Itwara C.F.R.
105	Ruimi Prison Farm
106	Kiburara
107	Mubuku\Sebwe Irr Scheme
108	Kahangi Estate
109	Bihanga prison Farm
110	Rwebitaba Tea Res Station
111	Kanyawara
112	Bundibugyo Cocoa Devt
113	Kyenjojo 1st Order Station
114	Mubuku Giant prison Farm
115	Kinyamasika TTC
116	Kakumiro Variety TC
117	Buyanja (Buyaga)
118	Kyegegwa
119	Nyakibale
120	Katwe
121	Kanungu
122	Rukungiri Dispensary
123	Bugangari Dispensary
124	Myeya
125	Burema
126	Rulind Swamp Inlet
127	Kihihi Tractor Hire
128	Kitahulira Forest Station
129	Uganda Institute of Ecology - Kasese
130	Kaniabizo
131	Ishasha River Camp
132	Rwashamaire
133	Bunyaruguru WFM
134	Bushenyi
135	Kitabi Seminary
136	Nyabusozi Saza Hqs
137	Kicheche
138	Kalinzu Forest
139	Kanoni Gombolola Hqs
140	Mitoma
141	Ibanda
142	Tufmac Kasenyi
143	Ankole Tea Company
144	Kazo Sub County
145	Bushenyi Agromet Station
146	Rubirizi Saza Hqs
147	Kisoro Police Station
148	Mutolere Sen Sec School
149	Karengere Pyrethrum Plant
150	Kisizi Health Centre
151	Bufundi Dispensary
152	Bwama Island
153	Bukimbiri
154	Rubaya Dispensary
155	Chananke
156	Kashambya
157	Nyarushanje Agric Centre
158	Rushanga Forest Station
159	Ruhiza Forest Station
160	Sabinio Forest Station
161	Echuya Forest Station
162	Muko Forest Station
163	Kitanga
164	Mparo Dispensary
165	Rwomuhororo - Mbarara
166	Pachwa Hydromet Station
167	Kinyara Sugar - Masindi
168	Kashwa Primary School - Mbararara
169	Rhino Camp Ginnery - Arua
170	Nyamugasani - Kabarole
171	Kamuli High School - Kamuli
172	Bogoro

photo: Vivian Nabyonga

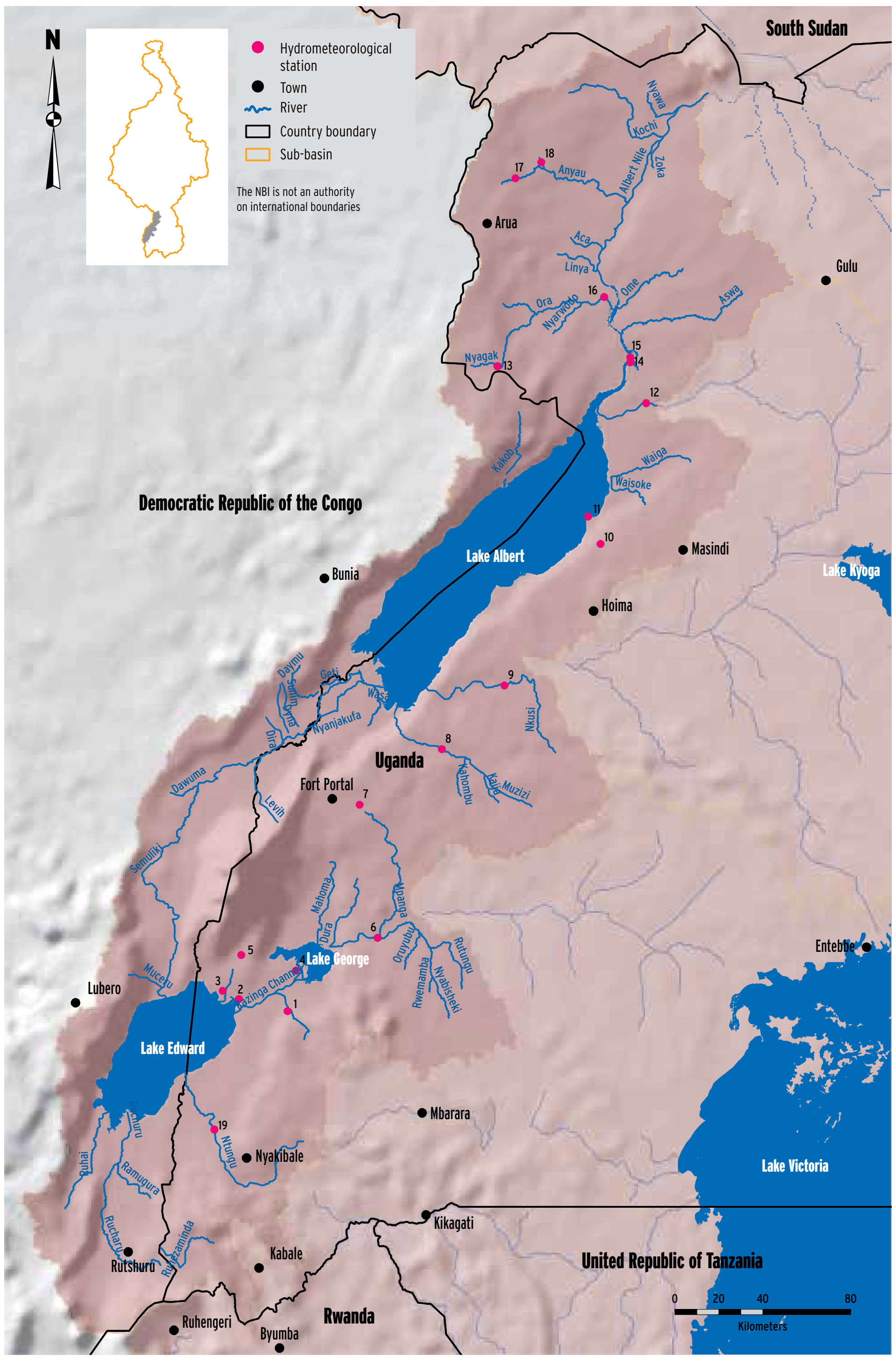
Taking ADCP readings

Hydrometric stations

There are 18 hydrometric stations in the sub-basin. The map below shows the location of the stations. The table adjacent to the map provides the list of hydrometric stations that were active at the time of the survey in 2014.

Improved monitoring of Lake Albert and Edward outflows would enhance understanding of the interaction between Victoria Nile and the Lake outflow.

Water quality monitoring in upper parts of the sub-basin requires emphasis in order to monitor and potentially avert pollution risks from oil exploration efforts there.



No	Name
1	R. Mitano at Kanungu - Rwensama
2	R. Chambura at Kichwamba
3	L. Edward at Katwe
4	R. Nyamugasani at Katwe - Zaire
5	L. George at Kasenyi
6	Nyamugasani
7	R. Mpanga at Fort Portal - Ibanda Road
8	R. Mpanga at Kampala - Fort Portal Road
9	Muzizi
10	R. Nkussi at Kyenjojo - Hoima R
11	R. Waki II at Biiso - Hoima Road
12	L. Albert at Butiaba
13	R. Kyoga Nile at Paraa
14	R. Nyagak at Nyapea
15	Albert Nile at Pakwach
16	R. Albert Nile at Panyango.
17	R. Ora at Inde - Pakwach Road
18	R. Anyau at Arua - Moyo Road
19	R. Oru at Arua - Yumbe Road

The Victoria Nile Sub-basin

The largest part of the Victoria Nile sub-basin lies in Uganda with a small part in Kenya and is the drained by the Victoria Nile once it leaves the Lake Victoria. The sub-basin has substantial hydropower potential. The average annual flow of Victoria Nile at Jinja station in Uganda is approximately 32 $10^9 m^3$. This is a sub-basin with relatively good monitoring infrastructure in the Nile Basin.


photo: Vivian Nabyonga

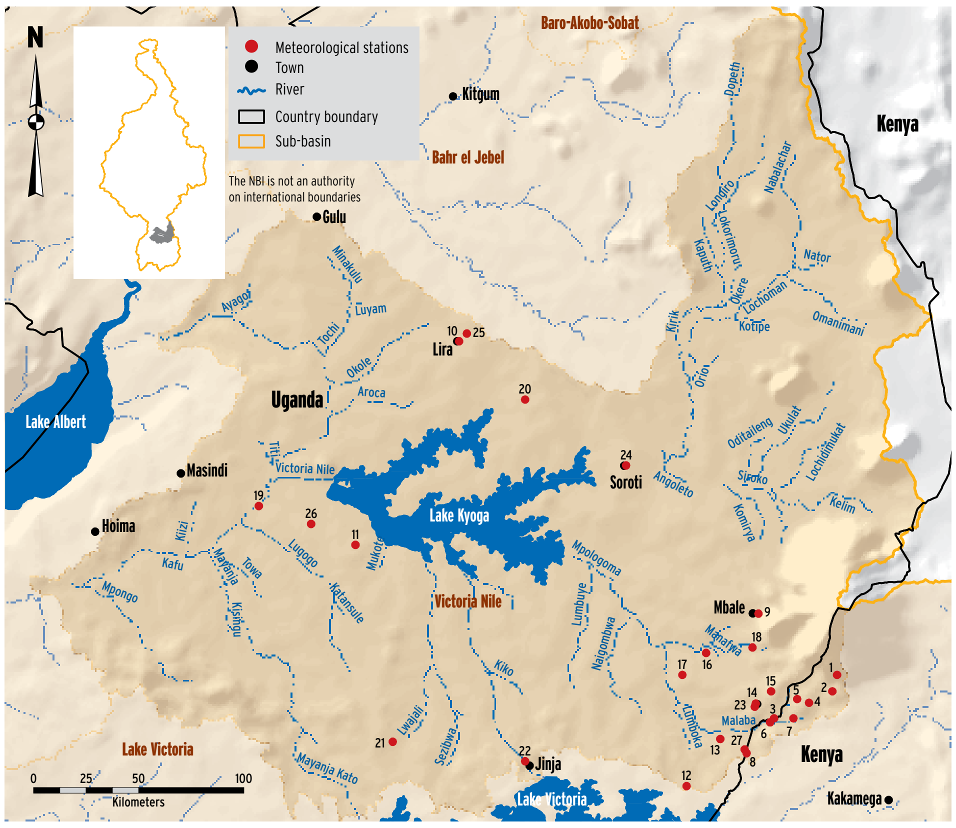
Station at River Kafu

Meteorological monitoring network

There are 48 meteorological stations in the sub-basin; distributed in Kenya (6) and Uganda (42).11 stations are full met stations. The distribution of the stations is shown in the map below.


photo: Vivian Nabyonga

Lake Kyoga at Bugondo during dry season



No	Name
1	Kimama Primary
2	Sirisia Chief's Camp
3	Lukolis Dispensary,Kakamega
4	Kolonya Boy's Sec. School
5	Angorai Chief's Centre
6	Machakusi Nursery
7	Amagoro D.o's Office
8	Alupe Cotton Research Station
9	Mbale
10	Lira
11	Nakasongola
12	Namayingo Health Centre
13	Busitema University
14	Tororo Met
15	Kwapa Sub County H/Q
16	Butaleja District H/Q
17	Budumba Health Centre
18	Manafwa Water Works
19	Kafu (Masindi)
20	Enget (Lira)
21	Namulonge Res Station
22	Jinja Met. Station
23	Tororo Met.station
24	Soroti Met Station
25	Lira Ngetta Agromet Station.
26	Nabiswera
27	Alupe Kari

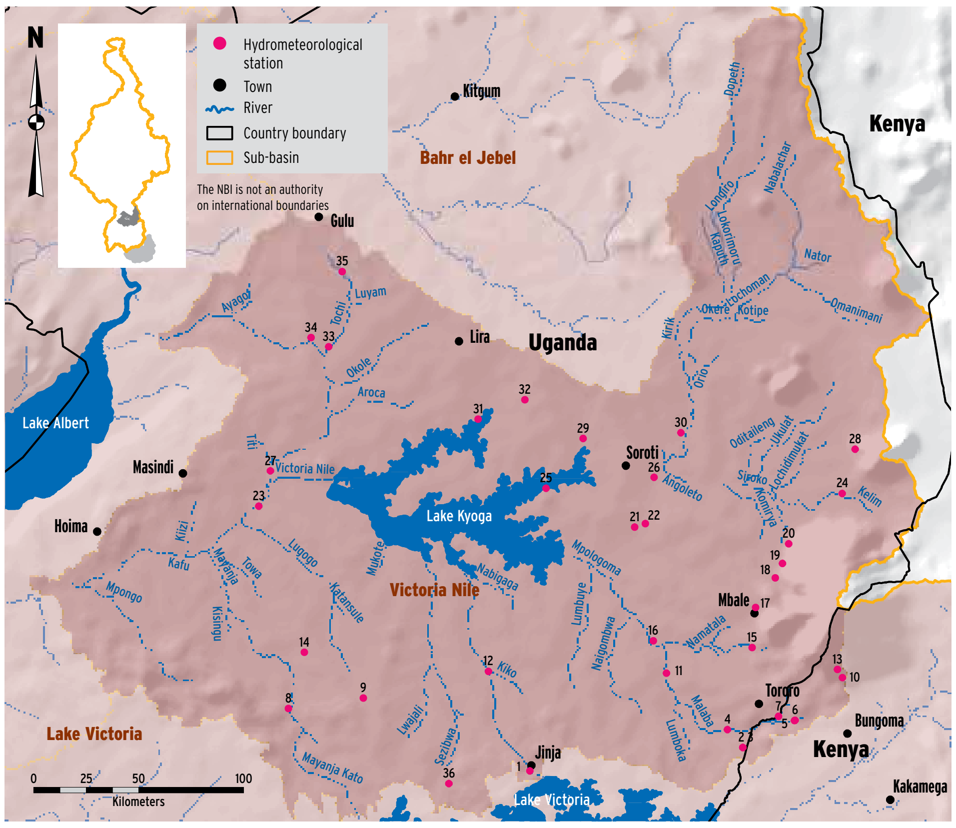

photo: Vivian Nabyonga

Lake Kyoga at Bugondo during wet season

Hydrometric stations

there are 53 hydrometric stations in the sub-basin; 6 in Kenya and 47 in Uganda. The map below shows the location of the station. The table adjacent to the map provides the list of hydrometric stations that were active at the time of the survey in 2014.

Enhancing reservoir operation of a cascade of hydropower dams (existing and planned ones) is one of the priority areas in the sub-basin. This requires enhanced real-time data collection and transmission system linked with appropriately built reservoir management system.



1	L. Victoria at Jinja Pier
2	Alupe
3	Alupe
4	R. Malaba at Jinja - Tororo Road
5	Malakisi
6	Malakisi
7	Malaba
8	R. Mayanja at Kapeeka - Kakunga
9	R. Kigwe at Semuto - Wobulenzi
10	Yala
11	R. Mpologoma at Budumba
12	R. Victoria Nile at Mbulamuti
13	Malakisi
14	Wamboli at Nabiswera - Gulu Rd
15	R. Manafwa at Mbale - Tororo Ro
16	R. Mpologoma at Tirinyi-Mbale road
17	R. Namatala at Mbale - Soroti R
18	R. Sironko at Mbale - Moroto Road
19	R. Simu at Mbale - Moroto Road
20	R. Sipi at Mbale - Moroto Road
21	R. Abuket at Kumi - Serere Road
22	R. Agu at Kumi - Serere Road
23	R. Kafu at Kampala - Gulu Road
24	R. Kelim (Greek) at Mbale - Moroto Road
25	L. Kyoga at Bugondo Pier
26	R. Kapiri at Kumi - Soroti Road
27	R. Kyoga Nile at Masindi Port
28	R. Namalu at Mbale - Moroto Rd
29	R. Omunyal Upper at Tiririri -
30	R. Akokorio at Soroti - Katakwi
31	L. Kwania at Kachung
32	R. Enget at Bata - Dokolo Road
33	R. Tochi II at Gulu - Atura Roa
34	R. Kyoga Nile at Kamdini
35	Tochi1
36	R. Sezibwa at Falls

The Lake Victoria Sub-basin

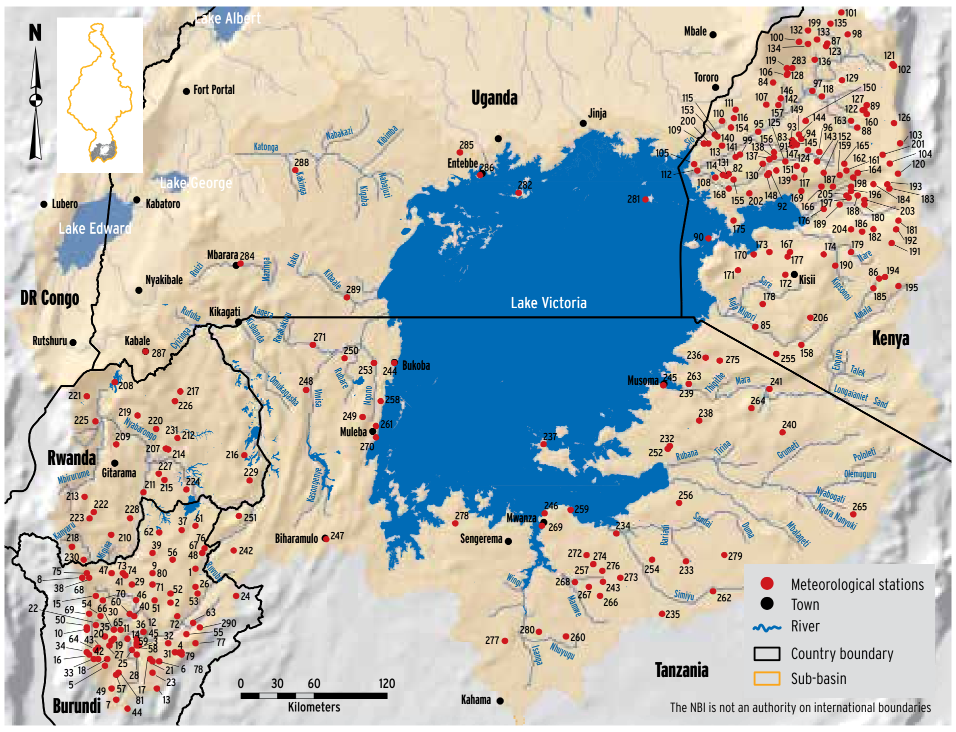
The Lake Victoria sub-basin makes the headwater of the White Nile. The Lake, with an area of about 68,000 km² offers a major regulation to the flow of Victoria Nile. Major tributaries of the Lake include the Kagera (draining parts of Burundi, Rwanda and Tanzania), Mara (originating in Kenya), Nzoiya (Kenya) and Yala (Kenya). The lake, which is a source of water for users in three countries is also used widely for navigation.


photo: Vivian Nabyonga

Station on River Kagera at Masangano

Meteorological monitoring network

There are 254 meteorological stations in the sub-basin; distributed in Burundi (31), Kenya (124), Rwanda (34), Tanzania (42) and Uganda (23). The distribution of the stations is shown in the map below.



No	Name
1	Muyinga
2	Karuzi
3	Gitega (Aero)
4	Ruyigi
5	Gisozi
6	Muriza
7	Ruvyironza
8	Rwegura
9	Nyamuswaga
10	Bugarama (B.aeronaut)
11	Giheta
12	Mugera (Paroisse)
13	Musongati
14	Gitega (Zege)
15	Teza (Nyabigondo)
16	Bukwavu
17	Burenza
18	Butora
19	Buziracanda
20	Fota
21	Gikwiye
22	Kiganda (Paroisse)
23	Mugege
24	Mugera (Cankuzo)
25	Mungwa
26	Muramba
27	Mwaro
28	Mweya
29	Ngozi (Kagoma)
30	Rutegama
31	Rutonganik
32	Butezi
33	Ijenda (Mission)
34	Ijenda (The Villag)
35	Kibumbu
36	Mugera (Lycee)
37	Mulehe
38	Munanira
39	Murehe (Mission)
40	Murongwe
41	Ngozi (Ocibu)
42	Nyakararo
43	Rusaka
44	Rutovu
45	Mashitsi
46	Burasira (Seminaire)
47	Busiga
48	Rugari (E.F.I.)
49	Bitezi (Gasibe)
50	Bugarama (Commune)
51	Bugenyuzi (Paroisse)
52	Buhiga
53	Buhinyuza
54	Bukeye (E.F.I.)
55	Bwagiriza
56	Gisanze
57	Gishubi
58	Gitega (Agri)
59	Gitega (Ndebe)
60	Gitongo
61	Kabuyenge
62	Kanyinya (E.F.I.)
63	Kayongozi
64	Kaziba
65	Kibimba
66	Kiganda (E.F.I.)
67	Kinazi
68	Matongo(Com)
69	Muramvya
70	Musema
71	Musenyi (E.F.I.)
72	Mutumba (Nyabikere)
73	Ngozi (Caprin)
74	Ngozi (College)
75	Remera
76	Rugari (Paroisse)
77	Rusengo (E.F.I.)
78	Ruyigi (Agri)
79	Ruyigi (Mission)
80	Musenyi (Paroisse)
81	Rweza (Nyangwa)
82	Siaya Atc
83	Masinde Muliro University
84	Chwele
85	Migori
86	Bomet
87	Kitale Met
88	Eldoret Airport
89	Eldoret Kapsoya Met
90	Suba Met, Rusinga Island Kaswanga Hdr. Stn
91	Kakamega Met
92	Nganyi Community Ranet
93	Kakamega Met New Site
94	Kakamega Airport
95	Mumias Sugar Factory
96	Kaimosi Farmers Training Centre
97	Lugari Forest Station
98	Kapsara Tea Factory
99	Uholo Chief's Office
100	Chorlim Adc
101	Kapenguria Wrma Office
102	Cheptongei Chief's Office
103	Kipkabus Forest Station
104	Nabkoi Forest Station
105	Bunyala Ranet Fm
106	Mukuyuni Dc's Office
107	Bungoma Water Yard
108	Kadenge Yala Swamp
109	Nangina Girls H. School
110	Nambale Agric. Office
111	Kwangamor Primary School
112	Bunyala Irrigation Scheme.
113	Wakhungu Nursery-Samia
114	Kaliwa Primary
115	Matayos Youth Polytechnic
116	Madende Secondary
117	Erusui Secondary
118	Lugari Water Yard
119	Kapsokwony Water Yard
120	Timboroa Forest
121	Chebara Dam
122	Eldoret Water Yard
123	Kitale Water Yard
124	Kakamega Forest Station
125	Ebusiratsi Health Centre.
126	Kaptagat Forest Station
127	Eldoret,Institute Of Agriculture
128	Kimilili Agric. Department.
129	Chief's Centre Kongoni
130	Yala Tn
131	Bondo Water Supply
132	Chorlim A.d.c.
133	A.d.c. Namandala Farm
134	Nakami Farm No.1
135	Leissa Farm,Kitale
136	Kitale Gloucester Vale Estate
137	Khwisero Met Station
138	Mwihila Secondary School,Yala
139	Kigama Primary School
140	Sega Primary School
141	Oholo Chief's Camp.
142	Malava Agiric. Station.
143	Kaimosi Tea Estate Ltd.
144	Shikusa Borstal Institution.
145	Kakamega Agromet Station
146	Bukembe
147	Eregi, St. Augustine's T.t.c.
148	Esalwa Secondary School
149	Mundoli
150	Malava Forest Guard Post.
151	Sabatia Chief's Office
152	Kabujoi Forest Station
153	Namuichula Nursery
154	Lugulu Primary School
155	Barding Harambee Secondary Sch.
156	Bukura Institute Of Agriculture
157	Nzoia Sugar Factory Bungoma
158	Shiakungu Sec. School
159	Nandi Hills, Savani Estate
160	Eldoret Kenya Coop. Creameries
161	Siret Tea Co. Ltd.,Nandi
162	Nandi Hills,Kibweri Tea Estate
163	Kapsaret Forest Station ,Eldoret
164	Kimwani A.d.c. Farm
165	Kapkeben Chemoni Estate
166	Miwani Sugar Section III
167	Oyugis Agricultural Station
168	Bondo Water Supply
169	Kibos Cotton Experimental Sta.
170	Homabay Farmers Training Centre
171	Lambwe Forest Station
172	Wanjare Chief's Camp
173	Ndiru Chief's Camp
174	Kebabe Primary School
175	Madiany Chief's Office
176	Masaka Apundo's Farm
177	Nyabola Girl's Secondary School
178	South Nyanza Sugar Factory
179	Kaminjeiwet Secondary School
180	Koru Homa Lime Co' Ltd
181	Londian, Keresoi Forest Station
182	Kericho Tea Research Foundation
183	Maragat Forest Station
184	Tenderet Tea Estate
185	Bomet Water Supply
186	Hail Research Station Kericho
187	Chemase Cane Grow
188	Mombwo Sugar Belt Co.
189	Awasi School
190	Aroket Tea Estate Sotik
191	Ndoinet Forest Station
192	Saino Forest Station
193	Tendeno Forest Station
194	Nyangores Forest Station
195	Narotia Forest Station
196	Achego Primary School
197	God Abuoro Primary School
198	Ogen Primary School
199	Naluwa Farm Endebess
200	Nangina Catholic Mission
201	Burnt Forest Agric. Station
202	Akala Dispensary
203	Koru, Coffee Board Sub-Station
204	Cheptenye Secondary School
205	Makindu Pri. School, Muhoroni
206	Kilgoris Divissional Agr.office
207	Kigali Aero
208	Ntaruka
209	Bakokwe
210	Butare Aero
211	Gihinga
212	Gikomero
213	Kaduha
214	Kanombe
215	Mayange
216	Ndego
217	Ngarama
218	Nyabimata
219	Rulindo
220	Rutongo
221	Busogo-Isae
222	Cyanika
223	Gikongoro Met
224	Karama Kilimbi
225	Muramba Paroisse
226	Nyagahanga Efa
227	Nyamata
228	Nyamiyaga
229	Nyarubuye
230	Runyombyi
231	Kigali Aero
232	Bunda/ Bitaraguru Met. Station
233	Kidinda Met. Station
234	Magu Met. Station
235	Maswa Met. Station
236	Randa Met. Station
237	Ukerewe Met. Station
238	Buhemba Met. Station
239	Kuruya Met. Station
240	Mugumu Met. Station
241	Nyabusara Met. Station
242	Rulenge Met. Station
243	Ngudu Met. Station
244	Bukoba
245	Musoma
246	Mwanza
247	Biharamulo
248	Kayanga Met. Station
249	Kishanda Met. Station
250	Kyakakera Met. Station
251	Ngara
252	Bitaraguru P/School
253	Bukoba Maji (Yard)
254	Busulwangili P/School
255	Busweta P/School
256	Bwai P/School
257	Chanongu P/School
258	Izigo
259	Kayenze P/School
260	Kikubiji P/School
261	Kikuku
262	Kisesa P/School
263	Kuruya P/School
264	Lukuba Island
265	Mugumu P/School
266	Mwabagole P/School
267	Mwadubi P/School
268	Mwanangwa P/School
269	Mwanza Maji (Yard)
270	Nshambya
271	Nyakanyasi
272	Sumve High School
273	Tallaga P/School
274	Tallo Secondary School
275	Utegi P/School
276	Walla P/School
277	Kharumwa P/School
278	Nyehunge P/School
279	Sagata P/School
280	Zunzuli P/School
281	Lolui
282	Kome
283	Molo Sub County H/Q
284	Mbarara Met Station
285	Mpanga Forest Statio
286	Entebbe Intl Airport
287	Kabake Met Station
288	Lwemiyaga
289	Kakuto
290	Cankuzo (Projet)

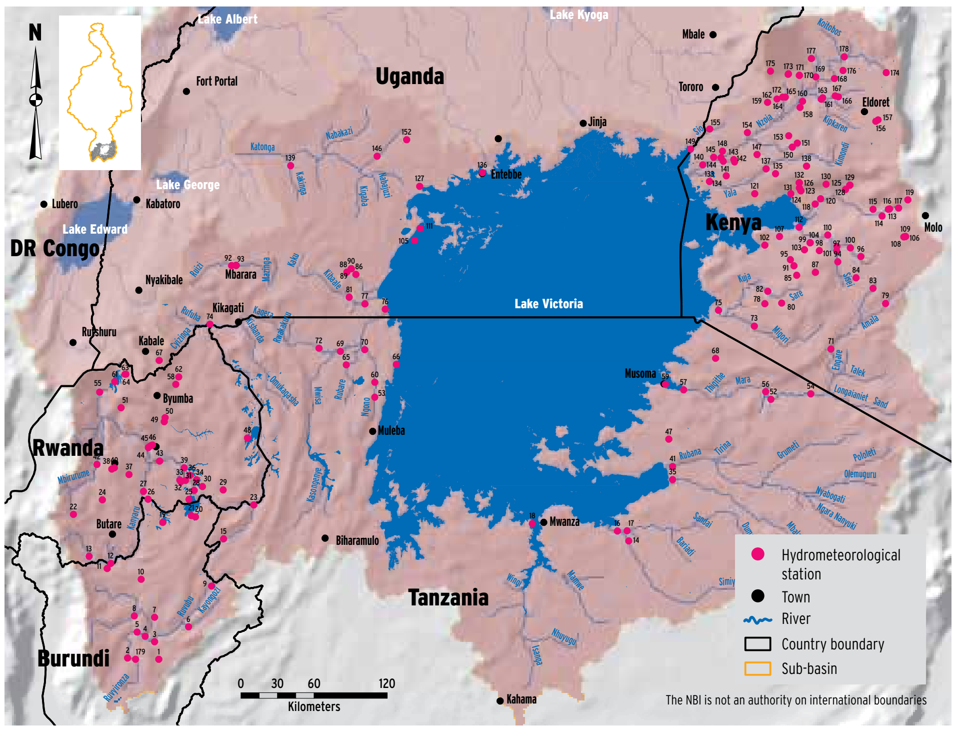
photo: Nile-SEC

Entebbe station

Hydrometric stations

There are 158 hydrometric stations in the sub-basin; 14 in Burundi (in Kagera catchment), 87 in Kenya, 36 in Rwanda (Kagera catchment), seven in Tanzania and four in Uganda. The map below shows the location of the stations. The table adjacent to the map provides the list of hydrometric stations that were active at the time of the survey in 2014.

Monitoring of water quality and lake water levels are two priority areas for strengthening the hydrometric monitoring system in the Lake Victoria Sub-basin. In the Kagera, sediment monitoring is a priority.



No	Name
1	Nyakijanda (Buhoro K10)
2	Ruvyironza (Muyange)
3	Nyabaha (Mubuga)
4	Ruvubu (Gitega)
5	Ruvyironza (Kibaya)
6	Kayongozi (Nyankanda)
7	Ndurumu (Shombo)
8	Mubarazi (Murongwe)
9	Ruvubu (Muyinga)
10	Nyamuswaga (Gisha)
11	Kayave (Mparamirundi
12	Rte Butare/Ngozi (Akanyaru)
13	Kibeho (Akanyaru)
14	Simiyu River at Lumeji
15	Ruvuvu/Mumwendo Ferry
16	Simiyu River at M/Bridge
17	Duma River at Sayaka
18	Mwanza South Port
19	Cohoha (Kigozi)
20	Kazingiri (Nyagatare)
21	Rweru (Nyagisozi)
22	Mudasomwa (Rukarara)
23	Rusumo (Akagera)
24	Nyabisindu (Mwogo)
25	Gakindo (Lac Rweru)
26	Shell (Lac Cyohoha S)
27	Gihinga (Akanyaru)
28	Mbuye (Akagera)
29	Nduruma (Cyunuzi)
30	Rubago (Lac Sake)
31	Gashora (Lac Mirayi)
32	Mfune (Nyabarongo)
33	Gashora (Lac Rumira)
34	Rukoma (Lac Sake)
35	Mbalageti
36	Shyembe (Lac Bilira)
37	Ururumanza (Ururumanza)
38	Gihuma (Gihuma)
39	Rwinzoka (Akagera)
40	Kavumu (Rugeramigozi)
41	Grumet River at M/Bridge
42	Mwaka (Nyabarongo)
43	Kanzenze (Nyabarongo)
44	Ruliba (Nyabarongo)
45	Nemba (Nyabugogo)
46	Yanze (Yanze)
47	Suguti
48	Ihema (Ihema Lake)
49	Gaseke (Nyamabuye)
50	Rusumo (Mwange)
51	Kinoni (Base)
52	Mara River at Nyansurura
53	Ngono/Muhutwe
54	Kogatende Ranger Post
55	Nyakinama (Mukungwa)
56	Mara River at Mara Mine
57	Mara River at Kirumi Ferry
58	Nyagahanga (Warufu)
59	Musoma Port
60	Ngono/Kalebe Bridge
61	Ntaruka (Lac Bulera)
62	Ngoma (Ngoma)
63	Kamiranzovu (Kamiranzovu)
64	Rusumo (Rugezi)
65	West Ngono at Kyakakera
66	Bukoba Port
67	R. Nyakizumba at Maziba
68	Mori River at Utegi
69	Kagera/Kyaka Ferry
70	Ngono/Kyaka Rd Bridge
71	Mara
72	Kagera/Nyakanyasi
73	Migori
74	Kagitumba (Muvumba)
75	Gucha Migori
76	R. Kagera at Masangano
77	R. Bukora at Katera
78	Sare
79	Amala
80	Nyangweta
81	R. Bukora at Mutukula - Kyotera
82	Gucha
83	Nyangores
84	Kipsonoi
85	Nyakobisara
86	R. Kisoma at Mutukula - Kyotera
87	Kenyamware
88	R. Lwanda at Kyotera - Rakai Ro
89	R. Kisoma Upper Stream at Kyote
90	R. Kisoma Upper at Kyotera - Ra
91	Mogusii
92	R. Ruizi at New Waterworks
93	R. Ruizi at Mbarara Water Works
94	Kipsonoi Kapsimbiri
95	Isanda
96	Kiptiget
97	Kipsonoi
98	Eaka Kioge
99	Awach Ober
100	New Itare
101	Yurith
102	Awach Tende
103	Awach
104	Awach Kabondo
105	Mapamujugu
106	Songon
107	Awach Kabuon
108	Lower Songon
109	Ainapkoi
110	Sondu
111	Katonga at Kampala Katonga Road
112	Miriu Sondu
113	Tugenon
114	Nyando
115	Namuting
116	Nyando
117	Masaita
118	Nyando (Ahero Bridge)
119	Masaita Dam
120	Nyando
121	Awach Seme
122	Lake Victoria at Kisumu
123	Kibos
124	Kibos
125	Mbogo
126	Awach
127	R. Katonga at Kampala - Masaka
128	Ainamatua
129	Ainopsiwa
130	Great Oruba
131	Tributary of Kibos
132	Kibos
133	Yala Kadenge
134	Yala
135	Zaaba
136	L. Victoria at Entebbe Pier
137	Edzawa
138	Garagoli
139	R. Kakinga Index Catchment
140	Nzoia Ruambwa
141	Uludhi
142	Wuroya
143	Wuroya
144	Nzoia
145	Gaula
146	R. Kibimba at Kinoni - Mubende
147	Firatsi
148	Placemark
149	R. Sio at Luhalali Near Bunadet
150	Isiukhu
151	Ikhamala
152	L. Wamala at Lubajja
153	Áisasala
154	Lairi
155	Sio River
156	Endoroto
157	Ellegirini
158	Chevaywa
159	Khalaba
160	Luandeti
161	Kipkarren
162	Chwele
163	Murgusi
164	Bokoli
165	Kuywa
166	Sosiani
167	Segoit
168	Large Nzoia
169	Rongai
170	Kamakoiwa
171	Kamukoywa
172	Kimilili Springs
173	Kimilili
174	Moiben
175	Kuywa
176	Little Nzoia
177	Tongaren
178	Nzoia
179	Ruvyironza (Nyabiraba)

NILE BASIN REGIONAL HYDROMET

Challenges and Opportunities

River basin monitoring is essential for knowledge-based water resources planning, efficient water resources management, socio-economic development, and environmental sustainability. The current system of Nile Basin monitoring is inadequate where many significant hydrologic portions of the Nile Basin are either un-gauged or very sparselyt gauged even with respect to basic hydrological parameters. To address these critical gaps and improve transboundary water resource collaboration, the NBI worked with the NBI riparian countries to develop design specifications and an implementation plan for the Nile Basin Regional Hydro-meteorological Monitoring System.

Based on the individual country inclusive assessments, it was clear that each of the riparian countries had the requisite institutions established for monitoring, but that the level of professional depth and breadth of training and staffing varied, as did the hardware and software available for collecting and managing the data and actual parameters being measured. The most important gaps identified and addressed in the development of the Nile Basin Regional Monitoring Network are: significant number of stations that are outdated and out of service, inadequate equipment calibration, limited or non-existent telemetry systems, lack of adequate or modern data acquisition and management systems, and weak national water quality, groundwater and sediment monitoring programs.

Recent developments

Recognizing the importance of a functional Nile River Basin Monitoring System, NBI developed the design of a regional hydromet system that addresses the severe gaps, responds to the strategic water resource management issues that had direct bearing on the socio-economic developments within the basin, builds on existing networks – including those of IGAD-HYCOS Program – is based on international guidelines and best practices, and considers national needs and limitations.

Meteorological Network Design

The meteorological network design was driven by the spatial distribution necessary to capture the meteorological variability within the basin. A total of 322 meteorological stations are proposed for the regional network of the Nile Basin. This includes 227 stations to measure a full suite of meteorological parameters and 95 to monitor rainfall only. The full meteorological (Full Met) stations include instruments to measure precipitation, wind, air temperature, humidity, barometric pressure and solar radiation which allows for the calculation of evaporation.

Proposed meteorological network for the Nile Basin

Meteorological stations per sub-basin

Sub-basin	Area (KM²)	Regional design
Lake Victoria - Kagera	197,181	30
Lake Victoria - Kenya/Mara	49,737	31
Lake Victoria - Tanzania/Mara	71,305	22
Lake Victoria - Uganda	27,660	13
Victoria Nile	85,521	28
Lake Albert	74,819	28
Bahr el Jebel	185,364	14
Bahr el Ghazal	604,746	23
Baro-Akobo-Sobat	204,288	17
White Nile	258,803	17
Blue Nile - Upper	175,374	41
Blue Nile - Lower	132,344	13
Tekeze-Atbara	232,374	35
Main Nile	592,637	10
	Total	322

Summary of proposed meteorological network by country

Country	Active	Inactive*	New	Total	# of Stations w/	
					Full Met	Rain Only
Burundi	9	1	1	11	10	1
DR Congo	3	2	4	9	7	2
Ethiopia	82	1	0	83	74	9
Kenya	28	5	0	33	21	12
Rwanda	10	1	0	11	11	0
South Sudan	5	22	5	32	18	14
Sudan	33	18	0	51	29	22
Tanzania	21	6	0	27	22	5
Uganda	48	17	0	65	35	30
Total	239	73	10	322	227	95
% of Total	74%	23%	3%	100%	70%	30%

*Inactive Stations also include unknown or "blank" status entries originally received

Hydrological Network Design

The primary purpose of the existing hydrometric stations for the regional design would be for measuring streamflow at rivers and water level at lakes. In addition, the hydrometric design also includes locations by water quality and sediment monitoring, which typically aligns with streamflow gauging locations. The regional design proposes monitoring of both basic and advanced water quality parameters. The Nile Basin hydrometric design focuses on achieving the monitoring of transboundary water management issues. A total of 79 hydrometric stations are proposed for the regional network of the Nile Basin.

Summary of Proposed Regional Hydrometric Network by Country

Country	Active	Inactive*	New	Total	# of Stations w/	
					WQ	Sediment
Burundi	2	0	0	2	1	2
DR Congo	0	0	1	1	1	0
Ethiopia	15	0	0	15	4	14
Kenya	6	0	0	6	6	1
Rwanda	6	0	1	7	6	5
South Sudan	4	6	2	12	5	2
Sudan	12	1	0	13	9	12
Tanzania	8	0	0	8	8	6
Uganda	14	1	0	15	12	1
Total	67	8	4	79	52	43
% of Total	85%	10%	5%	100%	66%	55%

*Inactive Stations also include unknown or "blank" status entries originally received

Proposed hydrometric network map

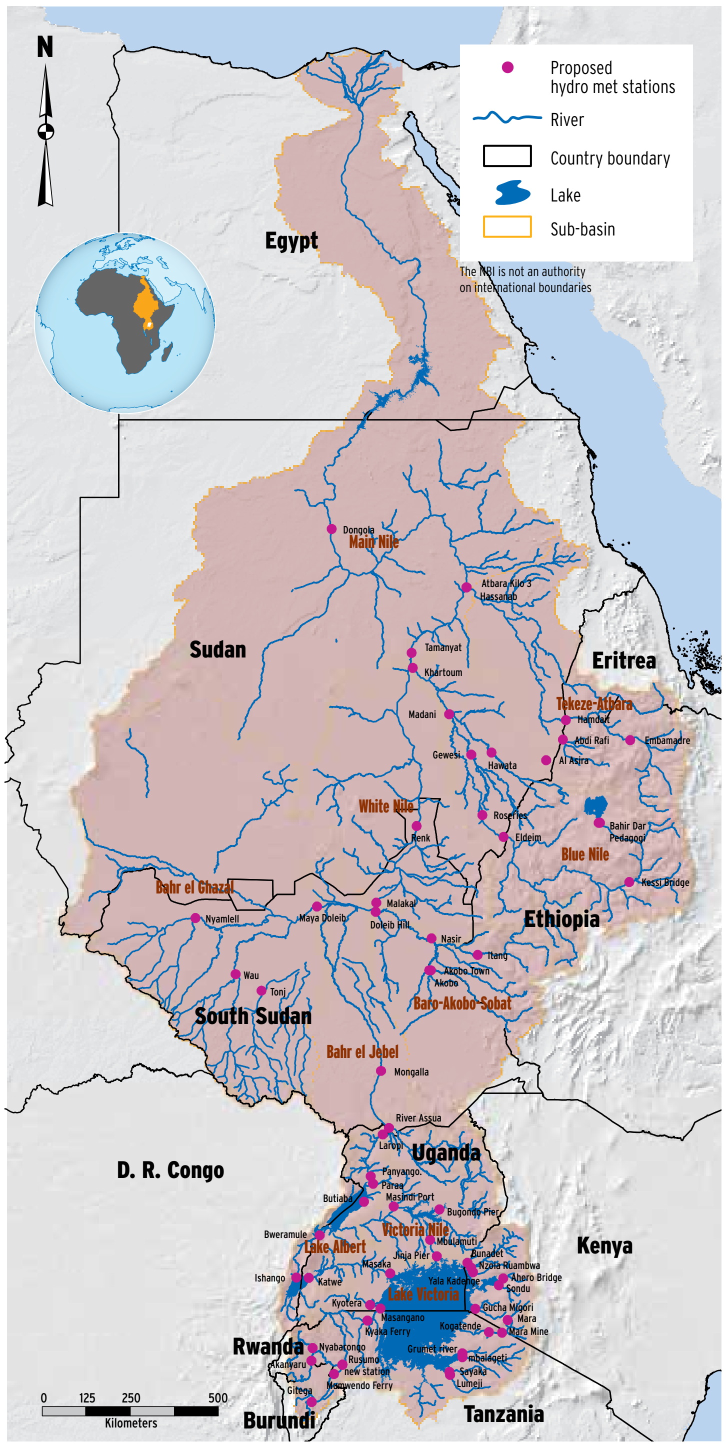



photo: Amy the Nurse/flickr.com

Meandering river in South Sudan


photo: Amy the Nurse/flickr.com

Meandering river in South Sudan

CONCLUSION

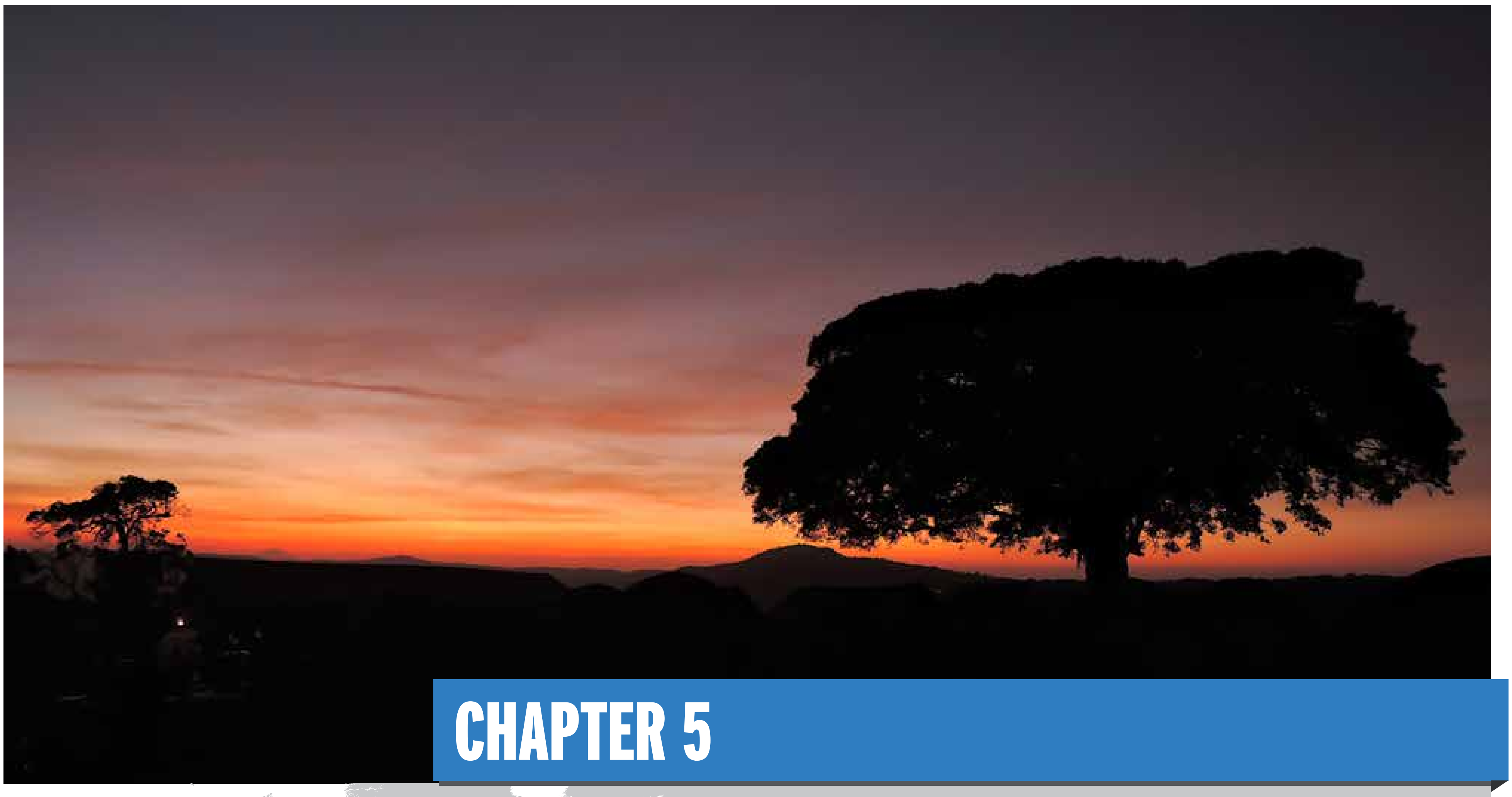
Photo: istock

The critical gap in data in the Nile Basin has been recognized early during the preparation of the first set of cooperative projects under NBI. As a result, NBI developed the Nile River Basin Monitoring Strategy to guide its activities for enhancing the monitoring system in the Nile Basin. The strategy was endorsed by the NBI governance and remains the guiding document for the design of the regional monitoring network.

Gaps in spatial coverage and time series in key catchments result in an incomplete understanding and knowledge of bio-physical conditions, setbacks in strategic assessment and water resources planning, suboptimal water management decisions, and delays in planning and execution of investment projects.

Some 14 issues were first identified by NBI Member States; these included: improved water resource planning and management; flood management; rain-fed agricultural management, irrigated agricultural management; drought management; soil erosion and sediment transport; surface water quality; groundwater management; hydropower; navigation; fisheries; watershed management; wetlands management; and climate change. These regional issues played a key role in the methodology of station selection for the regional network.

Information collected by the system will be accessible to all NBI Member States through the NBI Regional Data Management system; guided by the effective data sharing protocol among the NBI countries. NBI will compile all the data collected within the riparian countries and provide synthesized information, trends, patterns, and facts that will inform both national and regional water resources planning and management.



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.

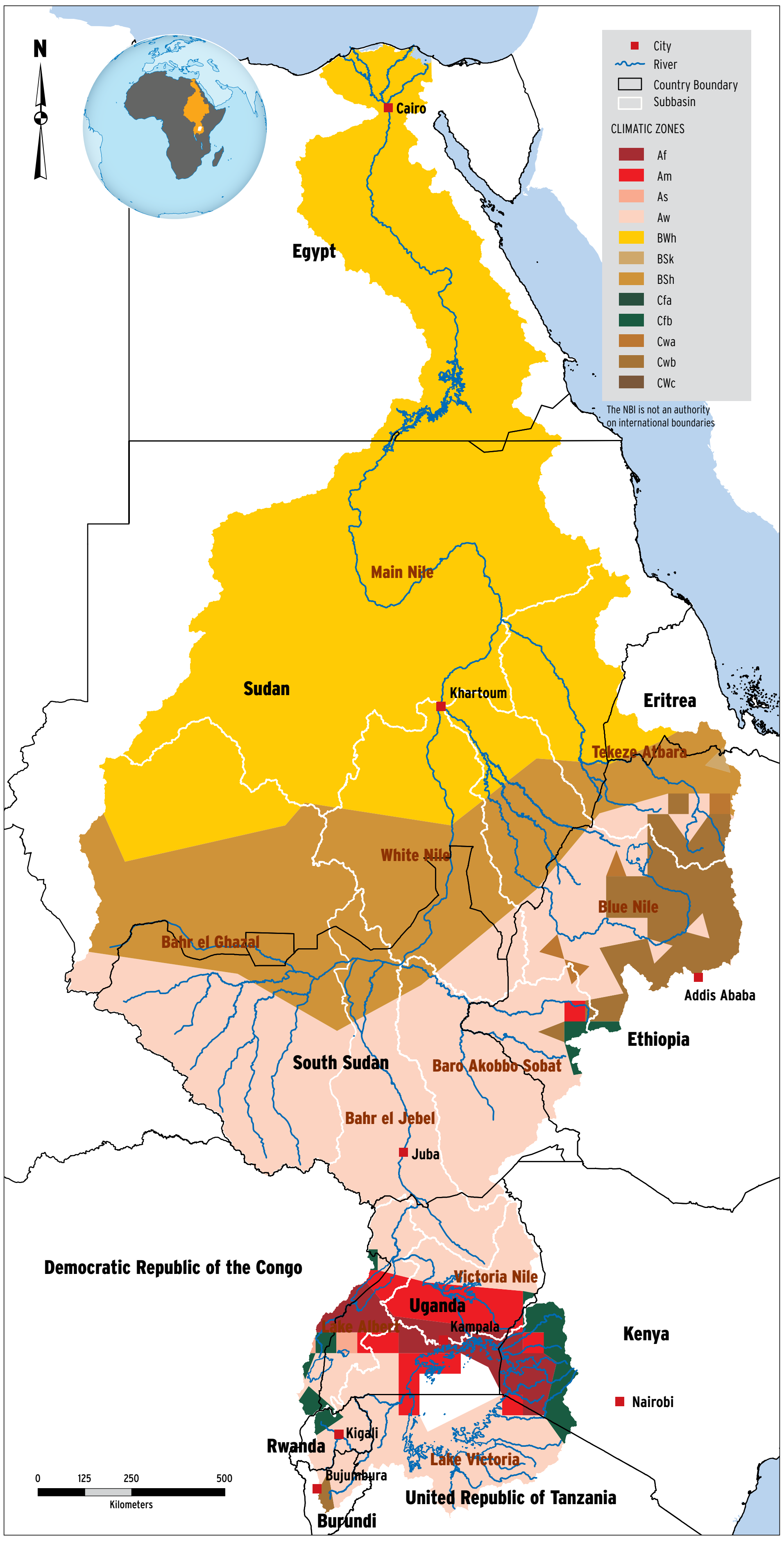
This chapter presents the main climate variables for which data/information was gathered (rainfall, temperature, relative humidity, evapotranspiration, and wind speed) mainly in terms of their monthly distribution within the Sub-basins.

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.

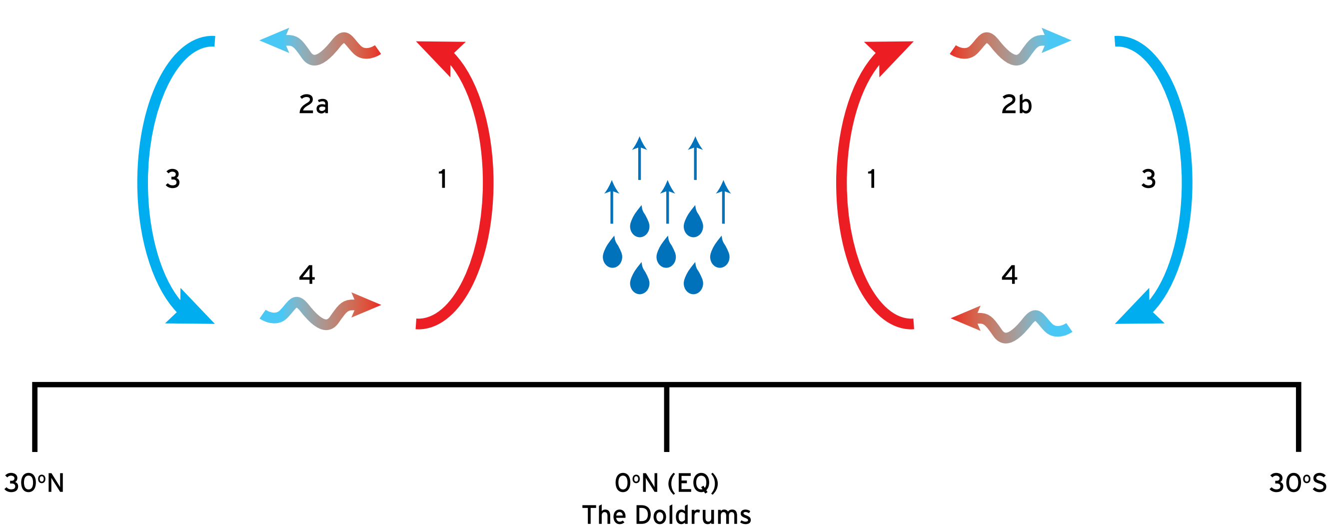
ATMOSPHERIC ACTIVITY AND INFLUENCE ON NILE CLIMATE


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 30º 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 30º 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 30º 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 20º and 40º 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.

RAINFALL

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.

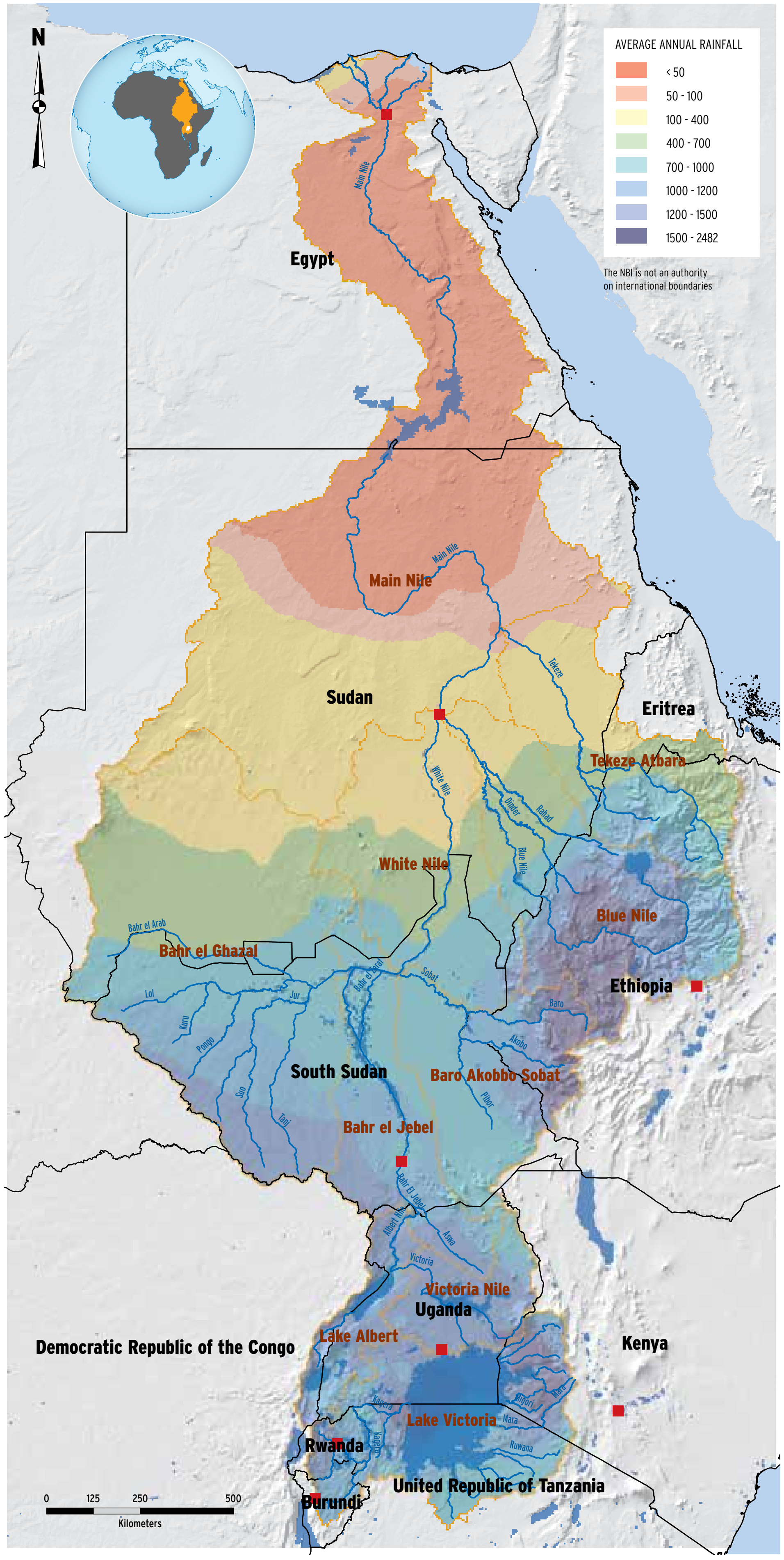
Rainfall is a major hydrological feature of the Nile basin and exhibits spatial and temporal variation at both the basin and country level. The Inter-Tropical Convergence Zone (ITCZ), which fluctuates seasonally, drives the region's rainfall regime and influences the hydrology of the Nile (Camberlin 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



The NBI is not an authority on international boundaries

Data Source: TRMM: 3B43 v7

---

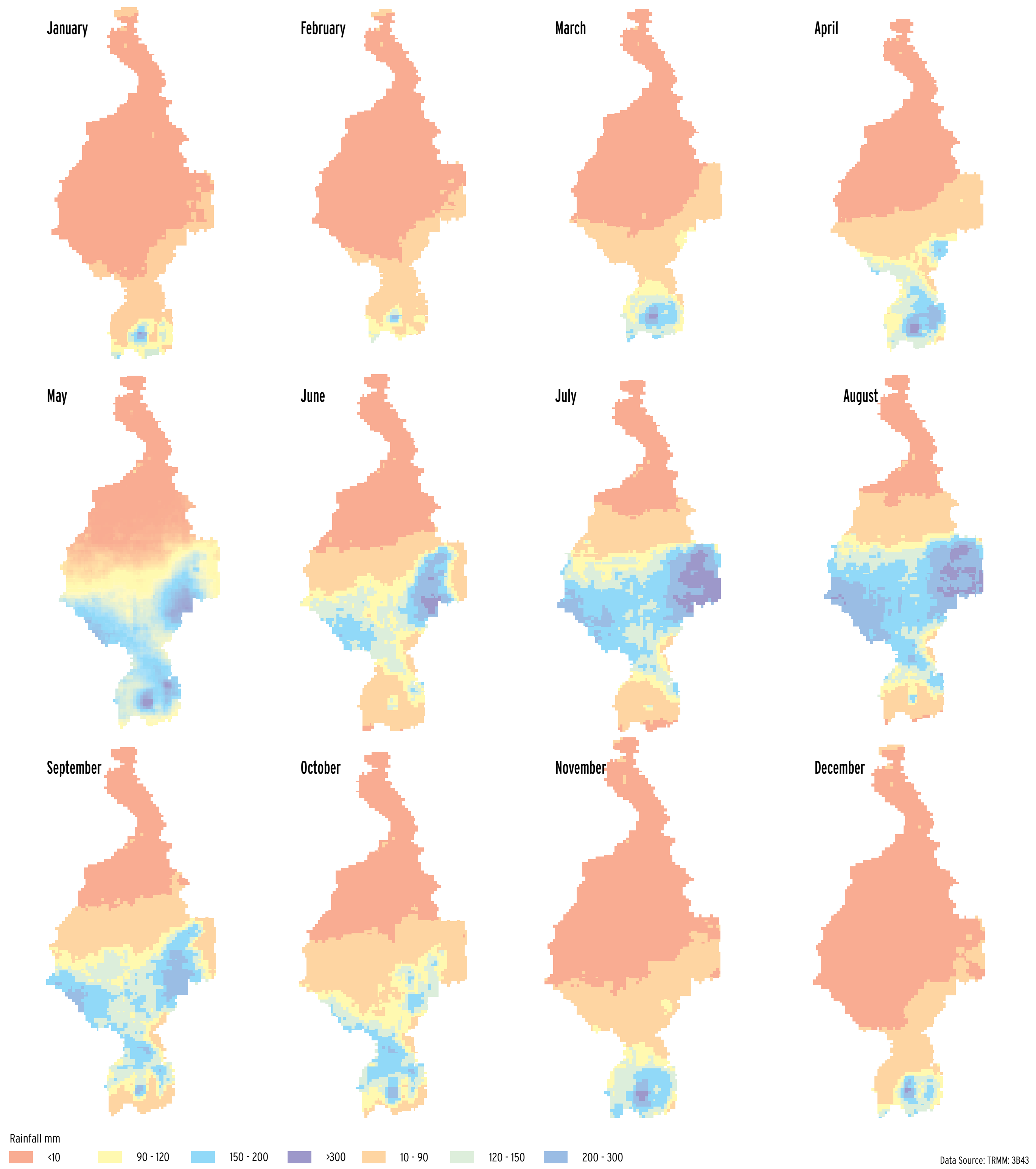
[1] Rainfall average up to 1972 for the stations available, the periods of record vary (Source: Sutcliffe and Parks 1999)
[2] CRU CL 2.0: Climate Research Unit Climatology data base version 2

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.

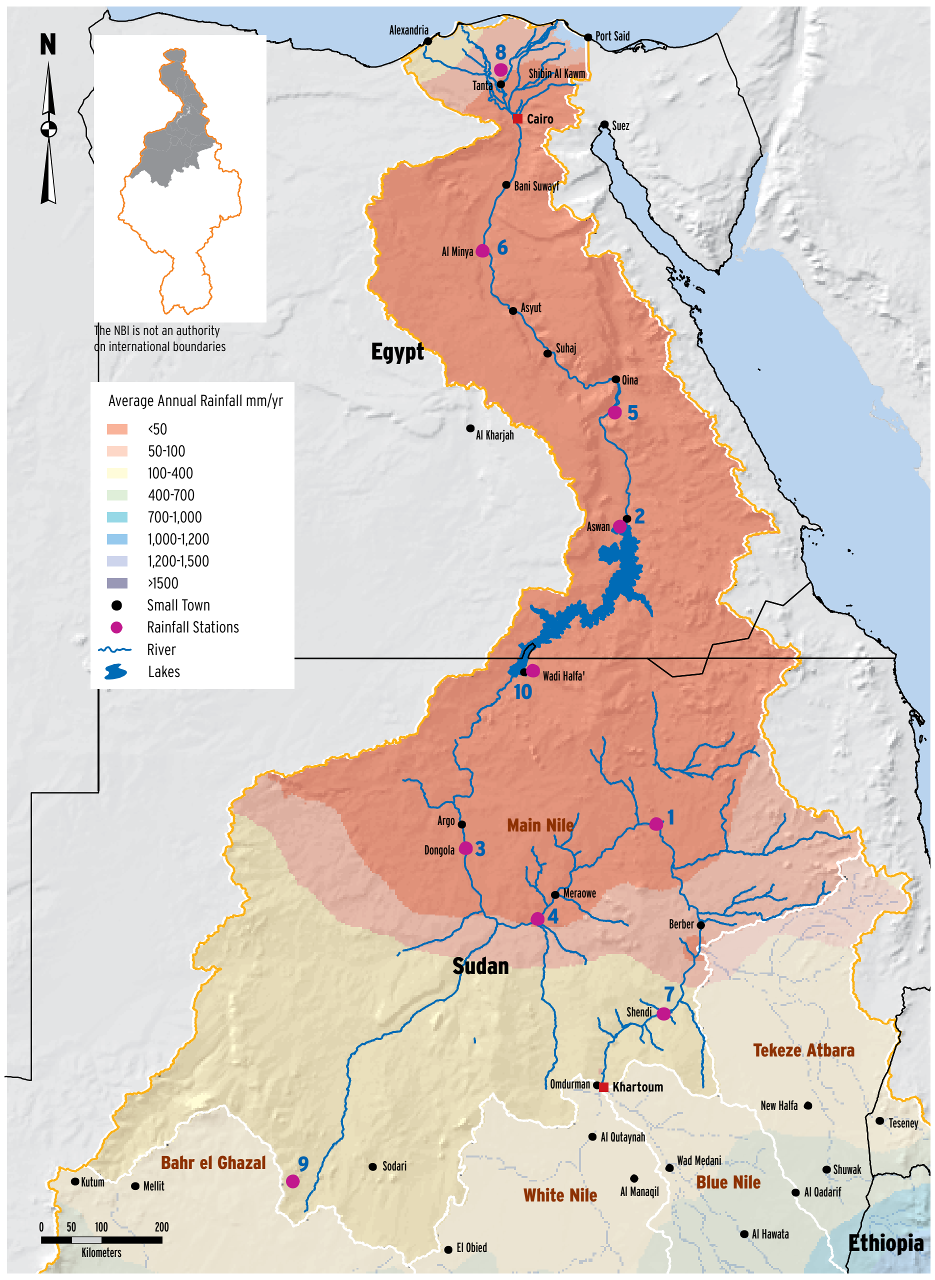
Rainfall by country

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

---

[3] Source: World Development Indicators, 2015

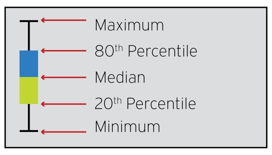
Mean monthly rainfall distribution - Main Nile Sub-basin



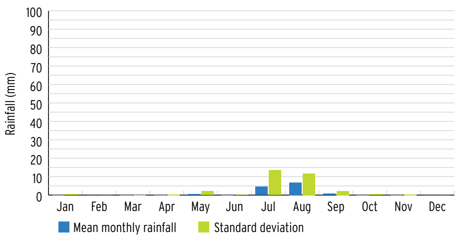
This part of the Nile basin experiences the driest conditions with very few rainfall amounts registered mainly in July and August. As you move further down to the Mediterranean Sea, there is some substantial rainfall recorded there and the rainfall pattern within the lower part of the basin is maintained.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

Station Identification

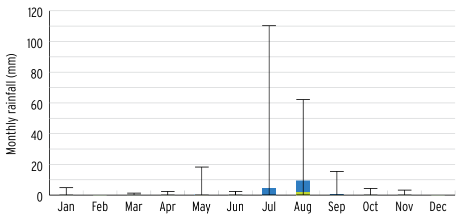
Station Name	Label No.	Record Length	Station Name	Label No.	Record Length
Abu-Hamed	1	1908-2011	Tanta	8	1904-2004
Asswan	2	1926-2011	Umm Badr	9	1902-2011
Dongola	3	1908-2011	Wadi-Halfa	10	1935-2011
Korti	4	1908-2011			
Luxor	5	1926-2011			
Minya	6	1925-1990			
Shendi	7	1937-1999			



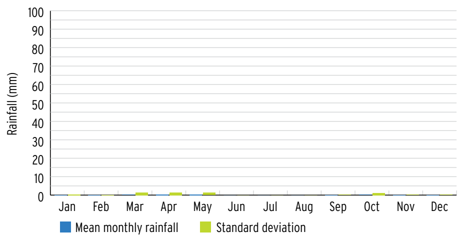
1 Mean monthly rainfall distribution - Abu Hamed



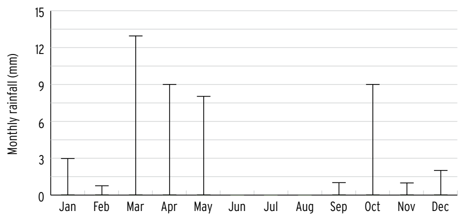
1 Monthly rainfall statistics - Abu Hamed



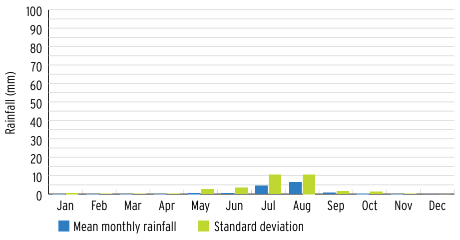
2 Mean monthly rainfall distribution - Aswan



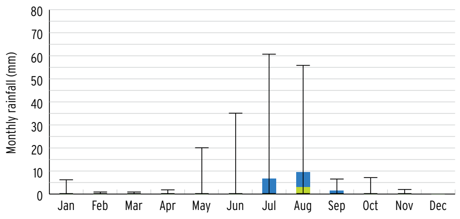
2 Monthly rainfall statistics - Aswan



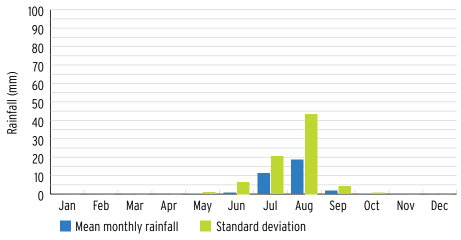
3 Mean monthly rainfall distribution - Dongola



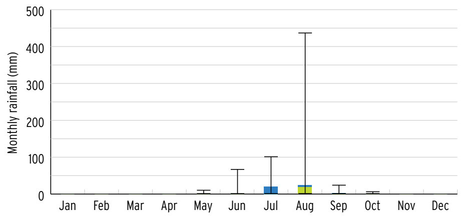
3 Monthly rainfall statistics - Dongola



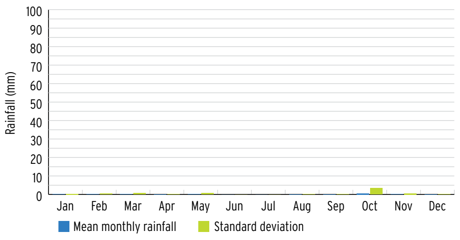
4 Mean monthly rainfall distribution - Korti



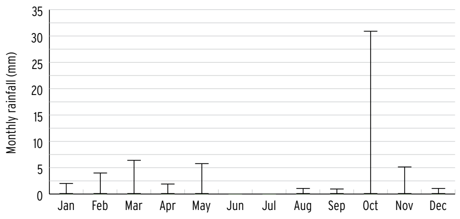
4 Monthly rainfall statistics - Korti



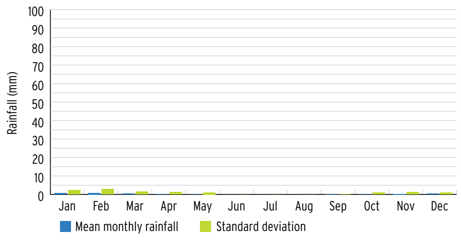
5 Mean monthly rainfall distribution - Luxor



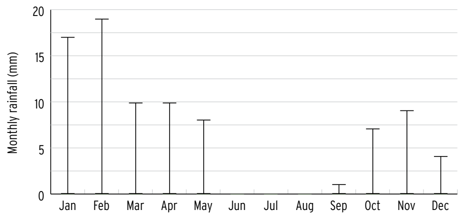
5 Monthly rainfall statistics - Luxor



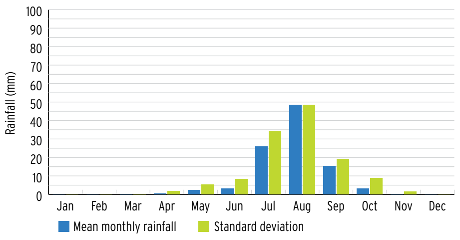
6 Mean monthly rainfall distribution - Minya



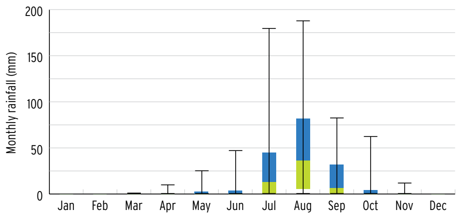
6 Monthly rainfall statistics - Minya



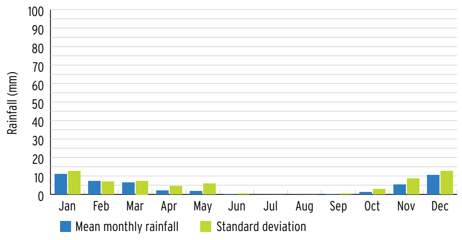
7 Mean monthly rainfall distribution - Shendi



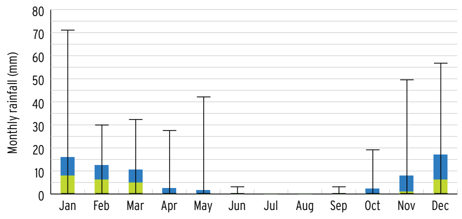
7 Monthly rainfall statistics - Shendi



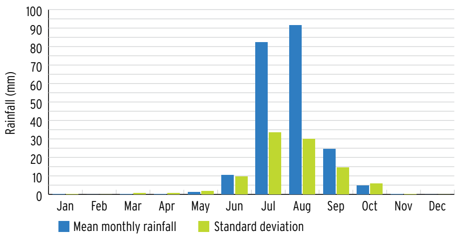
8 Mean monthly rainfall distribution - Tanta



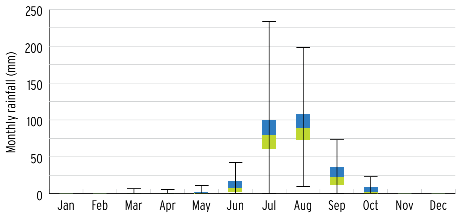
8 Monthly rainfall statistics - Tanta



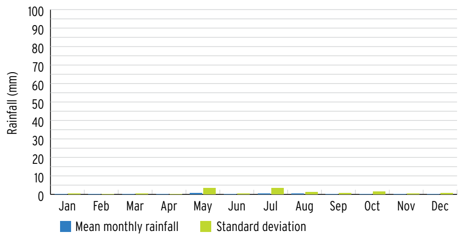
9 Mean monthly rainfall distribution - Umm Badr



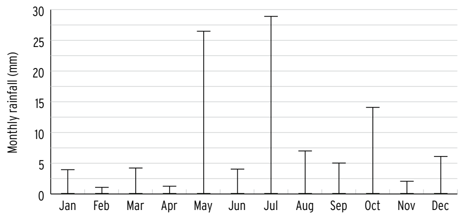
9 Monthly rainfall statistics - Umm Badr



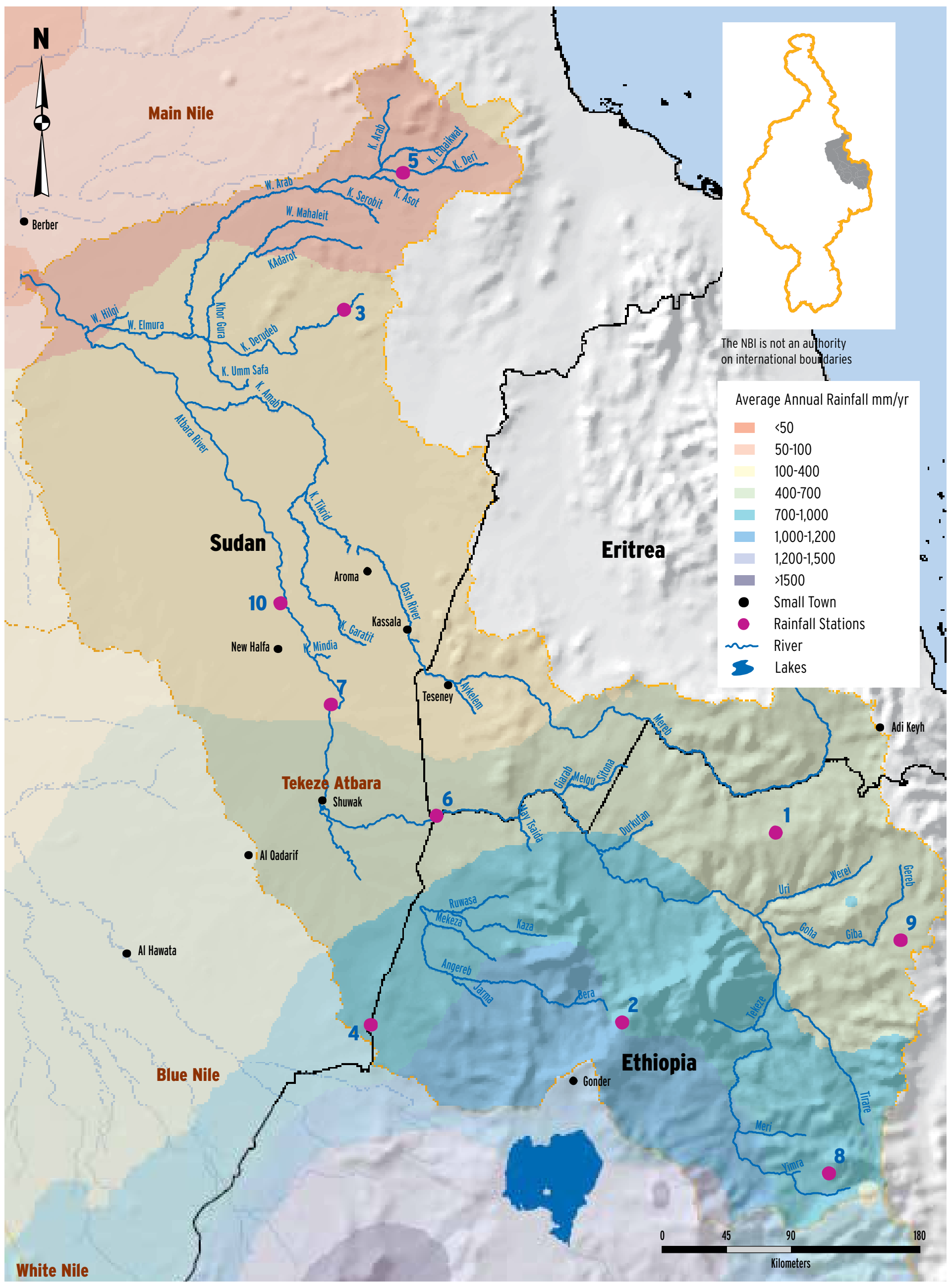
10 Mean monthly rainfall distribution - Wadi Halfa



10 Monthly rainfall statistics - Wadi Halfa



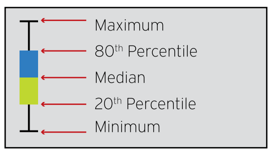
Mean monthly rainfall distribution – Tekeze Atbara Sub-basin



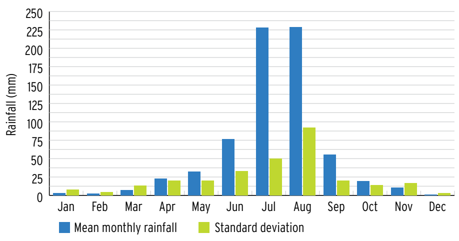
The Tekeze Atbara Sub-basin experiences rainfall in its upper part only in little amounts mainly in the months of July and august, and is relatively dry the other part of the year. The lower part of the Sub-basin lies in Sudan and is mainly dry with very few rainfall amounts recorded in the wet season.

Station Identification

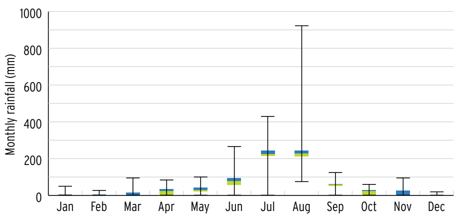
Station Name	Label No.	Record Length	Station Name	Label No.	Record Length
Axum	1	1920-2001	Lalibela	8	1973-1989
Dabat	2	1970-1988	Mekele	9	1912-2002
Derudeb	3	1912-1991	New-Halfa	10	1901-2011
Gallabat	4	1901-2007			
Haiya	5	1912-1991			
Humera	6	1901-2011			
Khashm El Girba	7	1901-2000			



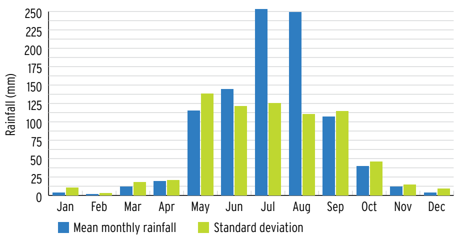
1 Mean monthly rainfall distribution - Axum



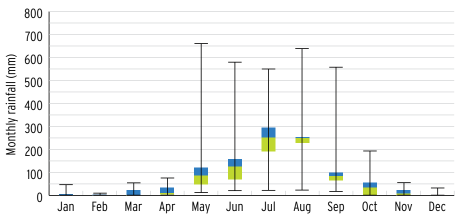
1 Monthly rainfall statistics - Axum



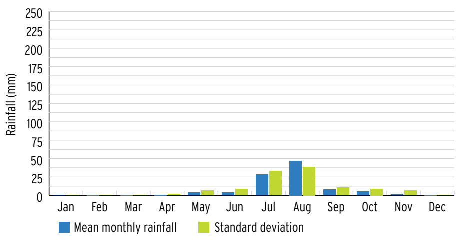
2 Mean monthly rainfall distribution - Dabat



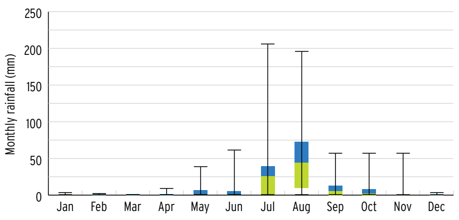
2 Monthly rainfall statistics - Dabat



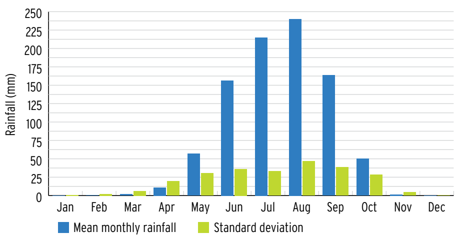
3 Mean monthly rainfall distribution - Derudeb



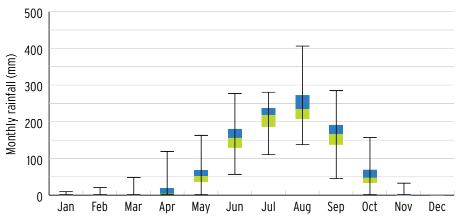
3 Monthly rainfall statistics - Derudeb



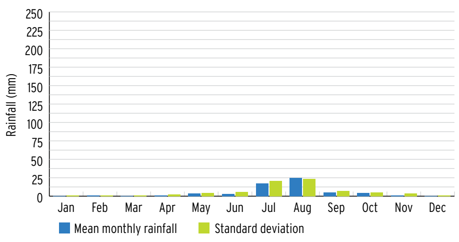
4 Mean monthly rainfall distribution - Gallabat



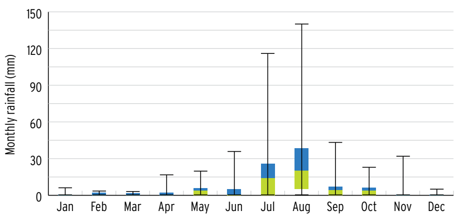
4 Monthly rainfall statistics - Gallabat



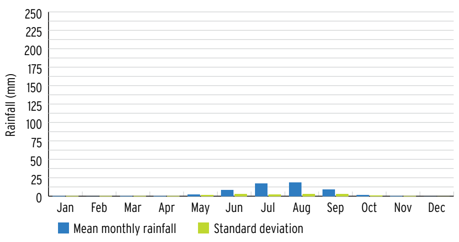
5 Mean monthly rainfall distribution - Haiya



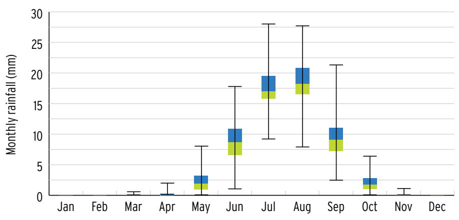
5 Monthly rainfall statistics - Haiya



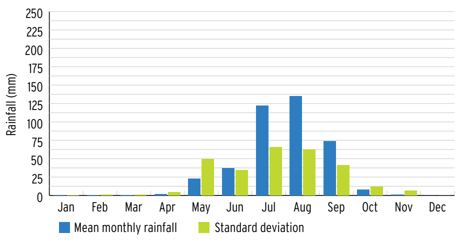
6 Mean monthly rainfall distribution - Humera



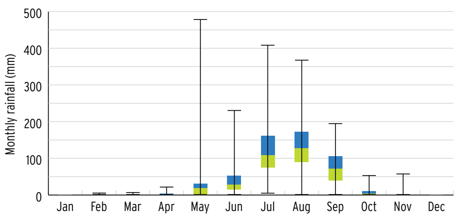
6 Monthly rainfall statistics - Humera



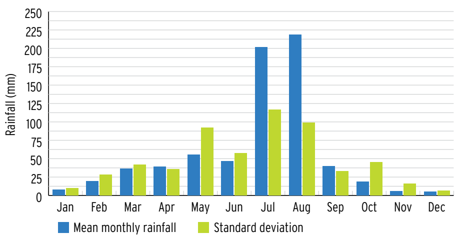
7 Mean monthly rainfall distribution - Khashm El Girba



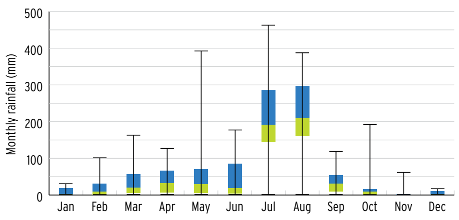
7 Monthly rainfall statistics - Khashm El Girba



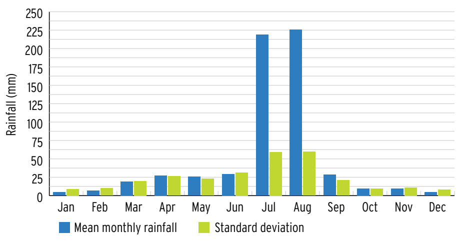
8 Mean monthly rainfall distribution - Lalibea



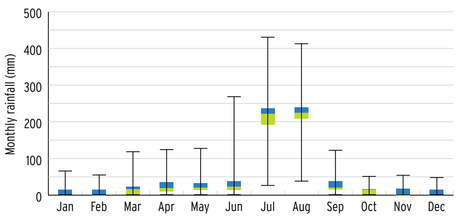
8 Monthly rainfall statistics - Lalibela



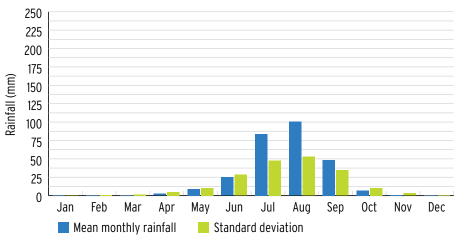
9 Mean monthly rainfall distribution - Mekele



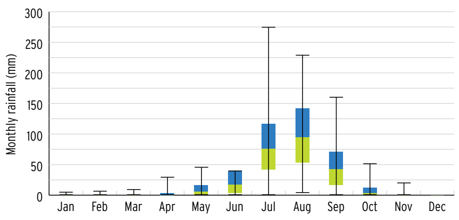
9 Monthly rainfall statistics - Mekele



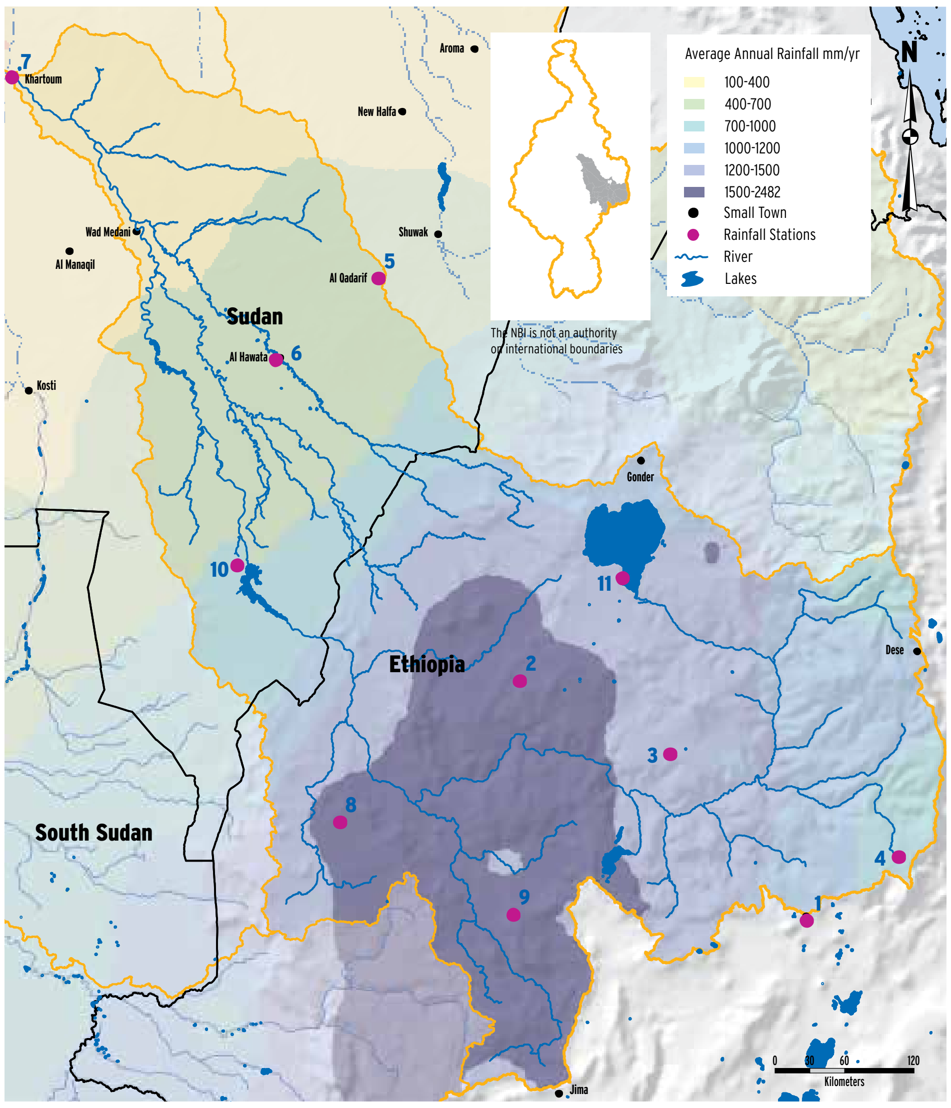
10 Mean monthly rainfall distribution - New Halfa



10 Monthly rainfall statistics - New Halfa



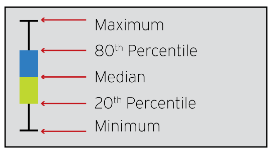
Mean monthly rainfall distribution – Blue Nile Sub-basin



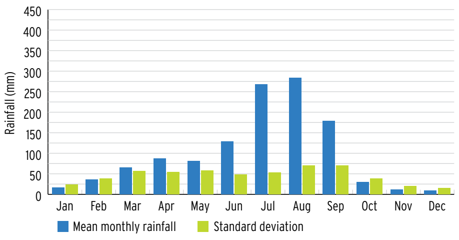
The upper part of Blue Nile records rainfall almost all year round in varying amounts but the main season occurs between May – October when very high amounts of rainfall are recorded. As you move downstream into Sudan, the amounts recorded diminishes almost registering rainfall only in the wet season 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

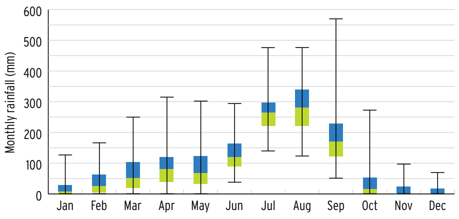
Station Name	Label No.	Record Length	Station Name	Label No.	Record Length
Addis Ababa	1	1900-2011	Mendi	8	1903-2011
Chagni	2	1903-2001	Nekemtewelega	9	1903-2001
Debremarcos	3	1953-2001	Roseires	10	1903-2001
Debresina	4	1900-2011	Zege	11	
El Gedarif	5	1901-2011			
Hawata	6	1900-2011			
Khartoum	7	1900-2011			



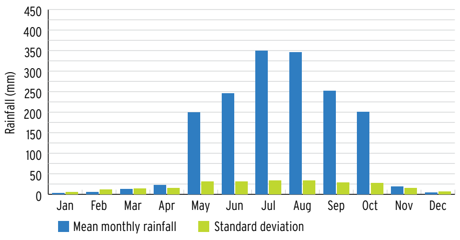
1 Mean monthly rainfall distribution - Addis Ababa



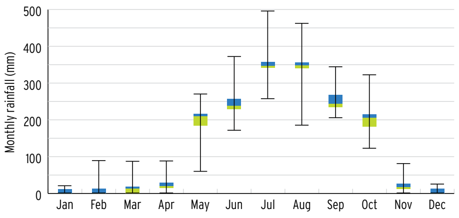
1 Monthly rainfall statistics - Addis Ababa



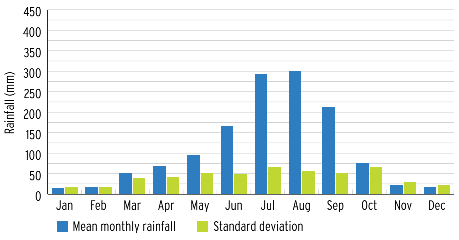
2 Mean monthly rainfall distribution - Chagni



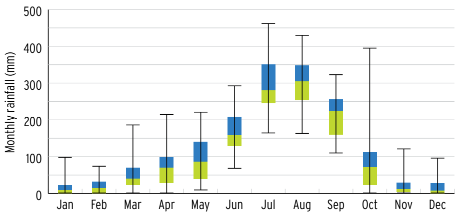
2 Monthly rainfall statistics - Chagni



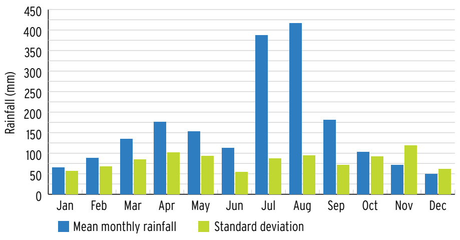
3 Mean monthly rainfall distribution - Debremarkos



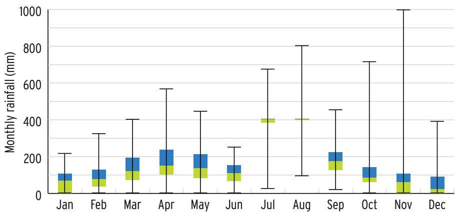
3 Monthly rainfall statistics - Debremarkos



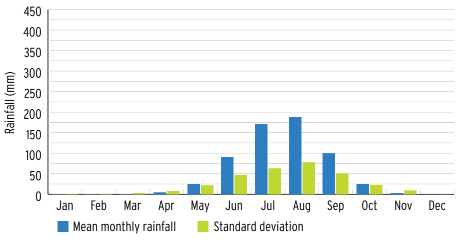
4 Mean monthly rainfall distribution - Debresina



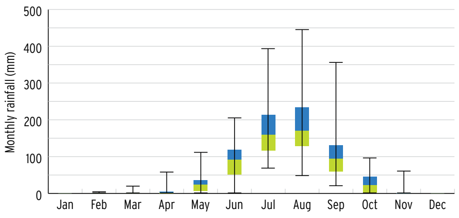
4 Monthly rainfall statistics - Debresina



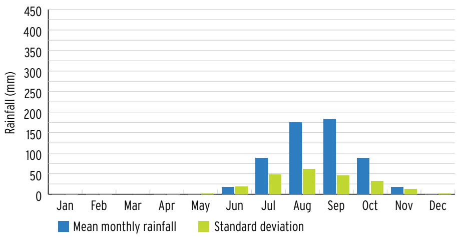
5 Mean monthly rainfall distribution - El Gedarif



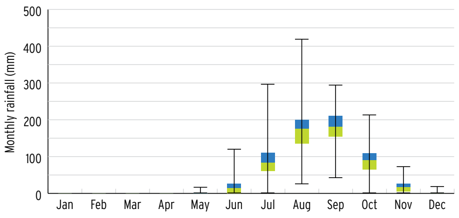
5 Monthly rainfall statistics - El Gedarif



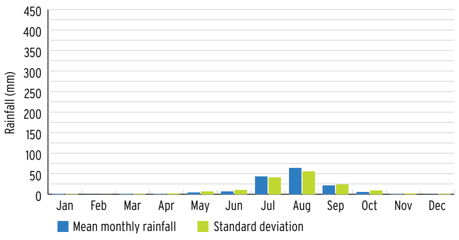
6 Mean monthly rainfall distribution - Hawata



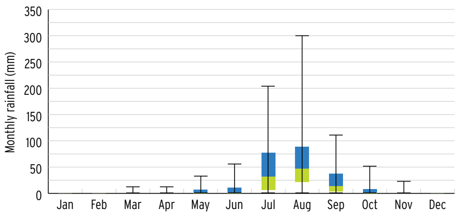
6 Monthly rainfall statistics - Hawata



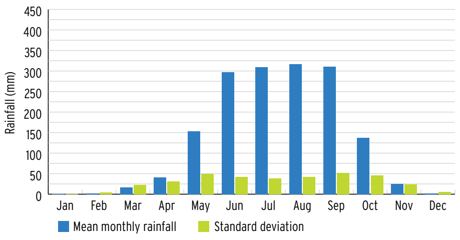
7 Mean monthly rainfall distribution - Khartoum



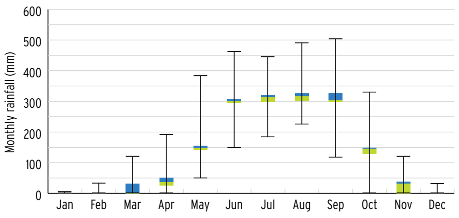
7 Monthly rainfall statistics - Khartoum



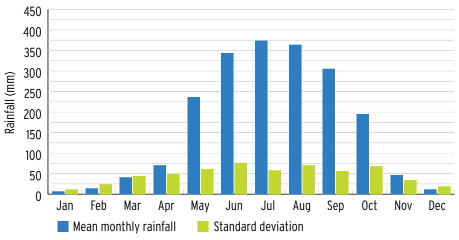
8 Mean monthly rainfall distribution - Mendi



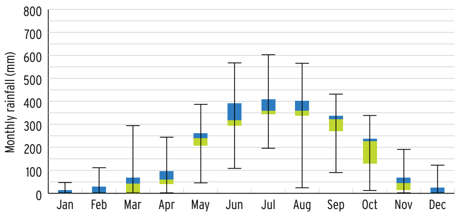
8 Monthly rainfall statistics - Mendi



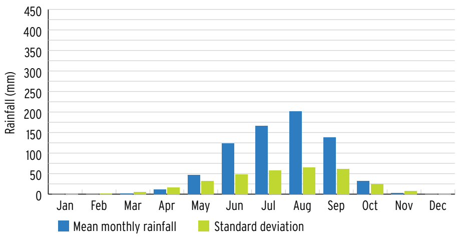
9 Mean monthly rainfall distribution - Nekemteweleg



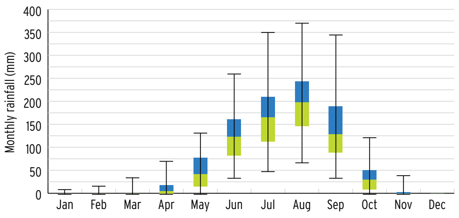
9 Monthly rainfall statistics - Nekemteweleg



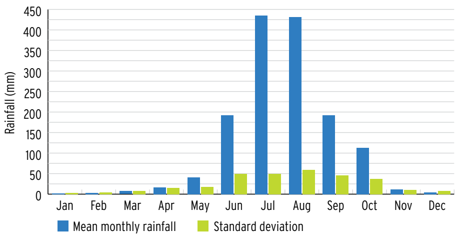
10 Mean monthly rainfall distribution - Roseires



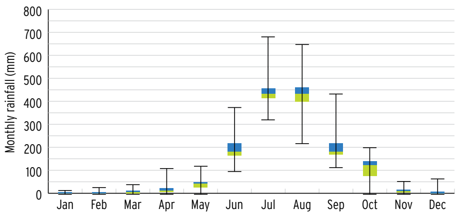
10 Monthly rainfall statistics - Roseires



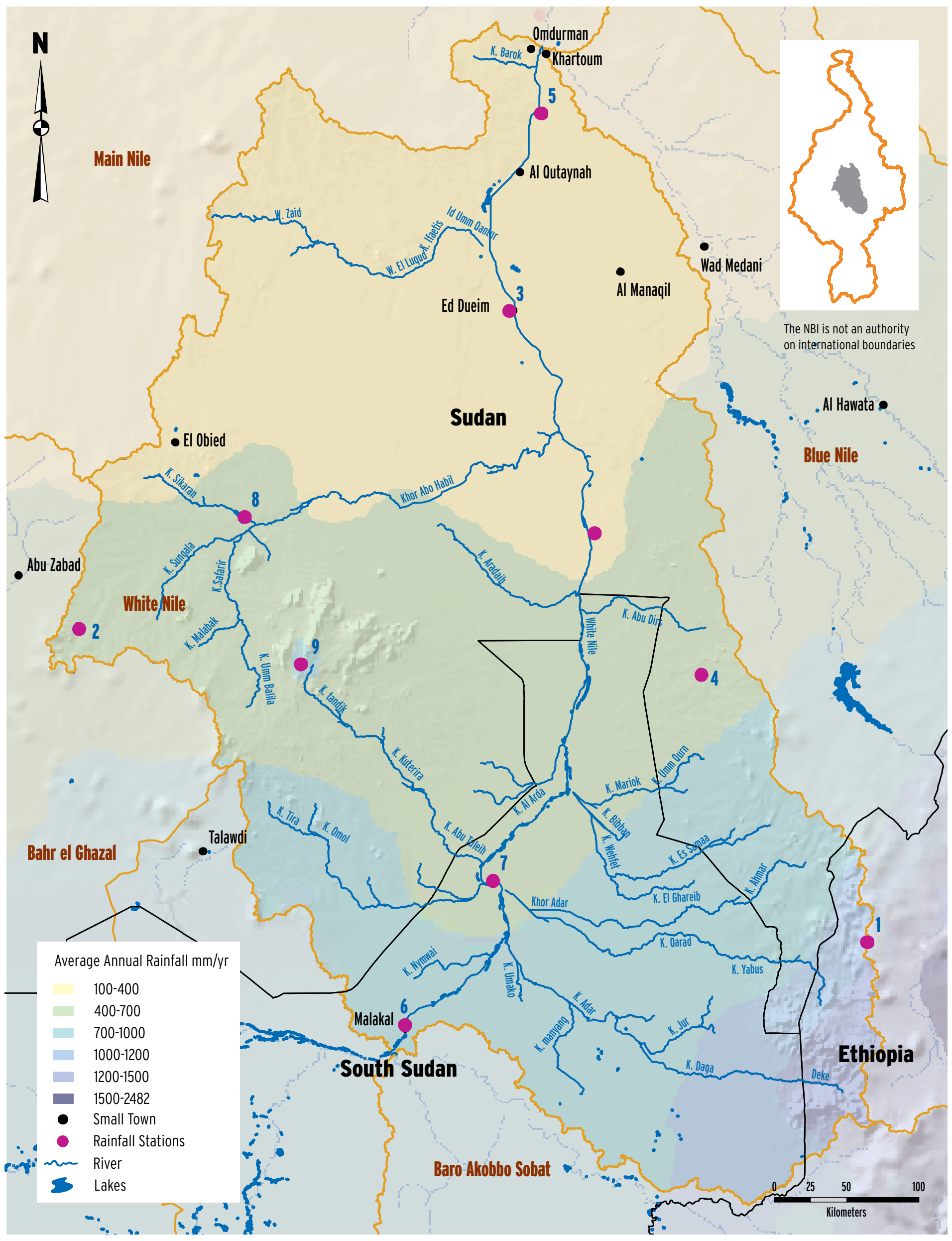
11 Mean monthly rainfall distribution - Zege



11 Monthly rainfall statistics - Zege



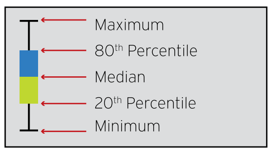
Mean monthly rainfall distribution – White Nile Sub-basin



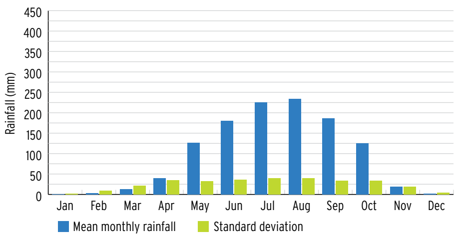
The Nile basin rainfall gets reduced towards downstream the basin. In the White Nile (which covers parts of north-eastern South Sudan, a very small part of south western part of Ethiopia and the south part of Sudan), there is generally low rainfall recorded in the single wet season; May – October with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

Station Identification

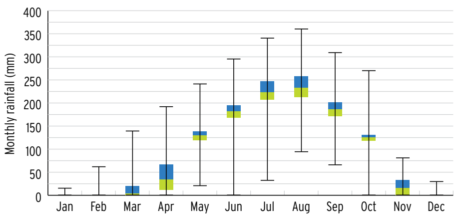
Station Name	Label No.	Record Length	Station Name	Label No.	Record Length
Asosa	1	1903-2001	Melut	7	1900-1984
Dilling	2	1909-2011	Rahad	8	1902-2011
Ed Dueim	3	1900-2011	Rashad	9	1909-2011
J.Guli	4	1903-2001			
Jebel Aulia	5	1900-2011			
Malakal	6	1909-2004			



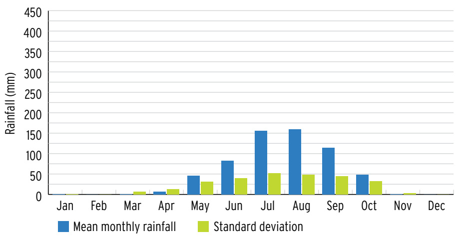
1 Mean monthly rainfall distribution - Asosa



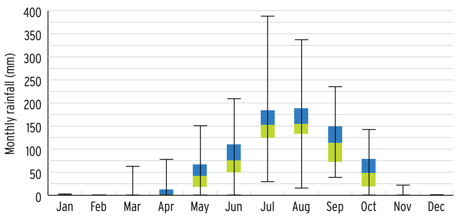
1 Monthly rainfall statistics - Asosa



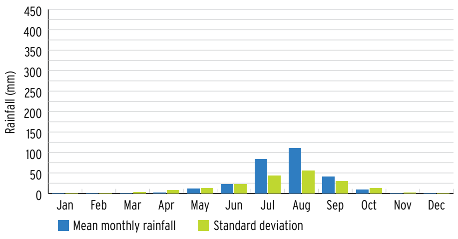
2 Mean monthly rainfall distribution - Dilling



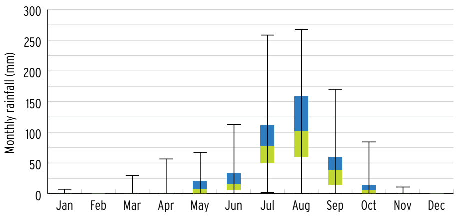
2 Monthly rainfall statistics - Dilling



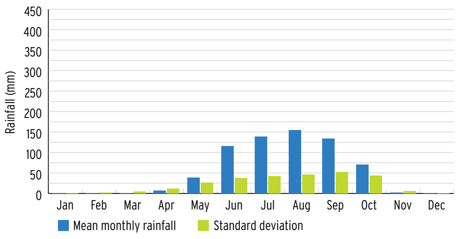
3 Mean monthly rainfall distribution - Ed Dueim



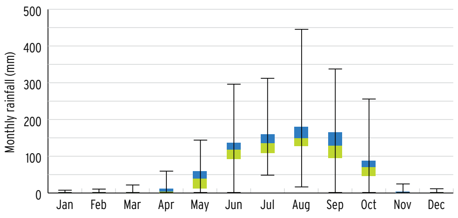
3 Monthly rainfall statistics - Ed Dueim



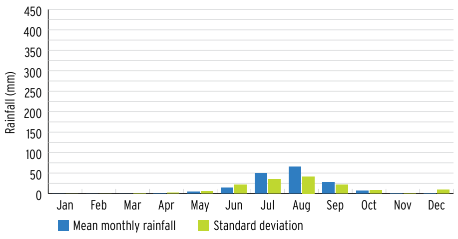
4 Mean monthly rainfall distribution - J. Guli



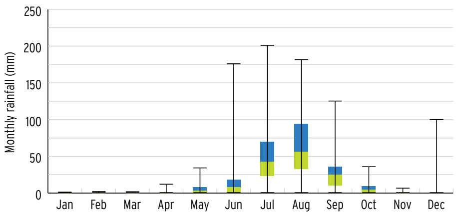
4 Monthly rainfall statistics - J. Guli



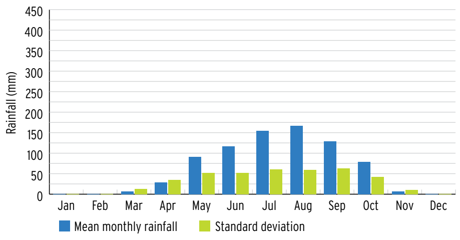
5 Mean monthly rainfall distribution - Jebel Aulia



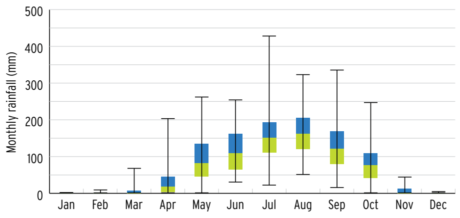
5 Monthly rainfall statistics - Jebel Aulia



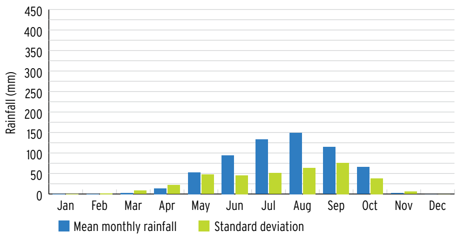
6 Mean monthly rainfall distribution - Malakal



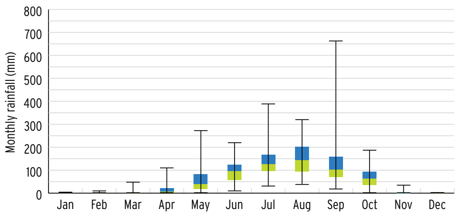
6 Monthly rainfall statistics - Malakal



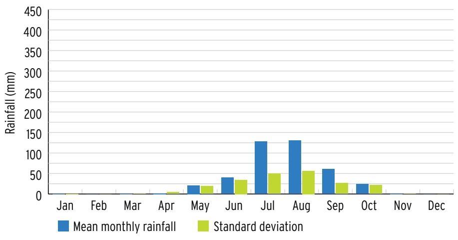
7 Mean monthly rainfall distribution - Melut



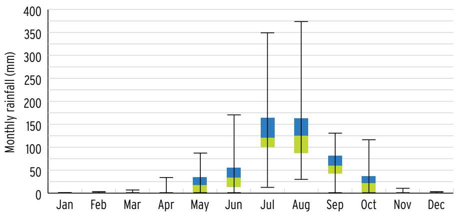
7 Monthly rainfall statistics - Melut



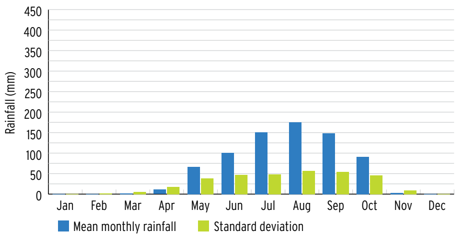
8 Mean monthly rainfall distribution - Rahad



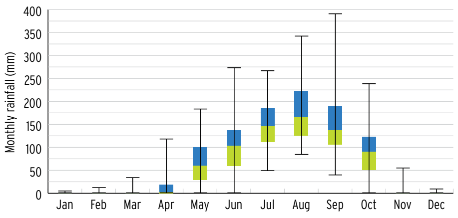
8 Monthly rainfall statistics - Rahad



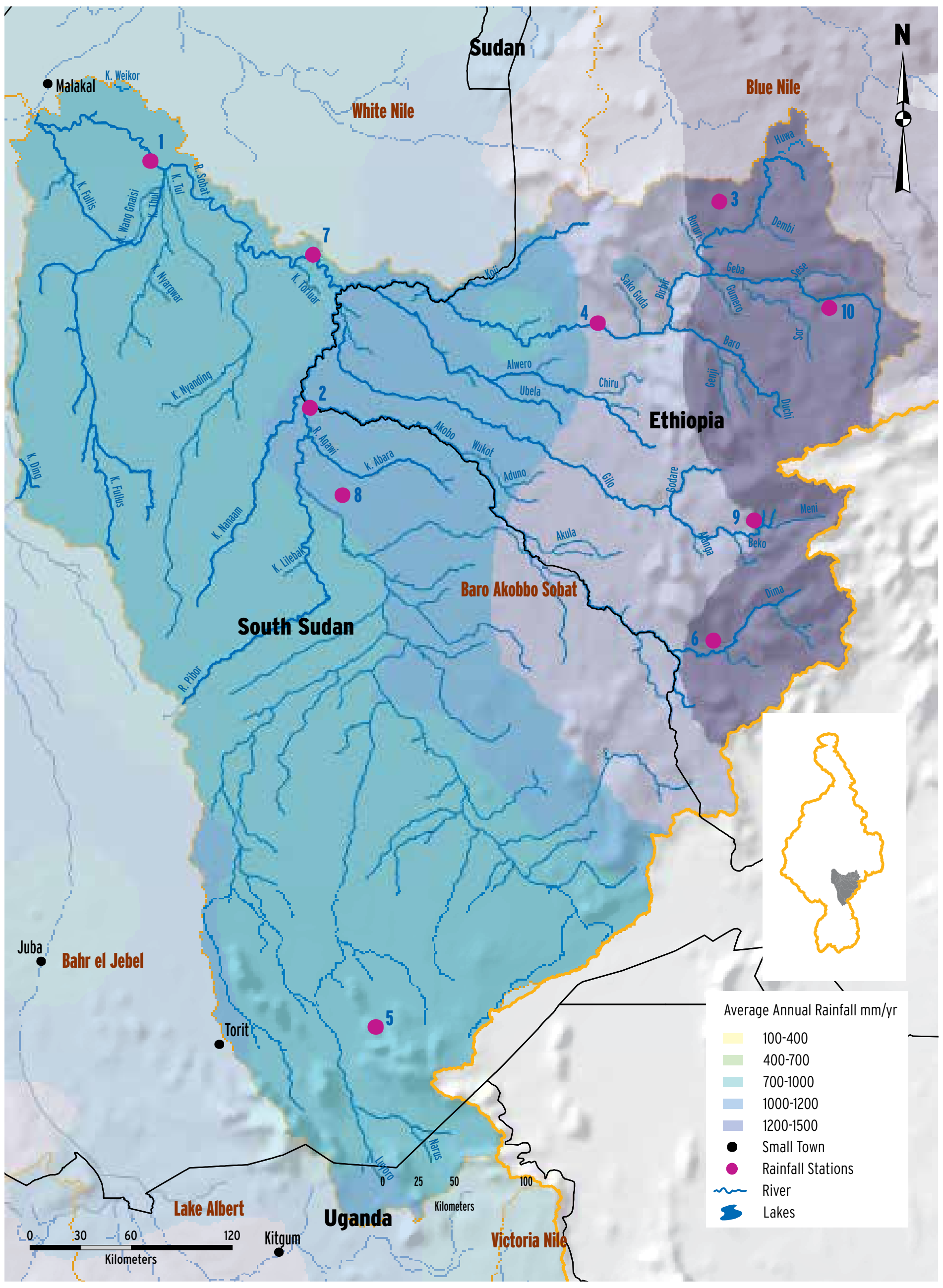
9 Mean monthly rainfall distribution - Rashad



9 Monthly rainfall statistics - Rashad



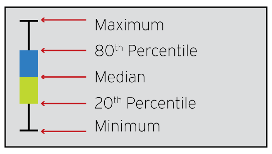
Mean monthly rainfall distribution – Baro Akobo Sobat Sub-basin



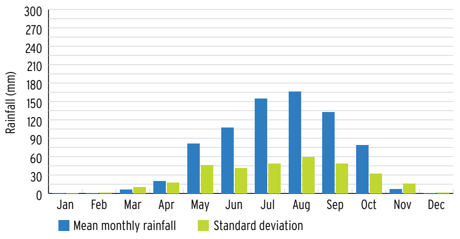
The Baro Akobo Sobat Sub-basin also exhibits a single wet season between May – October, however rainfall occurs all year round in varying amounts as seen from the mean monthly distribution plot. The monthly variation of this rainfall is big, especially in the wet season but it seems to be well distributed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

Station Identification

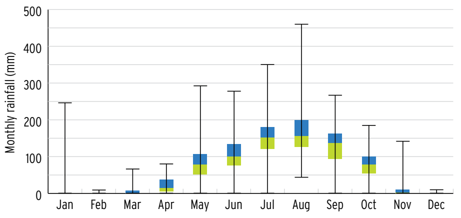
Station Name	Label No.	Record Length	Station Name	Label No.	Record Length
Abwong	1	1909-2003	Pibor	8	1905-2002
Akobo	2	1905-2002	Tepi	9	1952-2002
Alem Teferi School	3	1970-1989	Yayu	10	1952-1992
Gambella	4	1903-2002			
Kapoeta	5	1922-2002			
Mizan Teferi	6	1952-2011			
Nasser	7	1909-2003			



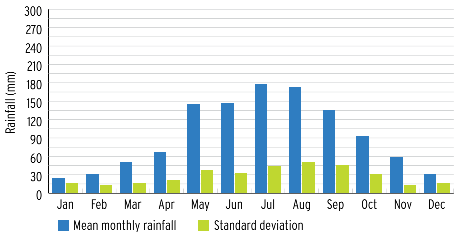
1 Mean monthly rainfall distribution - Abwong



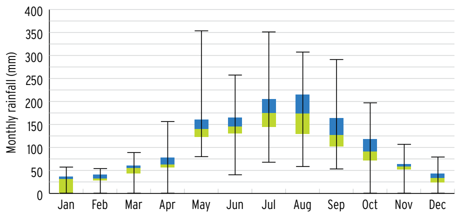
1 Monthly rainfall statistics - Abwong



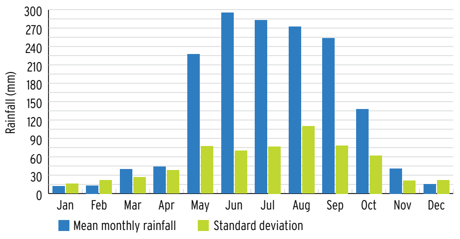
2 Mean monthly rainfall distribution - Akobo



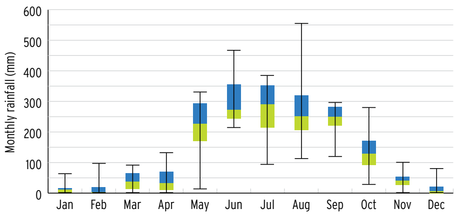
2 Monthly rainfall statistics - Akobo



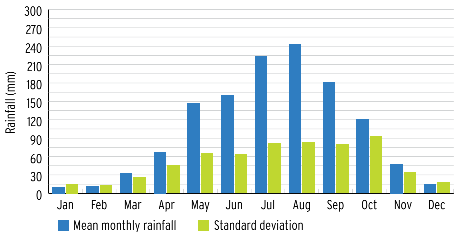
3 Mean monthly rainfall distribution - Alem Teferi



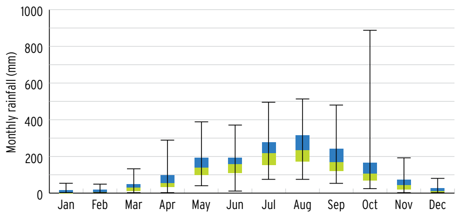
3 Monthly rainfall statistics - Alem Teferi



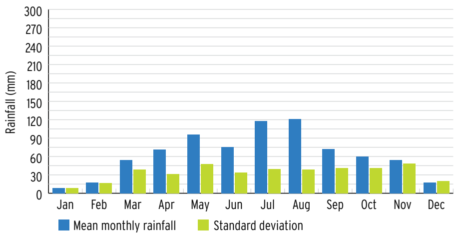
4 Mean monthly rainfall distribution - Gembella



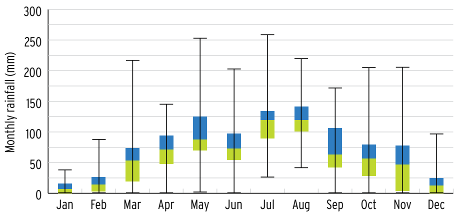
4 Monthly rainfall statistics - Gembella



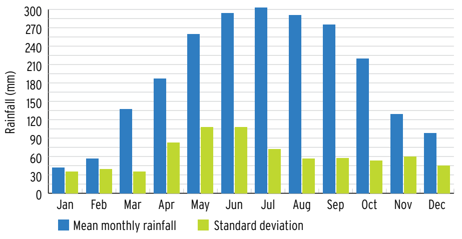
5 Mean monthly rainfall distribution - Kapoeta



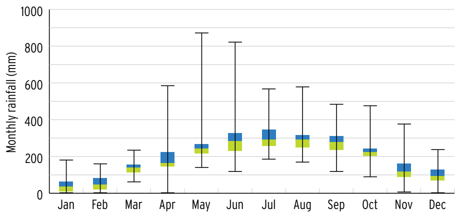
5 Monthly rainfall statistics - Kapoeta



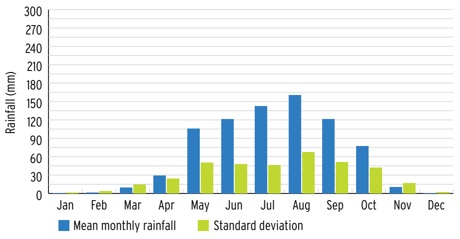
6 Mean monthly rainfall distribution - Mizan Teferi



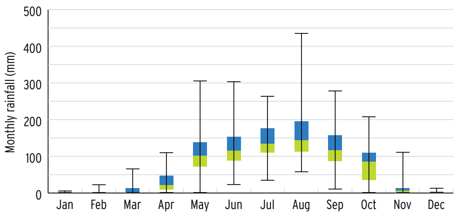
6 Monthly rainfall statistics - Mizan Teferi



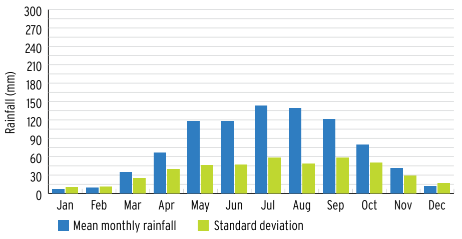
7 Mean monthly rainfall distribution - Nasser



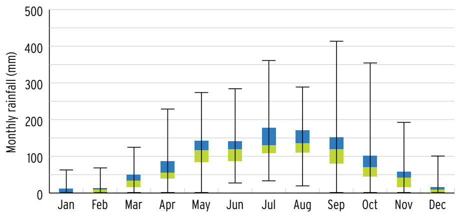
7 Monthly rainfall statistics - Nasser



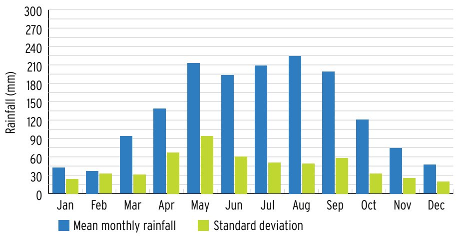
8 Mean monthly rainfall distribution - Pibor



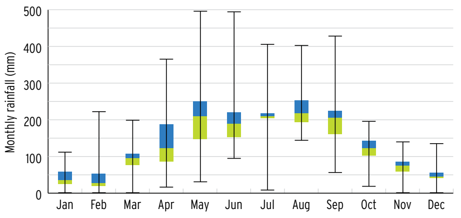
8 Monthly rainfall statistics - Pibor



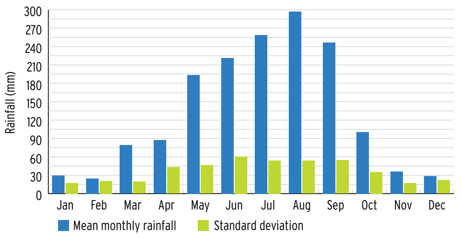
9 Mean monthly rainfall distribution - Tepi



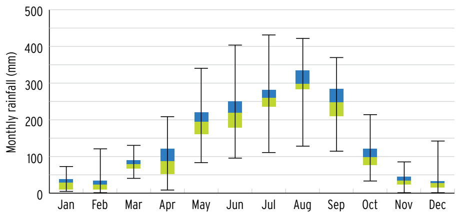
9 Monthly rainfall statistics - Tepi



10 Mean monthly rainfall distribution - Yayu

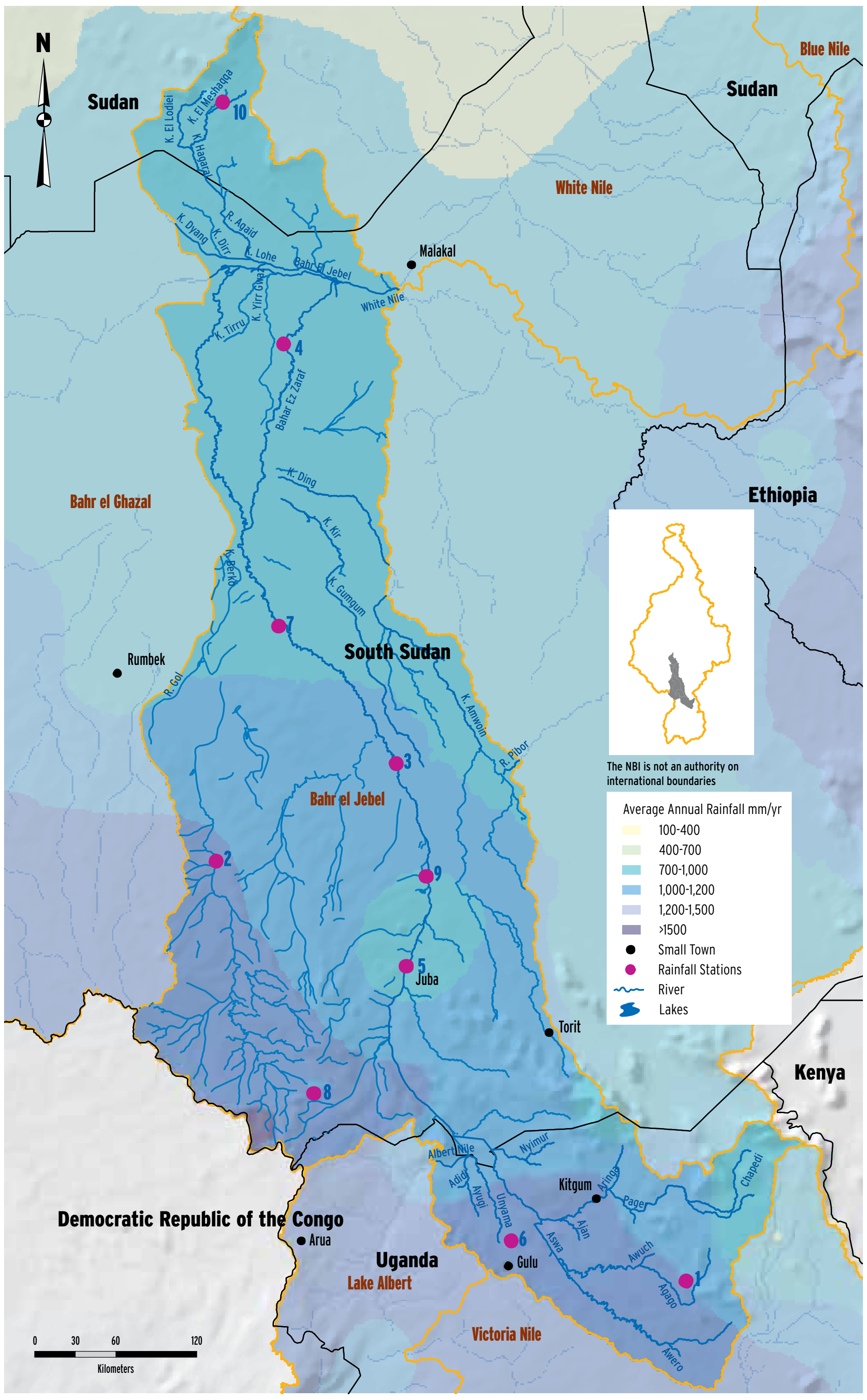


10 Monthly rainfall statistics - Yayu



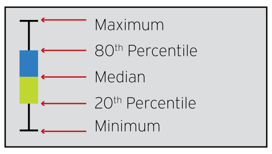
Mean monthly rainfall distribution – Bahr el Jebel Sub-basin

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

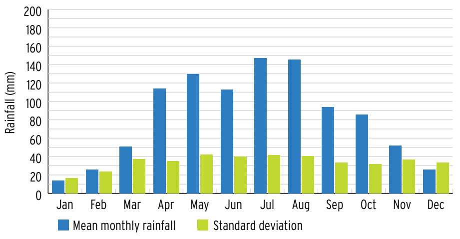


Station Identification

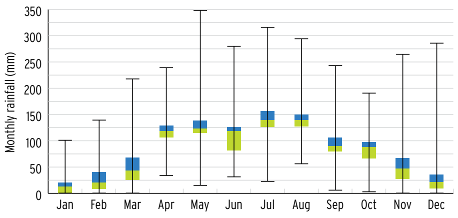
Station Name	Label No.	Record Length	Station Name	Label No.	Record Length
Adilang	1	1911-2003	Tambura	8	1914-2000
Amadi	2	1901-2004	Terakeka	9	1901-2004
Bor	3	1901-2004	Talodi	10	1909-2003
Fangak	4	1906-2003			
Juba	5	1901-2004			
Patiko	6	1911-1966			
Shambe	7	1907-1985			



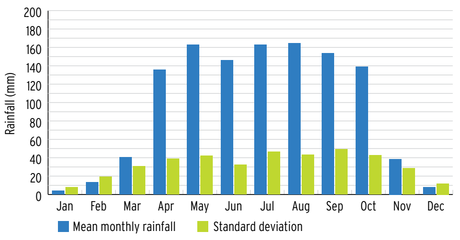
1 Mean monthly rainfall distribution - Adilang



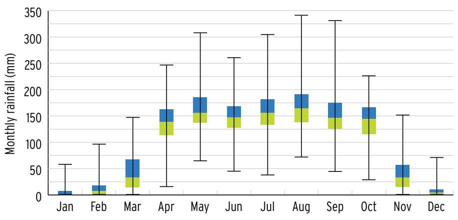
1 Monthly rainfall statistics - Adilang



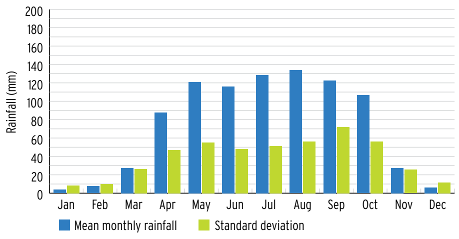
2 Mean monthly rainfall distribution - Amadi



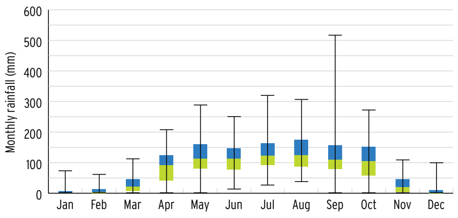
2 Monthly rainfall statistics - Amadi



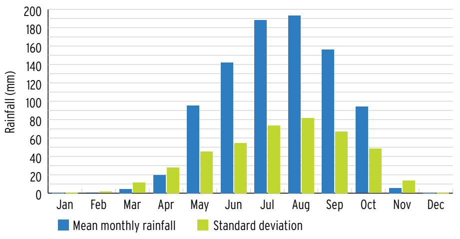
3 Mean monthly rainfall distribution - Bor



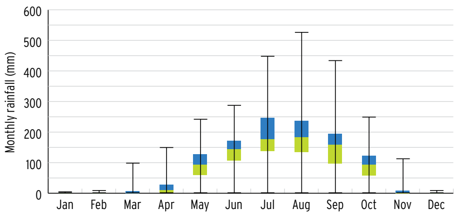
3 Monthly rainfall statistics - Bor



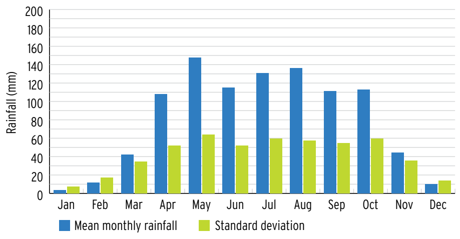
4 Mean monthly rainfall distribution - Fangak



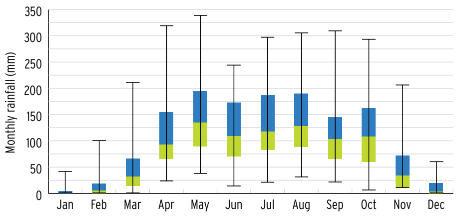
4 Monthly rainfall statistics - Fangak



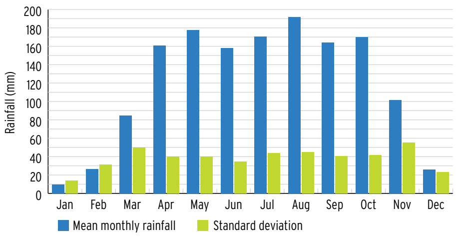
5 Mean monthly rainfall distribution - Juba



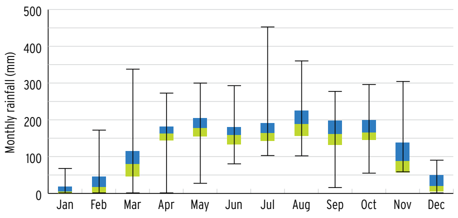
5 Monthly rainfall statistics - Juba



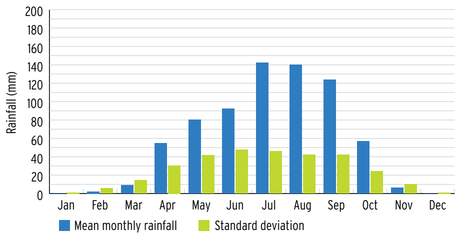
6 Mean monthly rainfall distribution - Patiko



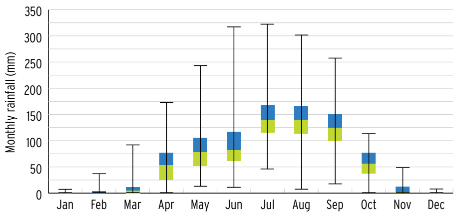
6 Monthly rainfall statistics - Patiko



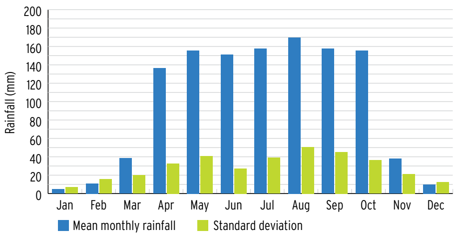
7 Mean monthly rainfall distribution - Shambe



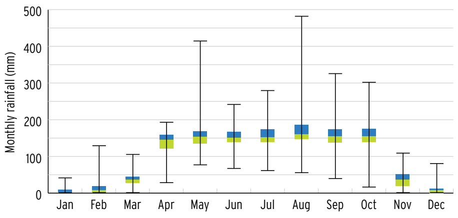
7 Monthly rainfall statistics - Shambe



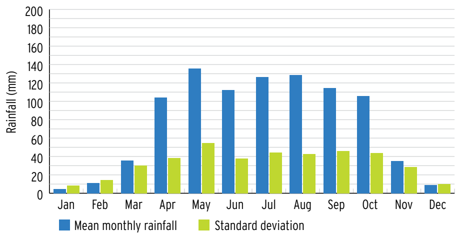
8 Mean monthly rainfall distribution - Tambura



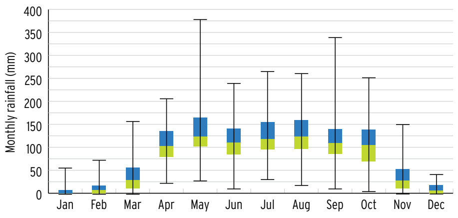
8 Monthly rainfall statistics - Tambura



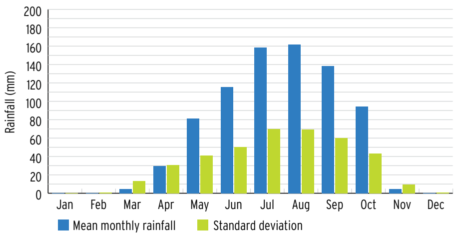
9 Mean monthly rainfall distribution - Terakeka



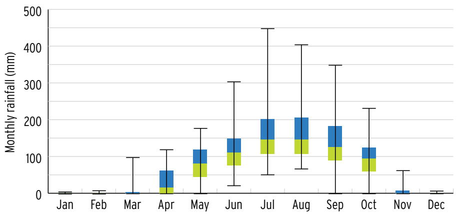
9 Monthly rainfall statistics - Terakeka



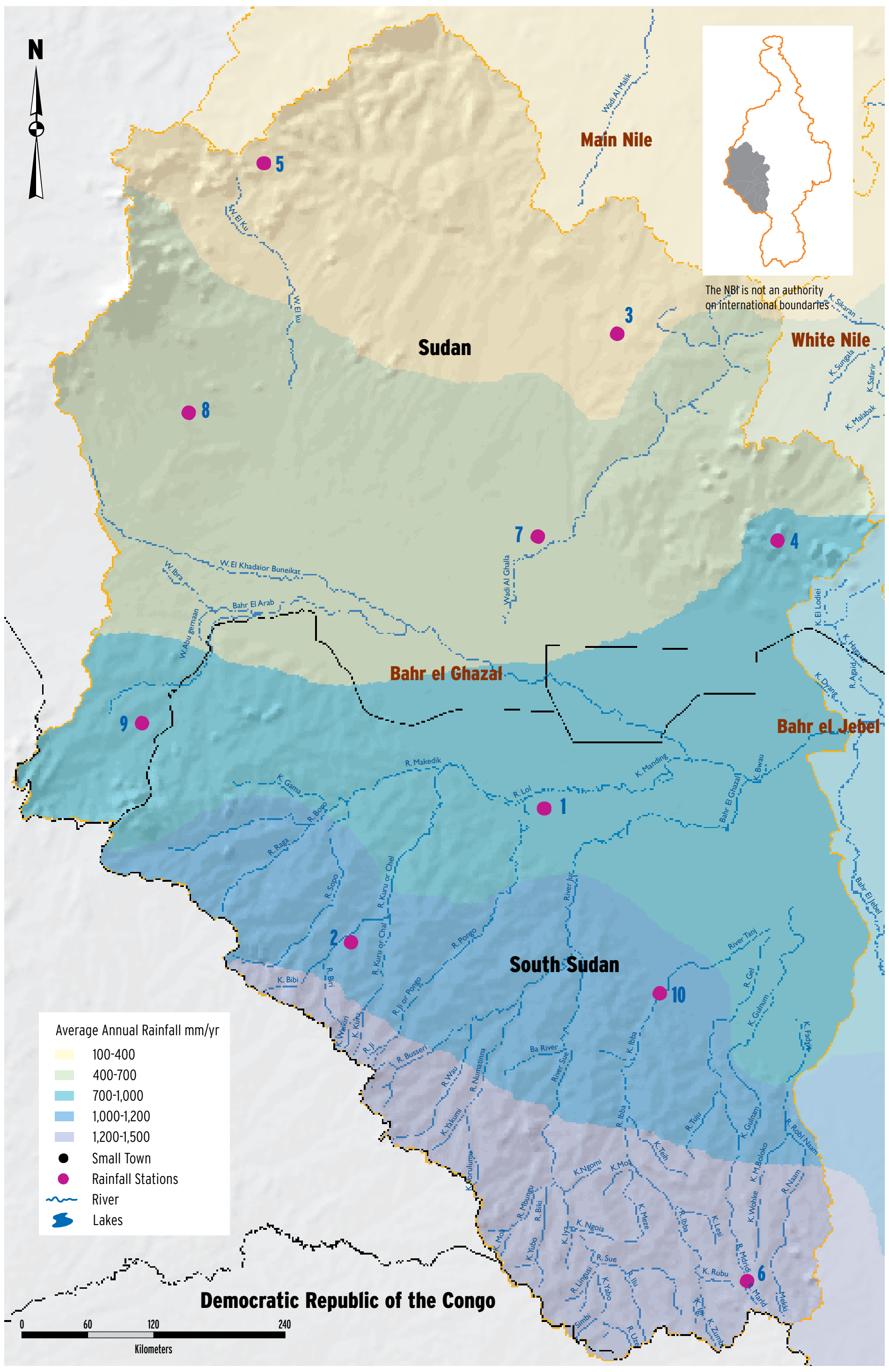
10 Mean monthly rainfall distribution - Tolodi



10 Monthly rainfall statistics - Tolodi



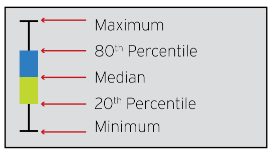
Mean monthly rainfall distribution - Bahr el Ghazal sun basin



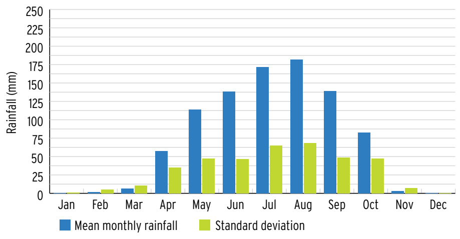
The rainfall in this Sub-basin exhibits a single wet season between April-October and the rest of the time in the year is generally dry. Within the months July - Sept., the basin hardly records zero monthly rainfall, however the northern part of the Sub-basin which lies in Sudan is seen to be dryer than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

Station Identification

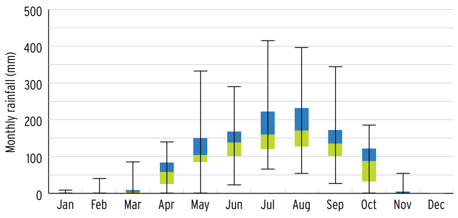
Station Name	Label No.	Record Length	Station Name	Label No.	Record Length
Aweil	1	1904-2002	Nyala	8	1911-2006
Deim Zubeir	2	1904-2002	Radom	9	1943-1993
En Nahud	3	1909-2011	Tonj	10	1904-2002
Kadugli	4	1909-2011			
Mellit	5	1950-1988			
Meridi	6	1901-2004			
Muglad	7	1911-2006			



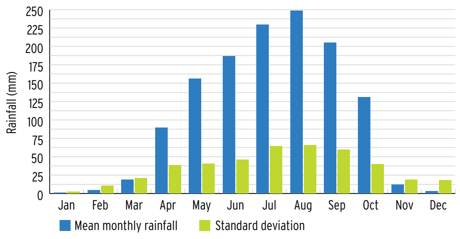
1 Mean monthly rainfall distribution - Aweil



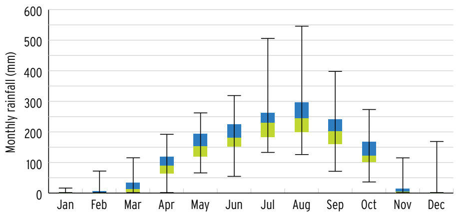
1 Monthly rainfall statistics - Aweil



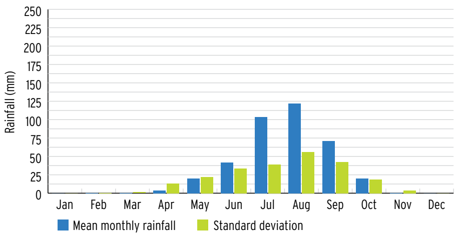
2 Mean monthly rainfall distribution - Deim Zubeir



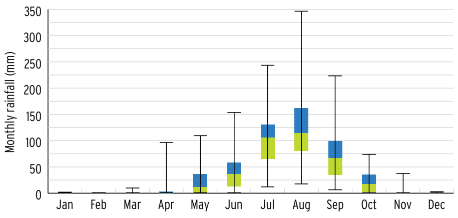
2 Monthly rainfall statistics - Deim Zubeir



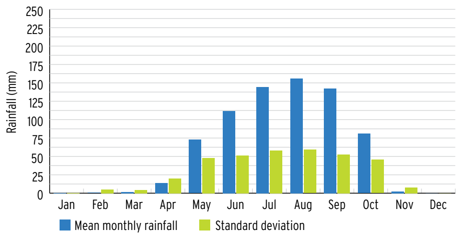
3 Mean monthly rainfall distribution - En Nahud



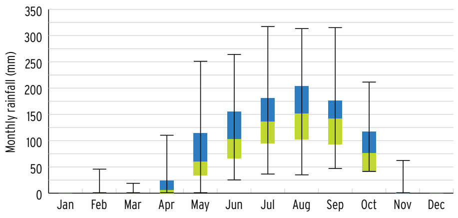
3 Monthly rainfall statistics - En Nahud



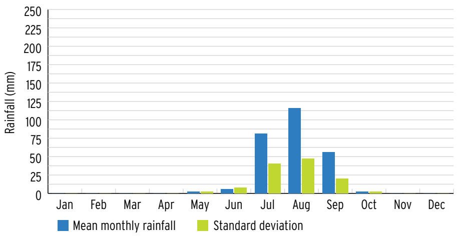
4 Mean monthly rainfall distribution - Kadugli



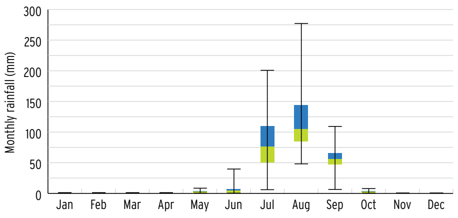
4 Monthly rainfall statistics - Kadugli



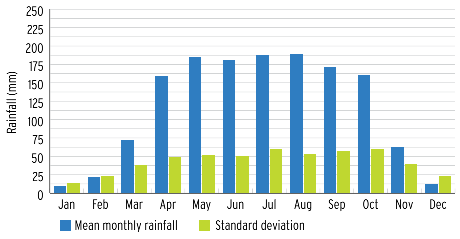
5 Mean monthly rainfall distribution - Mellit



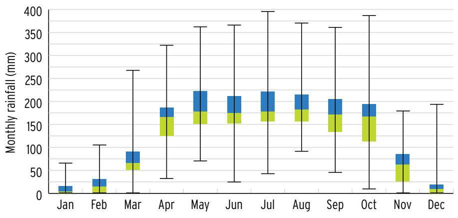
5 Monthly rainfall statistics - Mellit



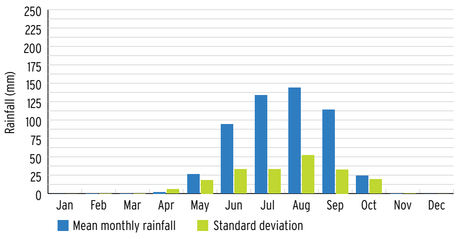
6 Mean monthly rainfall distribution - Meridi



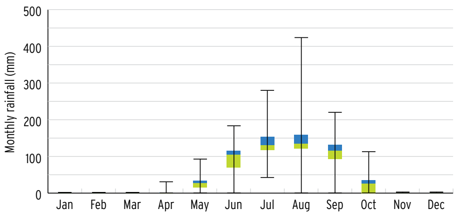
6 Monthly rainfall statistics - Meridi



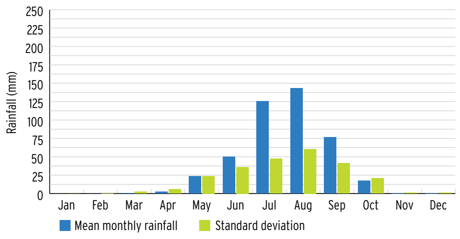
7 Mean monthly rainfall distribution - Muglad



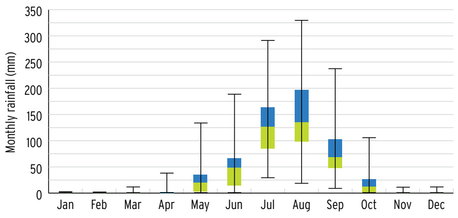
7 Monthly rainfall statistics - Muglad



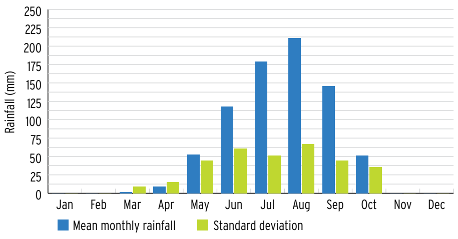
8 Mean monthly rainfall distribution - Nyala



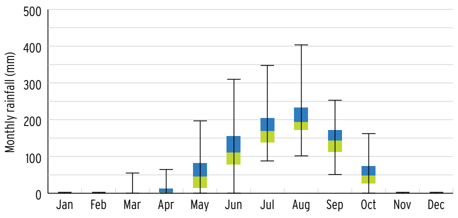
8 Monthly rainfall statistics - Nyala



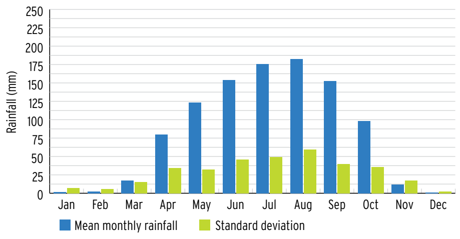
9 Mean monthly rainfall distribution - Radom



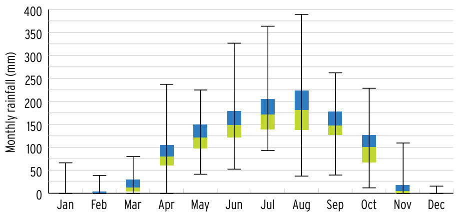
9 Monthly rainfall statistics - Radom



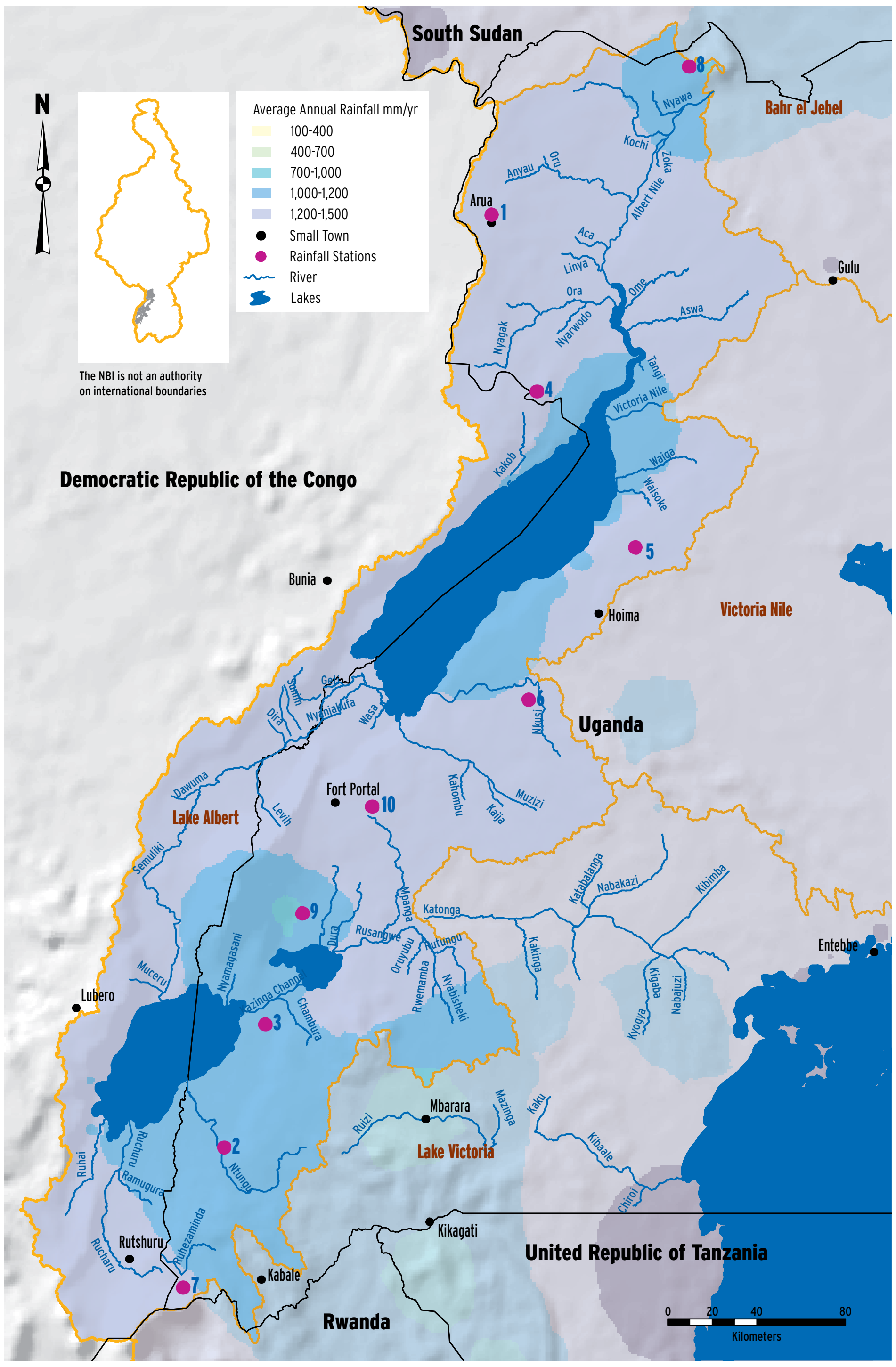
10 Mean monthly rainfall distribution - Tonj



10 Monthly rainfall statistics - Tonj



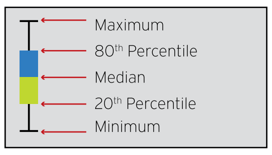
Mean monthly rainfall distribution – Lake Albert Sub-basin

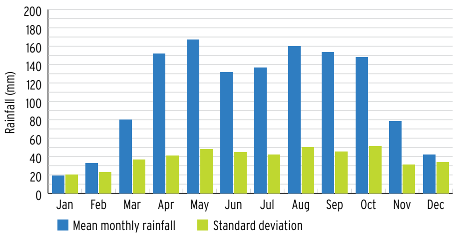


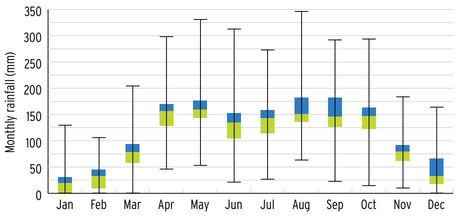
Similar to the other parts of the upper equatorial lakes region, the Lake Albert Sub-basin also has a bimodal rainfall pattern with competing rainfall amounts. Rainfall amounts recorded in the mountainous area (Mubuku and Kisoro) are seen to have low variations for the individual months as compared to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

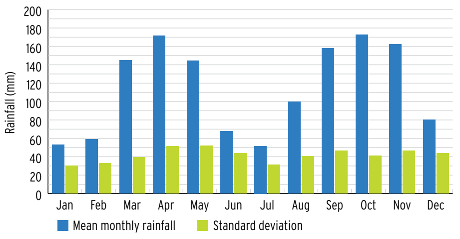
Station Identification

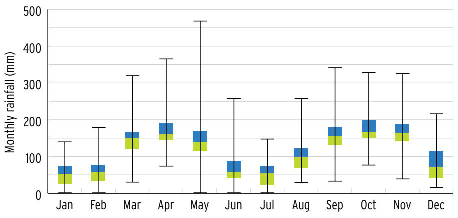
Station Name	Label No.	Record Length	Station Name	Label No.	Record Length
Arua Met Station	1	1906-2002	Moyo Boma	8	1938-2000
Bugangari Dispensary	2	1917-2005	Mubuku Giant prison Farm	9	1900-2005
Bunyaruguru	3	1903-2003	Rwebitaba Tea Res Station	10	1911-2005
Erusi Forest Station	4	1904-2002			
IHUNGU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

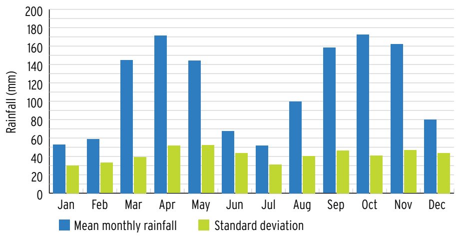


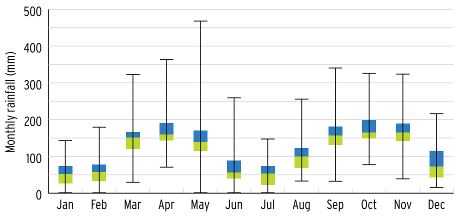

1 Mean monthly rainfall distribution - Arua

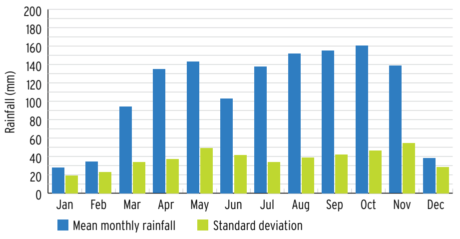

1 Monthly rainfall statistics - Arua

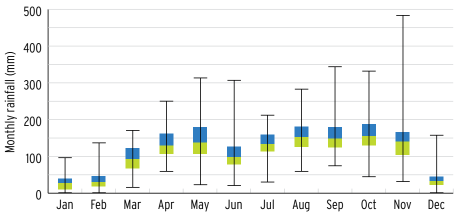

2 Mean monthly rainfall distribution - Bugangari

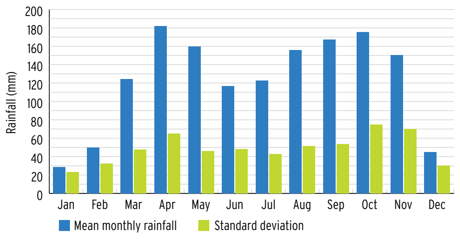

2 Monthly rainfall statistics - Bugangari

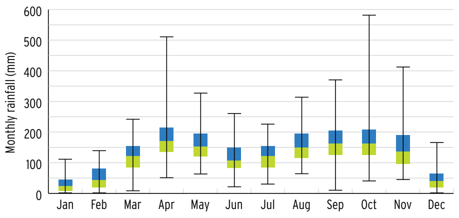

3 Mean monthly rainfall distribution - Bunyaruguru

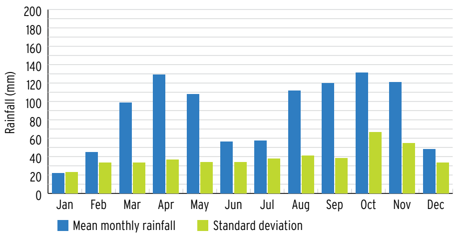

3 Monthly rainfall statistics - Bunyaruguru

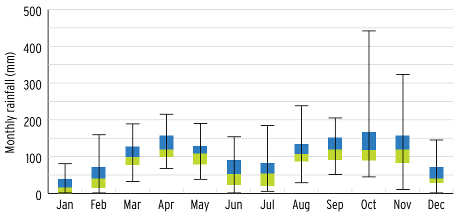

4 Mean monthly rainfall distribution - Erusi

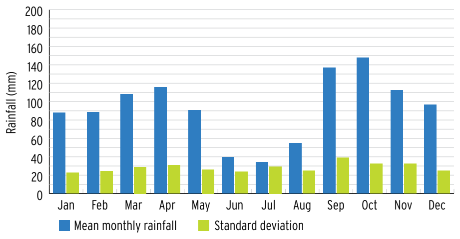

4 Monthly rainfall statistics - Erusi

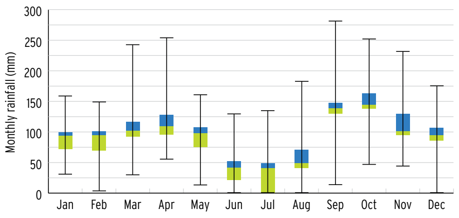

5 Mean monthly rainfall distribution - Ihungu

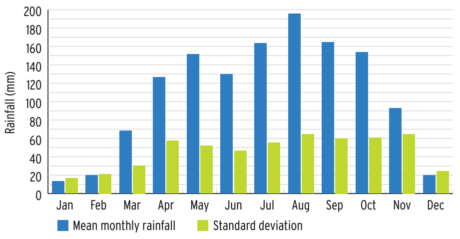

5 Monthly rainfall statistics - Ihungu

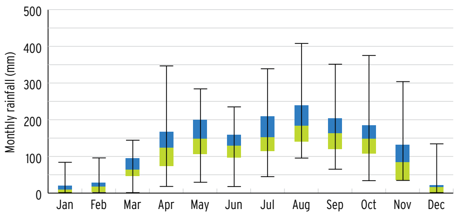

6 Mean monthly rainfall distribution - Kiryanga

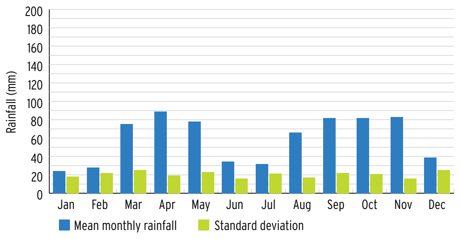

6 Monthly rainfall statistics - Kiryanga

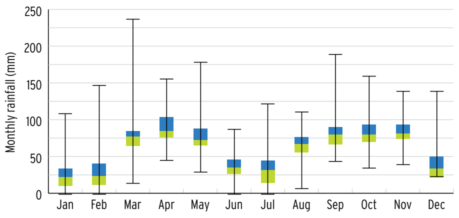

7 Mean monthly rainfall distribution - Kisoro

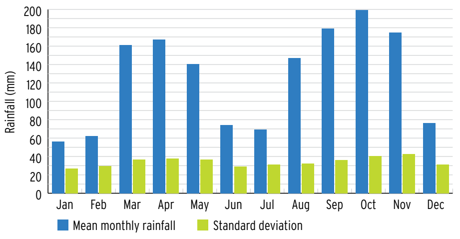

7 Monthly rainfall statistics - Kisoro

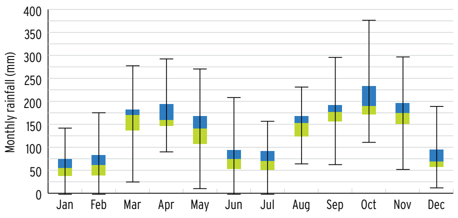

8 Mean monthly rainfall distribution - Moyo Boma


8 Monthly rainfall statistics - Moyo Boma

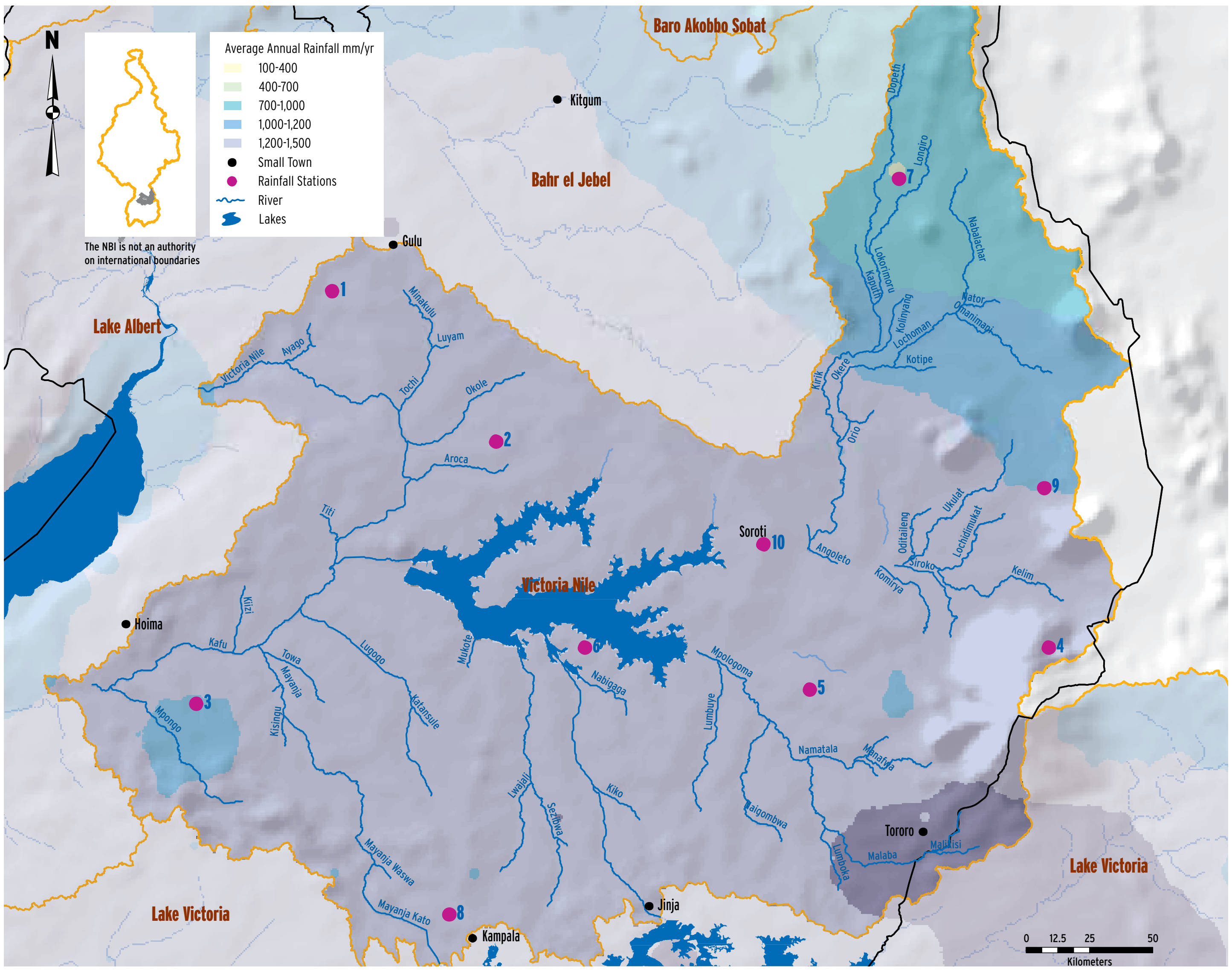

9 Mean monthly rainfall distribution - Mubuku


9 Monthly rainfall statistics - Mubuku


10 Mean monthly rainfall distribution - Rwebitaba


10 Monthly rainfall statistics - Rwebitaba

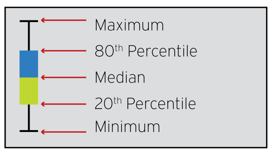
Mean monthly rainfall distribution - Victoria Nile Sub-basin



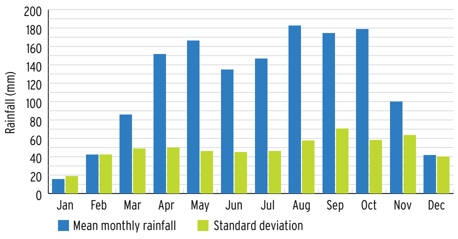
The Victoria Nile also depicts two wet rainfall seasons with fairly competing amounts and two dry seasons with the lowest rainfall amounts occurring between Dec – Feb. The standard deviation is seen to be high for the individual months and the 20th percentile registers more rainfall than in any other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

Station Identification

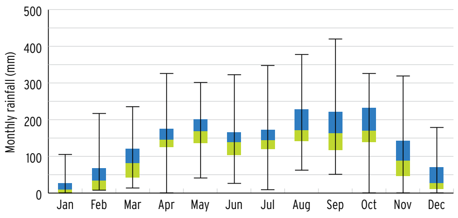
Station Name	Label No.	Record Length
Amar	1	1911-2000
Aninolal Mechanised Div	2	1940-2005
Butemba	3	1940-1981
Kapkwta Forest Station	4	1908-2004
Kibale	5	1900-2004
Kidera	6	1915-2006
Kotido	7	1922-2004
MATUNGA	8	1943-2005
Napianyenya	9	1908-2004
Soroti Met Station	10	1908-2004



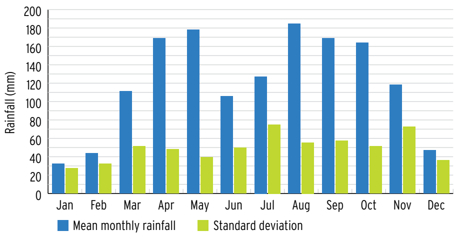
1 Mean monthly rainfall distribution - Amar



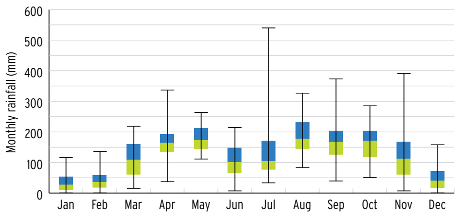
1 Monthly rainfall statistics - Amar



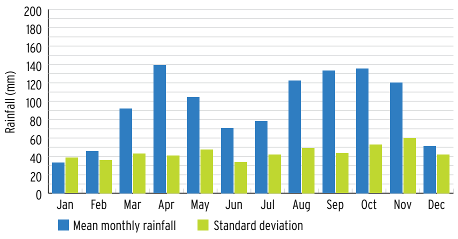
2 Mean monthly rainfall distribution - Aninolal



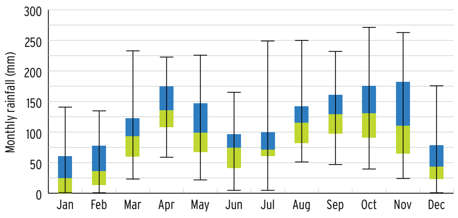
2 Monthly rainfall statistics - Aninolal



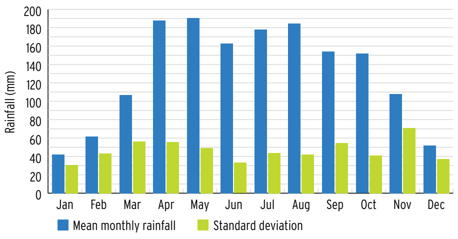
3 Mean monthly rainfall distribution - Butemba



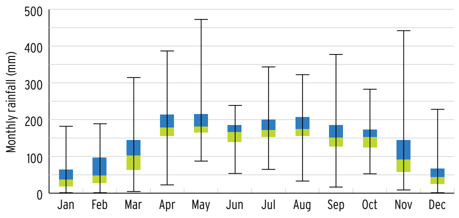
3 Monthly rainfall statistics - Butemba



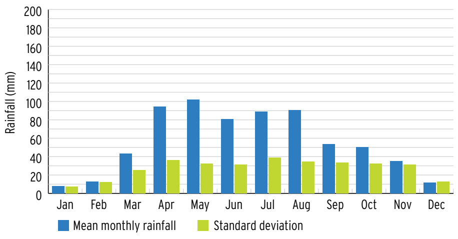
4 Mean monthly rainfall distribution - Kapkwta



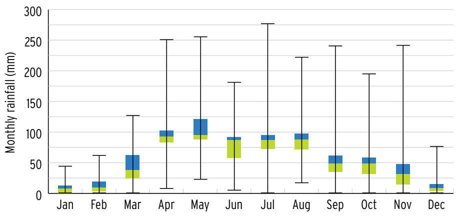
4 Monthly rainfall statistics - Kapkwta



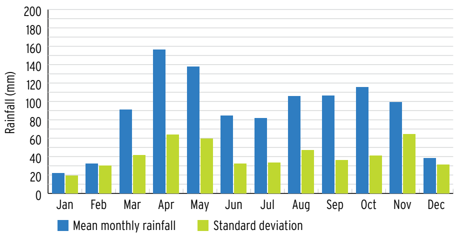
5 Mean monthly rainfall distribution - Kibale



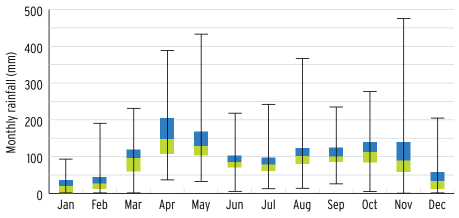
5 Monthly rainfall statistics - Kibale



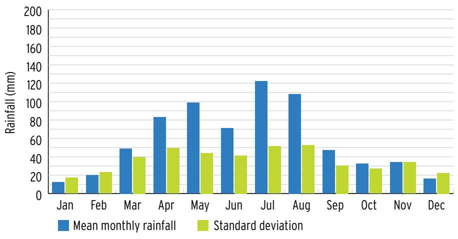
6 Mean monthly rainfall distribution - Kidera



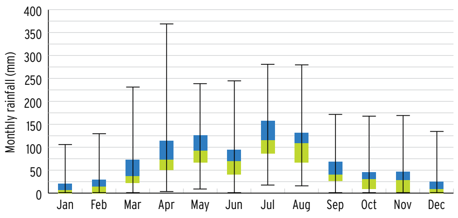
6 Monthly rainfall statistics - Kidera



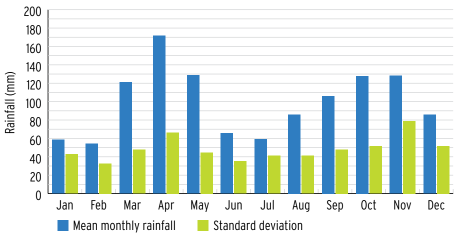
7 Mean monthly rainfall distribution - Kotido



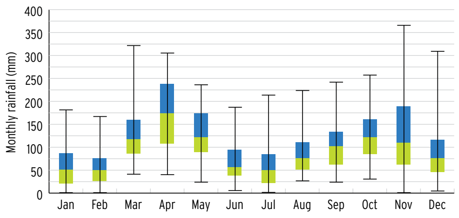
7 Monthly rainfall statistics - Kotido



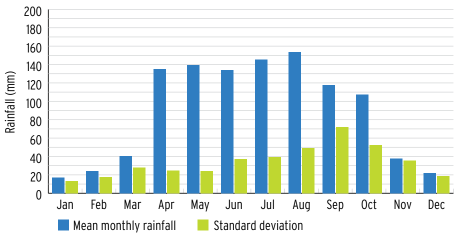
8 Mean monthly rainfall distribution - Matunga



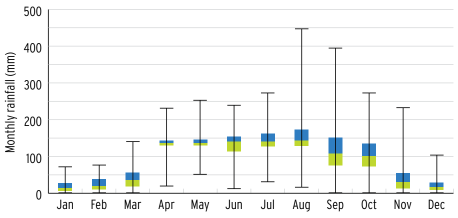
8 Monthly rainfall statistics - Matunga



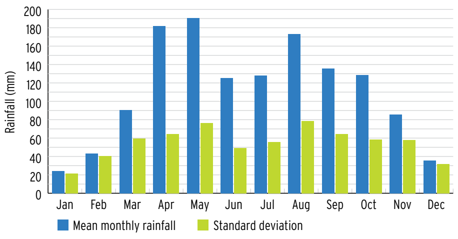
9 Mean monthly rainfall distribution - Napianyenya



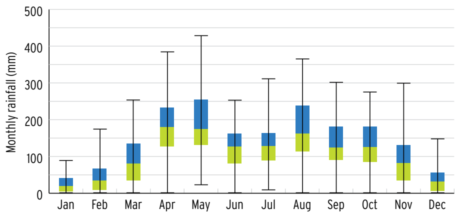
9 Monthly rainfall statistics - Napianyenya



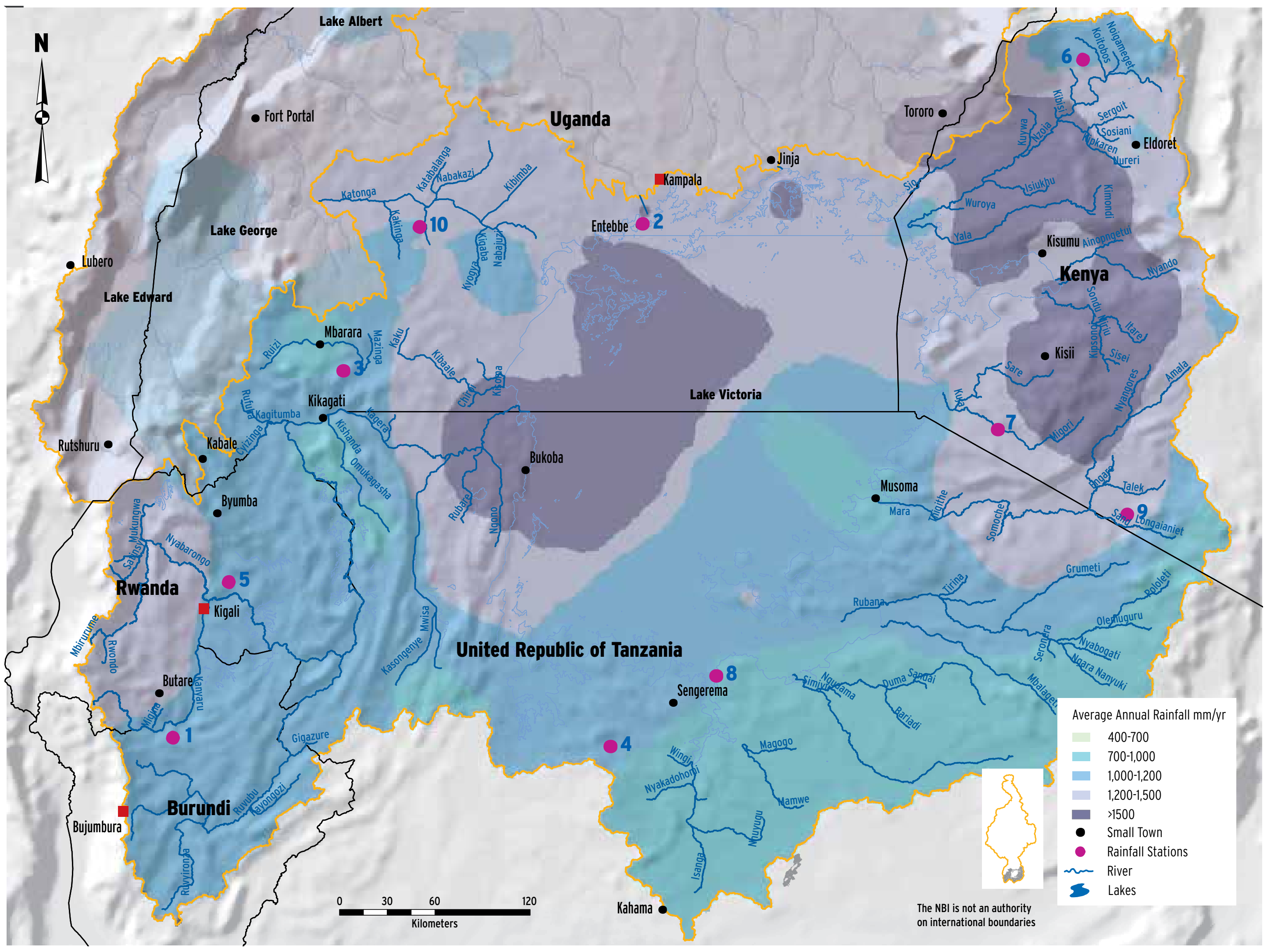
10 Mean monthly rainfall distribution - Soroti



10 Monthly rainfall statistics - Soroti



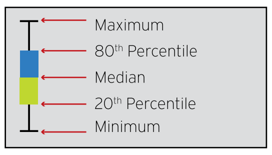
Mean monthly rainfall distribution – Lake Victoria Sub-basin



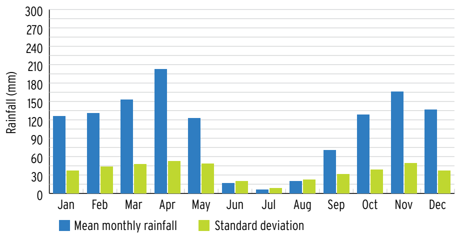
The Lake Victoria Sub-basin depicts a bimodal rainfall pattern with the main dry season occurring between June – August. Generally, wide variation in the monthly rainfalls can be seen from the standard deviation plots. The lake region indicates high dependable rainfall amounts (80th percentile) throughout 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

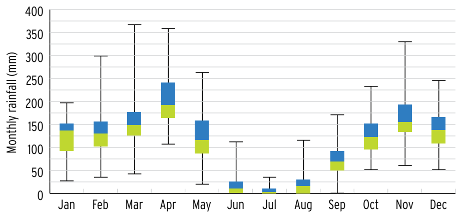
Station Name	Label No.	Record Length
Buye	1	1927-2001
Entebbe	2	1900-2006
Gayaza Isingiro	3	1917-2005
Geita, District Off.	4	1902-2004
Kigali Aero Nyabarongo	5	1960-2005
Kitale Meteorological Station	6	1908-2004
Migori Agric. Off.	7	1911-2004
Mwanza Met	8	1943-2005
Narok, Keekorok Game Lodge	9	1908-2004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



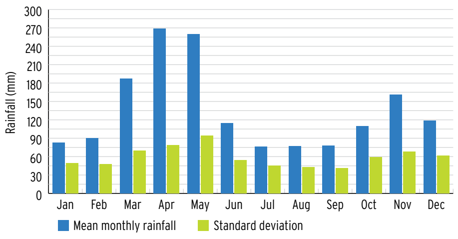
1 Mean monthly rainfall distribution - Buye



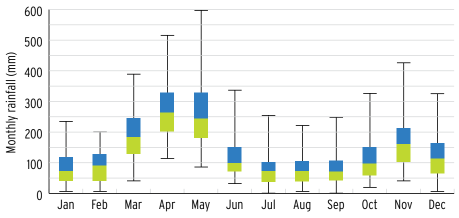
1 Monthly rainfall statistics - Buye



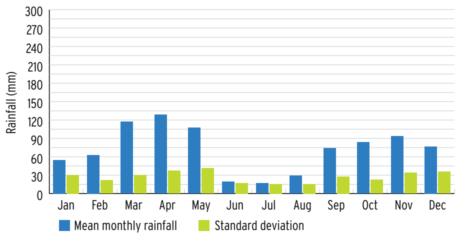
2 Mean monthly rainfall distribution - Entebbe



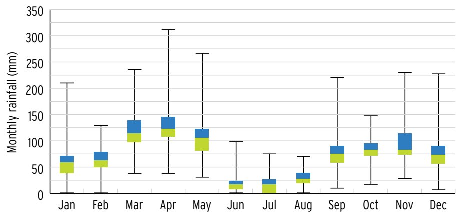
2 Monthly rainfall statistics - Entebbe



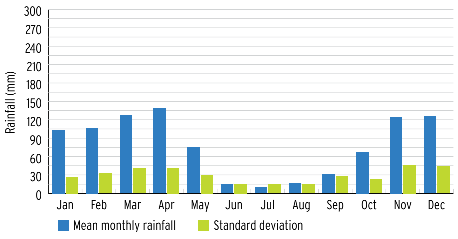
3 Mean monthly rainfall distribution - Gayaza



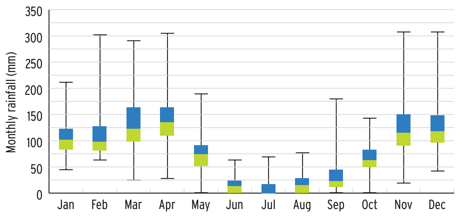
3 Monthly rainfall statistics - Gayaza



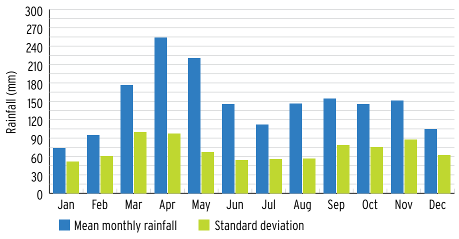
4 Mean monthly rainfall distribution - Geita



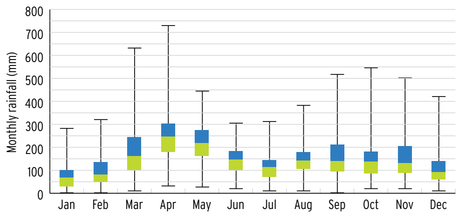
4 Monthly rainfall statistics - Geita



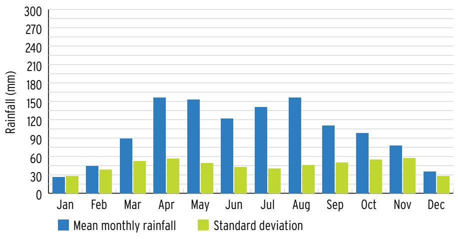
5 Mean monthly rainfall distribution - Kibangu



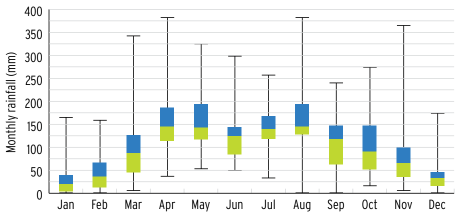
5 Monthly rainfall statistics - Kibangu



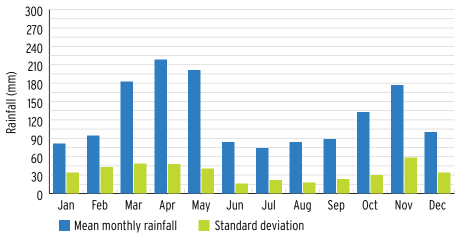
6 Mean monthly rainfall distribution - Kitale



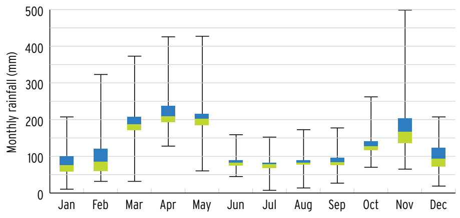
6 Monthly rainfall statistics - Kitale



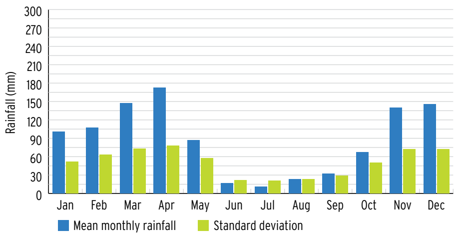
7 Mean monthly rainfall distribution - Migori



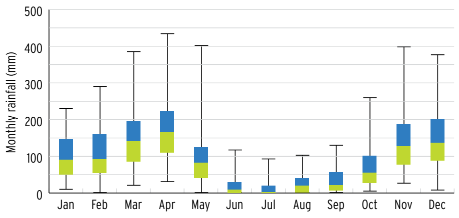
7 Monthly rainfall statistics - Migori



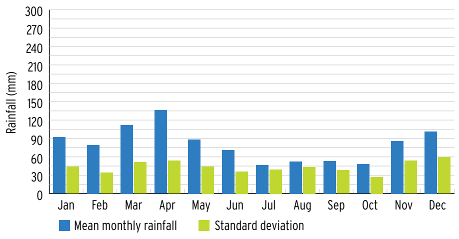
8 Mean monthly rainfall distribution - Mwanza



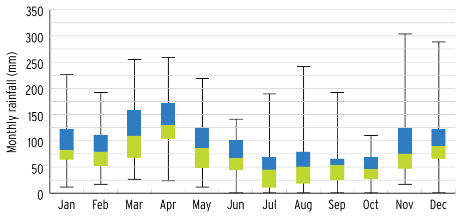
8 Monthly rainfall statistics - Mwanza



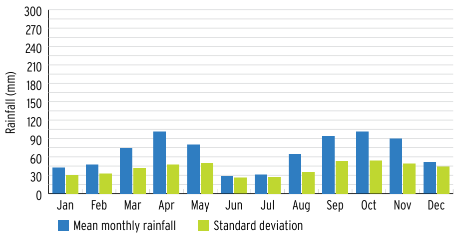
9 Mean monthly rainfall distribution - Narok Keekorok



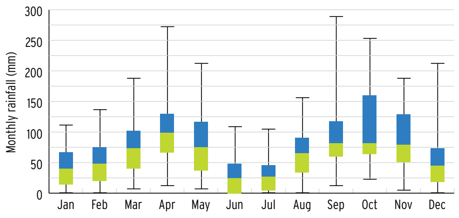
9 Monthly rainfall statistics - Narok Keekorok



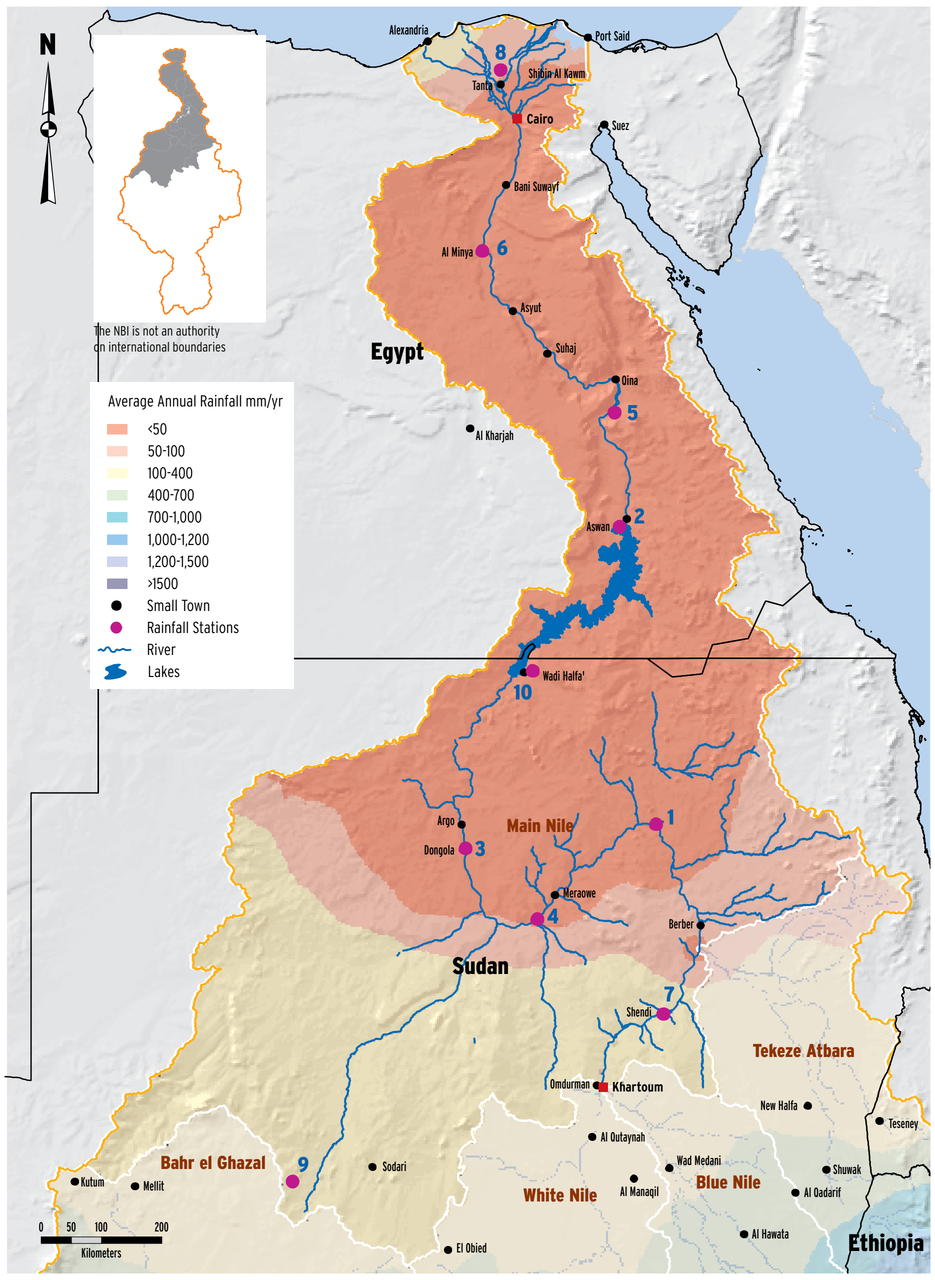
10 Mean monthly rainfall distribution - Ntusi



10 Monthly rainfall statistics - Ntusi



Annual rainfall patterns – Main Nile Sub-basin

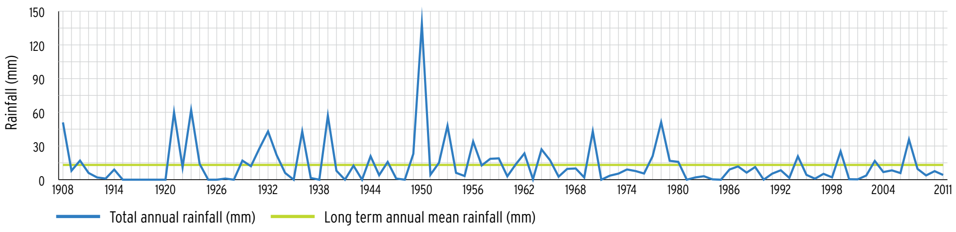


The main Nile is the part of the Nile Basin which receives the least rainfall, with fairly small spatial variation across the sub-basin. The sub-basin receives mean annual rainfall of, sometimes, less than 50mm, with high inter annual variation, sometimes registering 0mm.The most downstream part of the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

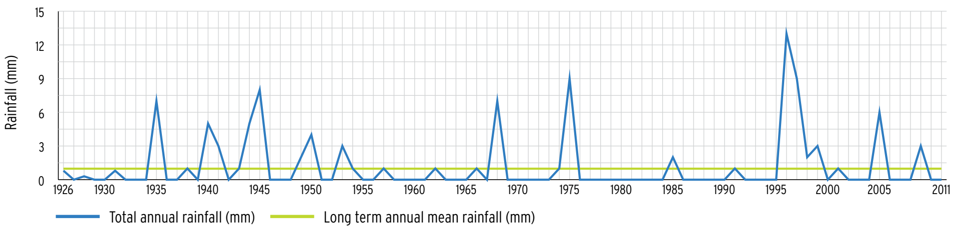
Station Identification

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

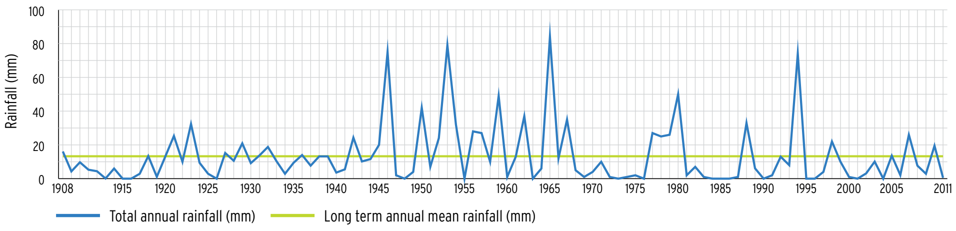
1 Annual rainfall pattern - Abu Hamed



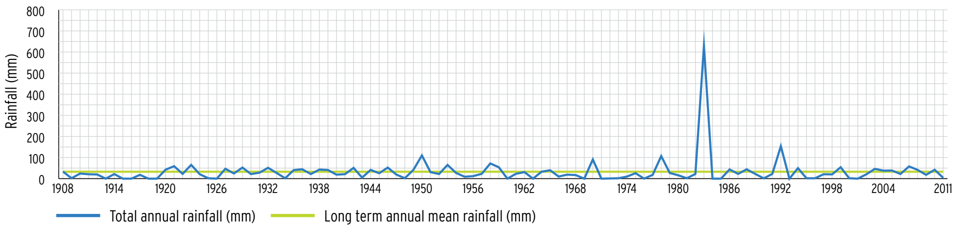
2 Annual rainfall pattern - Asswan



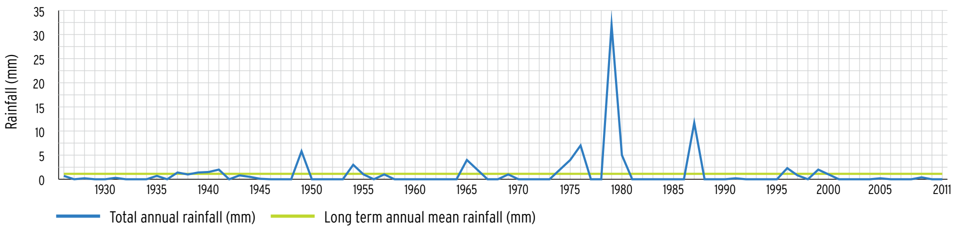
3 Annual rainfall pattern - Dongola



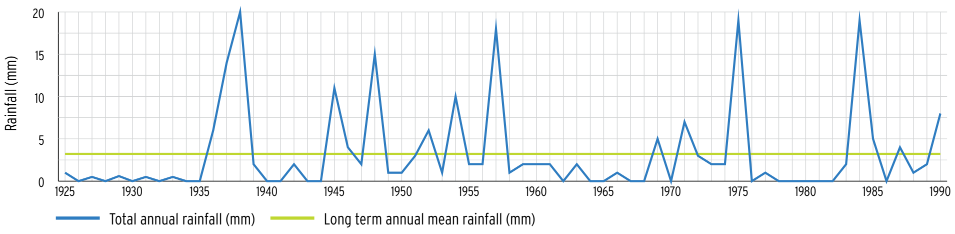
4 Annual rainfall pattern - Korti



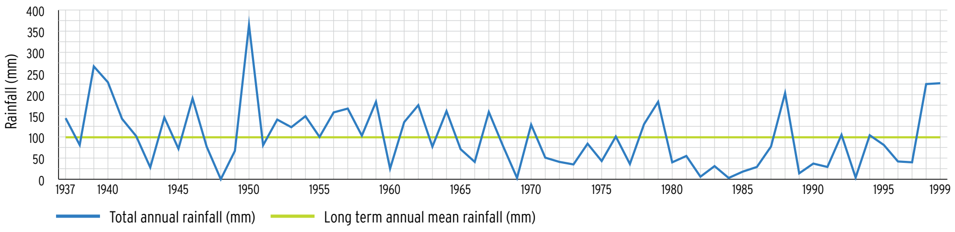
5 Annual rainfall pattern - Luxor



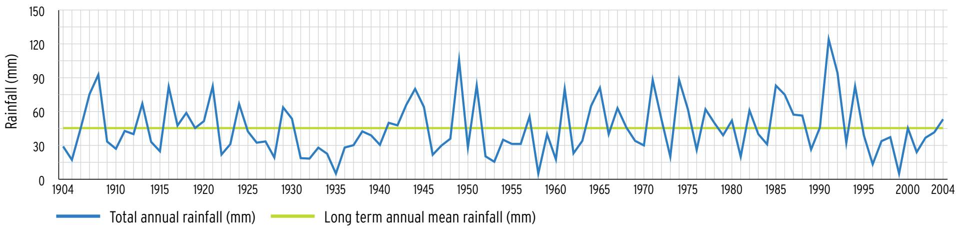
6 Annual rainfall pattern - Minya



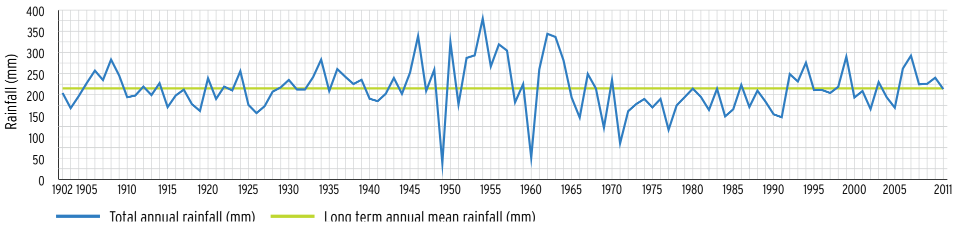
7 Annual rainfall pattern - Shendi



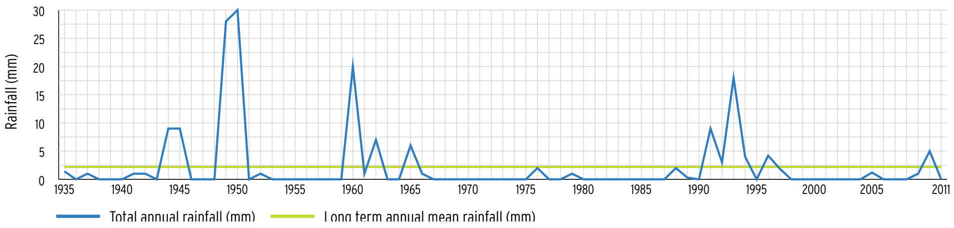
8 Annual rainfall pattern - Tanta



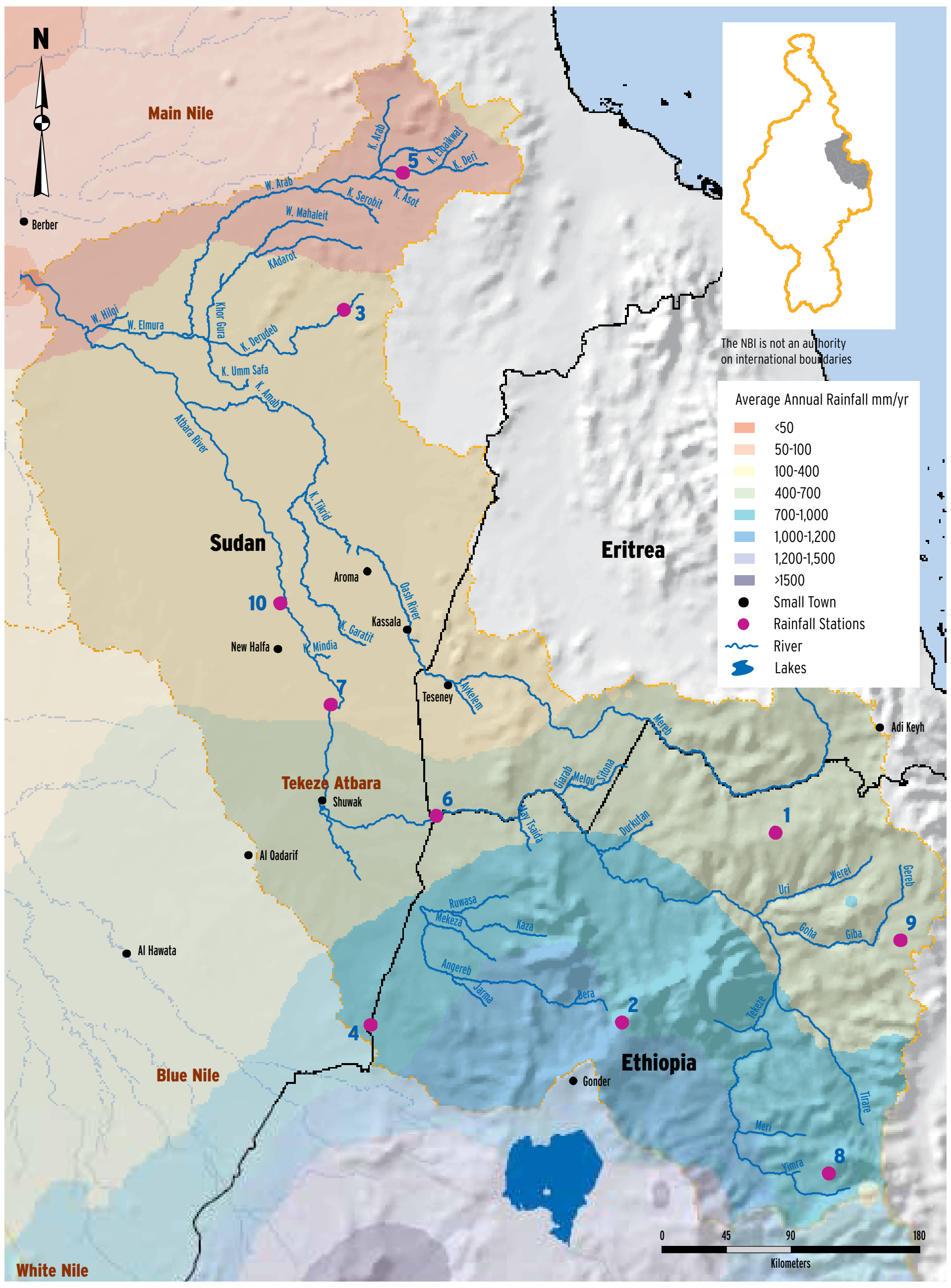
9 Annual rainfall pattern - Umm Badr



10 Annual rainfall pattern - Wadi Halfa



Annual rainfall patterns - Tekeze Atbara Sub-basin



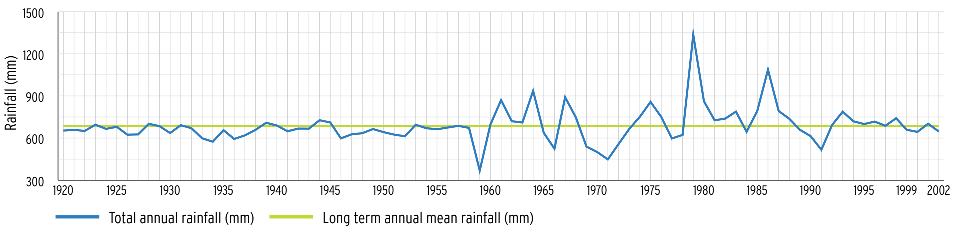
Tekeze Atbaba, like the Blue Nile, has its boundaries spanning from Ethiopia, Eritrea and down to Sudan and also receives highly spatially variable rainfall amounts. The upstream parts of the sub-basin receive mean annual rainfall amounts in excess of 800mm and some areas in Sudan receive less than 300mm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

The entire Atbara sub-basin is quite large. It covers an estimated 166,875km^2. 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.

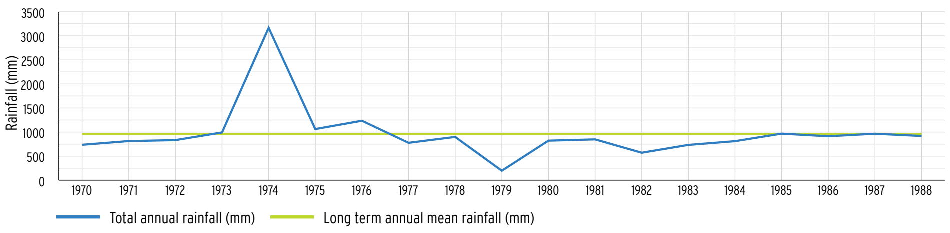
Station Identification

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

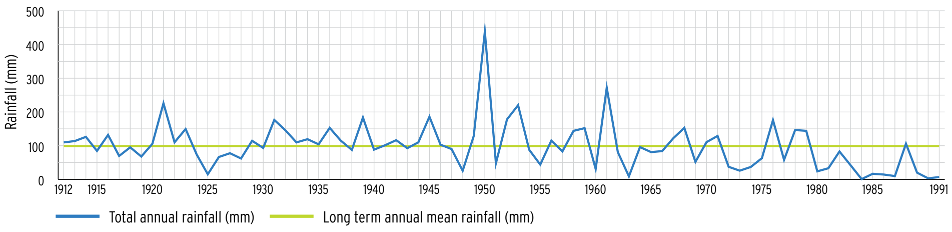
1 Annual rainfall pattern - Axum



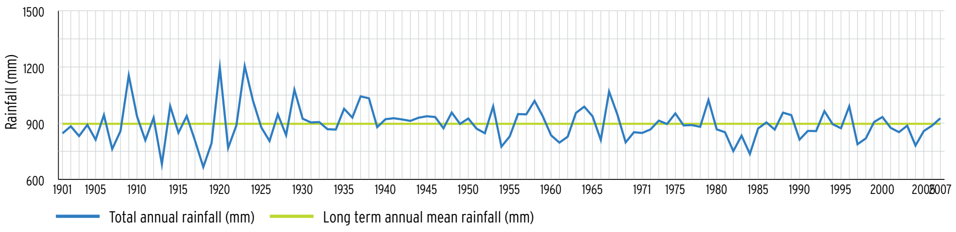
2 Annual rainfall pattern - Dabat



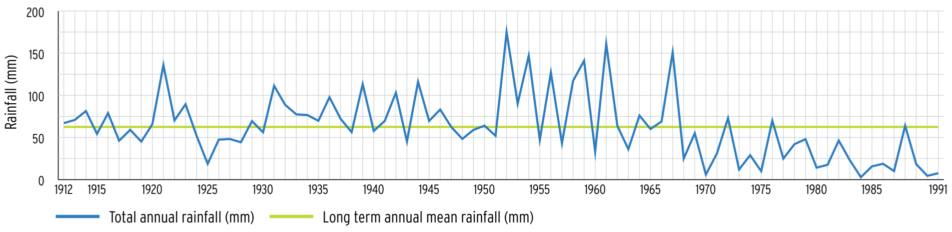
3 Annual rainfall pattern - Derudeb



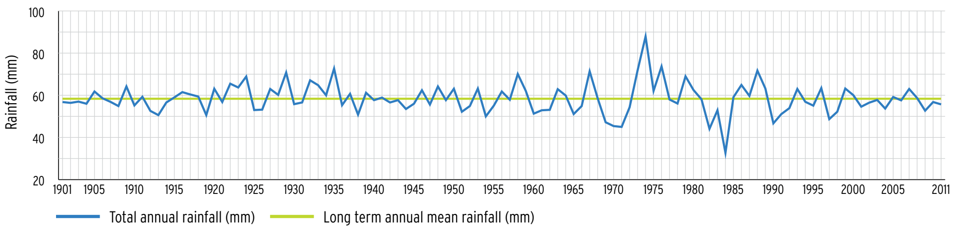
4 Annual rainfall pattern - Gallabat



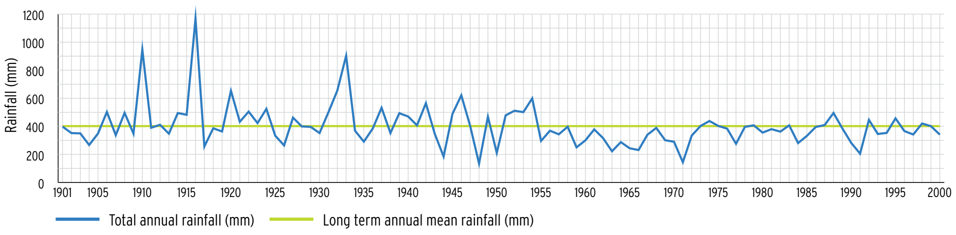
5 Annual rainfall pattern - Haiya



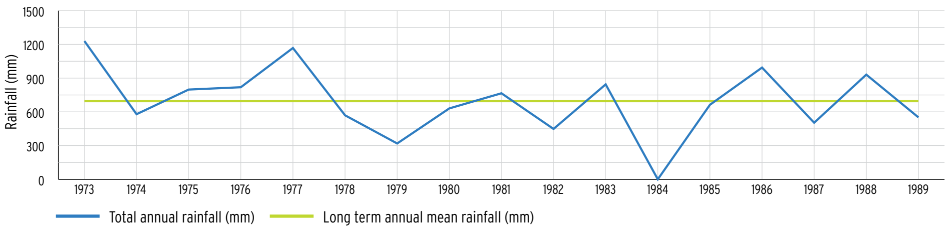
6 Annual rainfall pattern - Humera



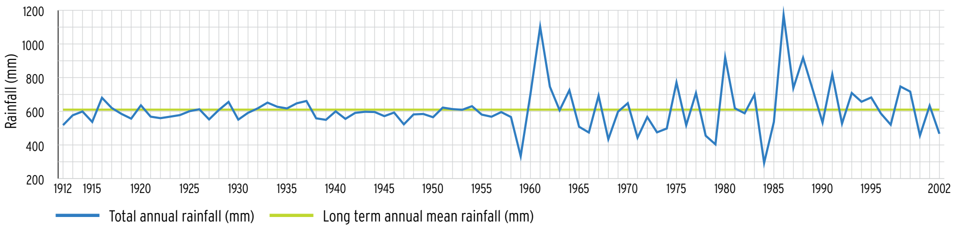
7 Annual rainfall pattern - Khashm El Girba



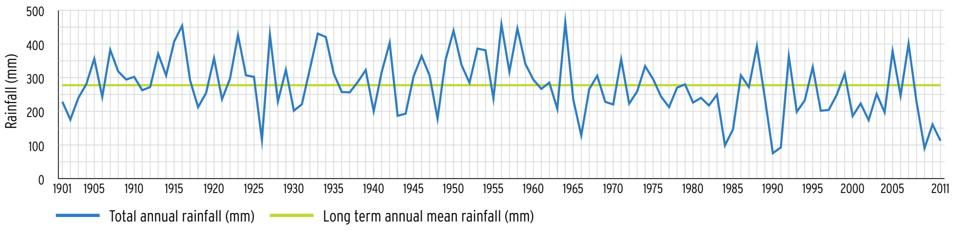
8 Annual rainfall pattern - Lalibela



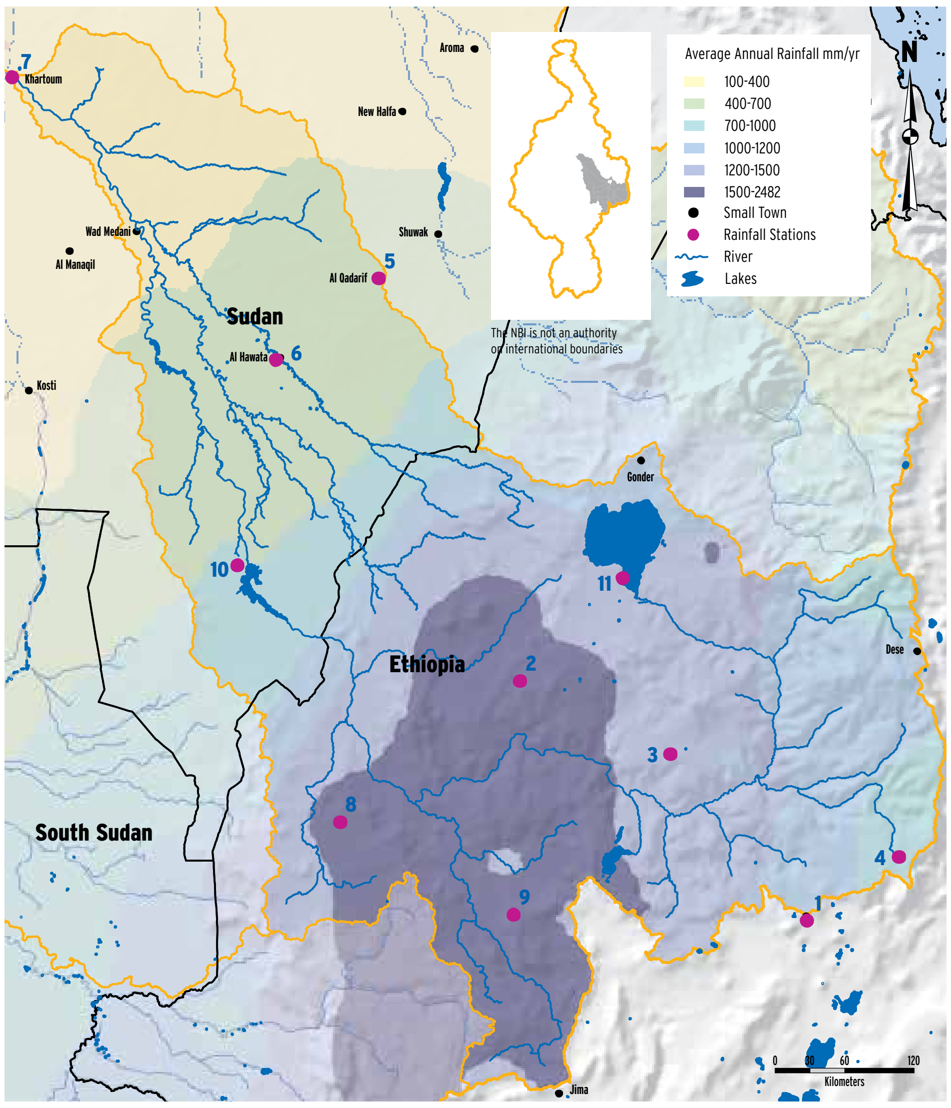
9 Annual rainfall pattern - Mekele



10 Annual rainfall pattern - New Halfa



Annual rainfall patterns – Blue Nile Sub-basin



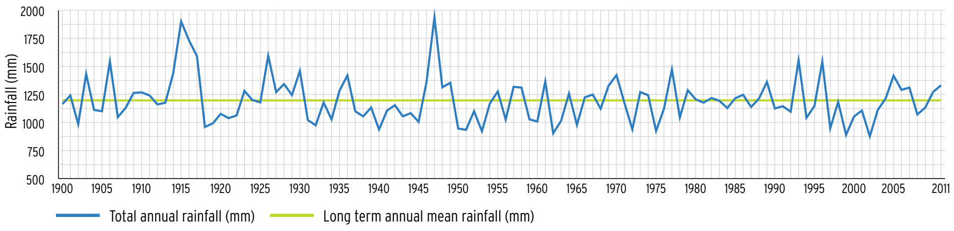
The Blue Nile with its spatial extent ranging from the Ethiopian highlands down to Sudan, receives highly spatially distributed rainfall amounts, with the highlands receiving mean annual rainfall amounts in excess of 1,200mm and some areas in Sudan receiving less than 400mm. There is also a noticeable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

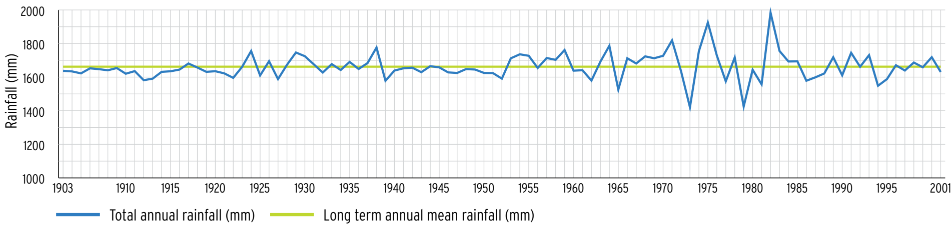
Station Identification

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			

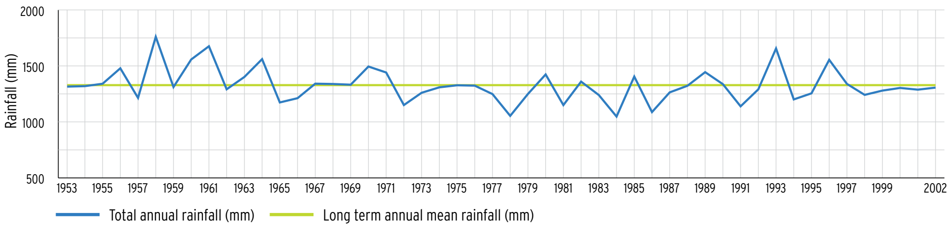
1 Annual rainfall pattern - Addis Ababa



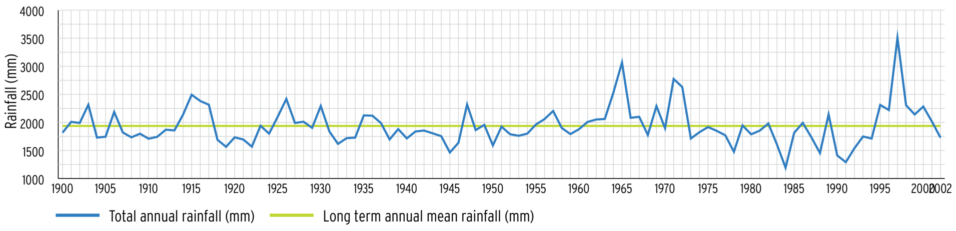
2 Annual rainfall pattern - Chagni



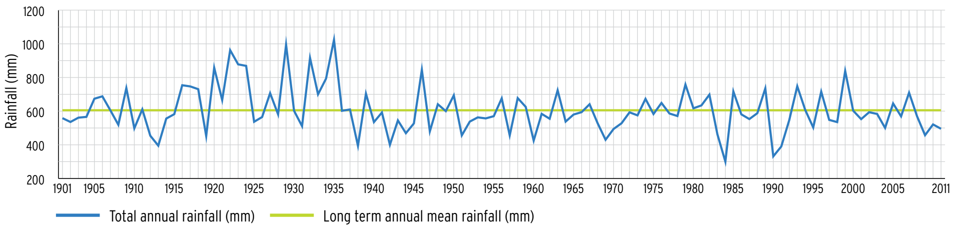
3 Annual rainfall pattern - Debremarkos



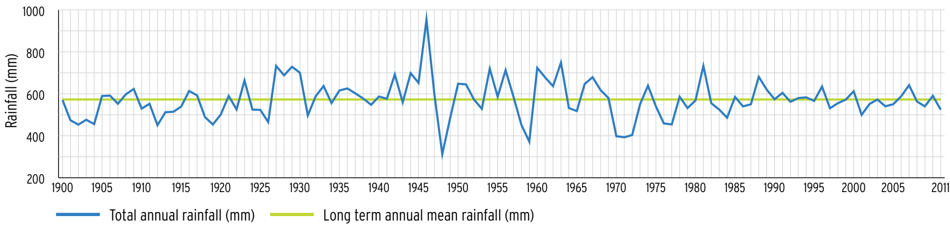
4 Annual rainfall pattern - Debresina



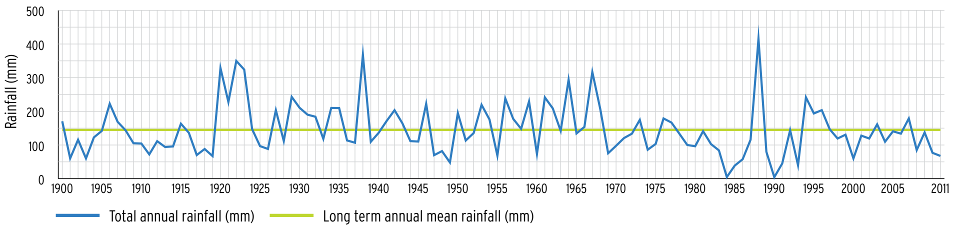
5 Annual rainfall pattern - El Gedarif



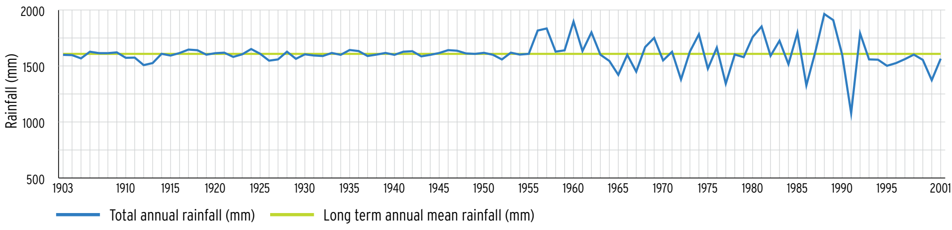
6 Annual rainfall pattern - Hawata



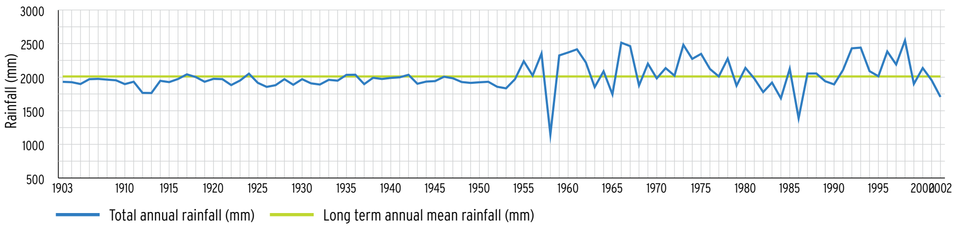
7 Annual rainfall pattern - Khartoum



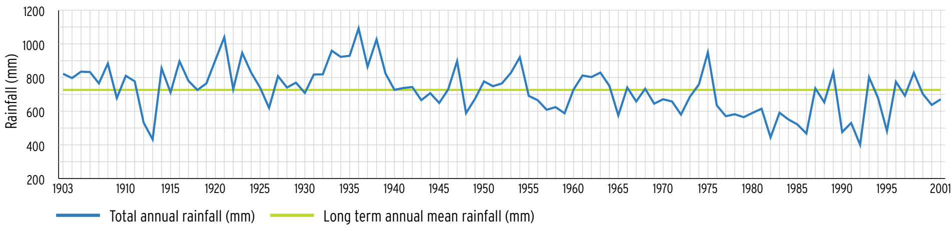
8 Annual rainfall pattern - Mendi



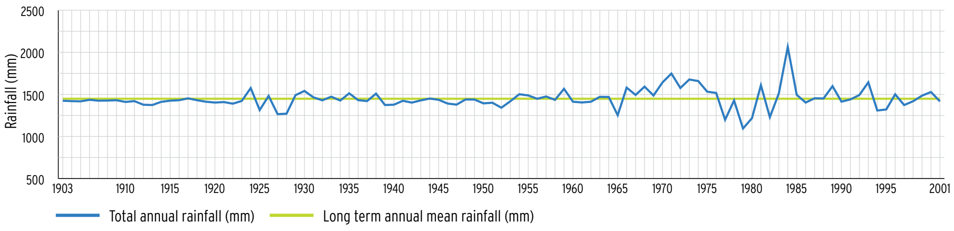
9 Annual rainfall pattern - Nekemteweleg



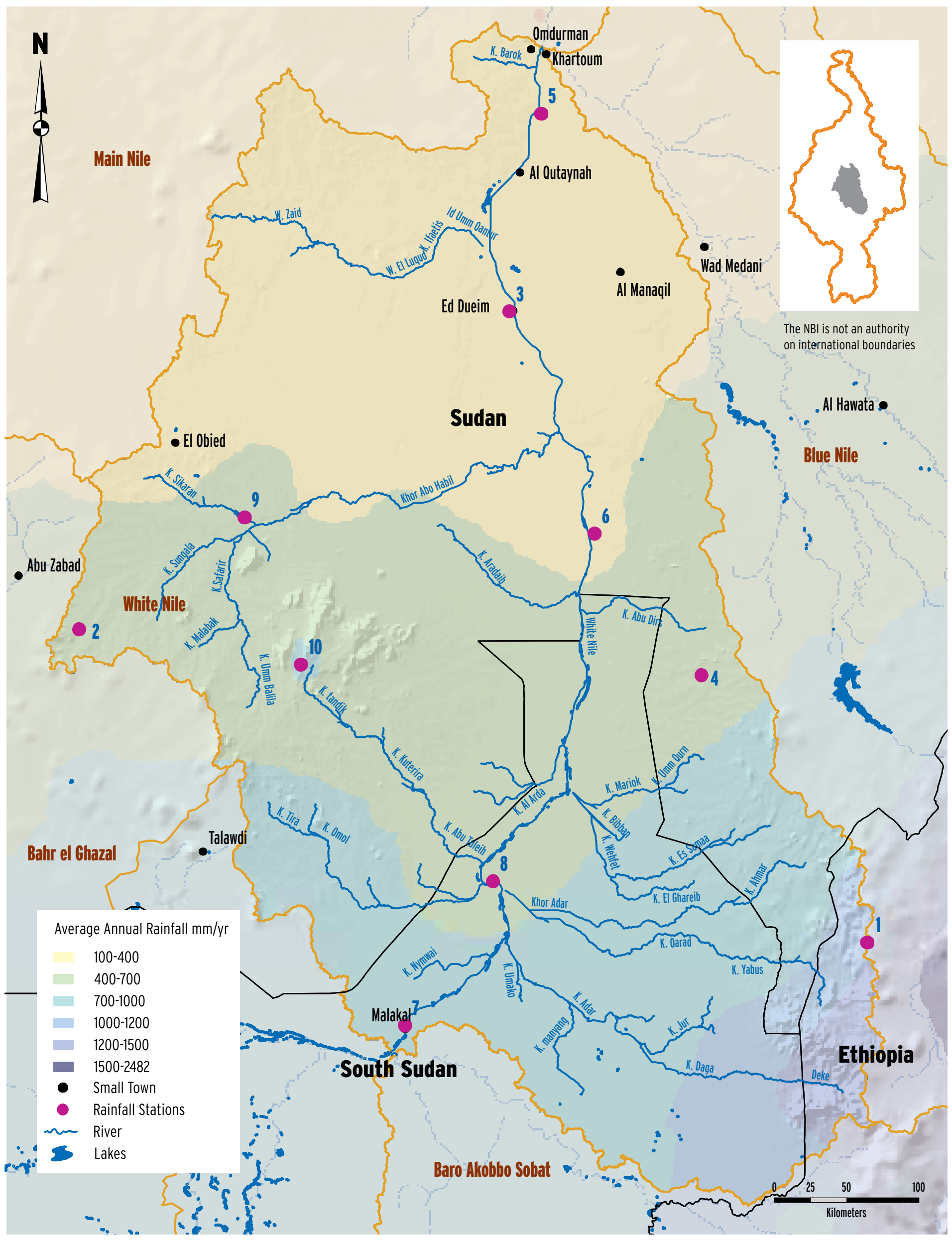
10 Annual rainfall pattern - Roseires



11 Annual rainfall pattern - Zege



Annual rainfall patterns - White Nile Sub-basin



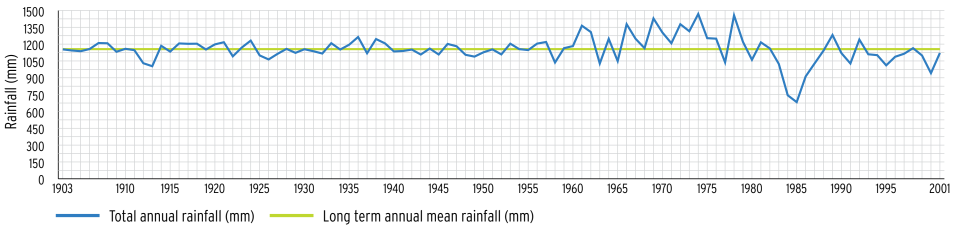
The upstream parts of the White Nile; western Ethiopia, receive high rainfall amounts in excess of 1,000mm whereas the downstream parts in Sudan receive less than 300mm indicating a wide spatial variation in rainfall within the sub-basin. As seen from the plots, the inter-annual variation is also very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

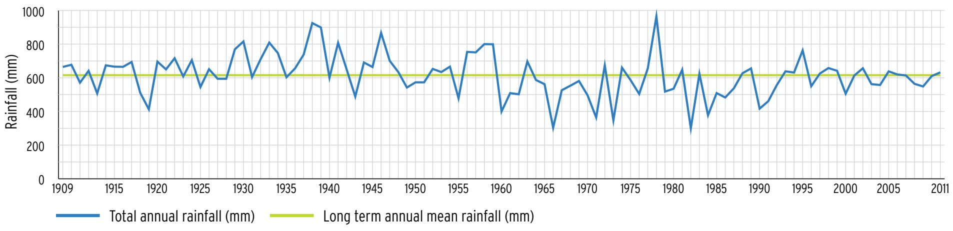
Station Identification

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

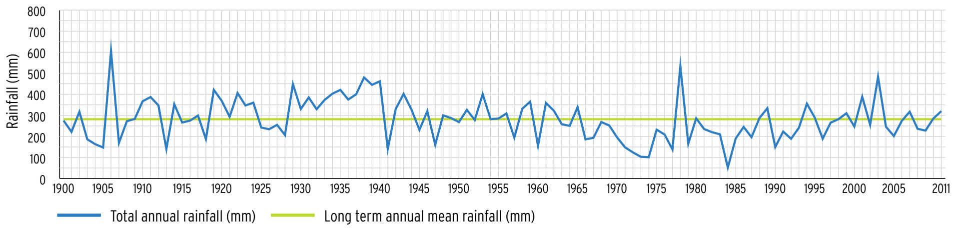
1 Annual rainfall pattern - Asosa



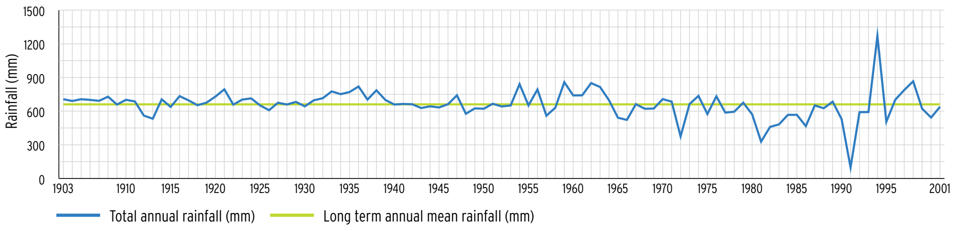
2 Annual rainfall pattern - Dilling



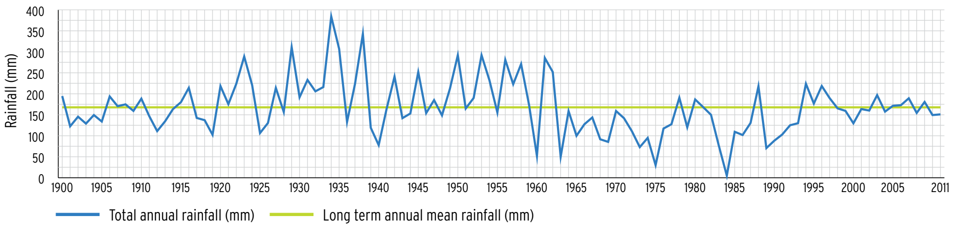
3 Annual rainfall pattern - Ed Dueim



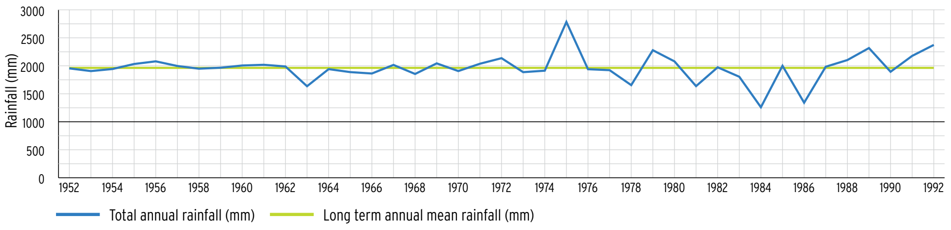
4 Annual rainfall pattern - J. Guli



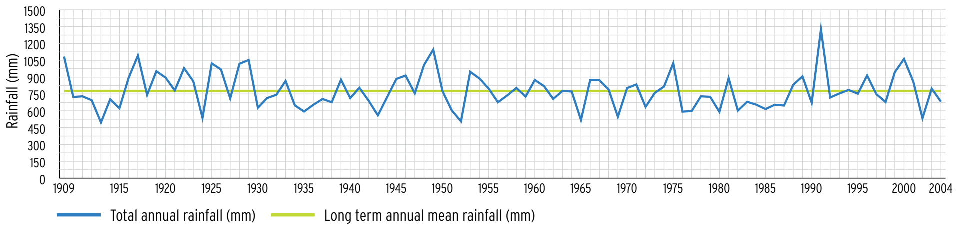
5 Annual rainfall pattern - Jebel Aulia



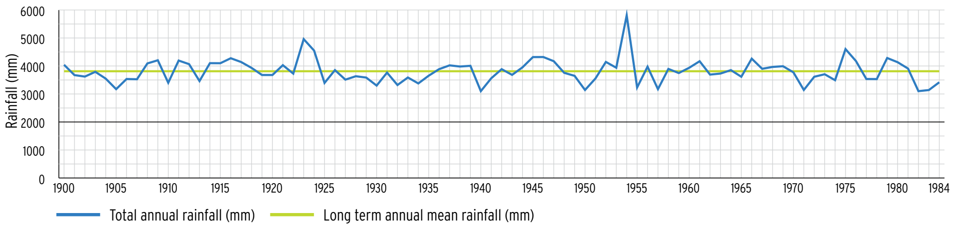
6 Annual rainfall pattern - Jebelein



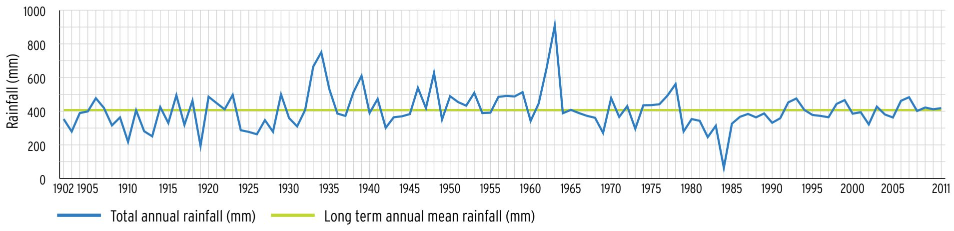
7 Annual rainfall pattern - Malakal



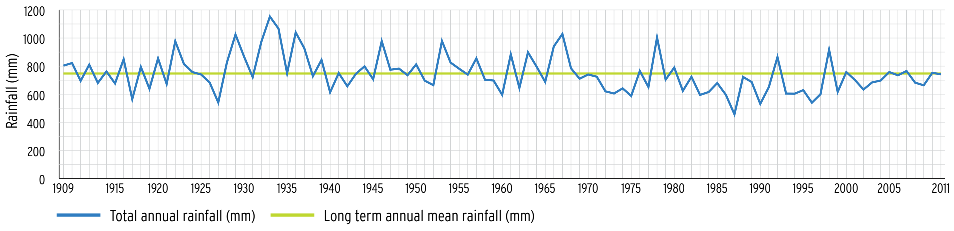
8 Annual rainfall pattern - Melut



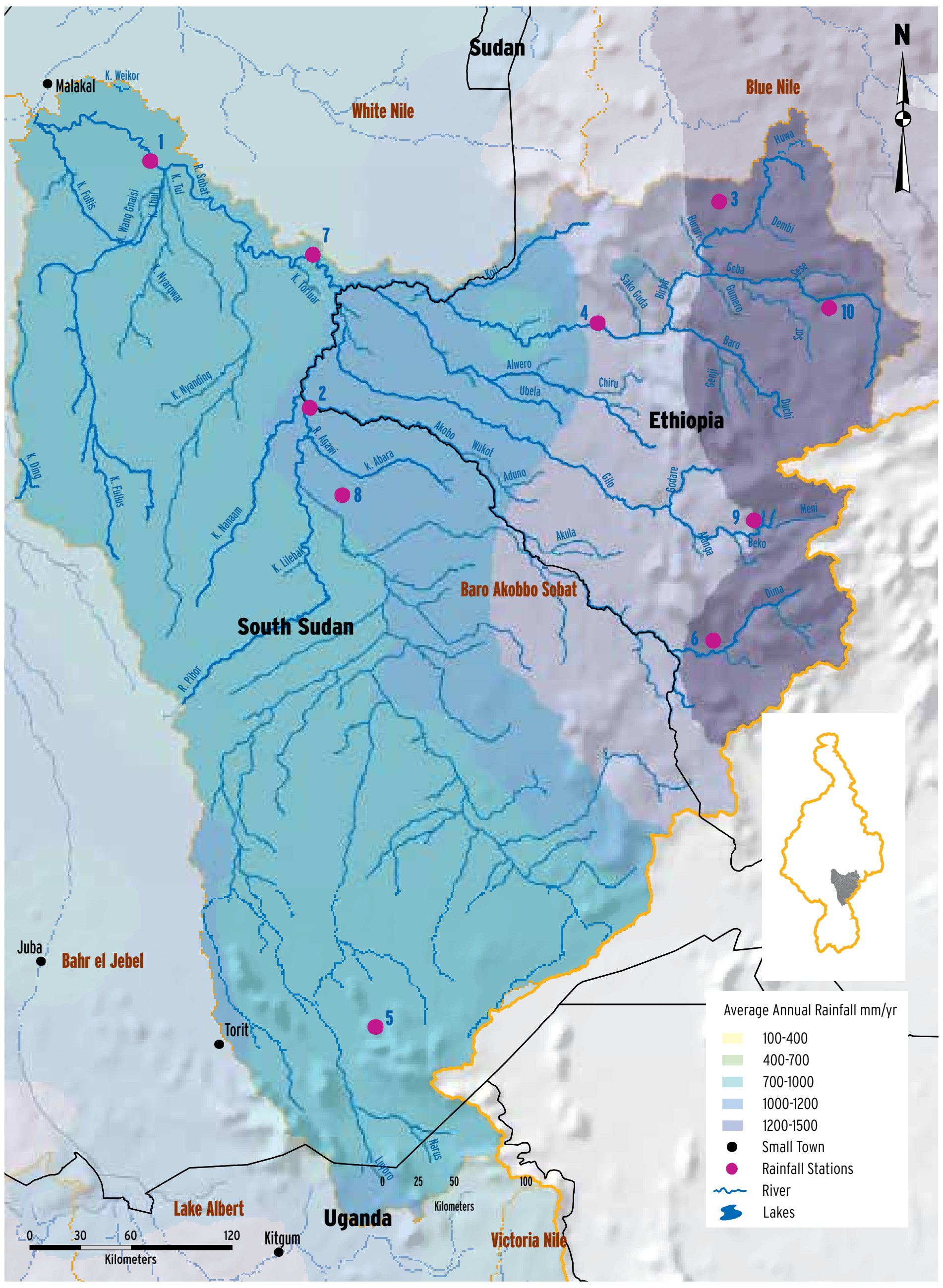
9 Annual rainfall pattern - Rahad



10 Annual rainfall pattern - Rashad



Annual rainfall patterns – Baro Akobo Sobat Sub-basin



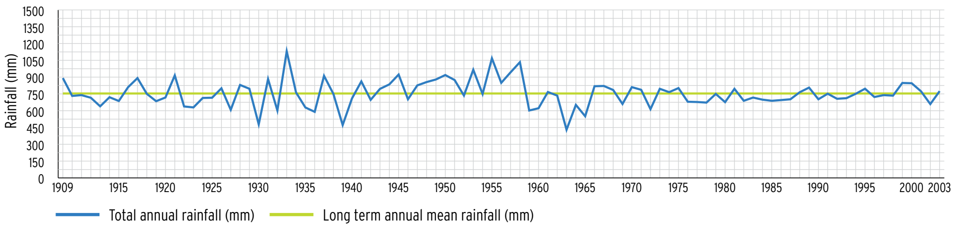
Generally, the spatial distribution of rainfall across the sub-basin is fairly reasonable with most areas receiving amounts of over 1,000mm but there is noticeable inter-annual variation. Specifically, areas in the Ethiopian part of the sub-basin receive more rainfall amounts as opposed to those in South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

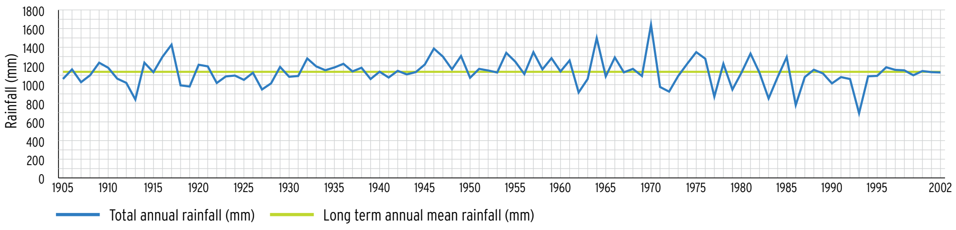
Station Identification

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

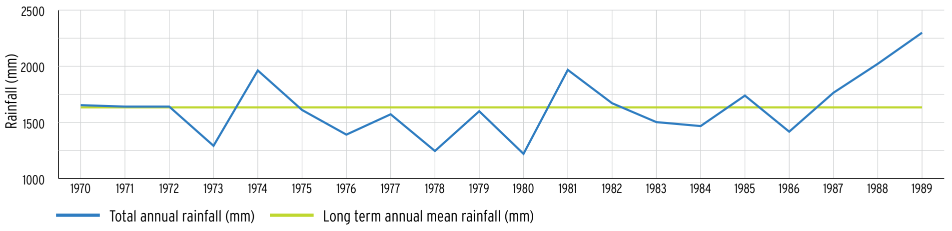
1 Annual rainfall pattern - Abwong



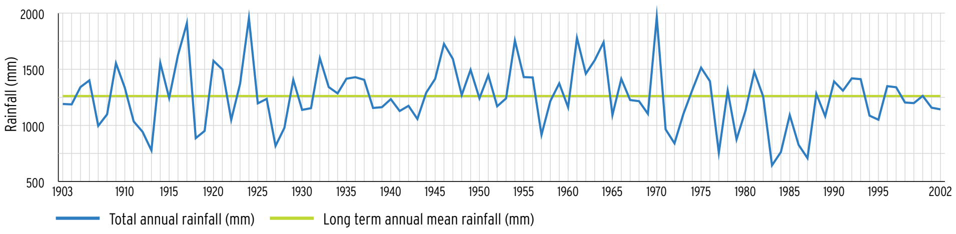
2 Annual rainfall pattern - Akobo



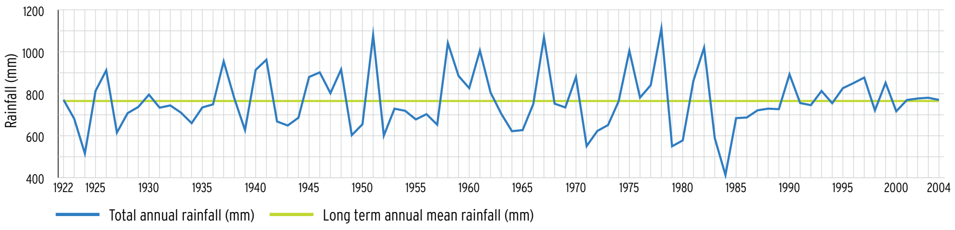
3 Annual rainfall pattern - Alem Teferi



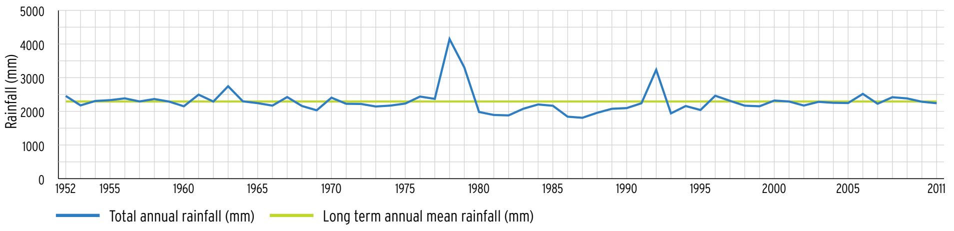
4 Annual rainfall pattern - Gambella



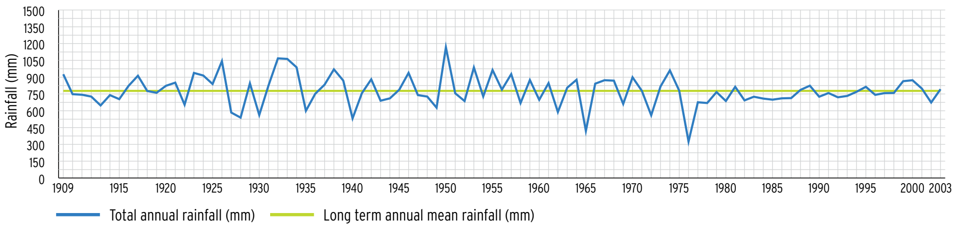
5 Annual rainfall pattern - Kapoeta



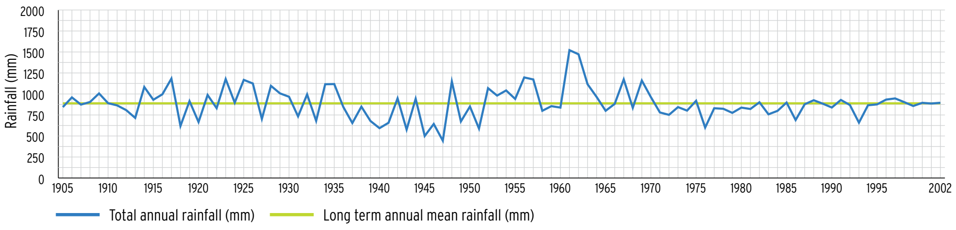
6 Annual rainfall pattern - Mizan Teferi



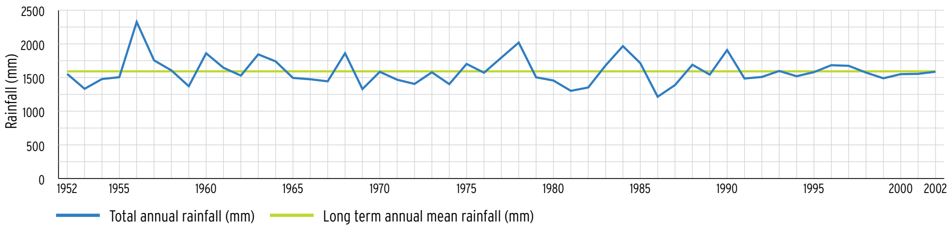
7 Annual rainfall pattern - Nasser



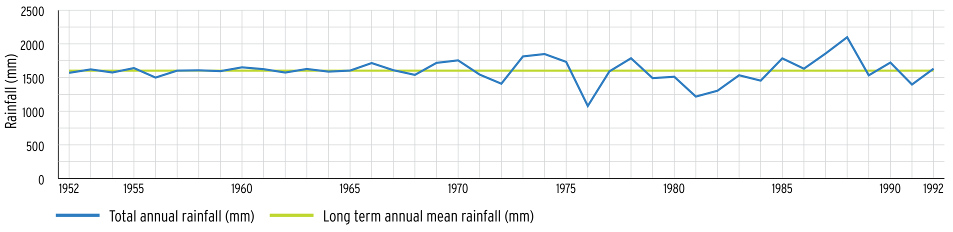
8 Annual rainfall pattern - Pibor



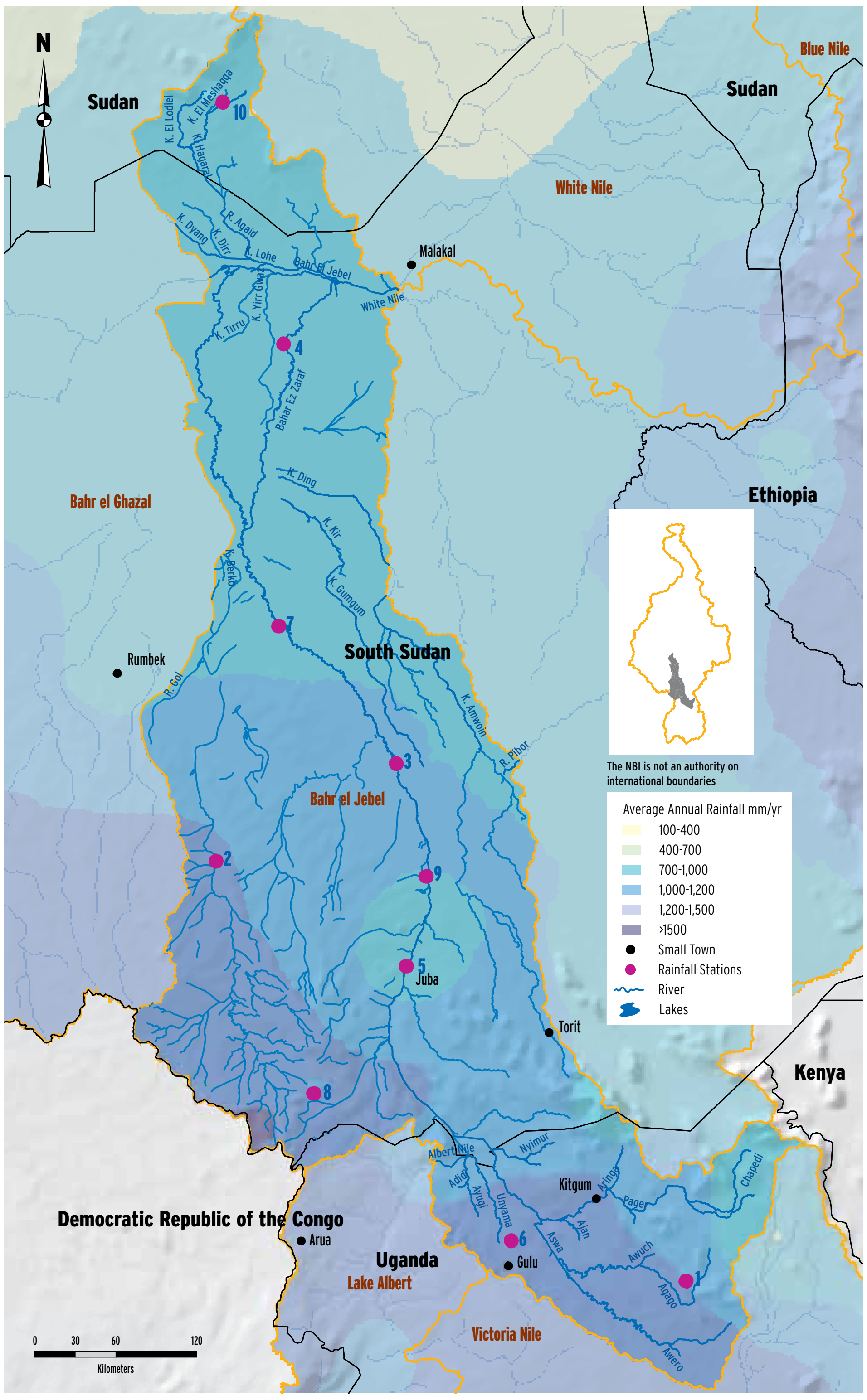
9 Annual rainfall pattern - Tepi



10 Annual rainfall pattern - Yayu



Annual rainfall patterns - Bahr el Jebel Sub-basin

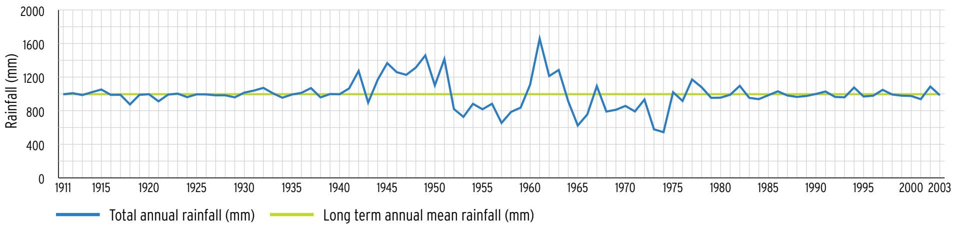


Rainfall stations in the Bahr el Jebel sub-basin reveal inter annual variations in the mean annual rainfall and reduction in the rainfall amounts is realized as we move further downstream in the sub-basin. The upstream part of the Sub-basin realizes mean annual rainfall of over 1,000mm whereas the downstream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

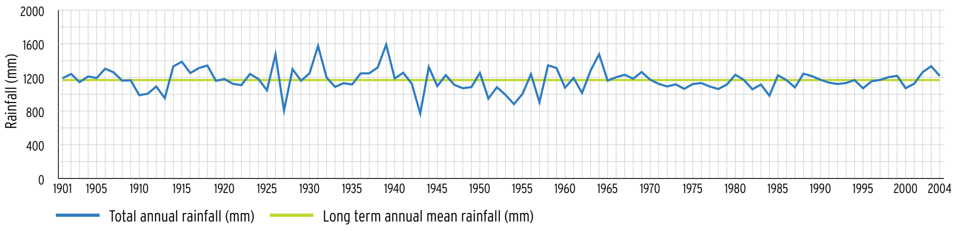
Station Identification

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

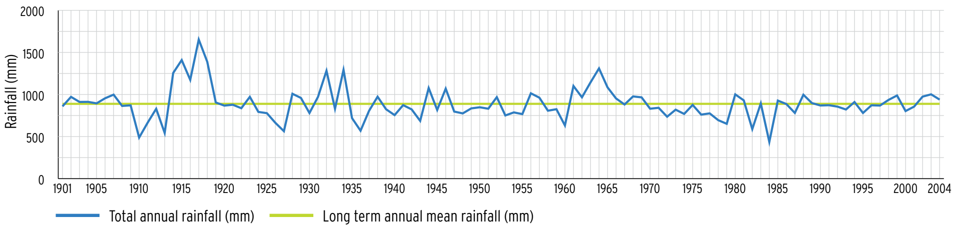
1 Annual rainfall pattern - Adilang



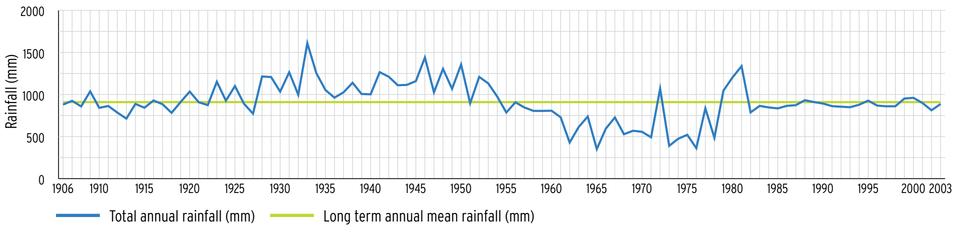
2 Annual rainfall pattern - Amadi



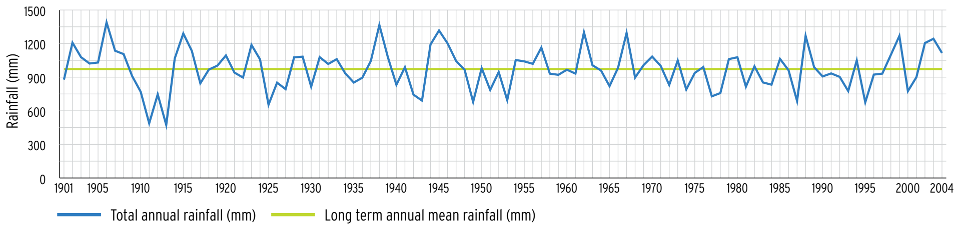
3 Annual rainfall pattern - Bor



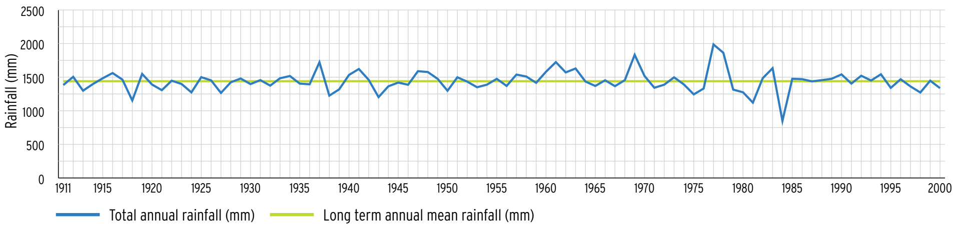
4 Annual rainfall pattern - Fangak



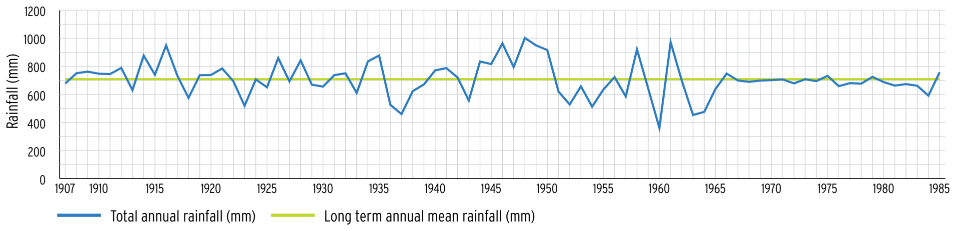
5 Annual rainfall pattern - Juba



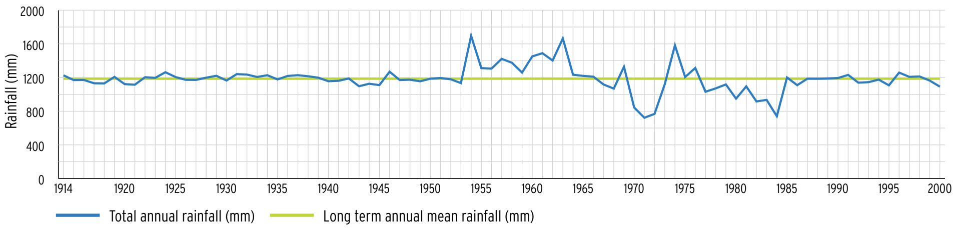
6 Annual rainfall pattern - Patiko



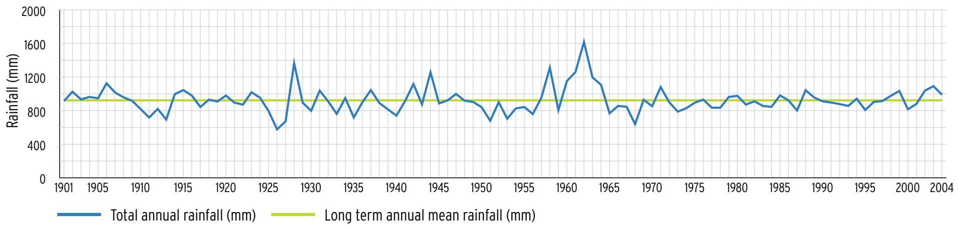
7 Annual rainfall pattern - Shambe



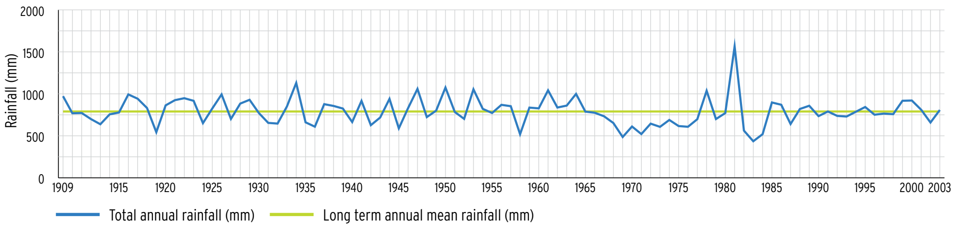
8 Annual rainfall pattern - Tambura



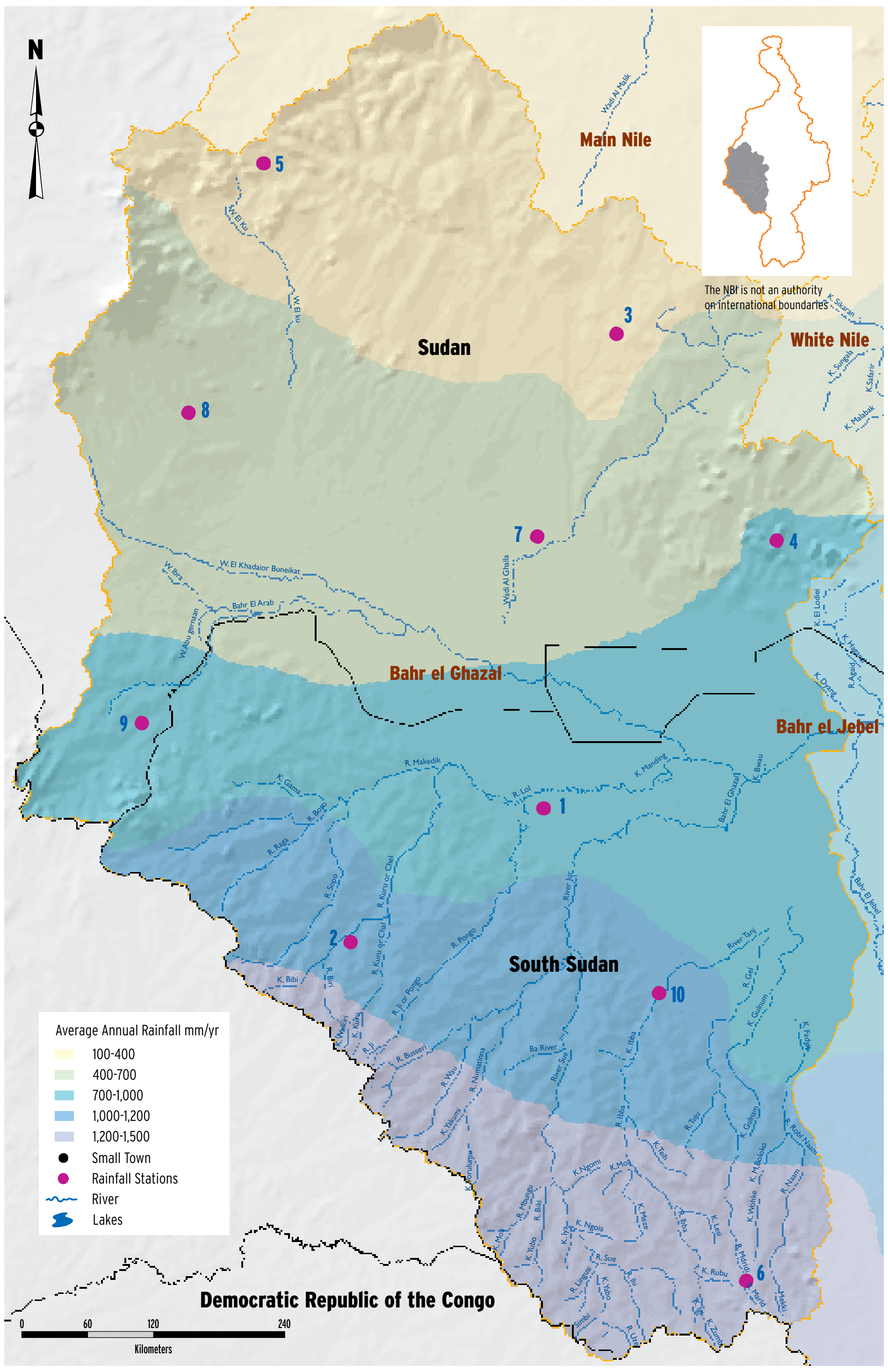
9 Annual rainfall pattern - Terakeka



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.

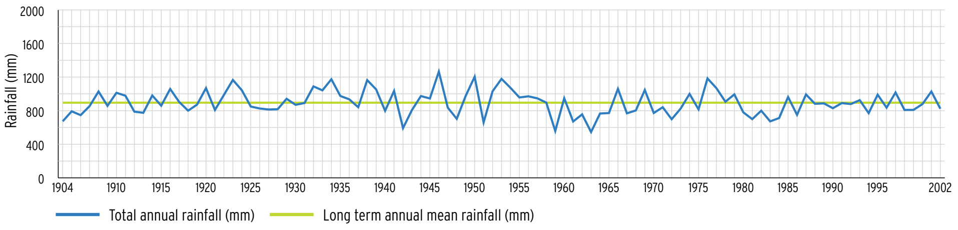
Stations in Sudan record mean annual values of about 500mm whereas those in South Sudan receive on average 900mm of rain.

> 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.

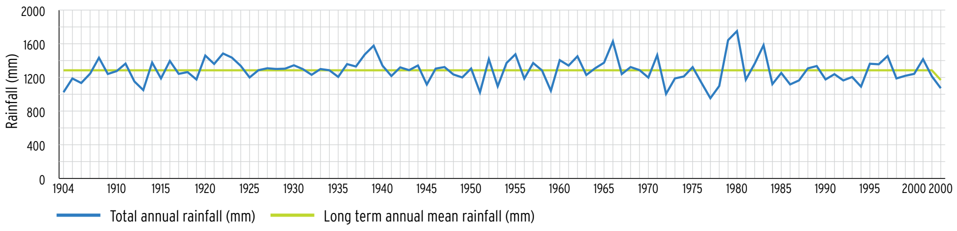
Station Identification

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

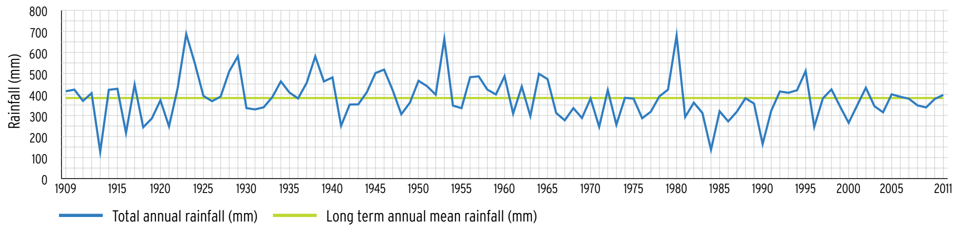
1 Annual rainfall pattern - Aweil



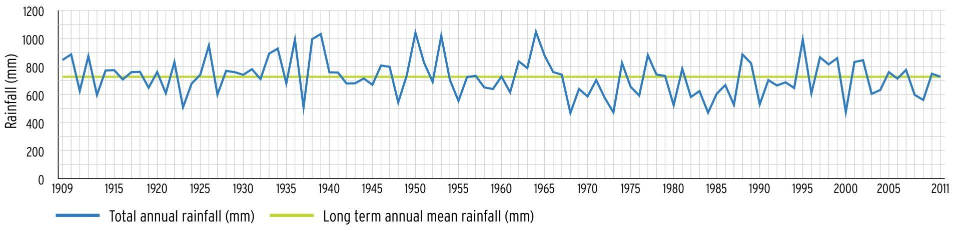
2 Annual rainfall pattern - Deim Zubeir



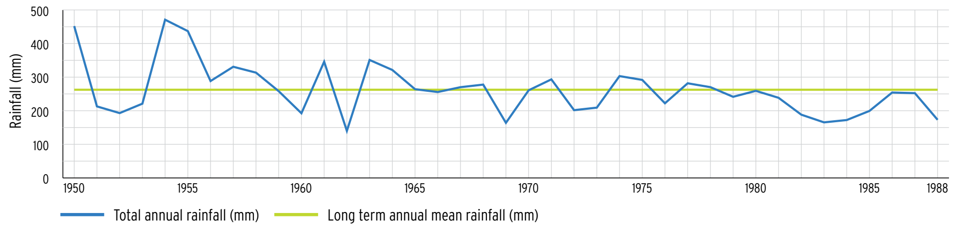
3 Annual rainfall pattern - En Nahud



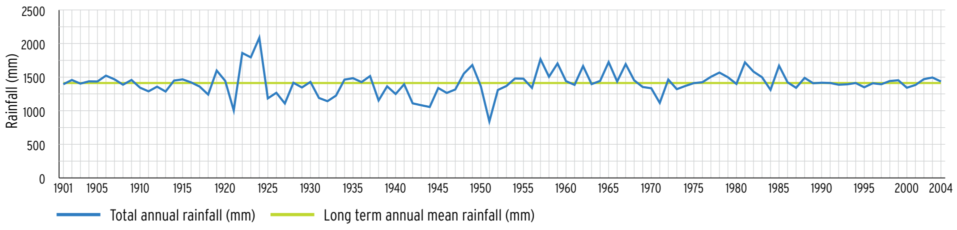
4 Annual rainfall pattern - Kadugli



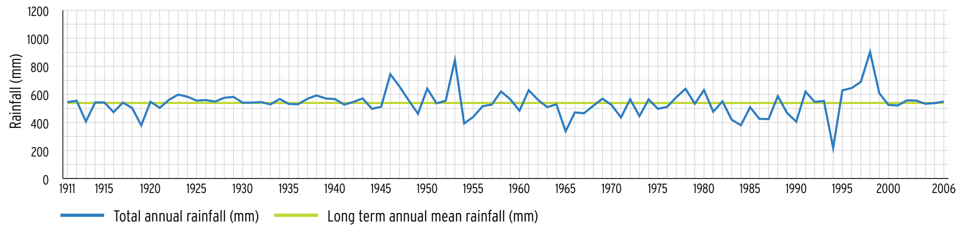
5 Annual rainfall pattern - Mellit



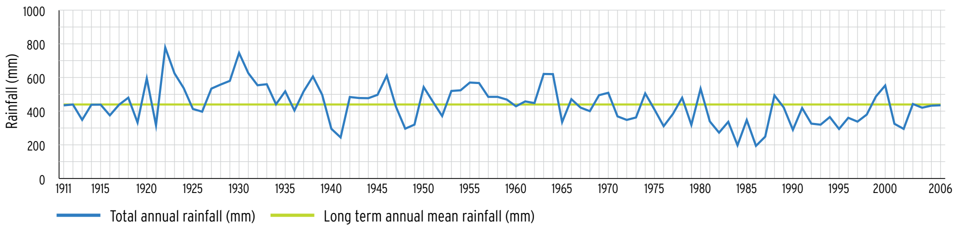
6 Annual rainfall pattern - Meridi



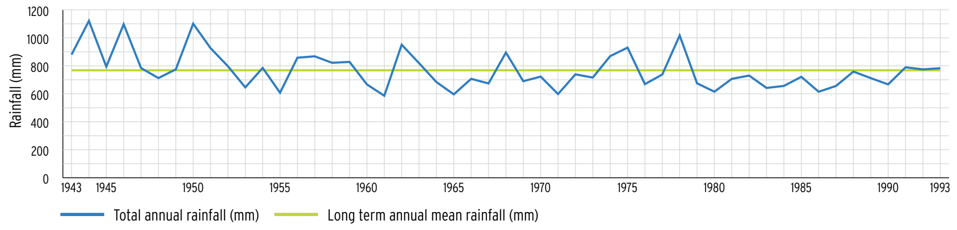
7 Annual rainfall pattern - Muglad



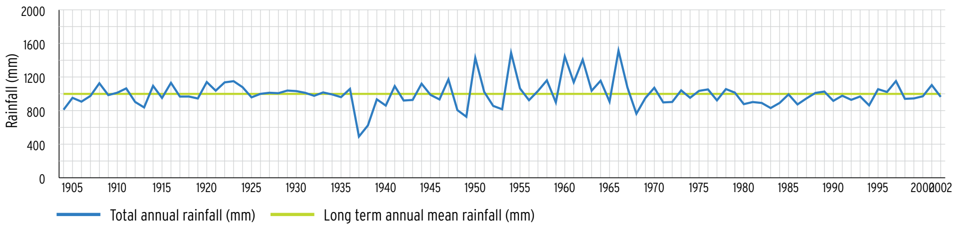
8 Annual rainfall pattern - Nyala



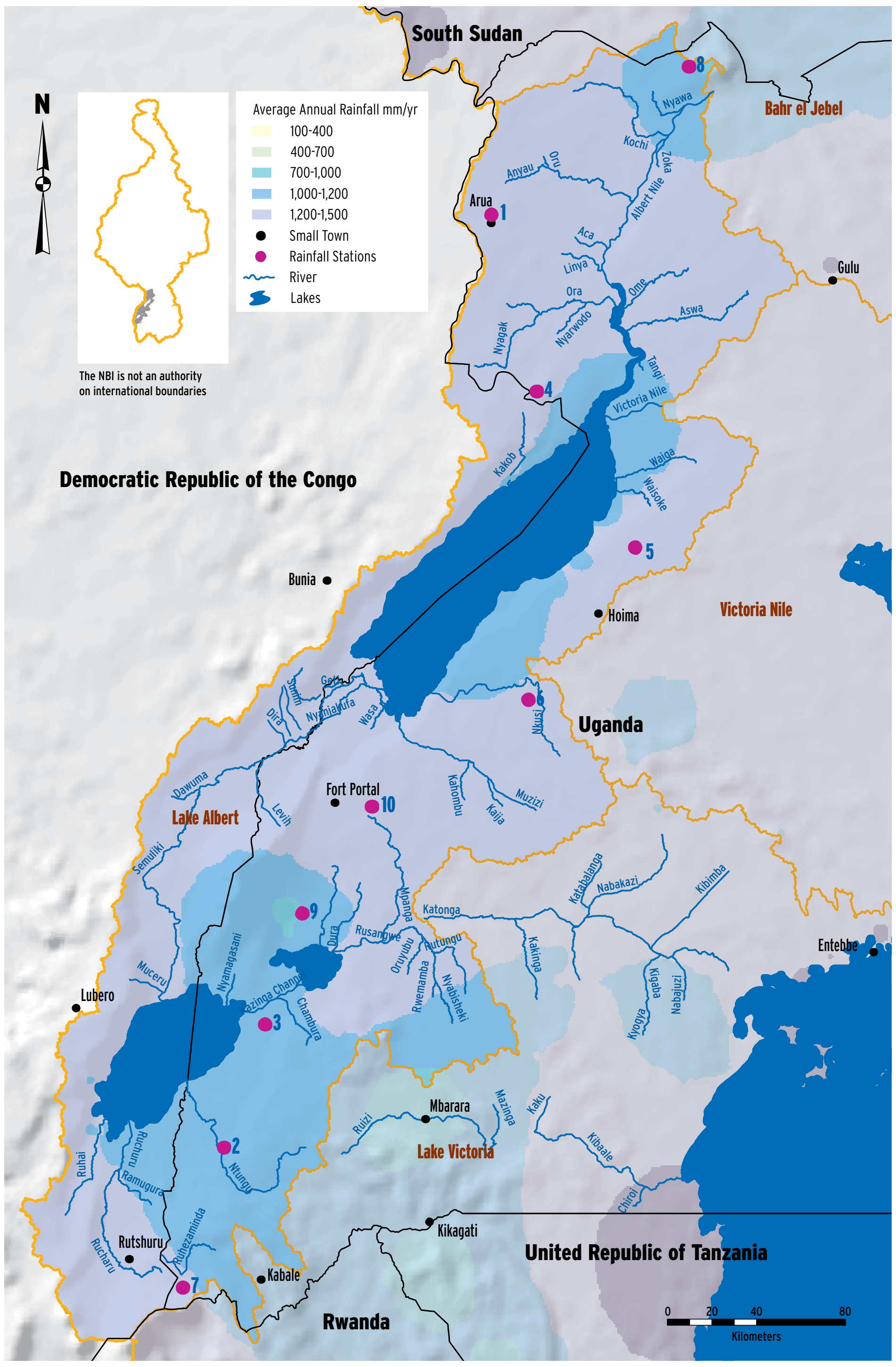
9 Annual rainfall pattern - Radom



10 Annual rainfall pattern - Tonj



Annual rainfall patterns - Lake Albert Sub-basin

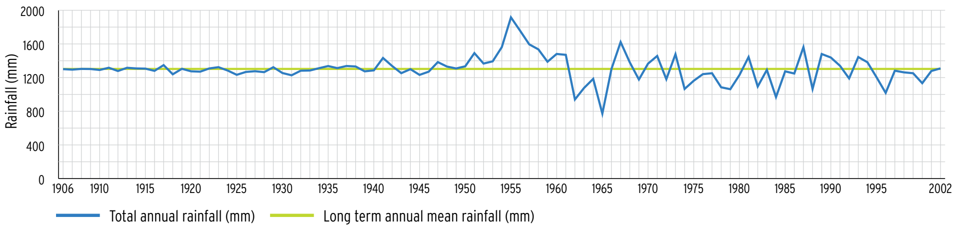


The average annual rainfall within the Lake Albert sub-basin is fairly constant with small inter-annual variations. However, there is a noticeable increment in rainfall amounts in the early 1960s'. This area is also influenced by the Rwenzori Mountains and most of the stations record a mean annual rainfall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

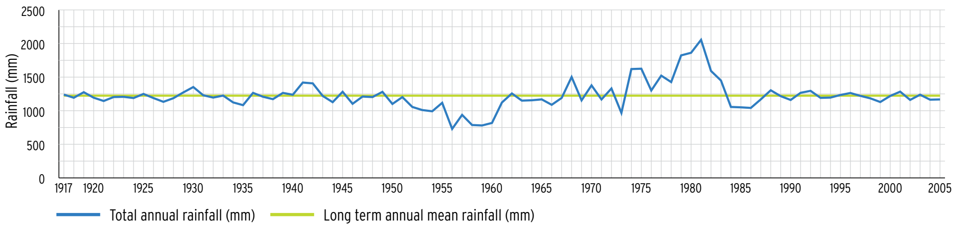
Station Identification

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

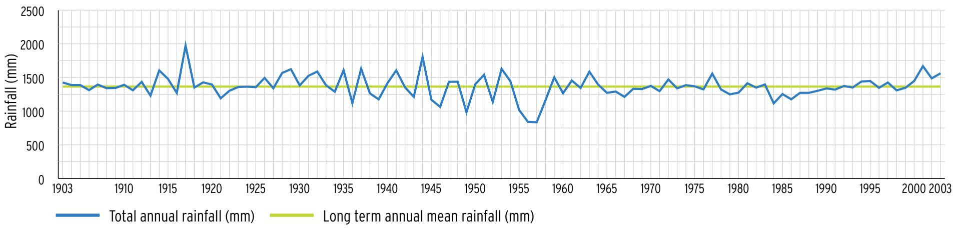
1 Annual rainfall pattern - Arua



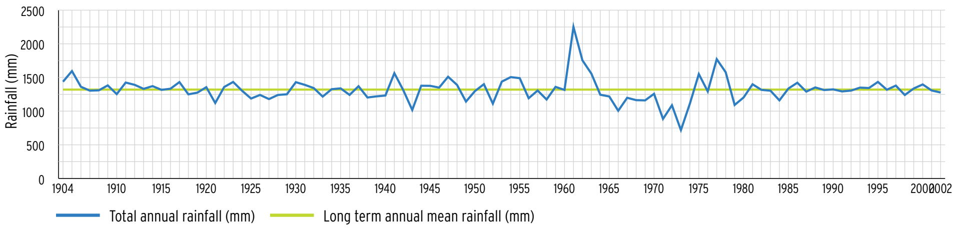
2 Annual rainfall pattern - Bugangari



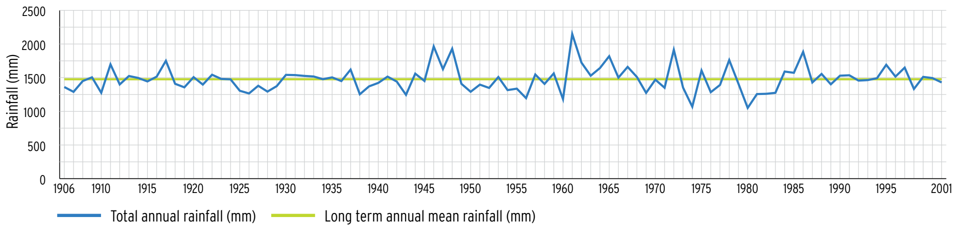
3 Annual rainfall pattern - Bunyaruguru



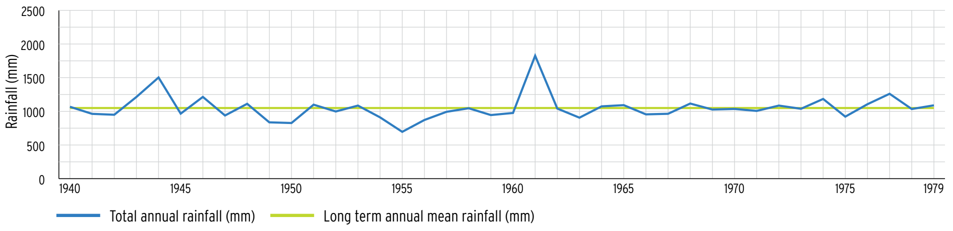
4 Annual rainfall pattern - Erusi



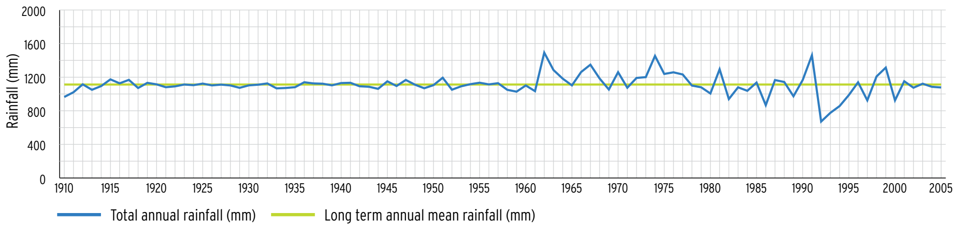
5 Annual rainfall pattern - Ihungu



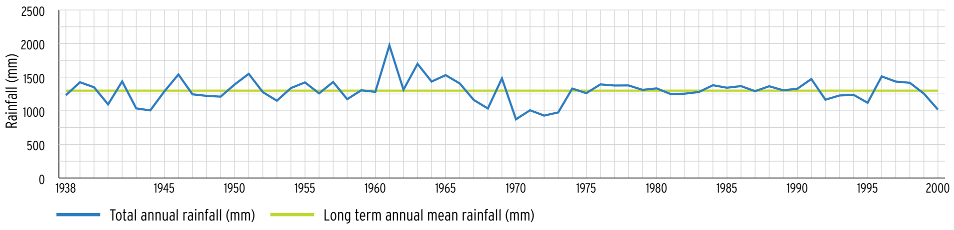
6 Annual rainfall pattern - Kiryanga



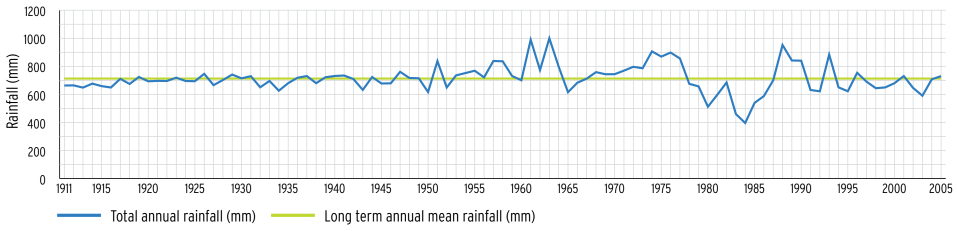
7 Annual rainfall pattern - Kisoro



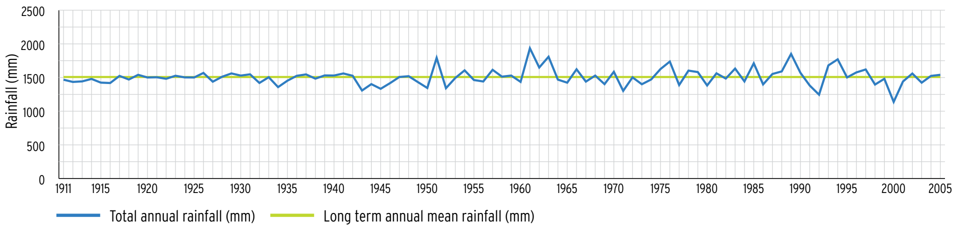
8 Annual rainfall pattern - Moyo Boma



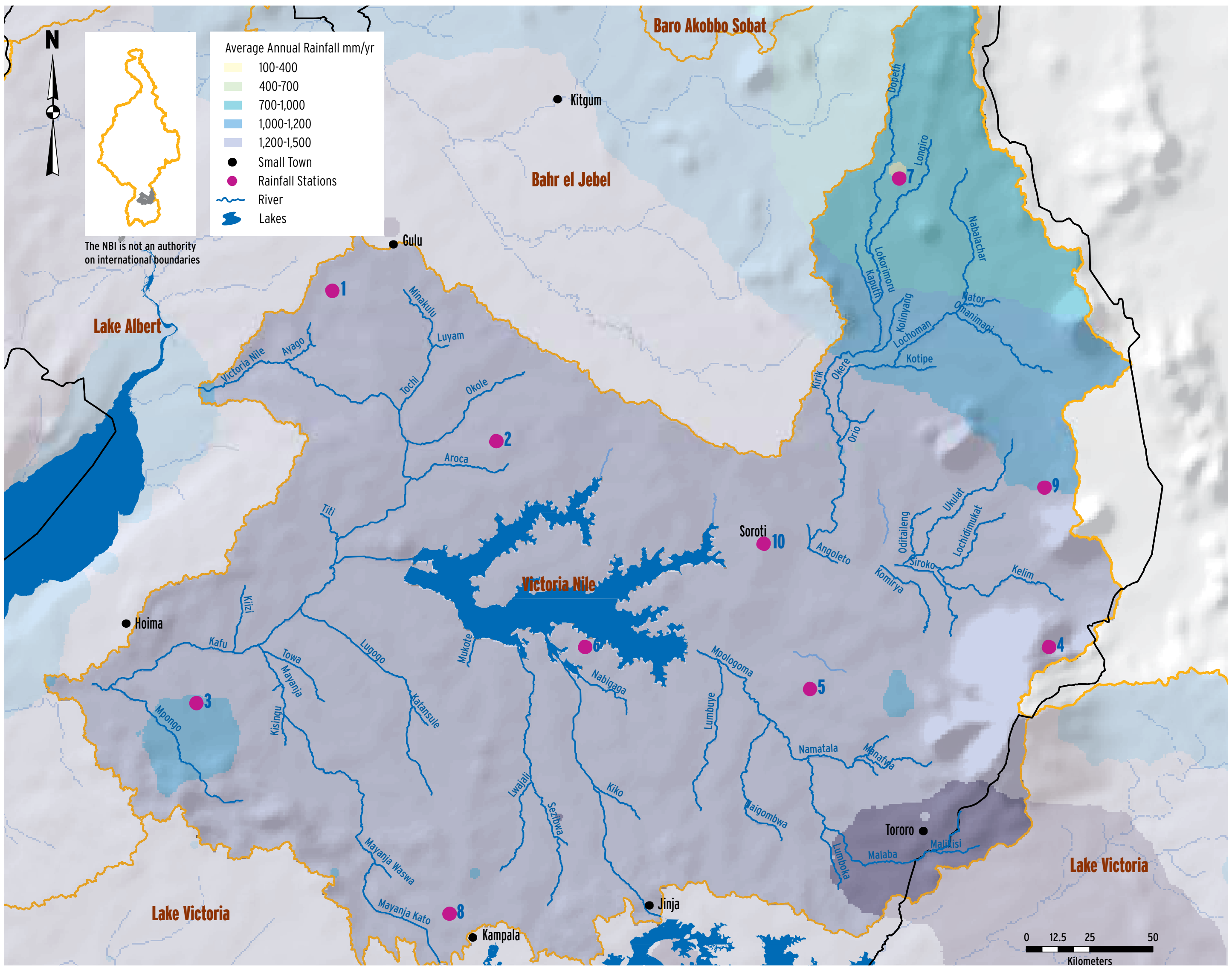
9 Annual rainfall pattern - Mubuku



10 Annual rainfall pattern - Rwebitaba



Annual rainfall patterns – Victoria Nile Sub-basin

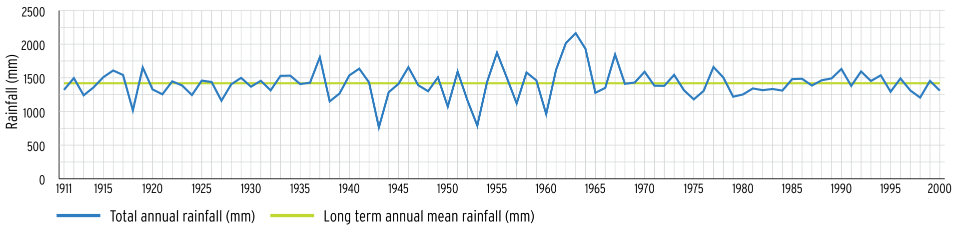


The mean annual rainfall within the Victoria Nile sub-basin is seen to exhibit high inter-annual variation with a vivid increase in the 1960s for most of the stations. Stations in the north eastern part of Uganda are seen to register almost half of the rainfall amounts recorded in the upstream stations, 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.

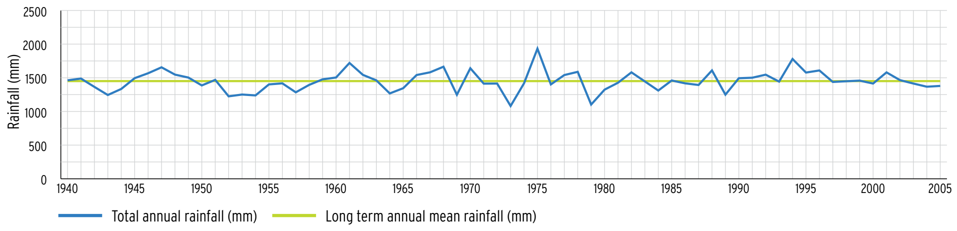
Station Identification

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

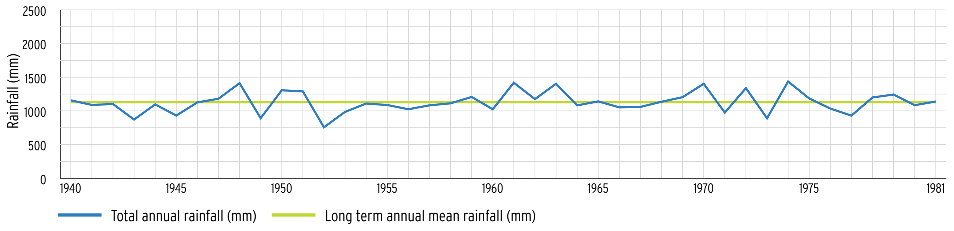
1 Annual rainfall pattern - Amart



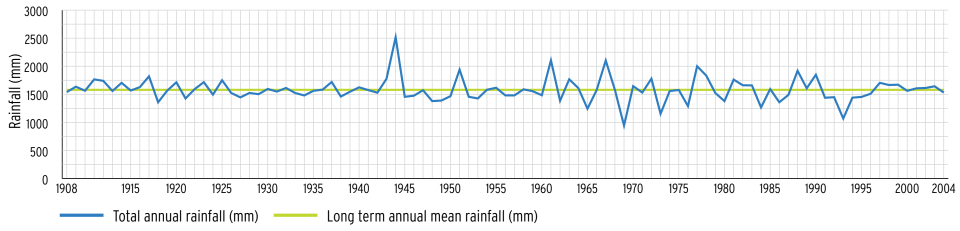
2 Annual rainfall pattern - Aninolal



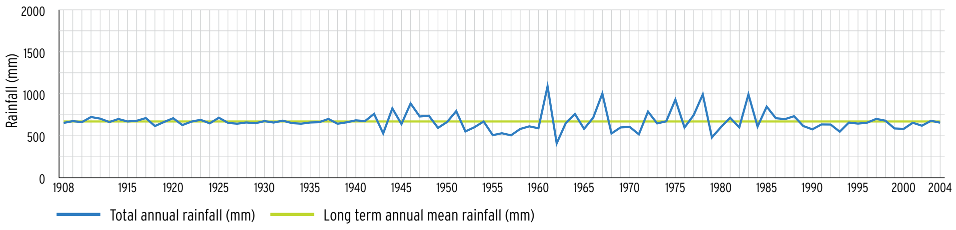
3 Annual rainfall pattern - Butemba



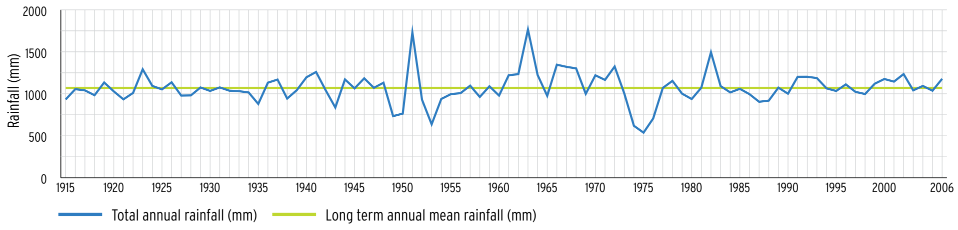
4 Annual rainfall pattern - Kapkwta



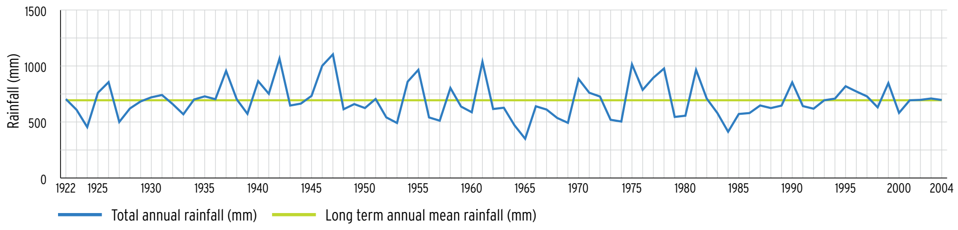
5 Annual rainfall pattern - Kibale



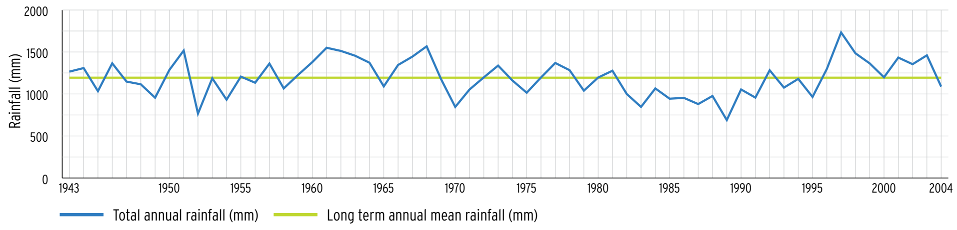
6 Annual rainfall pattern - Kidera



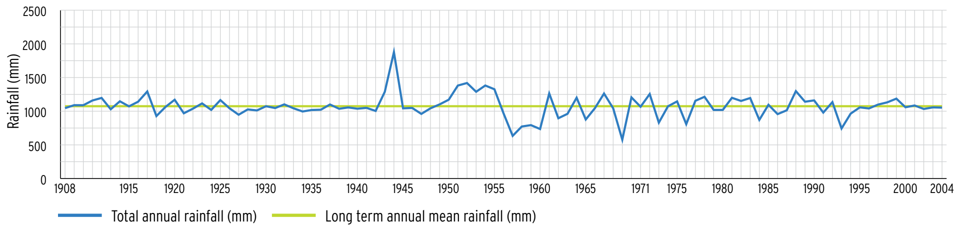
7 Annual rainfall pattern - Kotido



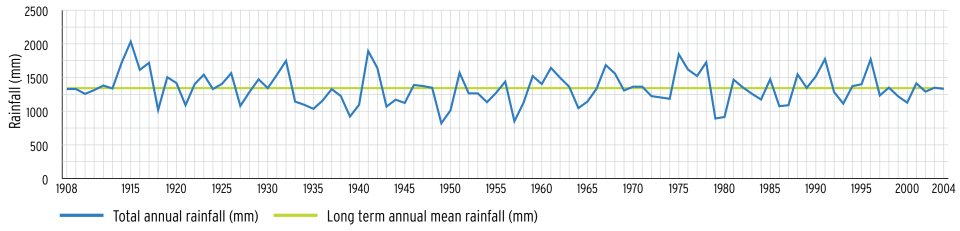
8 Annual rainfall pattern - Matunga



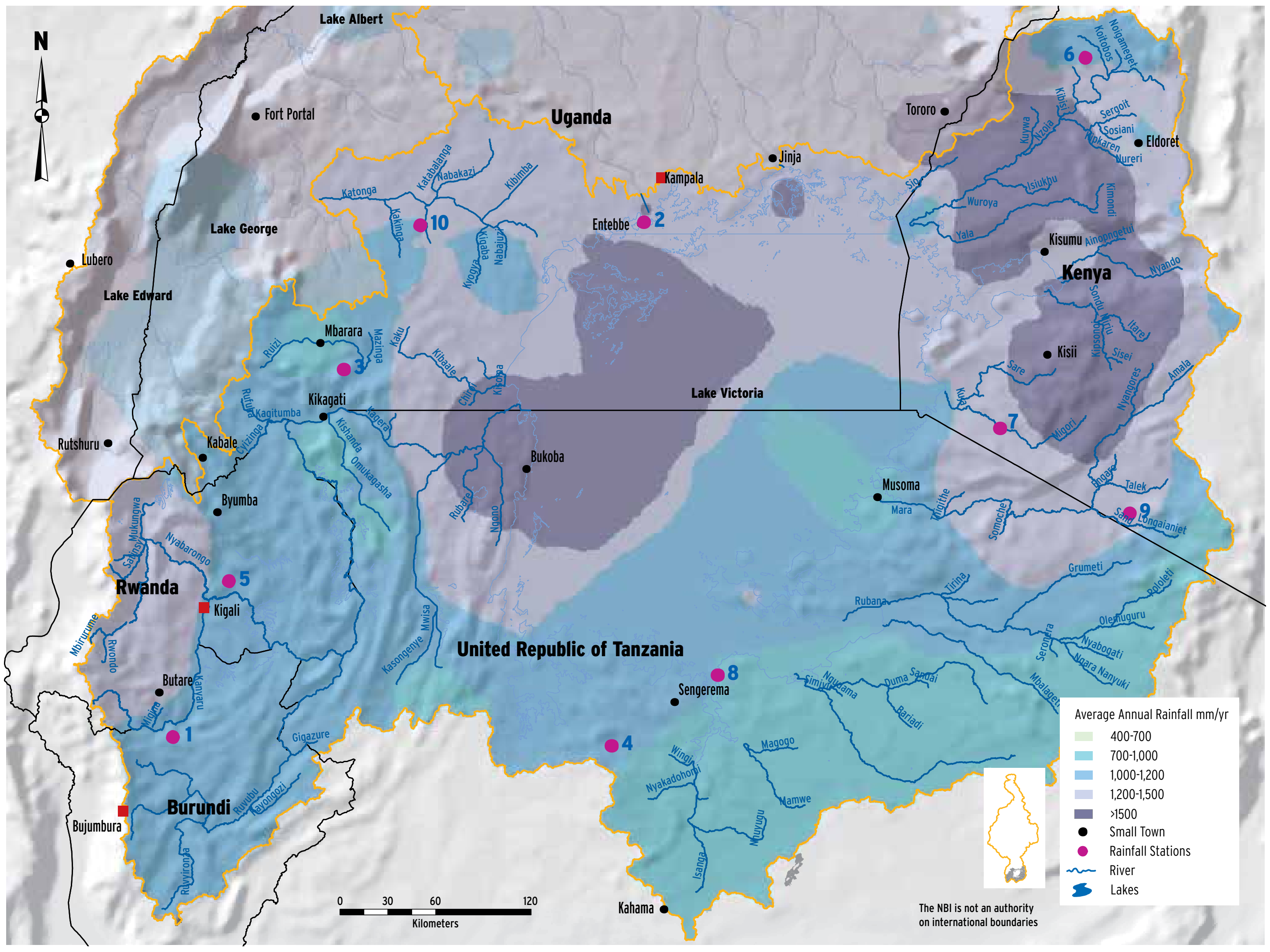
9 Annual rainfall pattern - Napianyenya



10 Annual rainfall pattern - Soroti



Annual rainfall patterns – Lake Victoria Sub-basin

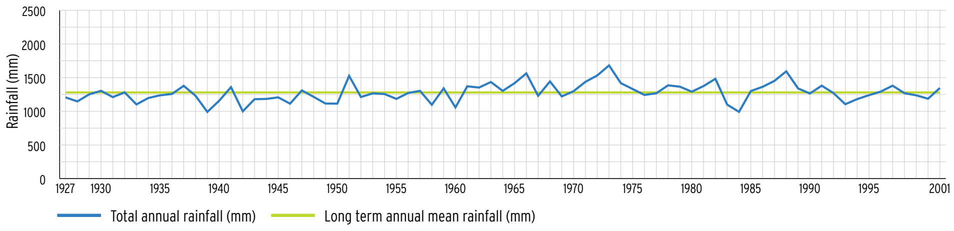


Generally, most of the rainfall stations within the Lake Victoria sub-basin record annual rainfall amounts in excess of 1,000mm with some (in the western part of the sub-basin) going up to as high as 1,600mm. Apart from the noticeable increment in the early 1960s, there is relatively small inter annual 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.

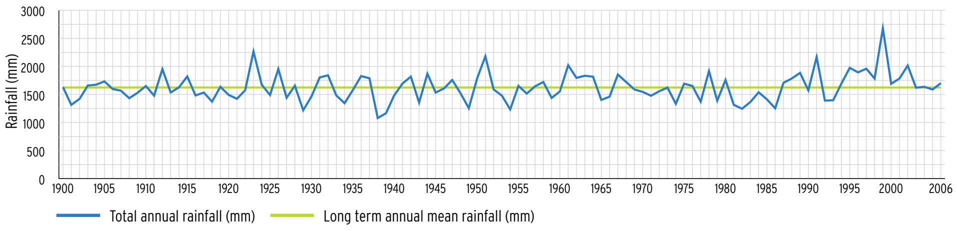
Station Identification

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

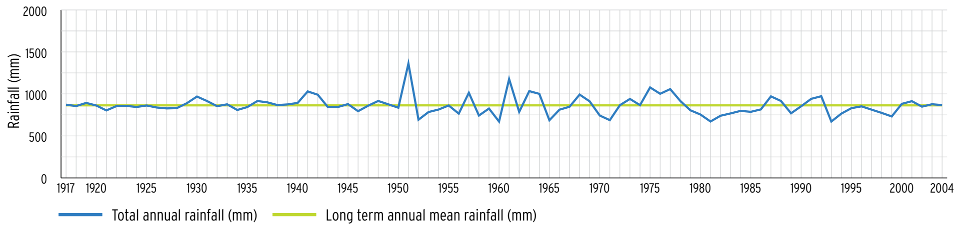
1 Annual rainfall pattern - Buye



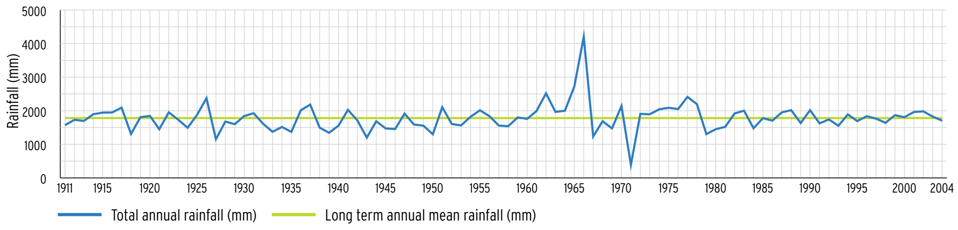
2 Annual rainfall pattern - Entebbe



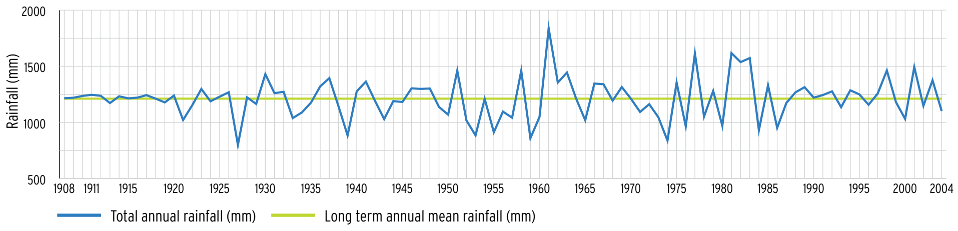
3 Annual rainfall pattern - Gayaza



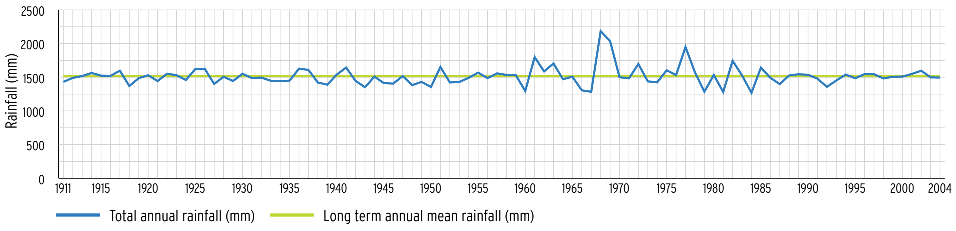
4 Annual rainfall pattern - Geita



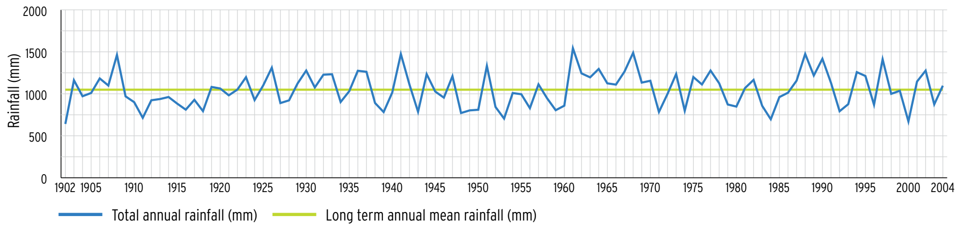
5 Annual rainfall pattern - Kitale



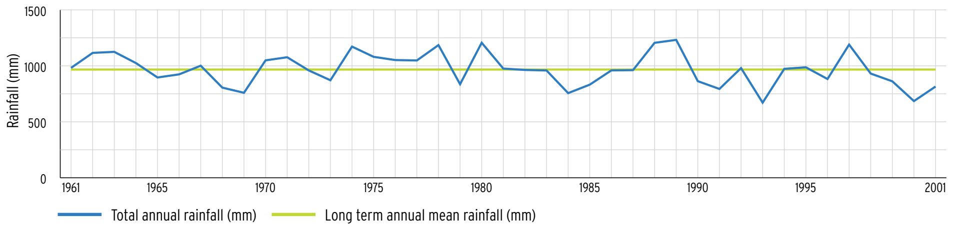
6 Annual rainfall pattern - Migori



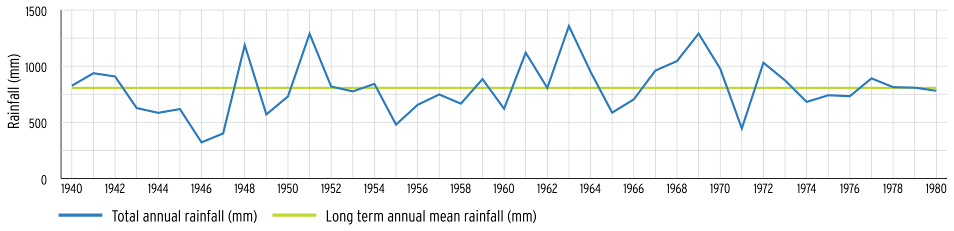
7 Annual rainfall pattern - Mwanza



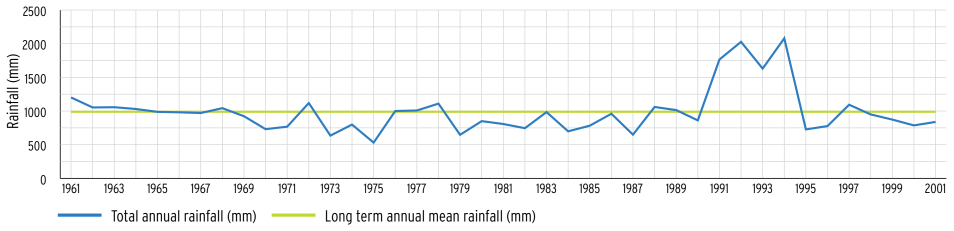
8 Annual rainfall pattern - Narok Keekorok



9 Annual rainfall pattern - Ntusi



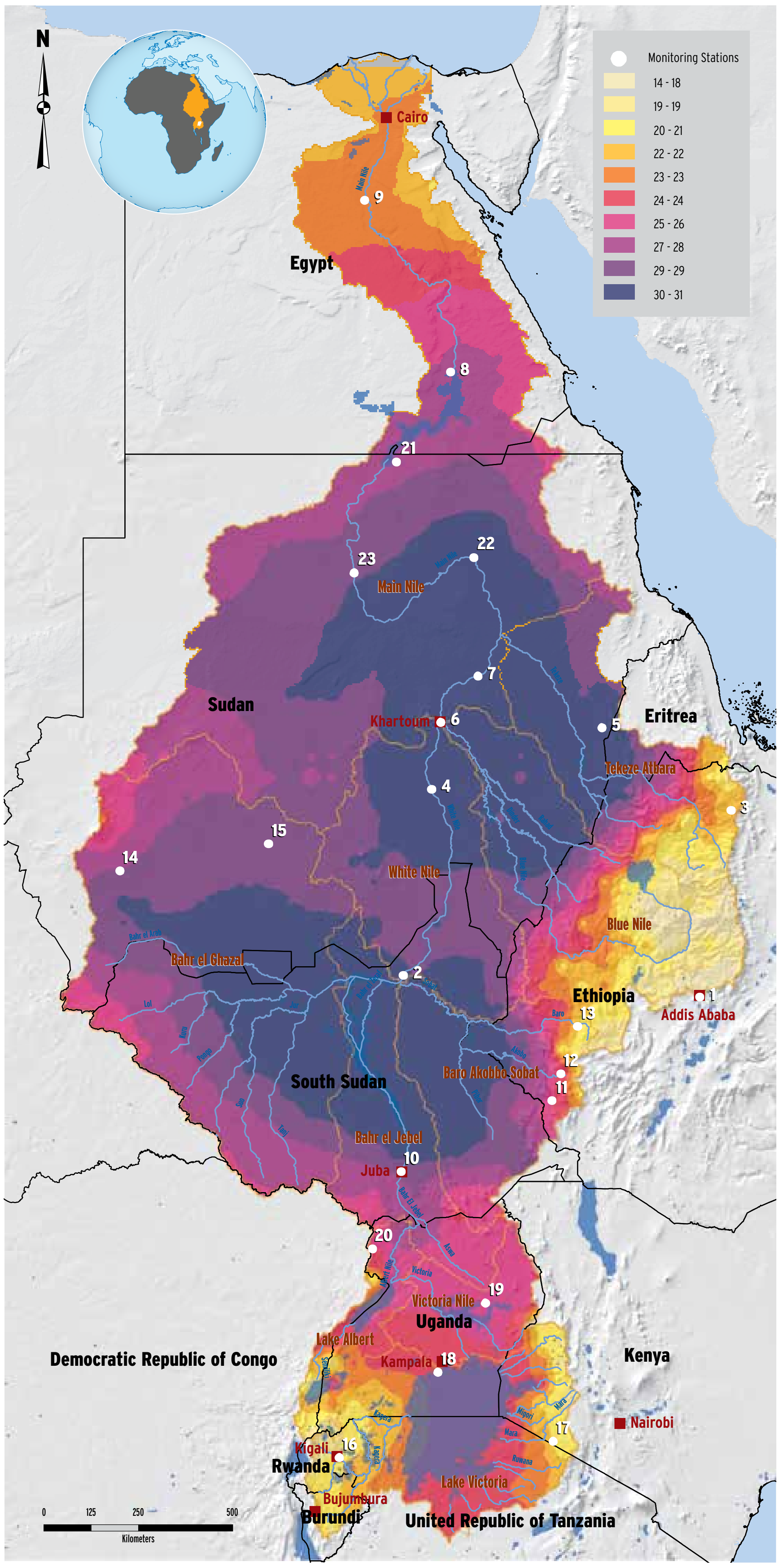
10 Annual rainfall pattern - Seronera



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 30°C and the main Nile, parts of the Blue Nile, Tekeze Atbara and the White Nile in Sudan receiving maximum temperatures of up to 45°C. 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 38°C.

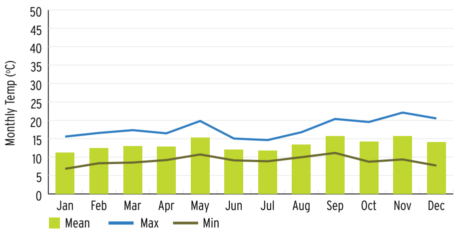
Station Name	Label No.	Station Name	Label No.	Station Name	Label No.	Station Name	Label No.	Station Name	Label No.	Station Name	Label No.	Station Name	Label No.	Station Name	Label No.
Addis Ababa	1	Ed-Dueim	4	Shendi	7	Juba	10	Yayu	13	Kigali	16	Soroti	19	Abu Hamad	22
Malakal	2	Kassala	5	Asswan	8	Mizan 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		



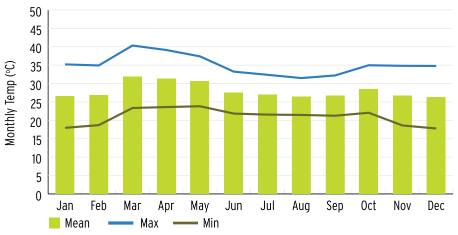
As with rainfall, temperature exhibits temporal and spatial differences over the basin. There are larger variations in temperature in the arid regions of northern Sudan and most of Egypt, with smaller deviations around the equator (Mohammed 2006).


Photo: istock

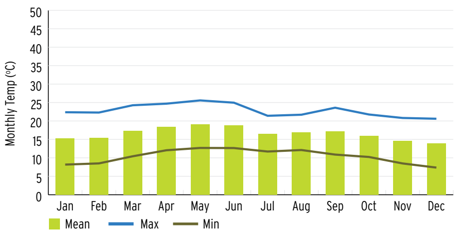
1 Addis Ababa: 2004 - 2008



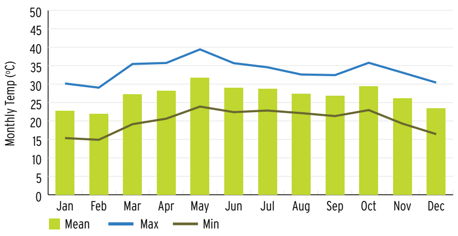
2 Malakal: 1950-1999



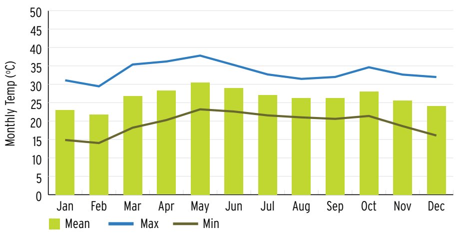
3 Mekelle: 1964-1994



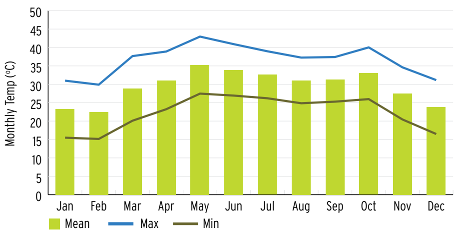
4 Ed Dueim: 1950-1999



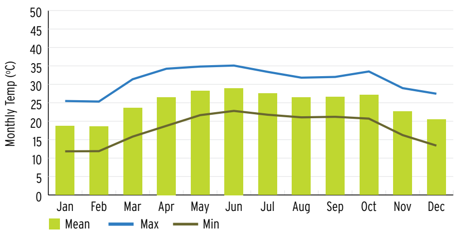
5 Kassala: 1950-2008



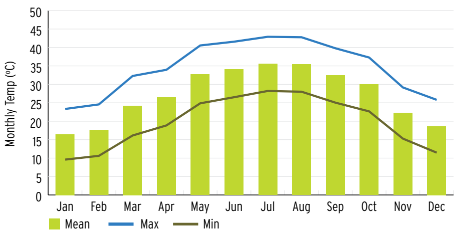
6 Khartoum: 1950-1999



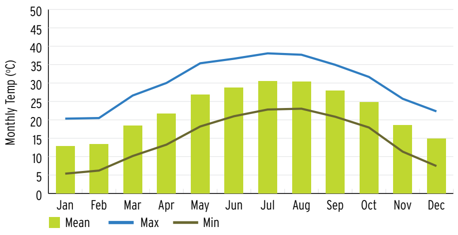
7 Shendi: 1950-1999



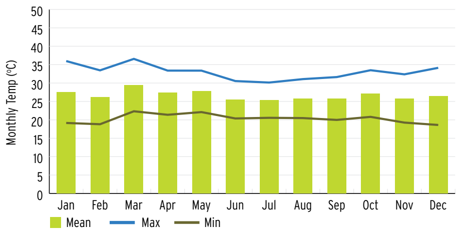
8 Asswan: 2004-2008



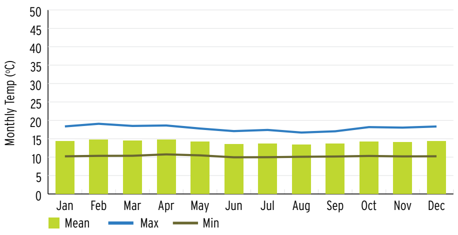
9 Minya: 2004-2008



10 Juba: 1950-1999



11 Mizan Teferi: 1977-1988



12 Tepi: 1981-1988

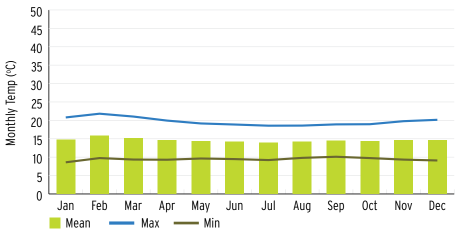
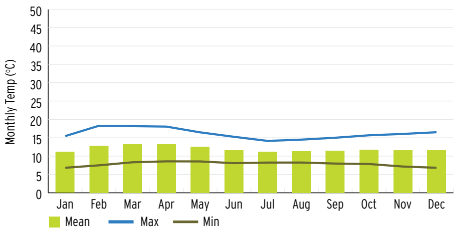
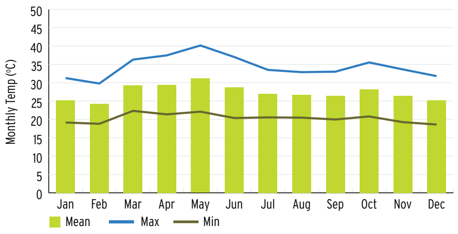


Photo: istock

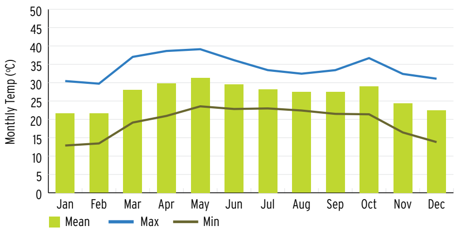
13 Yayu: 1982-1988



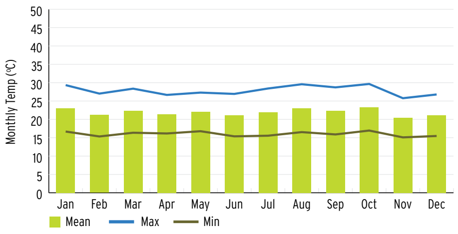
14 Nyala: 1950-1999



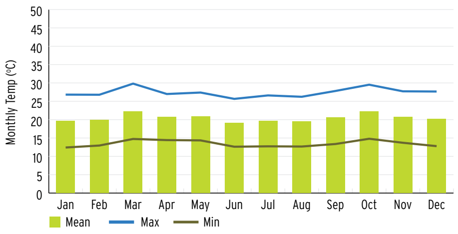
15 En Nahud: 1950-1999



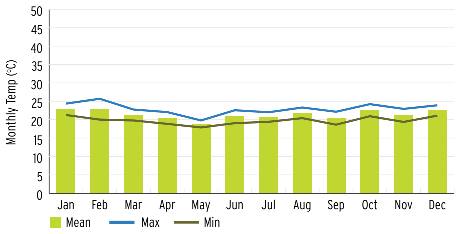
16 Kigali: 1971-2000



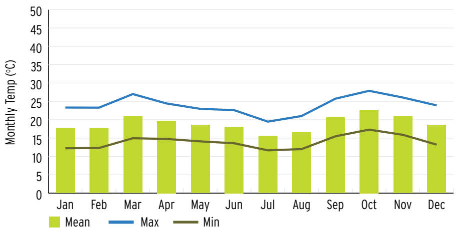
17 Narok: 1970-1990



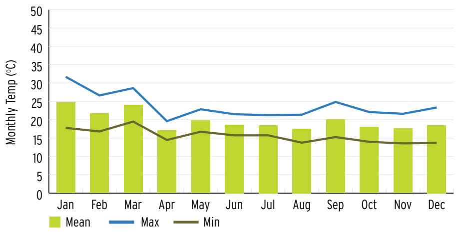
18 Entebbe: 1960-2000



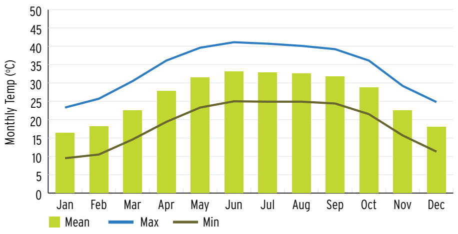
19 Soroti: 2004-2008



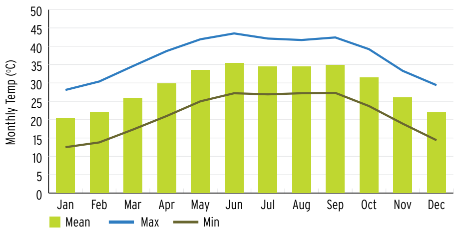
20 Arua: 1992-2000



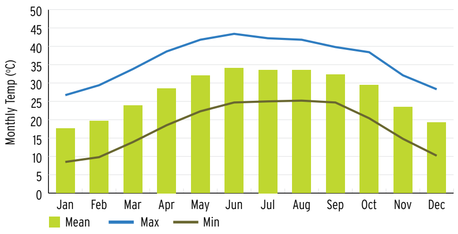
21 Wadi Halfa



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%

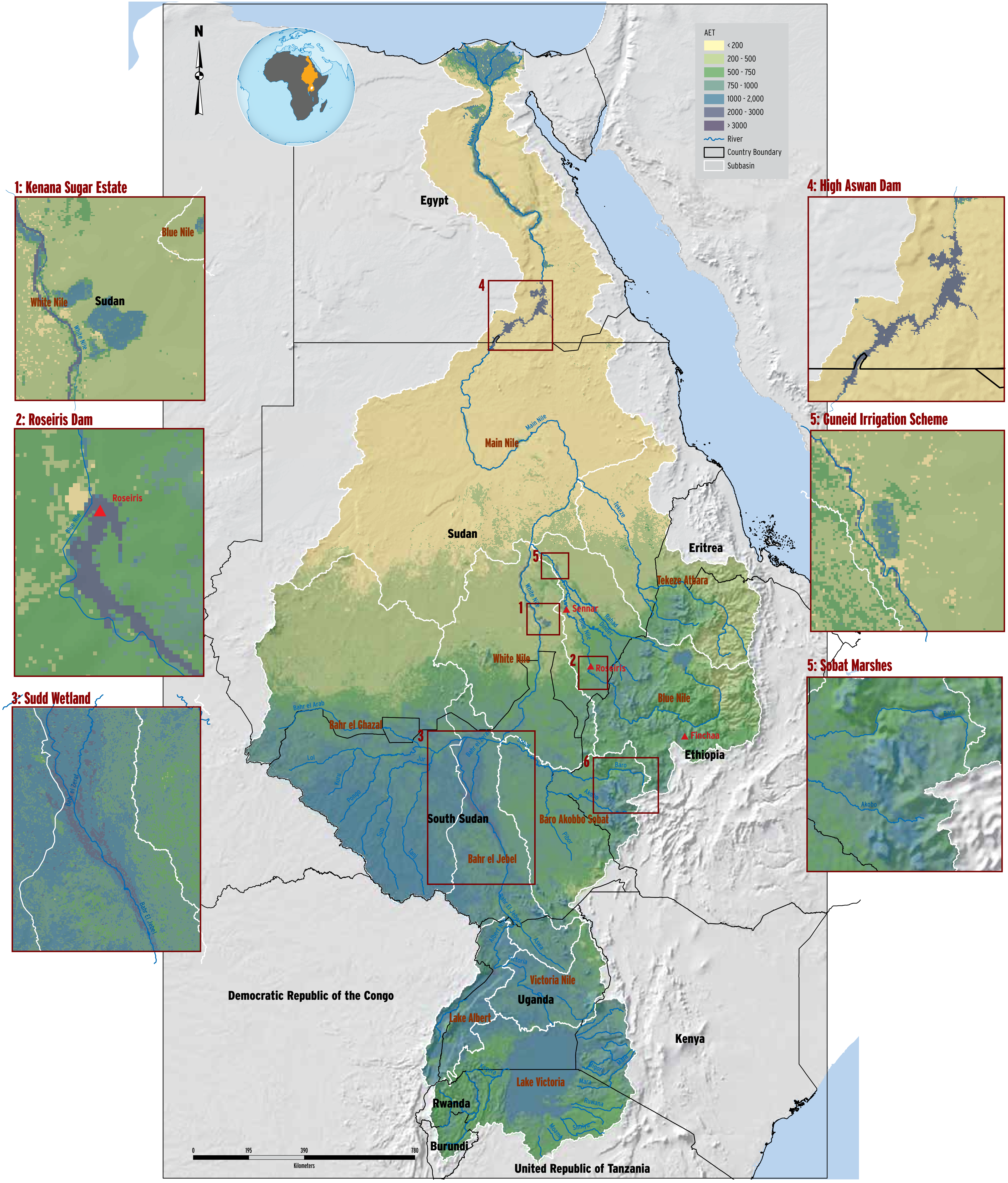
Precipitation projections for area 5°N to 5° S by 25°E to 35°E (Southern NEL region) Changes are relative to the year 2000 (evolution for the period 2000 / 2050)

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.

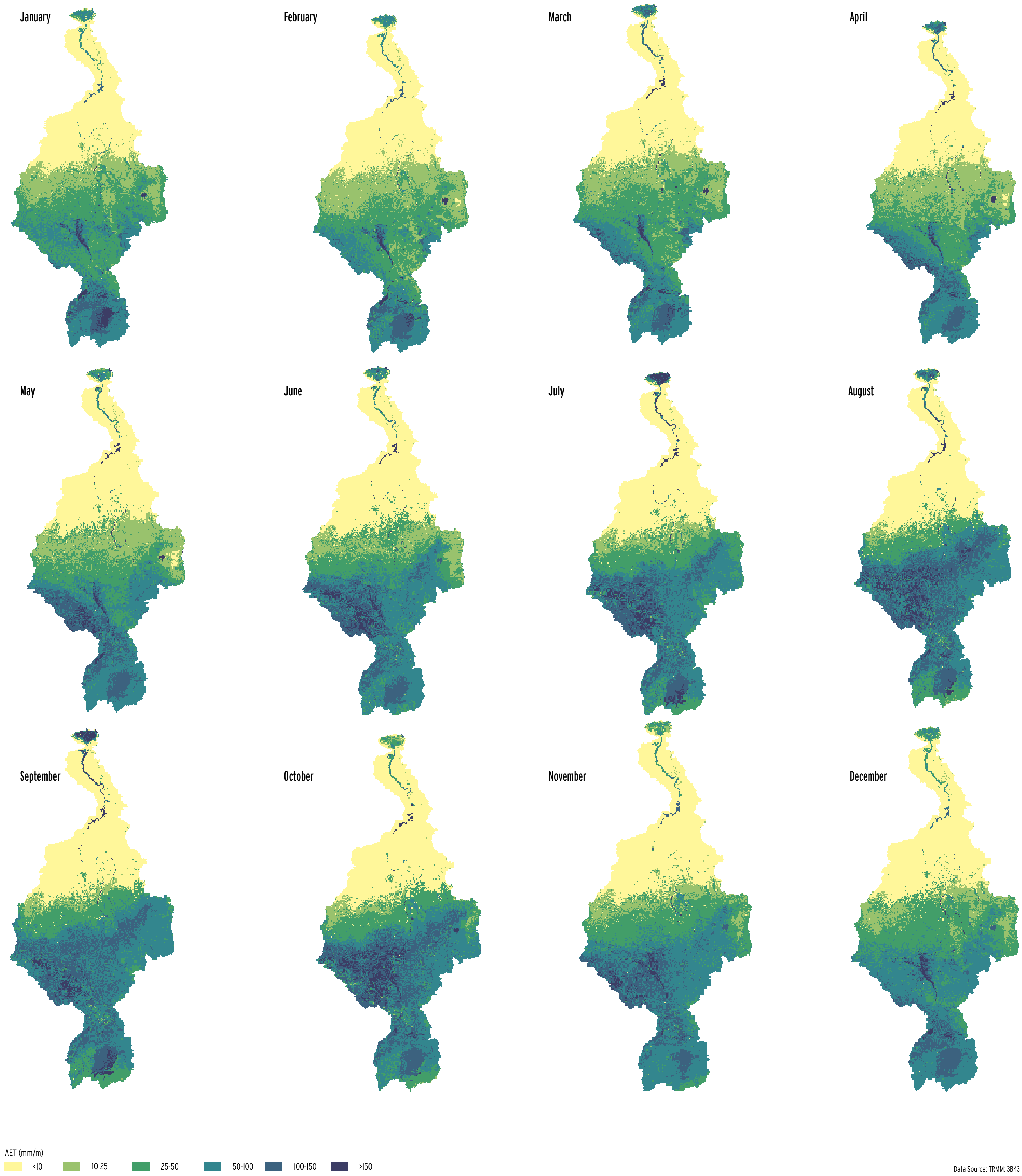
In this atlas, we present the mean annual actual evapotranspiration, the mean monthly actual evapotranspiration, and the actual evapotranspiration for lakes Victoria and Tana. From the maps, it can be observed that the equatorial lakes region and the Ethiopian highlands as well as the open water bodies 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

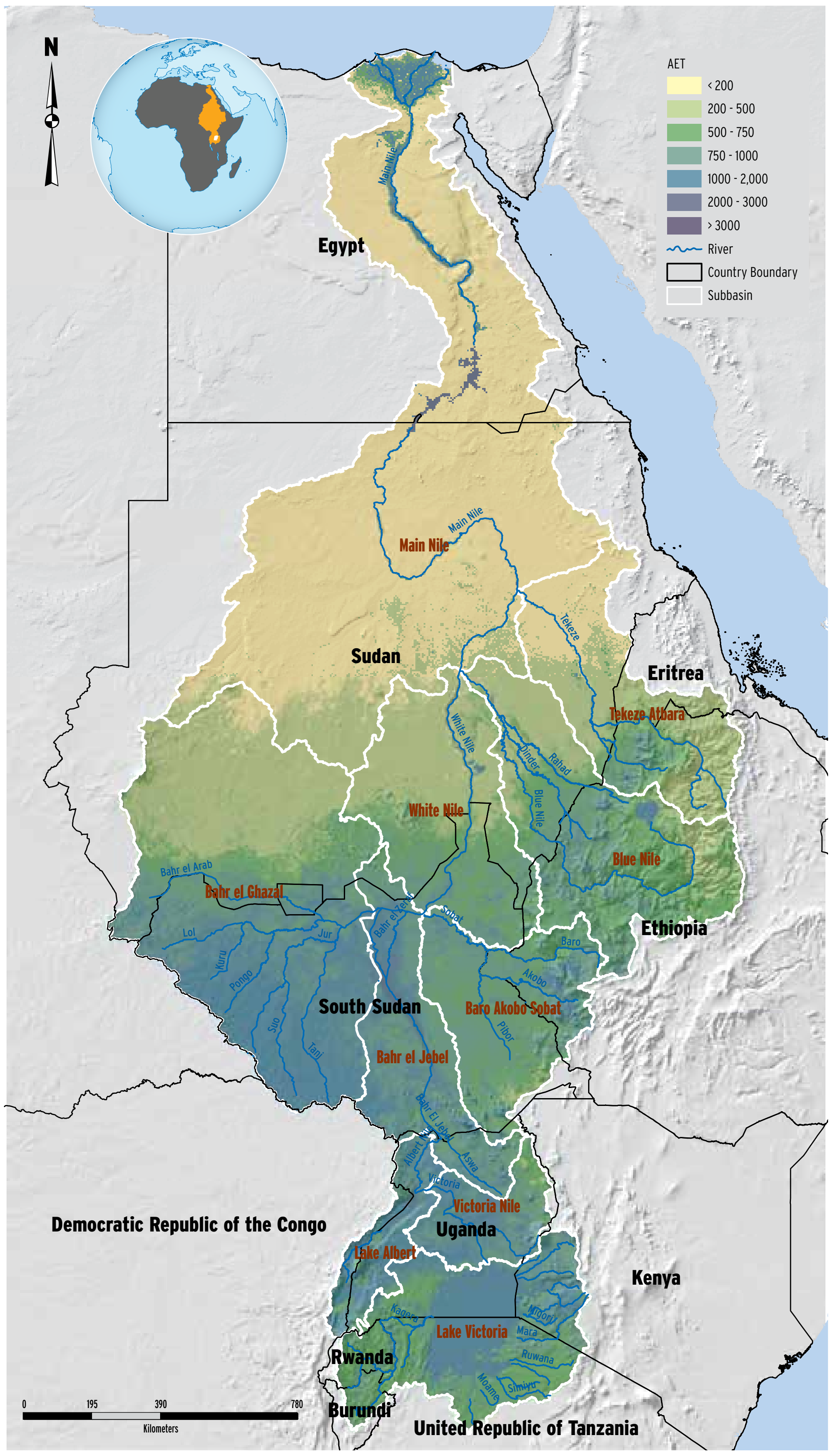
The mean monthly actual evapotranspiration presented in the map below shows a clear seasonal pattern, which follows the rainfall seasons within the basin. Within the equatorial lakes region and the Ethiopian highlands, which experience high losses due to evapotranspiration, it is seen that the highest 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



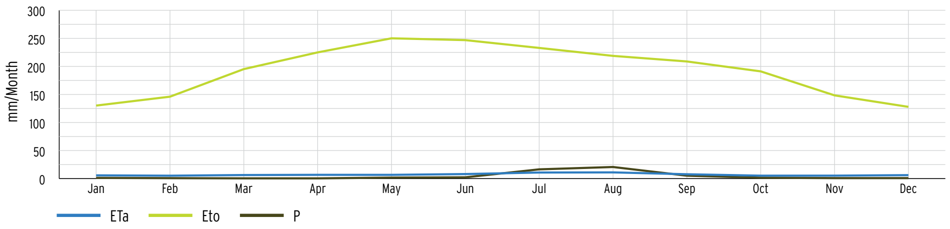
Data Source: TRMM: 3B43

MEAN MONTHLY ACTUAL EVAPOTRANSPIRATION FOR SUB-BASINS

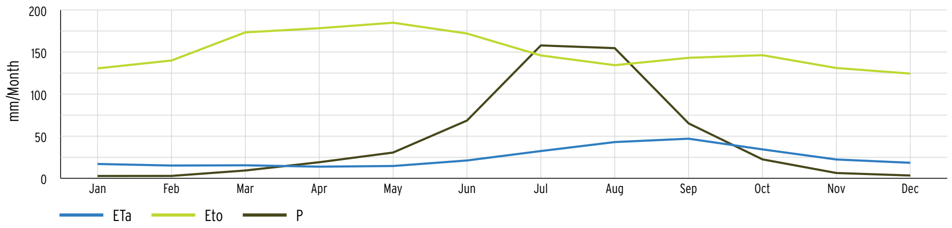


A comparison of the mean monthly actual evapotranspiration for the sub-basins within the Nile basin is presented here together with the precipitation and the potential evapotranspiration. The rainfall seasons can be seen on each of the sub-basin graphs. In some cases, the rainfall is much higher than 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.

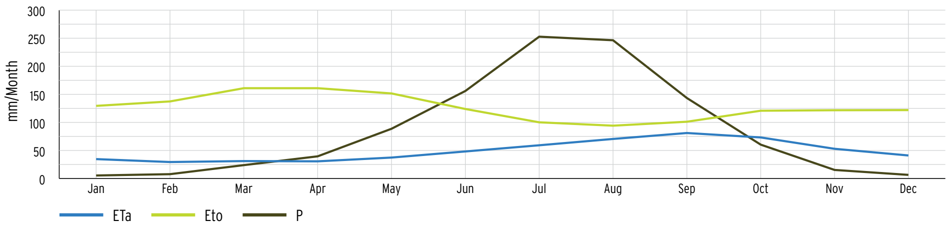
Main Nile



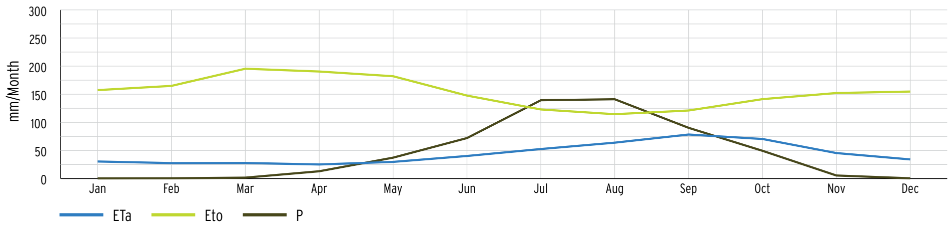
Tekeze Atbara



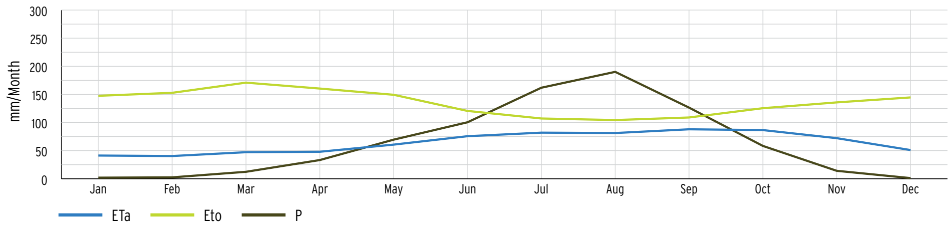
Blue Nile



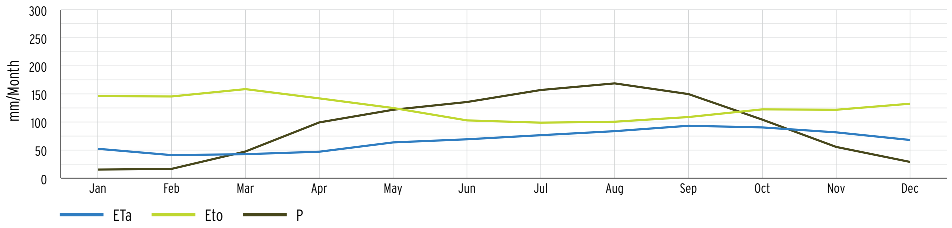
White Nile



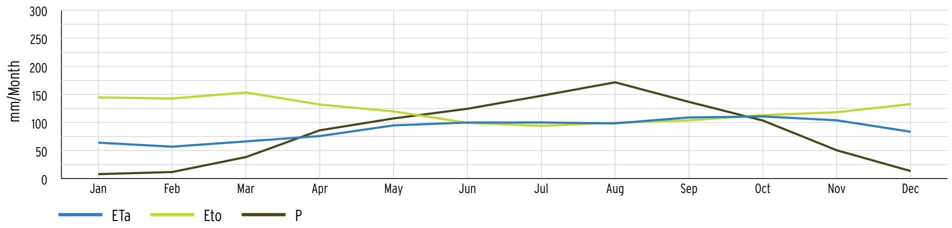
Bahr El Gazal



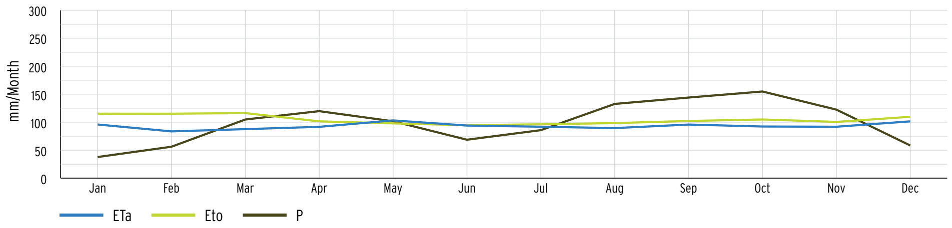
Baro Akobbo Sobat



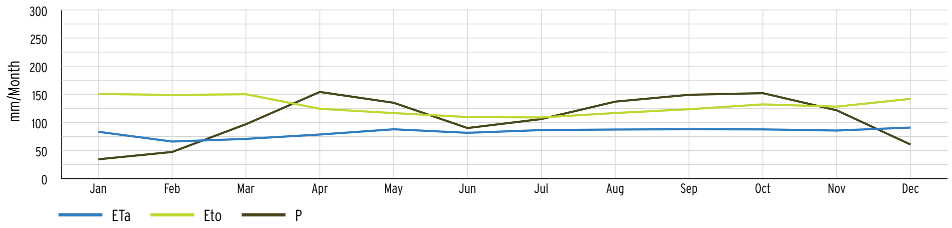
Bahr El Jebel



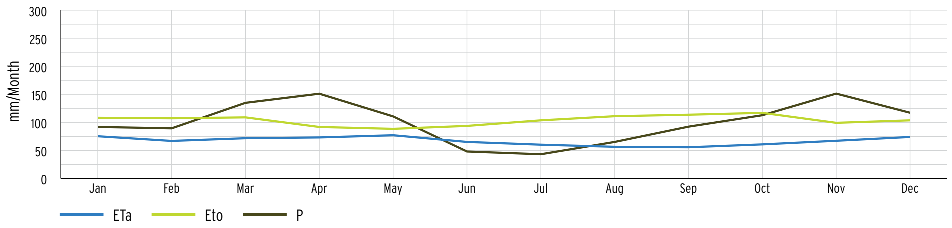
Lake Albert



Victoria Nile



Lake Victoria

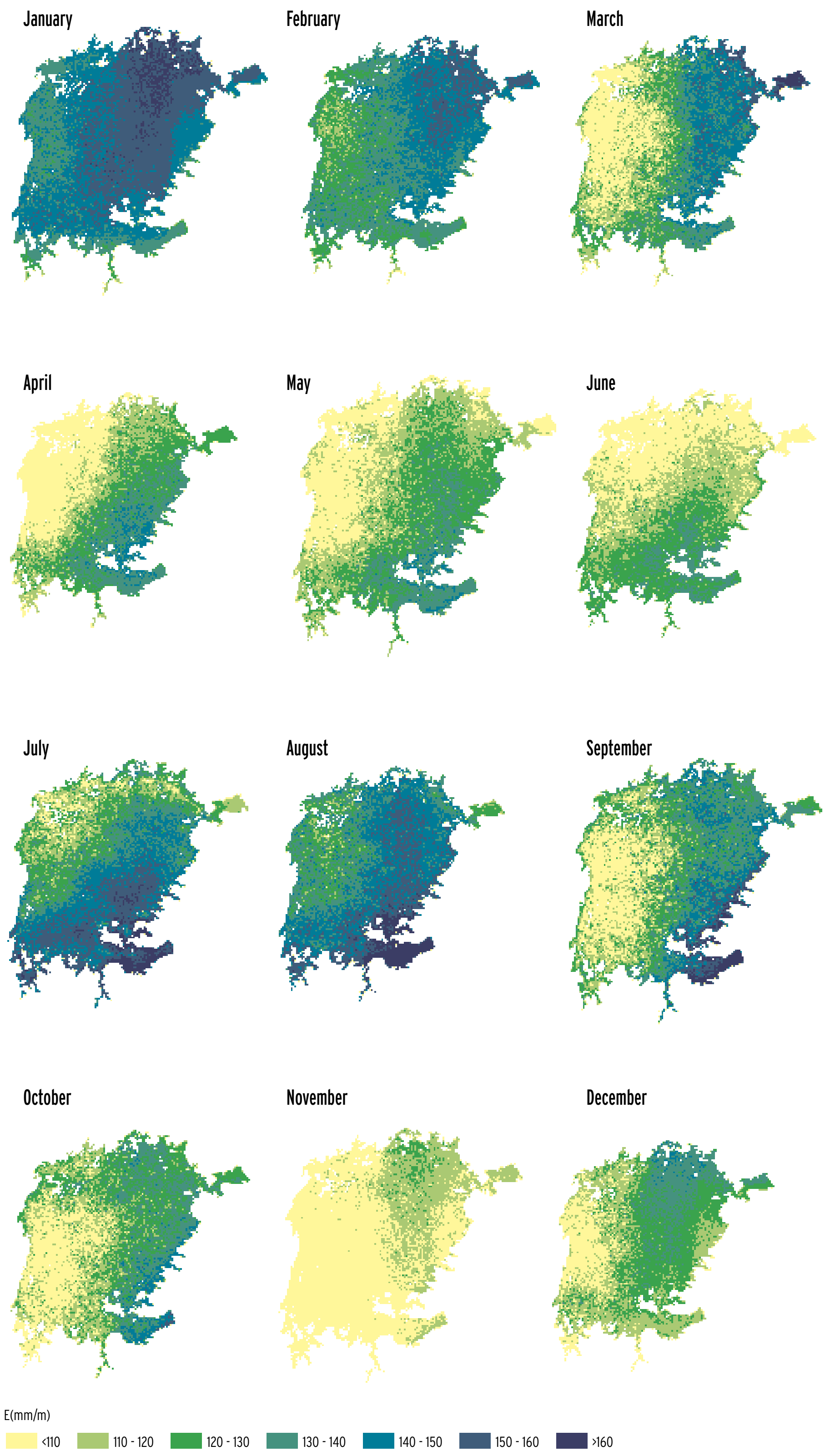


MEAN MONTHLY EVAPORATION OVER NILE BASIN LAKES

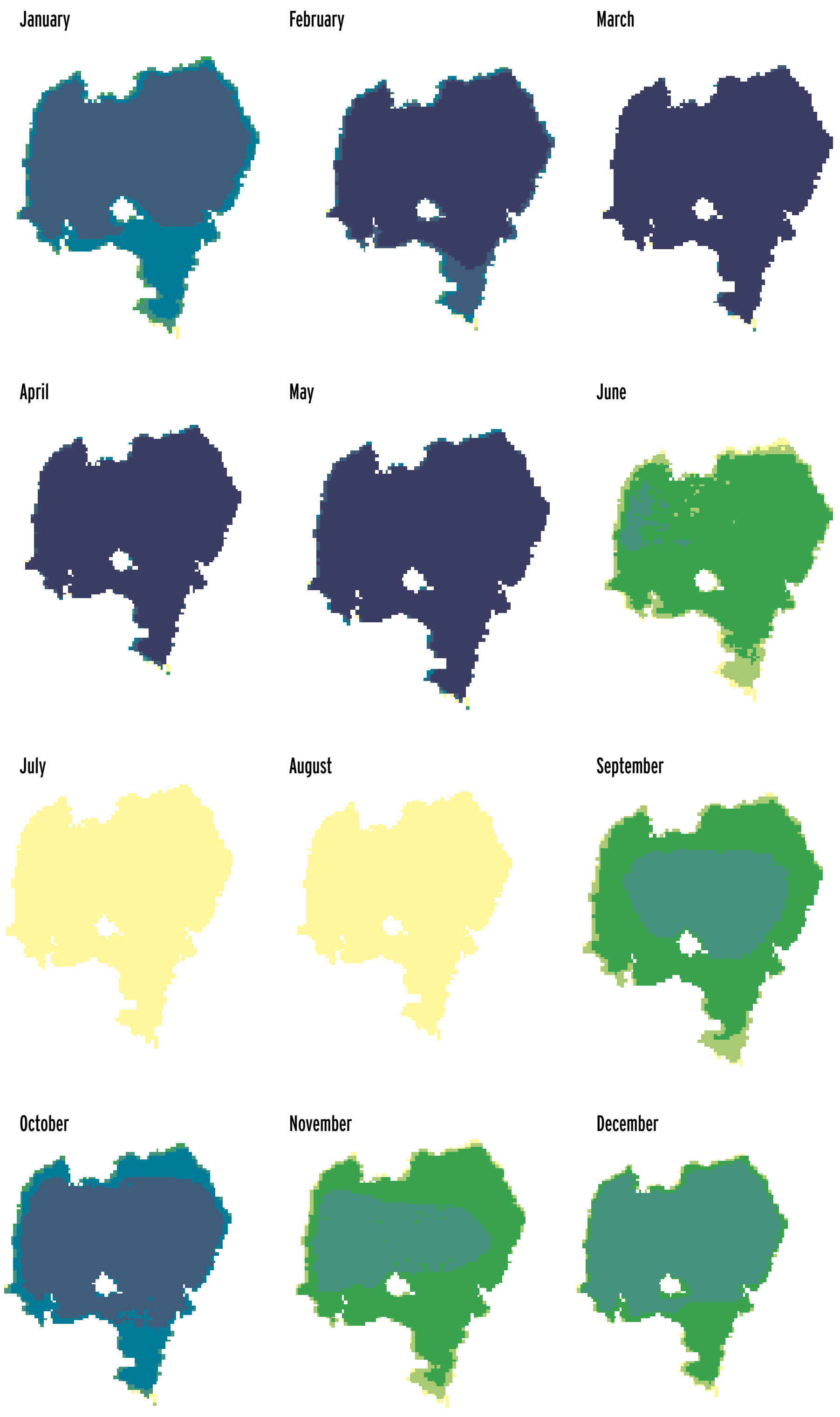
Open water bodies also experience high evaporation losses depending on the prevailing climatic conditions within their locality with very high values registered in the dry seasons. Lake Victoria experiences very high values in the months of January – February and July – August during which time, low 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

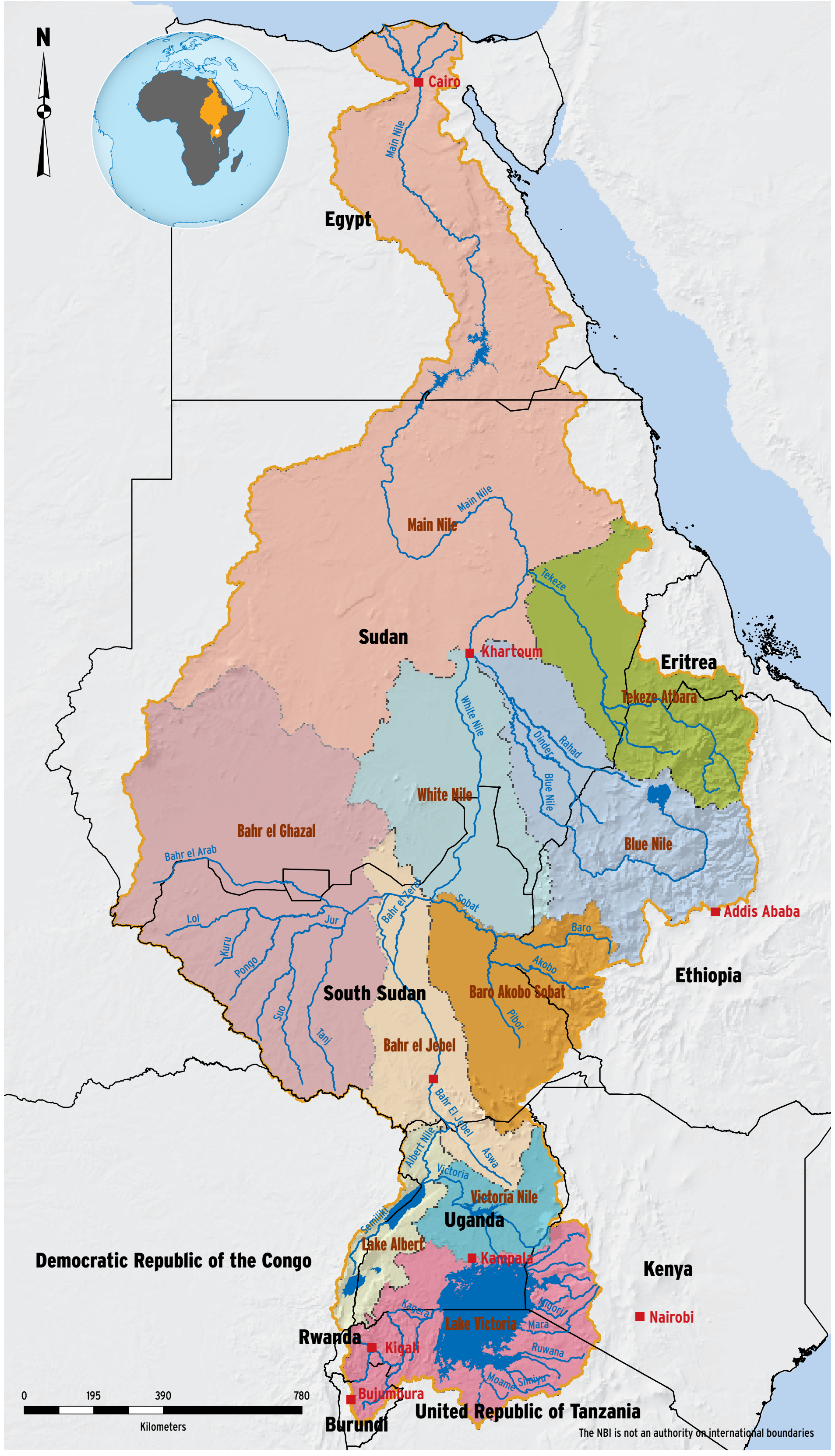


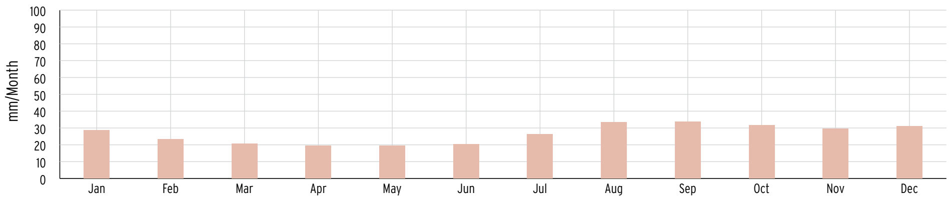
AVERAGE MONTHLY EVAPORATION OVER LAKE TANA

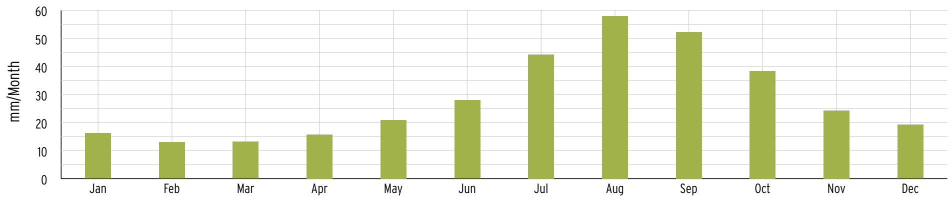


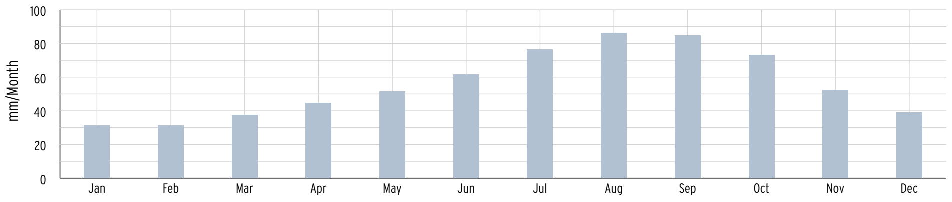
RELATIVE HUMIDITY

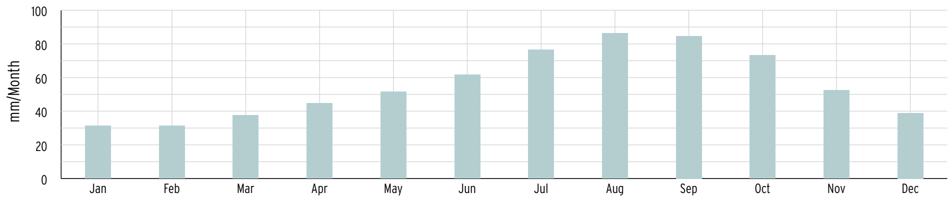
Relative humidity data was obtained from the Earth System Research Laboratory (ESRL, http://www.esrl.noaa.gov/psd/data/timeseries/) covering a period 1948 – 2014 on monthly time step. The mean monthly relative humidity for each sub-basin is presented here, which indicates that the equatorial lakes region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

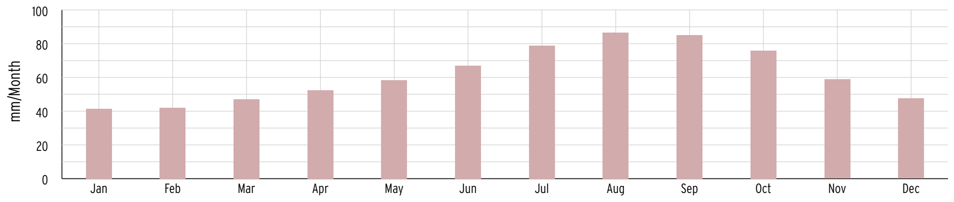


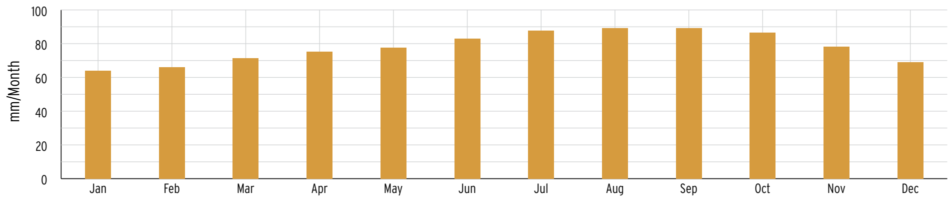

Main Nile: 1948-2014

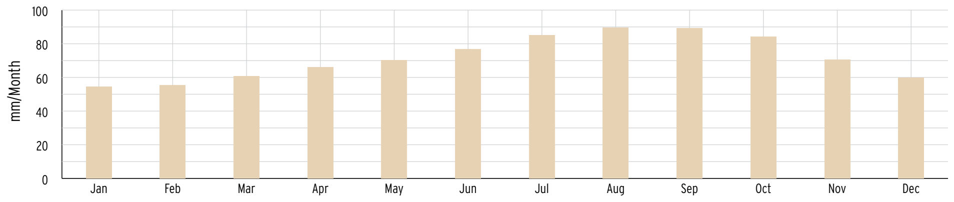

Tekeze Atbara: 1948-2014

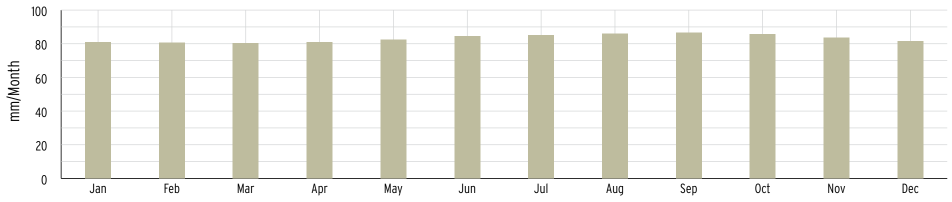

Blue Nile: 1948-2014

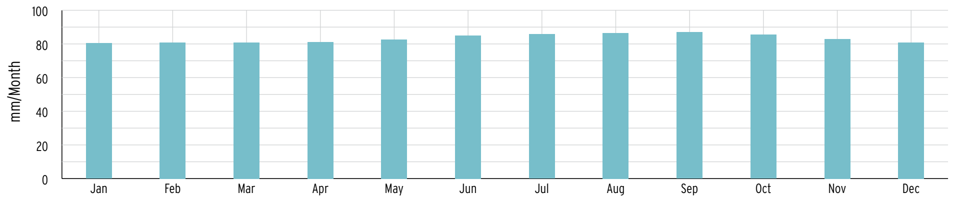

White Nile: 1948-2014

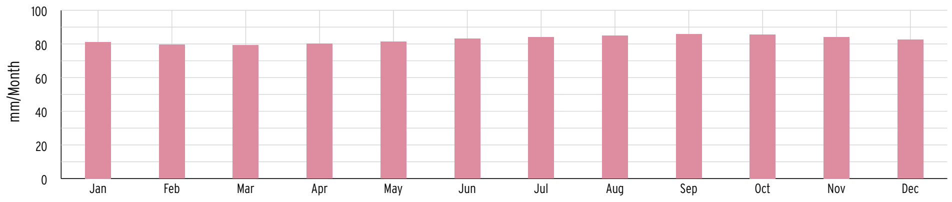

Bahr El Ghazal: 1948-2014


Baro Akobo: 1948-2014


Bahr El Jebel: 1948-2014


Lake Albert: 1948-2014

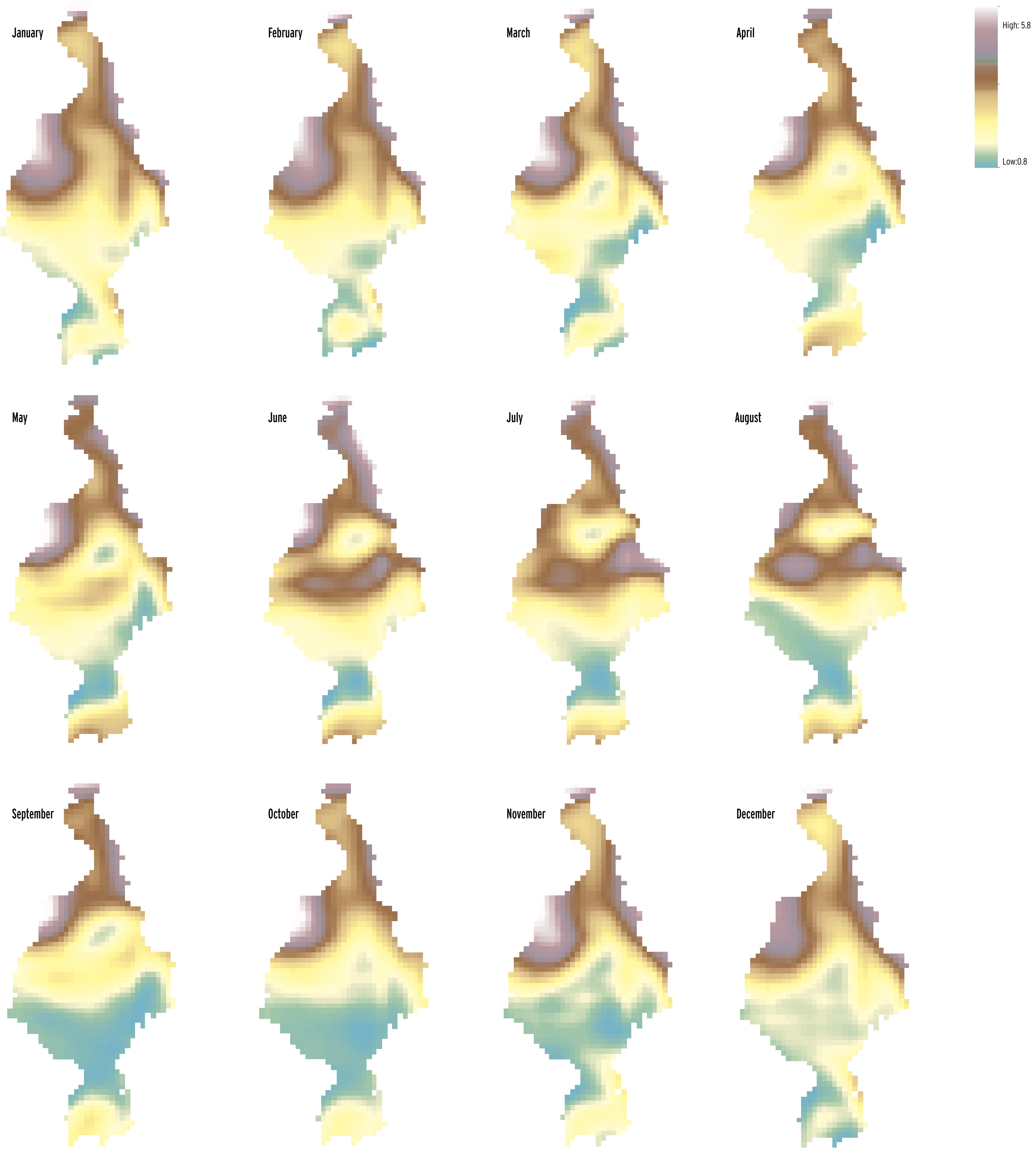

Victoria Nile: 1948-2014


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

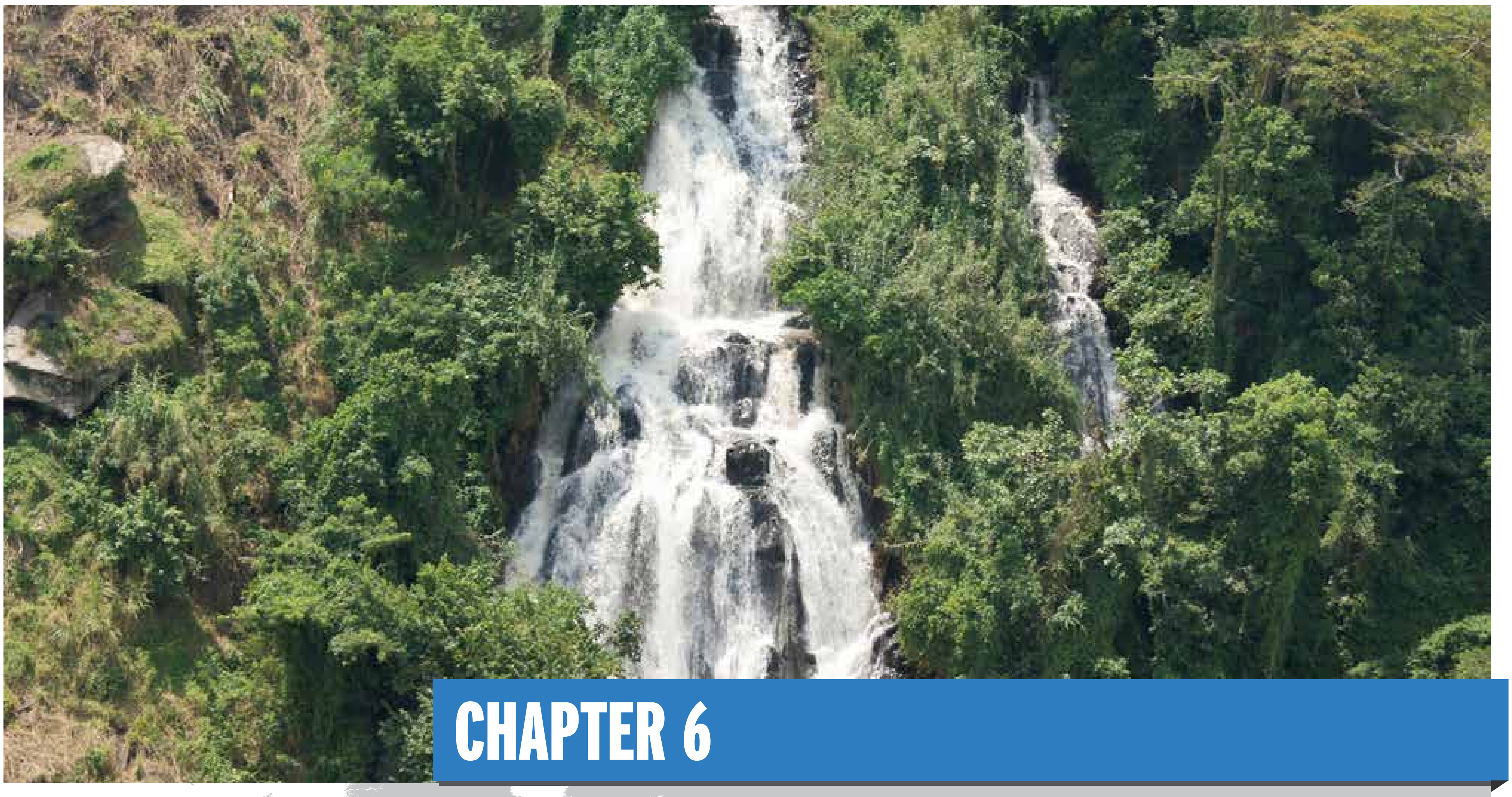
The Nile River spatial extent from south-north (range in latitude of 40 S to 350 N), creates various climates zones with distinct features, diverse and rich natural resources of wetlands, water resources, biophysical and ecological zones.

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.

References

- dr. J.C.J. Kwadijk (February, 2007); Climate scenarios for the Nile basin and some consequences for its water management
- East African Community/ Lake Victoria Basin Commission. Consultancy on the Development of a new Lake Victoria Water Release Policy Final Report, October 2008
- UNEP. (2013). "Adaptation to Climate-change Induced Water Stress in the Nile Basin: A Vulnerability Assessment Report". Division of Early Warning and Assessment (DEWA). United Nations Environment Programme (UNEP). Nairobi, Kenya.
- Food and Agriculture Organization of the United Nations (FAO). 1997. Irrigation Potential in Africa – A Basin Approach. FAO Land and Water Bulletin 4. FAO Land and Water Development Division: Rome, Italy.
- Said, R. 1993. The River Nile: Geology, Hydrology and Utilization, 1st edition. Pergamon Press: Oxford, UK.
- Shahin, M.M.A. 2002. Hydrology and Water Resources of Africa. Kluwer Academic Publishers: New Jersey, U.S.A. E-book accessed at http://site.ebrary.com/lib/sfu/Doc?id=10067251&ppg=295.
- Shahin, M. 1985. Hydrology of the Nile Basin. Elsevier: Amsterdam.
- United Nations Environment Programme (UNEP). No date. Vital Climate Graphics. Accessed at: http://www.grida.no/climate/vital/index.htm on November 30th, 2005.
- UNEP. (2013). "Adaptation to Climate-change Induced Water Stress in the Nile Basin: A Vulnerability Assessment Report". Division of Early Warning and Assessment (DEWA). United Nations Environment Programme (UNEP). Nairobi, Kenya.
- M. T. Taye1, V. Ntegeka1, N. P. Ogiramoi1,2, and P. Willems; Assessment of climate change impact on hydrological extremes in two source regions of the Nile River Basin
- Riebsame et al.(1995). As Climate Changes: International Impacts and Implications, chap3, Complex River Basins
- Santer, B.D. and Wigley, T.M.L. (1990). Regional validation of means, variances and spatial patterns in General Circulation Model control runs. Journal of Geophysical Research 95, 829-850 (R).
- Sene, K.J., Tate, E.L. & Farquharson, F.A.K. (2001) Sensitivity studies of the impacts of climate change on White Nile flows. Climatic Change, 50, 177-208.
- Strzepek, K., and Yates, D.N. (1996) Economic and social adaptations to climate change impacts on water resources: A case study of Egypt. Water Resources Development, 12, 229-244.
- Sutcliffe and Parks (1999). The hydrology of the Nile. IAHS Special publication
- Yates and Strzepek (1998) Modelling the Nile Basin under Climatic Change. J. Hydrologic Engineering., Volume 3, Issue 2, pp. 98-108



CHAPTER 6

HYDROLOGY OF THE NILE

KEY MESSAGES

The Nile River basin has very complex hydrology with high interconnection between floodplains, wetlands, swamps, lakes, highlands and the rivers drainage networks systems, some with strong seasonality and others with year-round consistent flows – call for an integrated approach.

The highlands subjects to soil erosion and land degradation, particularly the Eastern Nile system. The Ethiopian highlands generates huge volumes of sediment as compared to the other parts of the basin. Call for joint regional efforts by riparian countries on watershed management to improve land management practices, improve livelihood - to protect and restore degraded lands.

The selection of the stations presented in this chapter was solely based on availability of data of fairly good quality and longer record. Data scarcity and reliability has been a huge problem in hydrologic system, actual data is an indispensable in rivers basins. Efforts should be made to establish network of gauges and strengthen capacity for a better understating of the temporal, spatial characteristics and provide a better insight of the basin system.

The Nile basin has such a huge hydrological diversity. The basin, like any other part of the world experiences extreme events including droughts, floods, landslides, heat waves, etc. – efforts need to be exerted to improve on hydrologic modelling, climate change scenarios and forecasting.

Groundwater is widely used across the basin for domestic water supply (for drinking and other domestic uses) for both rural and urban communities. However, the basin ground water has not been adequately studied and so, information in this area is still scanty.

INTRODUCTION


Photo: istock

River Nile scenery around Murchison Falls

The hydrology of the Nile is mainly characterized and influenced by high variations in climate and altitude/topography which have a great bearing on flow magnitudes and patterns in the different parts of the basin. These differences are more pronounced in the two tributaries of the Nile; the White and Blue Nile with the White Nile exhibiting relatively steady flows and the Blue Nile exhibiting highly seasonal flows. Presentation of the hydrology of the Nile in this atlas focused on key stations within the sub basins of the Nile starting from down stream to upstream; Main Nile, Tekeze Atbara, Baro Akobo Sobat, White Nile, Bahr el Jebel, Bahr el Ghazal, Albert Nile and ends with Lake Victoria sub-basin. There are also swamps and wetlands in the Nile basin which play and influence the hydrology of the Nile mainly the Sudd, Bahr el Ghazal swamps, and the Machar marshes.

As seen in the graphics in this chapter, discharge of the Nile River is highly dependent on the flow patterns from the river tributaries which are principally dependent on rainfall and climate patterns save for areas where infrastructure and regulation influence the downstream flow. Flows from the White Nile are seen to contribute small but more consistent year-round flow.

This chapter presents the water towers of the Nile Basin and an analysis of selected key stations along the Nile followed by the individual sub basins.

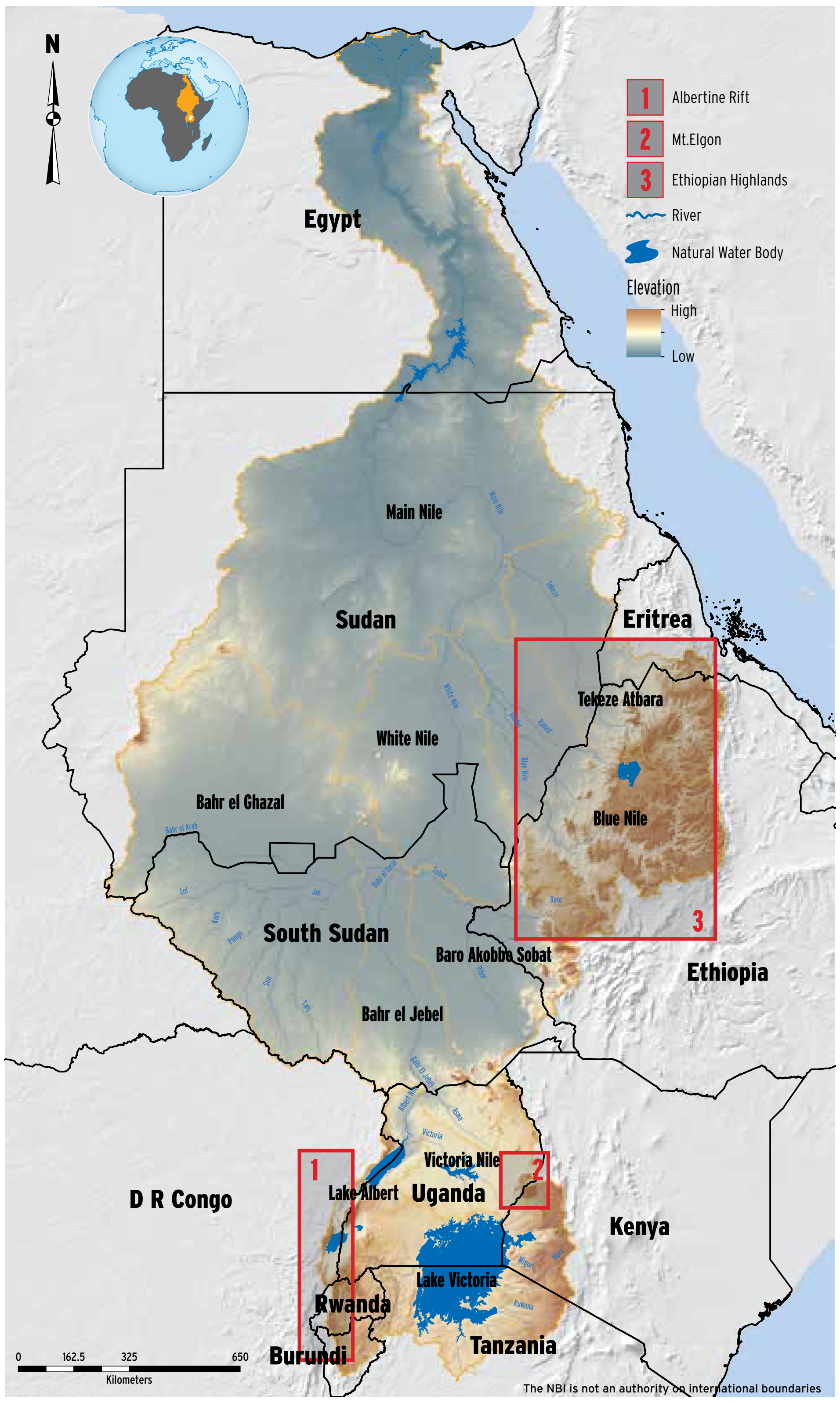
MAJOR NILE BASIN WATER TOWERS

Water towers are considered to be the areas that generate high stream flows in comparison with others. Within the Nile basin, highlands and other elevated areas greatly contribute to total stream flow of the major rivers in the basin. These areas, referred to as water towers, normally receive more rainfall than their lower surroundings. They also usually lose less water to evapotranspiration because temperatures are lower. The major water towers within the Nile Basin are shown in the figure below.


Photo: Jørn Eriksson/flickr.com

Rwenzori mountain

Major Nile Basin water towers



The NBI is not an authority on international boundaries


photo: International space station

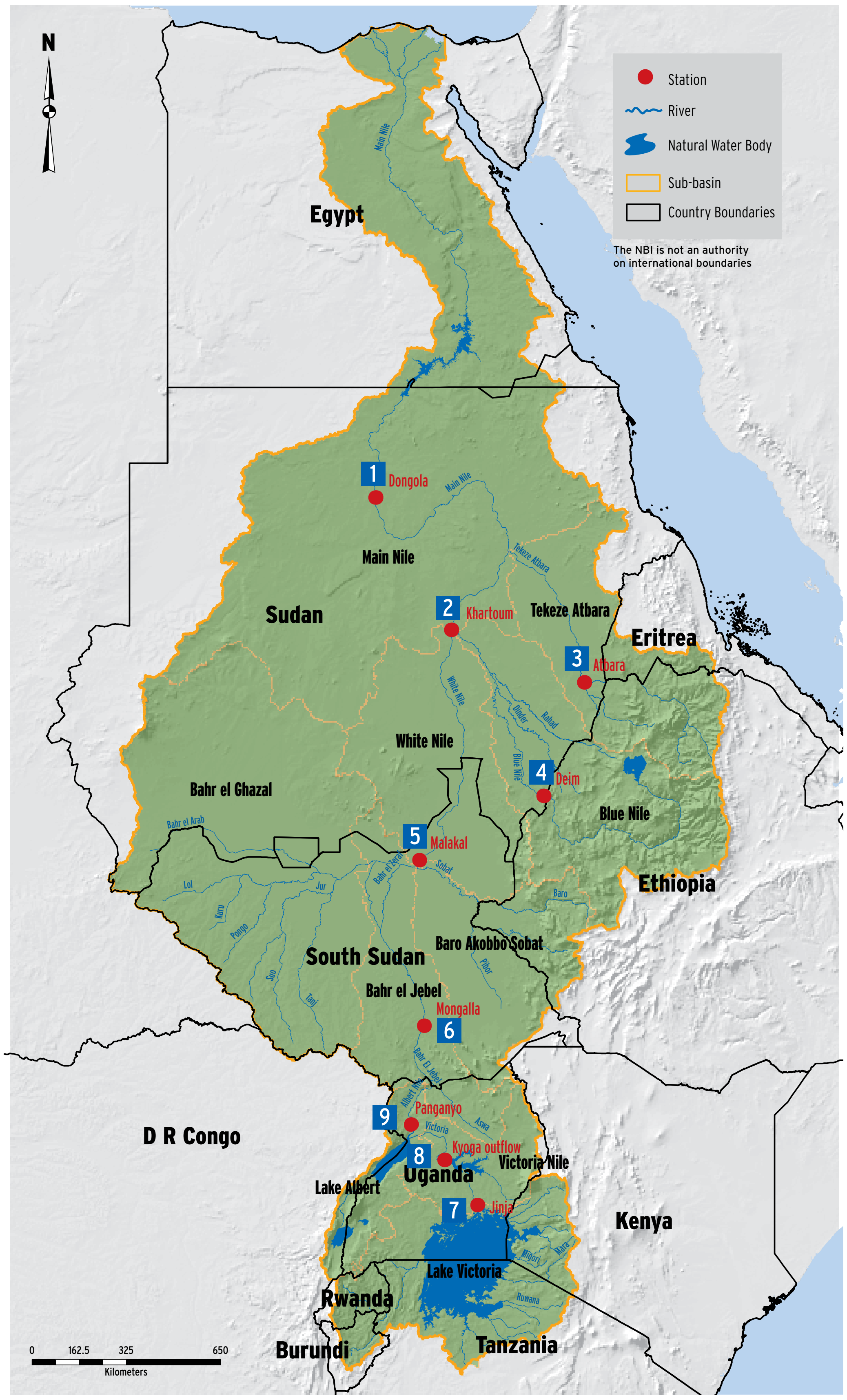
Mount Elgon at the border of Uganda and Kenya photographed from the International Space Station 13:55 GMT January 14, 2012


Photo: Arne Hoel / World Bank

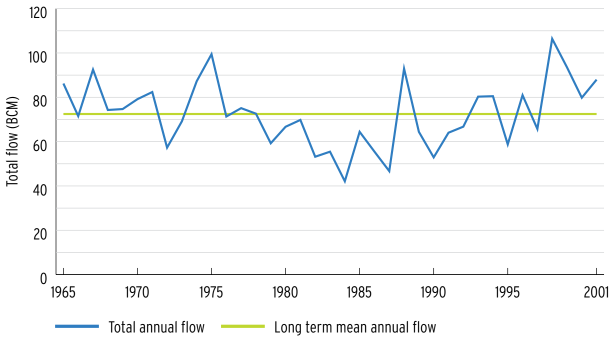
View from Entoto Mountain in Ethiopia

ANNUAL RIVER FLOW PATTERNS FOR KEY NILE HYDROLOGICAL STATIONS

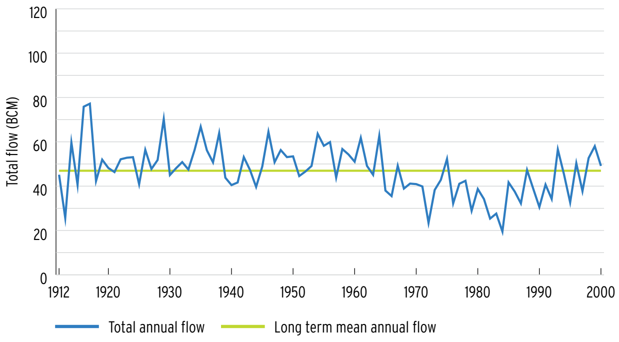
Along the River Nile, there are quite a number of hydrological stations as shown in the basin monitoring network. However, a few key stations have been selected for presentation in the map below to the annual flow patterns along the Nile. The annual volumes are seen to be highly variable across the years apart from flow at Malakal. Upstream of the stations White at Malakal, Blue Nile at Diem, where the Atbara tributaries enter the Sudan, the Nile tributaries undergo very little alternations due to man-made interventions. Therefore, the flows at these stations can be considered approximately natural flow conditions. Downstream of these stations the Nile River undergoes considerable changes due to flow regulation through dams and major abstractions for consumptive use. In addition, downstream of these stations, the Nile receives very little flow contributions from surrounding catchments as this part of the Nile Basin obtains very little rainfall.



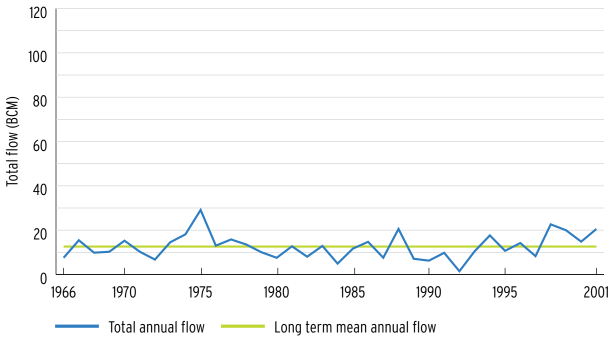
1 Annual flow volume - Dongola



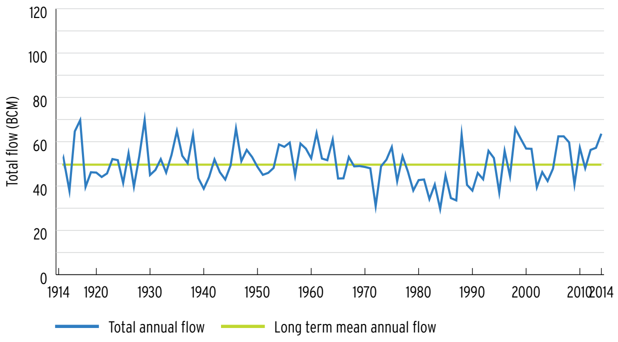
2 Annual flow volume - Khartoum



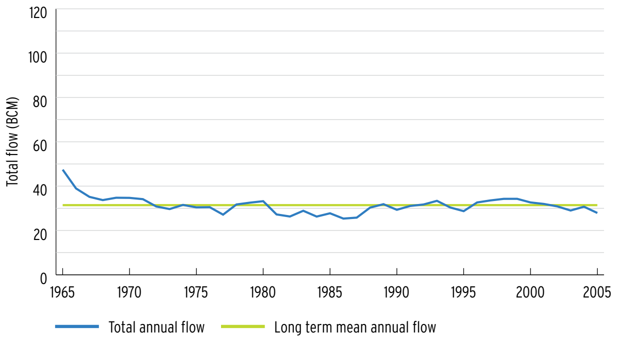
3 Annual flow volume - Atbara (on Atbara River)



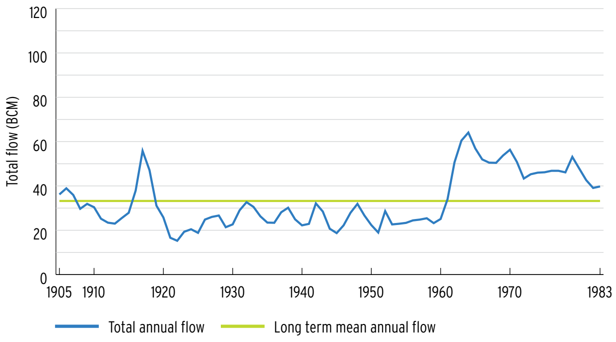
4 Annual flow volume - Diem



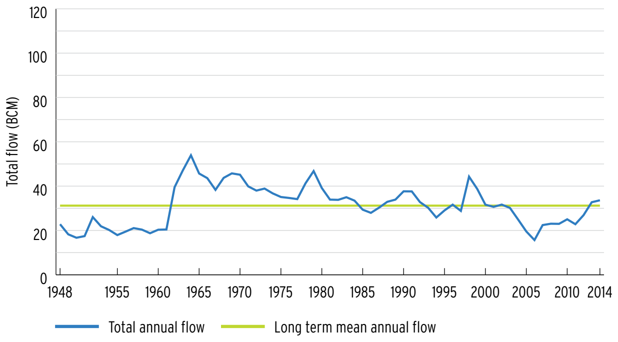
5 Annual flow volume - Malakal



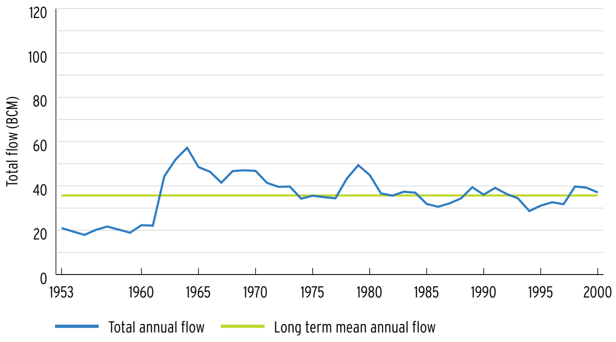
6 Annual flow volume - Mongalla



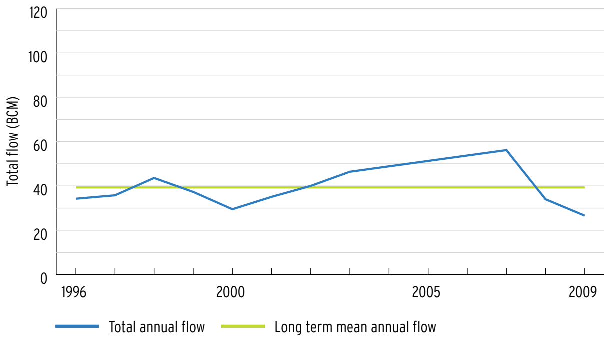
7 Annual flow volume - Jinja



8 Annual flow volume - Kyoga outlet



9 Annual flow volume - Albert Nile, Panyango



SEASONAL FLOW PATTERNS

Main Nile Sub-basin

This sub section highlights the seasonal patterns, key statistics, and flow reliability of selected stations within the basin presented sub basin by sub basin. In doing this, mean monthly flow has been presented together with the standard deviation, then the Box Plot indicating the Maximum, Minimum. Median as well as the 1st and 3rd Quartiles on a monthly basis, and the monthly flow duration curve. Presentation of this follows the sub basins Upstream (in the Nile Equatorial Lakes region) followed by the Eastern Nile and the main Nile. The selection of the stations presented in this chapter was solely based on availability of data of fairly good quality and longer record. The image below is the key for interpretation of the box plots for the monthly flow statistics in this section.

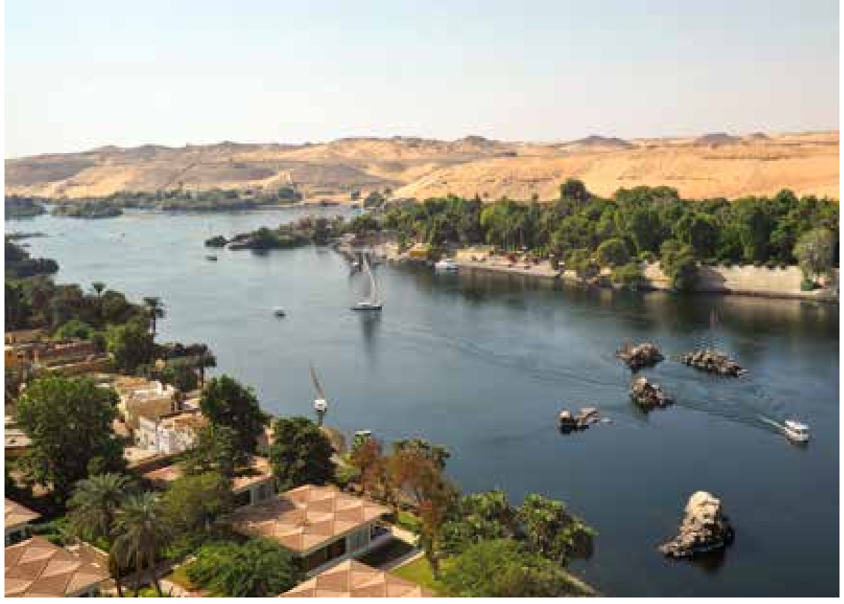
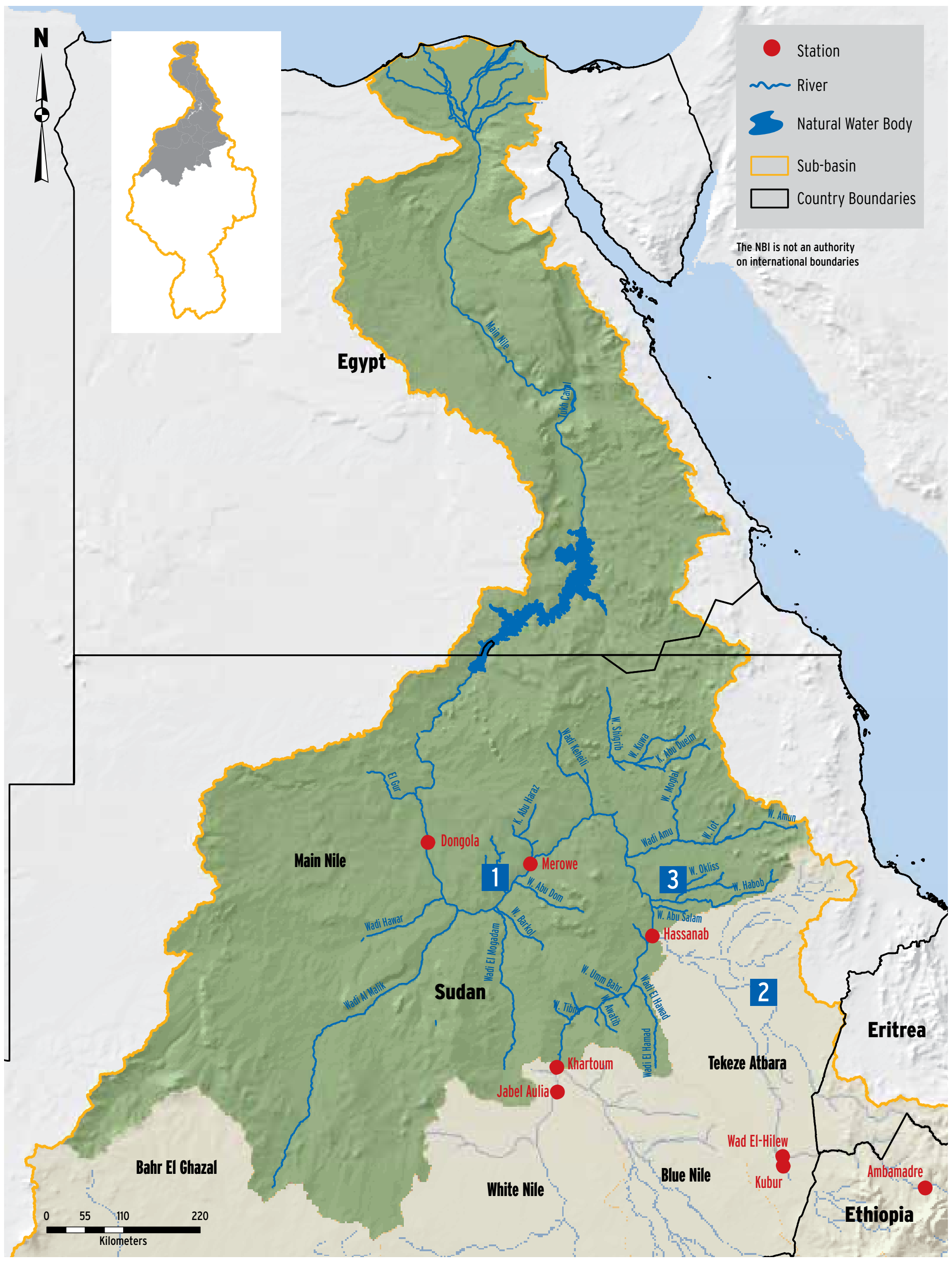


Photo: istock

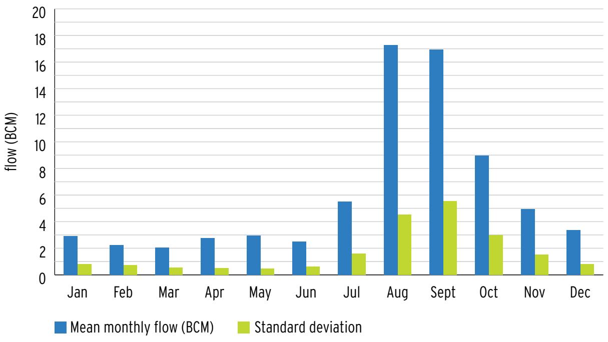
Aswan Dam

This is the most downstream part of the Nile Basin where more than 80 percent of the current consumptive water use occurs. Major features of the hydrology of this sub-basin include High Aswan Dam, which has the capacity to store nearly twice the annual average flow of the Nile and the Merowe Dam (live storage of 12.5 BCM) built in Sudan. The monthly flows depict peaks between August and September as a result of high flow from the Blue Nile within this time of the year.

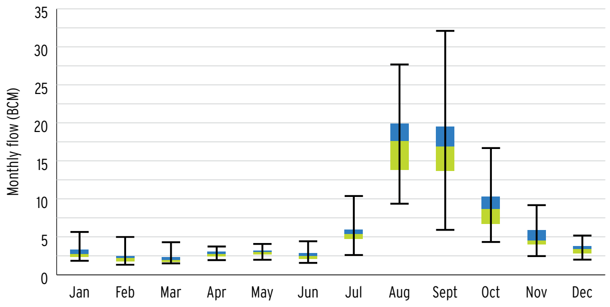


The NBI is not an authority on international boundaries

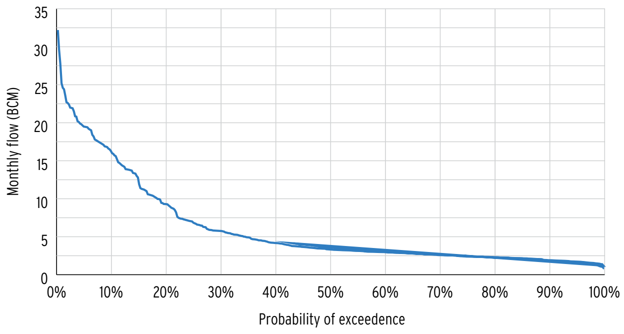
1 Monthly Flow Distribution - Dongola



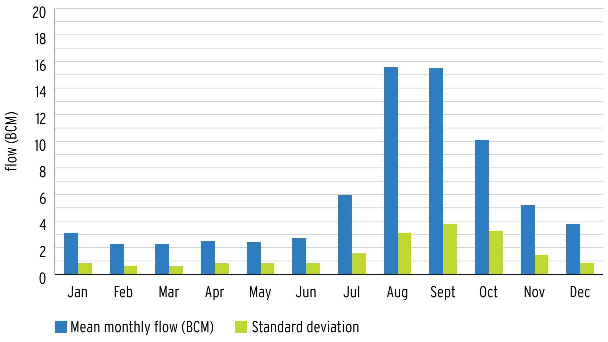
1 Monthly Flow Statistics - Dongola



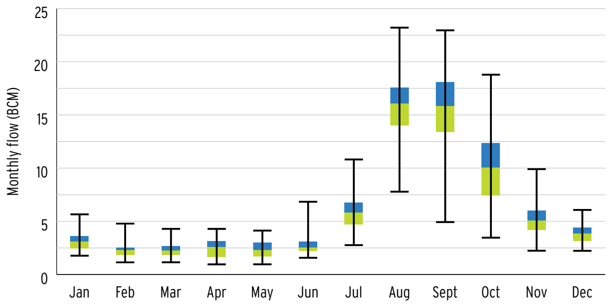
1 Flow Duration Curve - Dongola



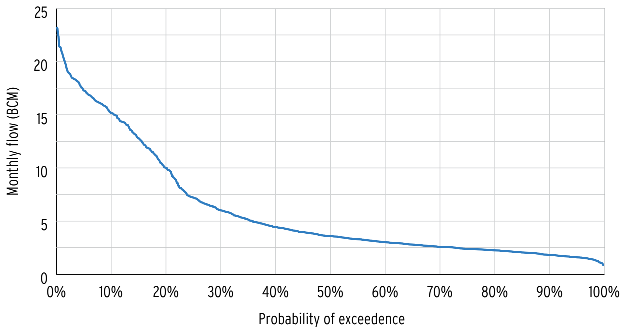
2 Monthly Flow Distribution - Hassanab



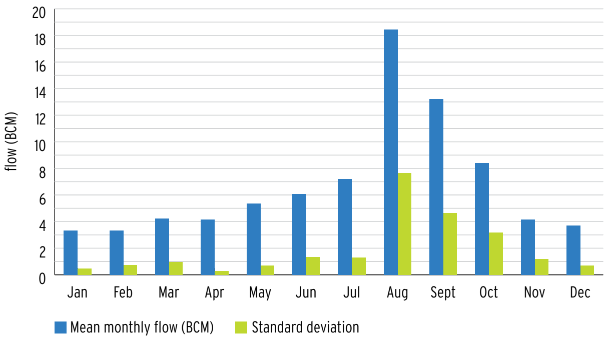
2 Monthly Flow Statistics - Hassanab



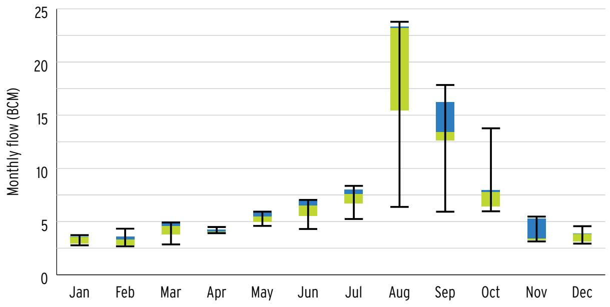
2 Flow Duration Curve - Hassanab



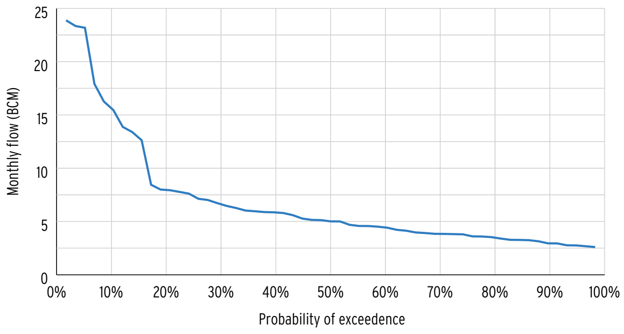
3 Monthly Flow Distribution - Merowe



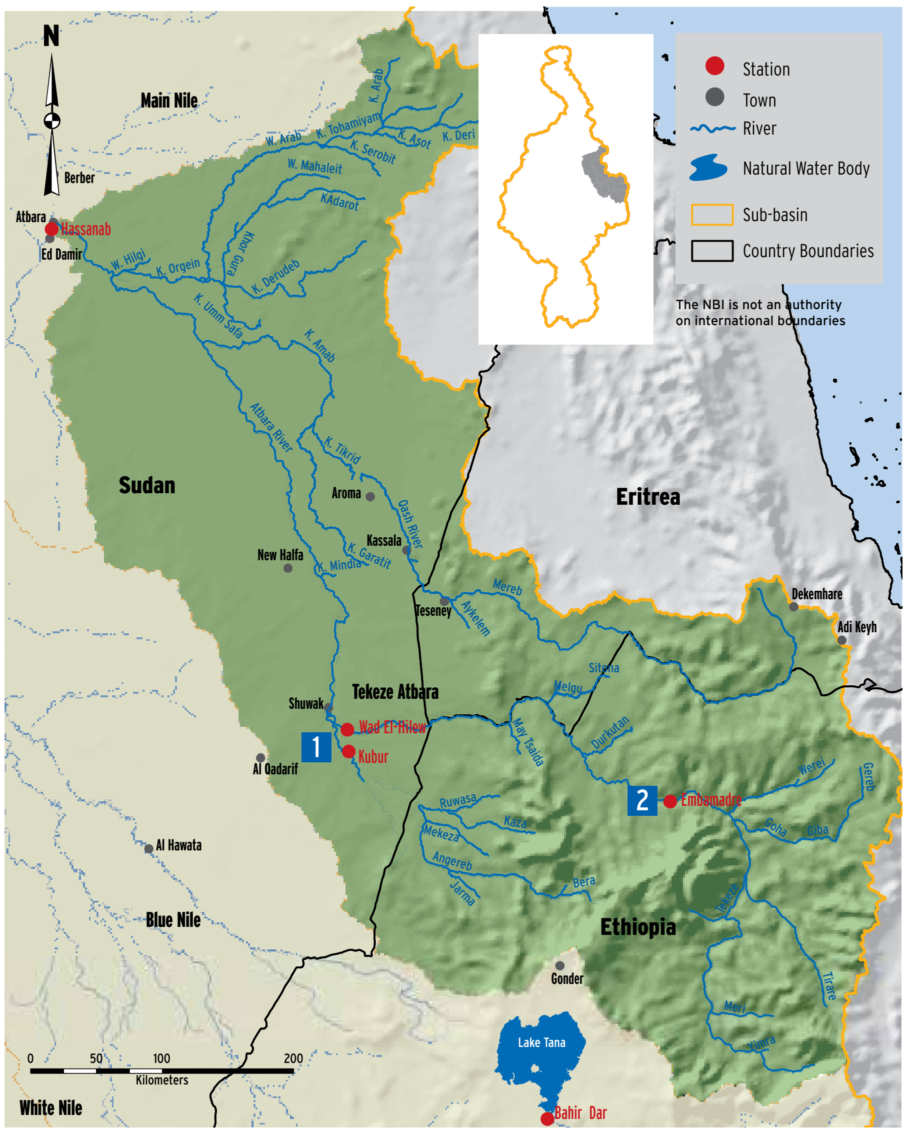
3 Monthly Flow Statistics - Merowe



3 Flow Duration Curve - Merowe



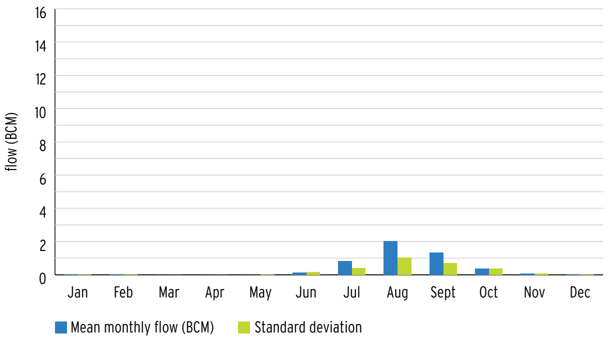
Tekeze-Atbara Sub-basin



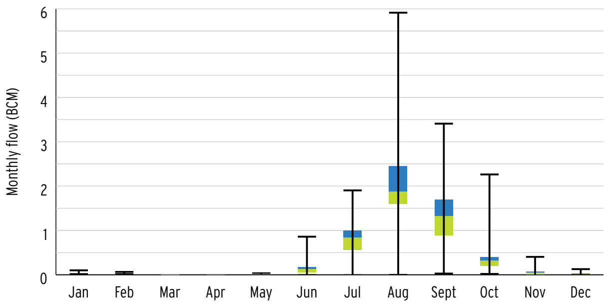
Simien Mountains, Ethiopia

The main rivers of the sub-basin are the Tekezze (also known as Setit), Angereb (a tributary of Gwang) and Gwang. The Atbara is formed after Tekezze (Setit) is joined by Gwang River. The Atbara is the most seasonal of major tributaries of the Nile as can be deduced from the charts of monthly stream flow. There are three storage dams in the sub-basin: TK5 (live storage: 9.2 BCM) in Ethiopia, Khashim el Girba Dam (live storage: 654 MCM) Sudan and the new Atbara dam complex recently built by Sudan to increase water supply for irrigation downstream. The average annual flow for River Atbara at Khashim el Girba dam is 11.4 BCM.

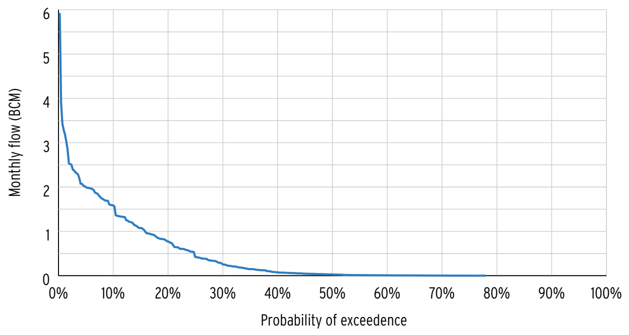
1 Monthly Flow Distribution - Kubur



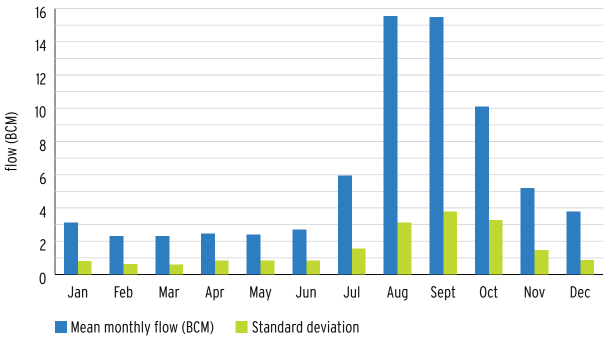
1 Monthly Flow Statistics - Kubur



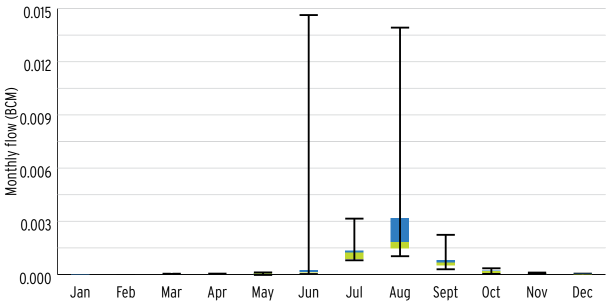
1 Flow Duration Curve - Kubur



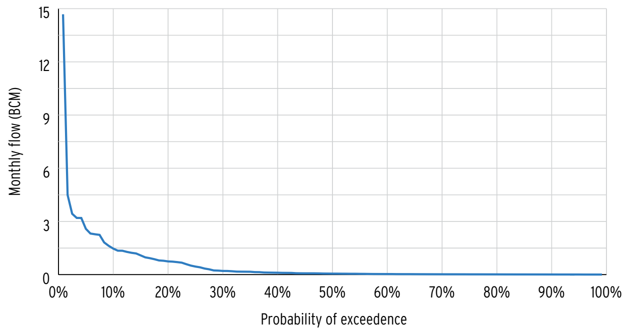
2 Monthly Flow Distribution - Embamadre



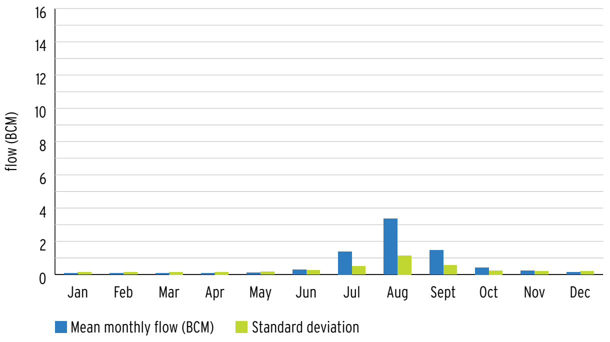
2 Monthly Flow Statistics - Embamadre



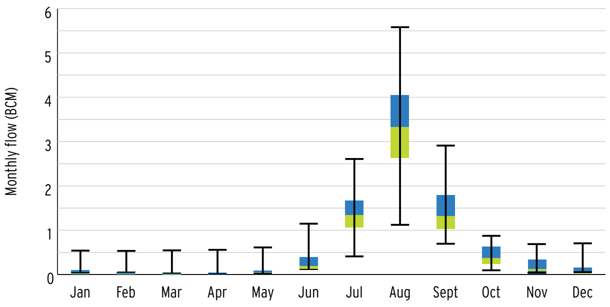
2 Flow Duration Curve - Embamadre



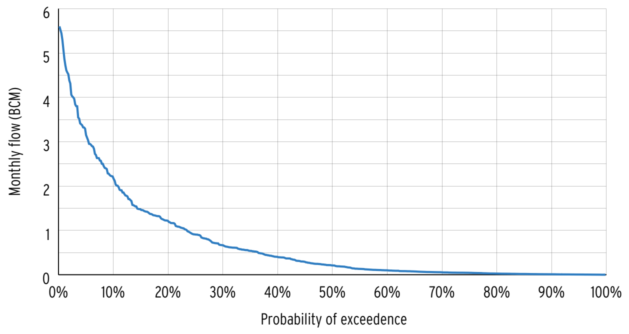
3 Monthly Flow Distribution - Seteit



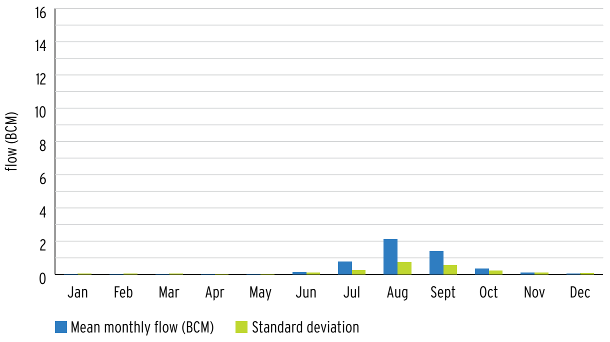
3 Monthly Flow Statistics - Seteit



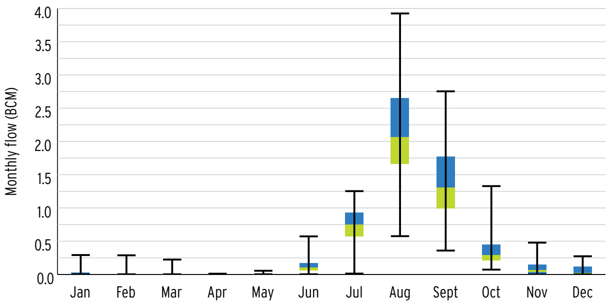
3 Flow Duration Curve - Seteit



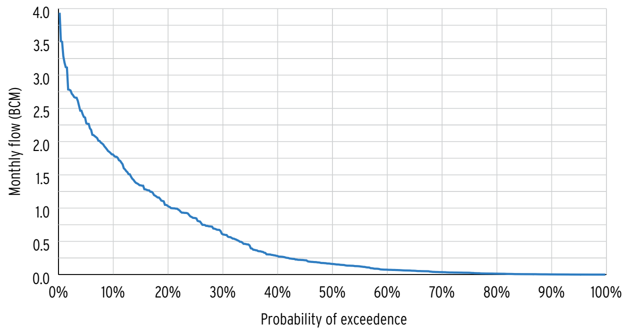
4 Monthly Flow Distribution - Upper Atbara



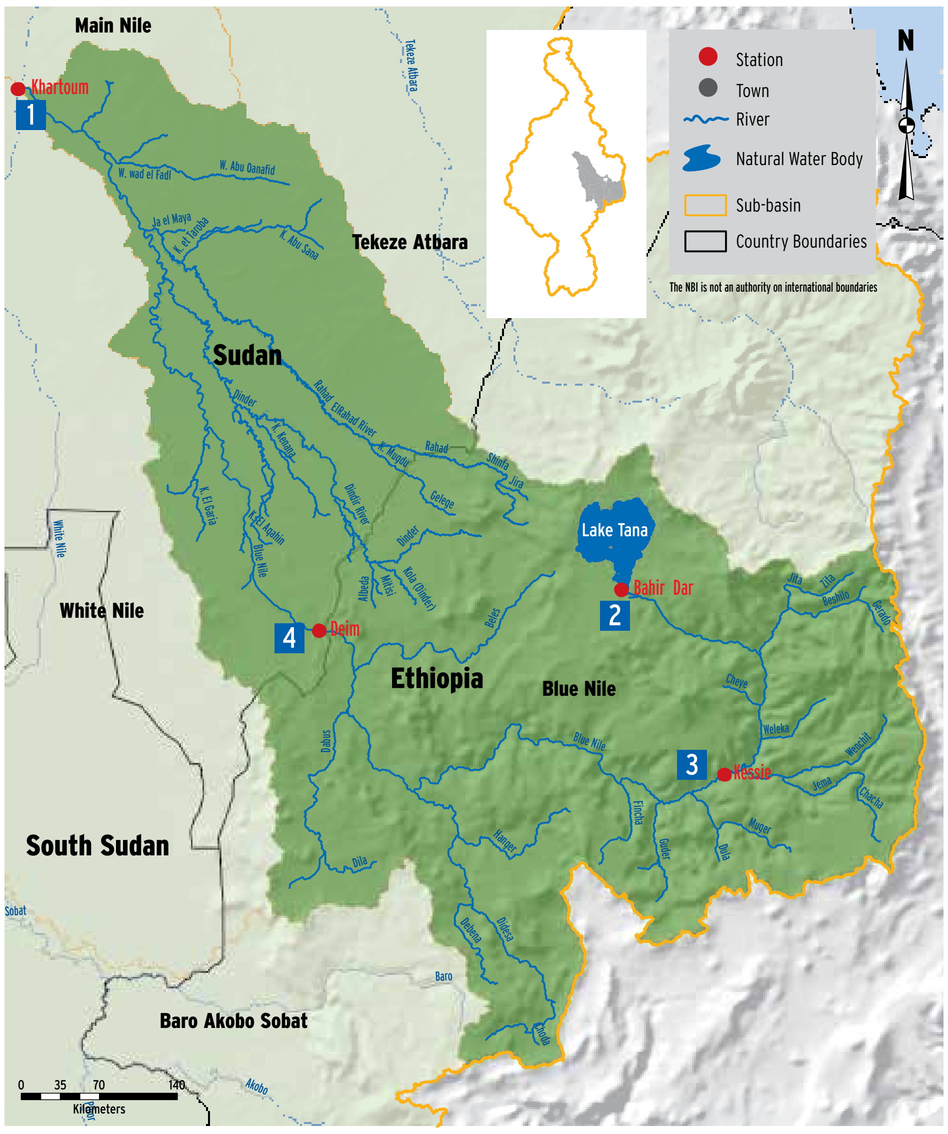
4 Monthly Flow Statistics - Upper Atbara



4 Flow Duration Curve - Upper Atbara



Blue Nile Sub-basin



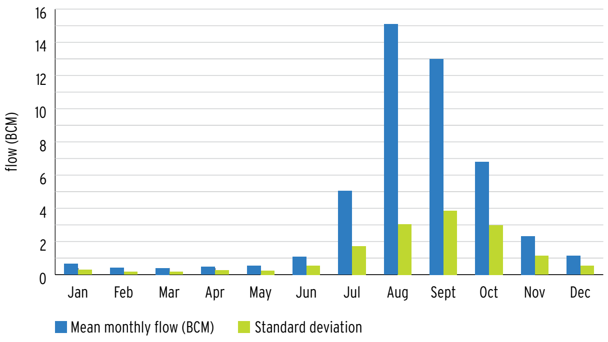

Blue Nile Falls from the Air

Photo: Travel Aficionado/flickr

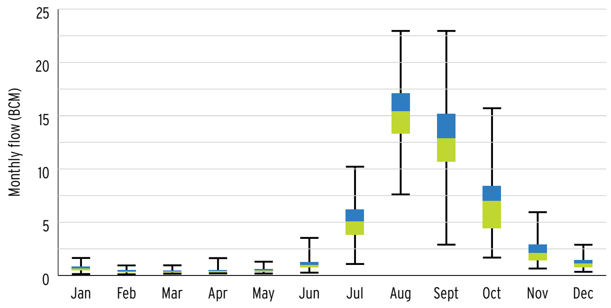
The Blue Nile is the largest contributor of flow to River Nile. For the period 1915 to 2014, the average annual river flow at the Diem station is about 50 BCM. The total contribution of the major tributaries of the Blue Nile including Dinder and Rahad) is about 55BCM which is about 60 percent of the combined flows of all Nile tributaries.

The Blue Nile is highly seasonal in with approximately 70 percent of its flow occurring in just 4 months (peak flows registered between July-September).

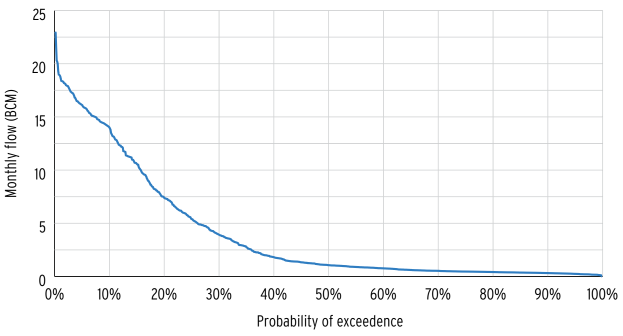
1 Monthly Flow Distribution - Khartoum



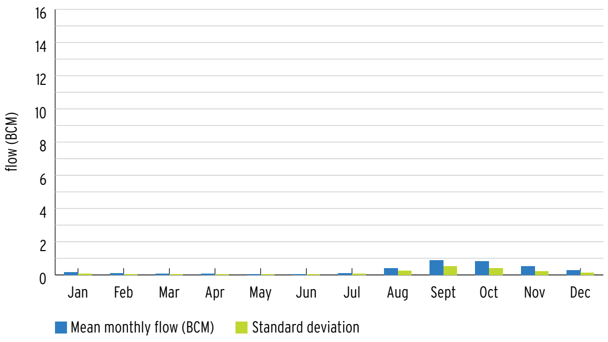
1 Monthly Flow Statistics - Khartoum



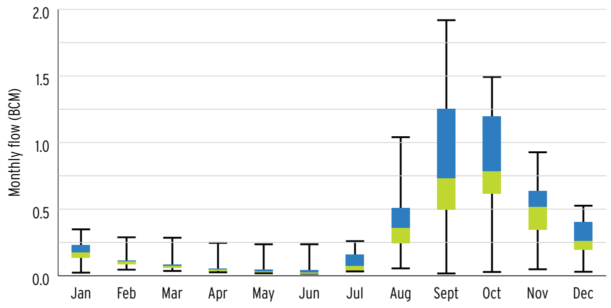
1 Flow Duration Curve - Khartoum



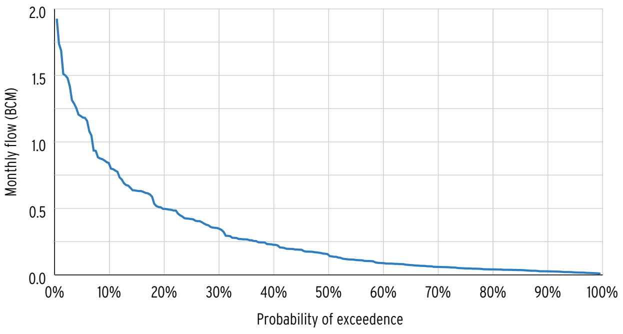
2 Monthly Flow Distribution - Bahir Dar



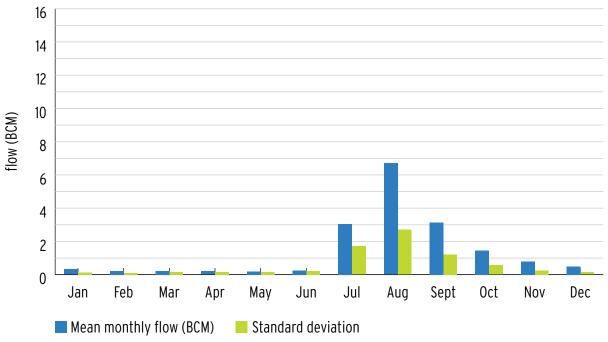
2 Monthly Flow Statistics - Bahir Dar



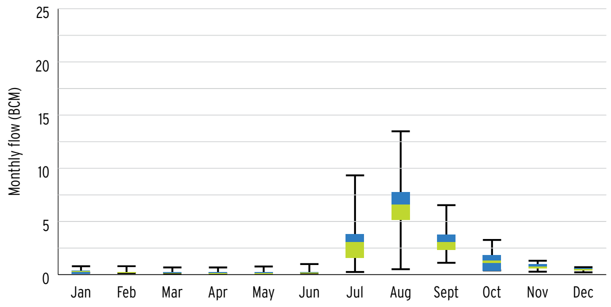
2 Flow Duration Curve - Bahir Dar



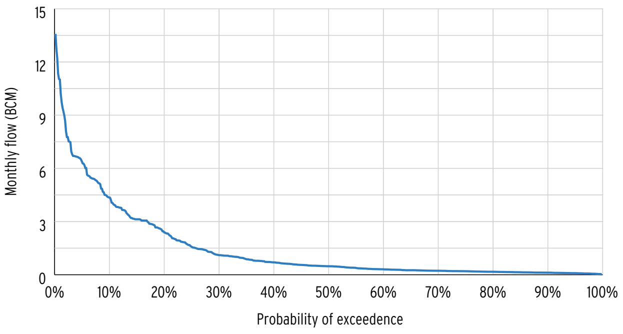
3 Monthly Flow Distribution - Kessie



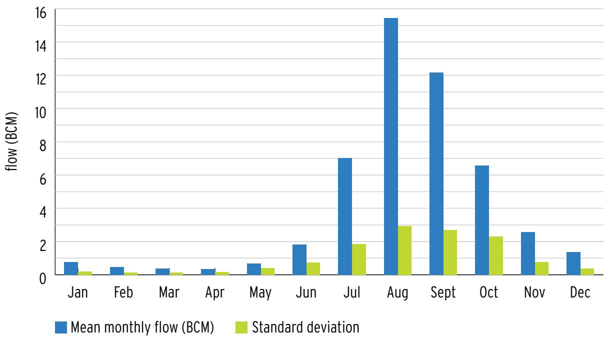
3 Monthly Flow Statistics - Kessie



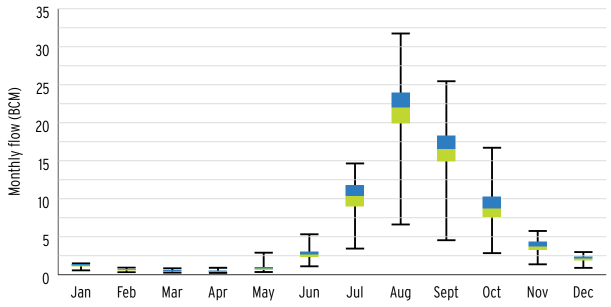
3 Flow Duration Curve - Kessie



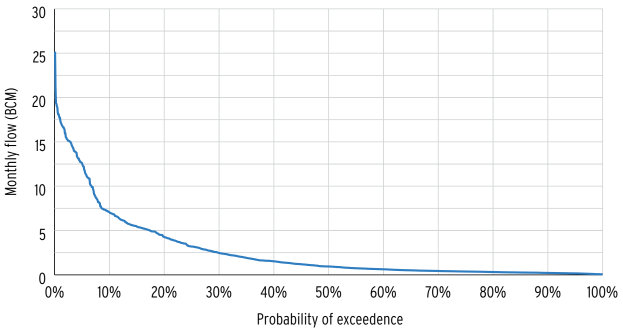
4 Monthly Flow Distribution - Diem



4 Monthly Flow Statistics - Diem



4 Flow Duration Curve - Diem



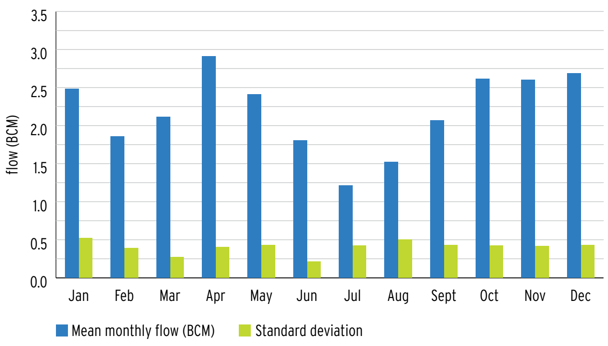
White Nile Sub-basin

Jebel Aulia dam

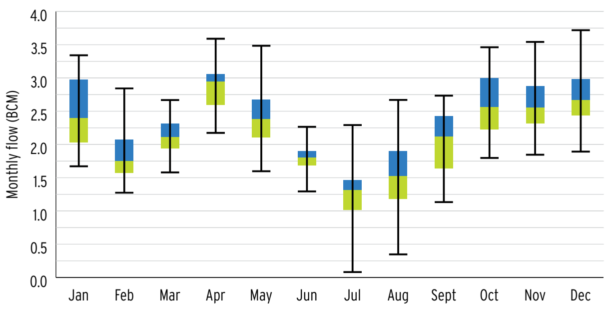
White Nile

A major feature in the White Nile sub-basin is the Gebel Aulia dam whose backwater curve is reported to extend for more than 600 kilometers. The flow recorded at Mogren station in Khartoum is the release from the dam. In the months of July – August, the Blue Nile acts as a barrier and causes the White Nile to back up and slow down.

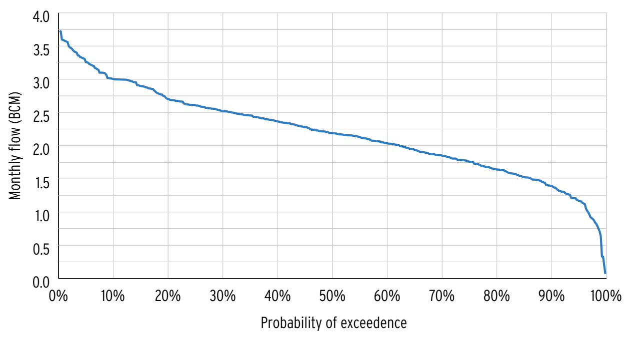
1 Monthly Flow Distribution - Jebel Aulia



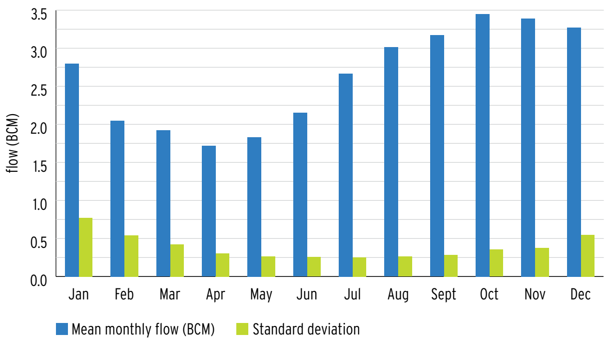
1 Monthly Flow Statistics - Jebel Aulia



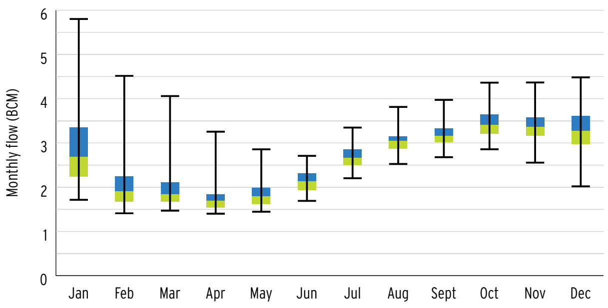
1 Flow Duration Curve - Jebel Aulia



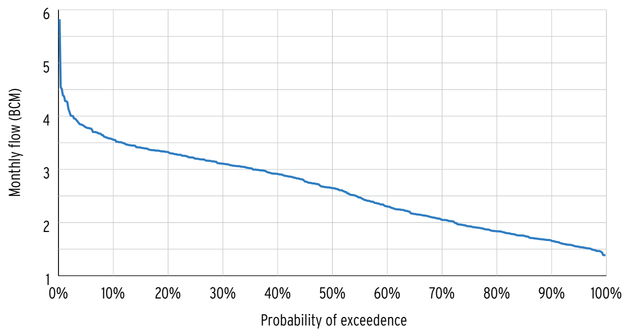
2 Monthly Flow Distribution - Malakal



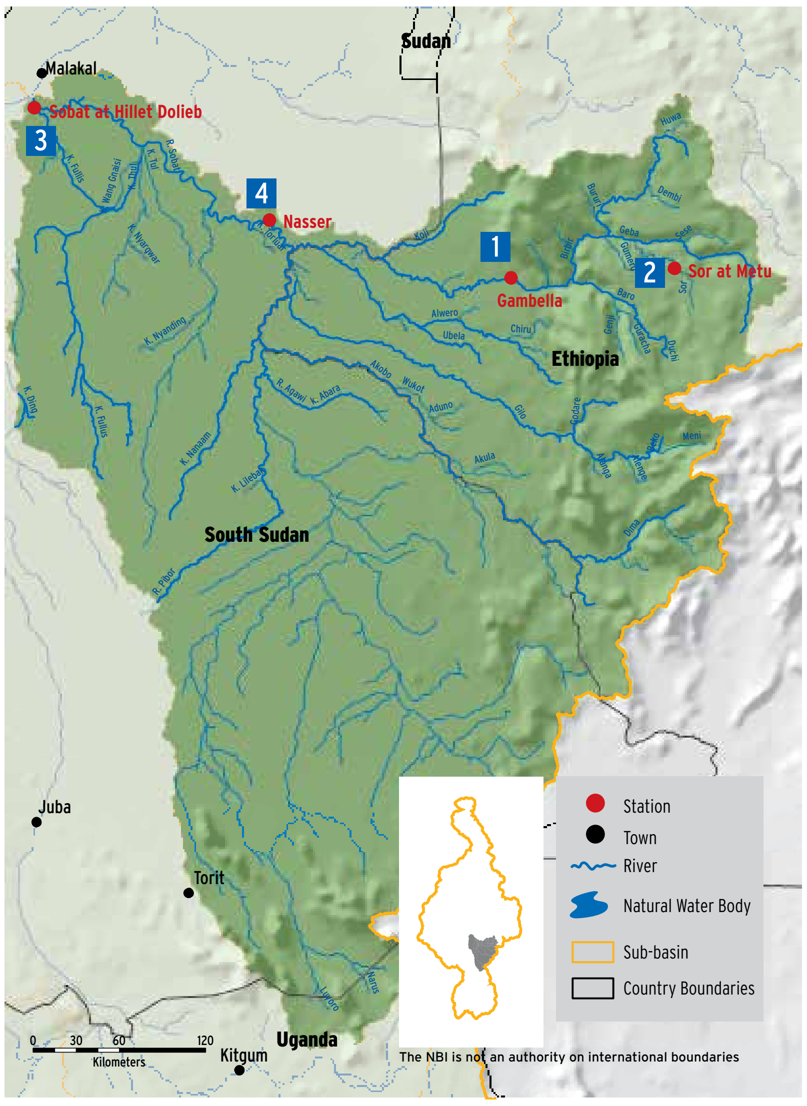
2 Monthly Flow Statistics - Malakal



2 Flow Duration Curve - Malakal



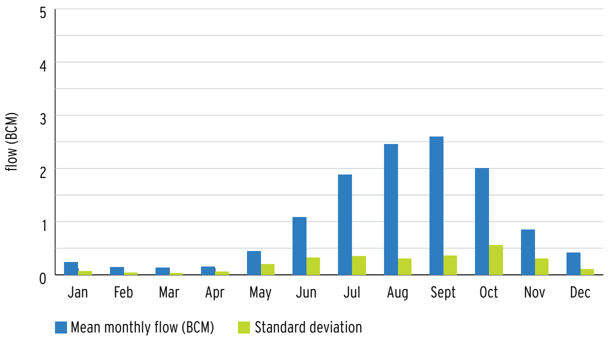
Baro Akobo Sobat Sub-basin



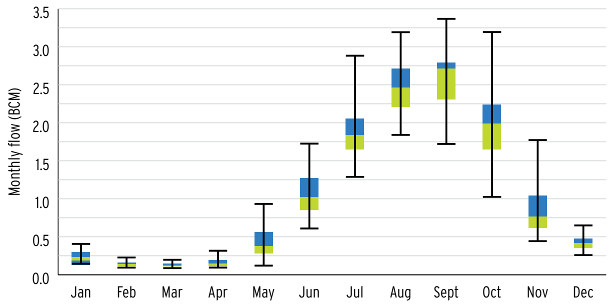
The Sobat River on the edge of Nasir, South Sudan

Flow in the Baro Akobo Sobat Sub-basin is characterized by high seasonality with a distinct high flow season occurring between July and October. This sub-basin is one of the least monitored Sub-basins and yet has very complex hydrology. A key feature of this sub-basin is high interconnection between floodplains and the river network with braided and bifurcating streams. Downstream of Gambella station, Baro River overflows into the Machar marshes, which are in the White Nile sub-basin.

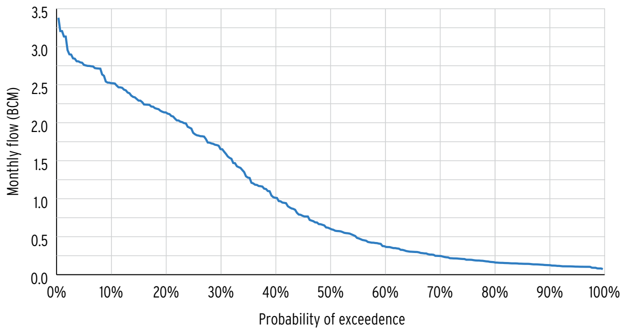
1 Monthly Flow Distribution - Gambela



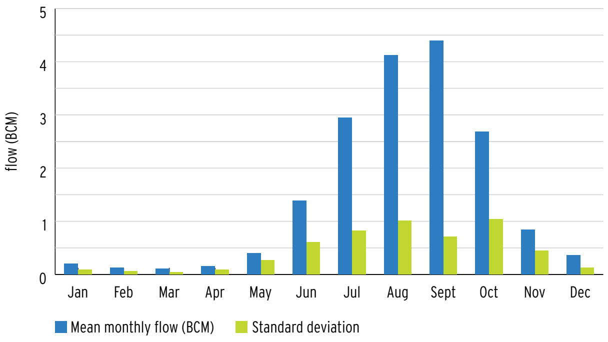
1 Monthly Flow Statistics - Gambela



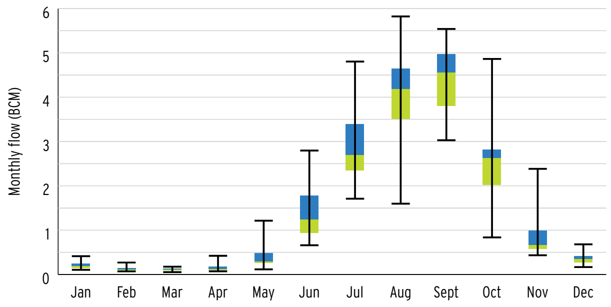
1 Flow Duration Curve - Gambela



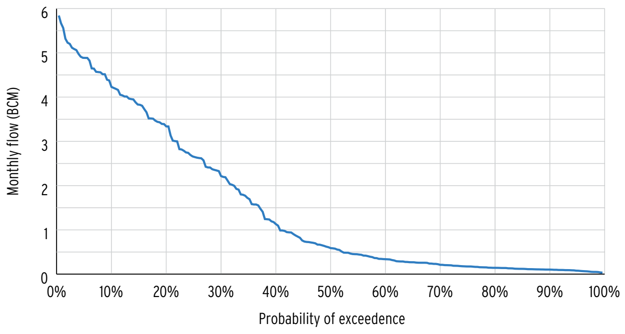
2 Monthly Flow Distribution - Sor



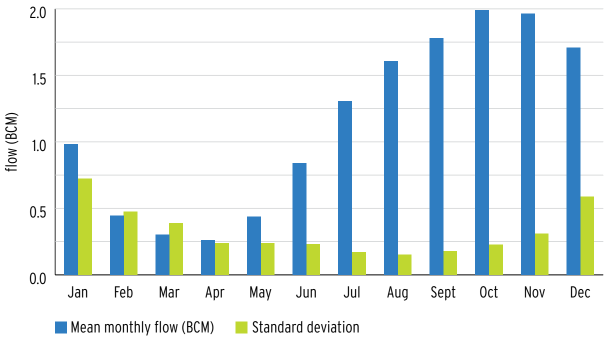
2 Monthly Flow Statistics - Sor



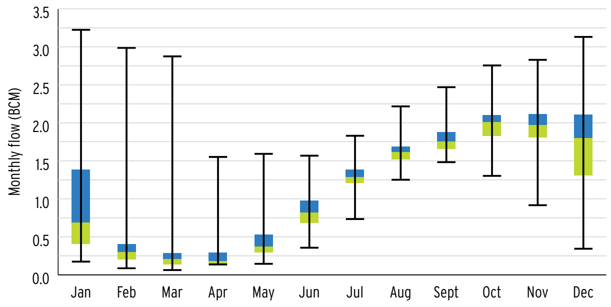
2 Flow Duration Curve - Sor



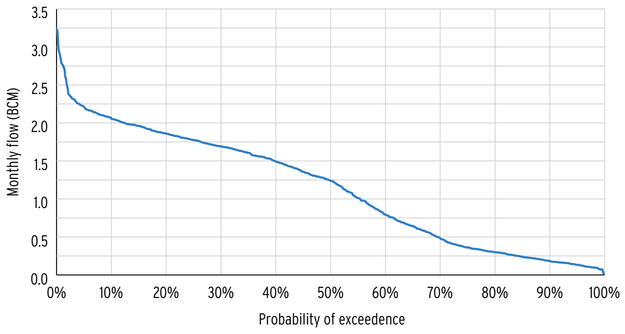
3 Monthly Flow Distribution - Sobat at Hillet Dolieb



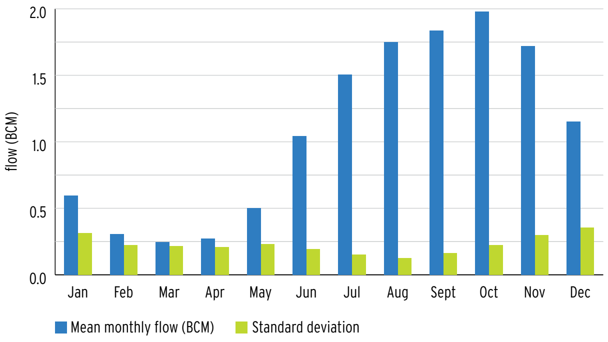
3 Monthly Flow Statistics - Sobat at Hillet Dolieb



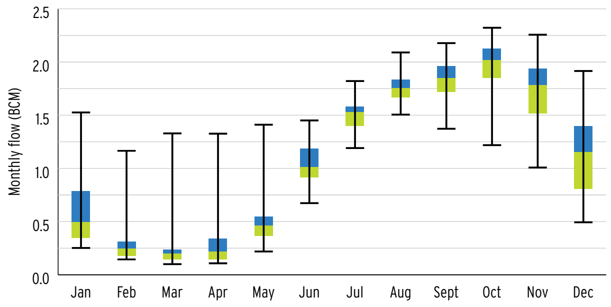
3 Flow Duration Curve - Sobat at Hillet Dolieb



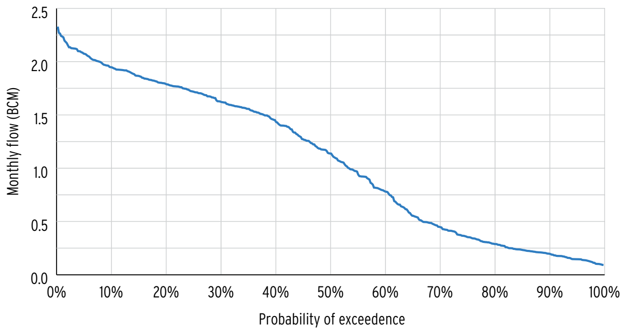
4 Monthly Flow Distribution - Nasser



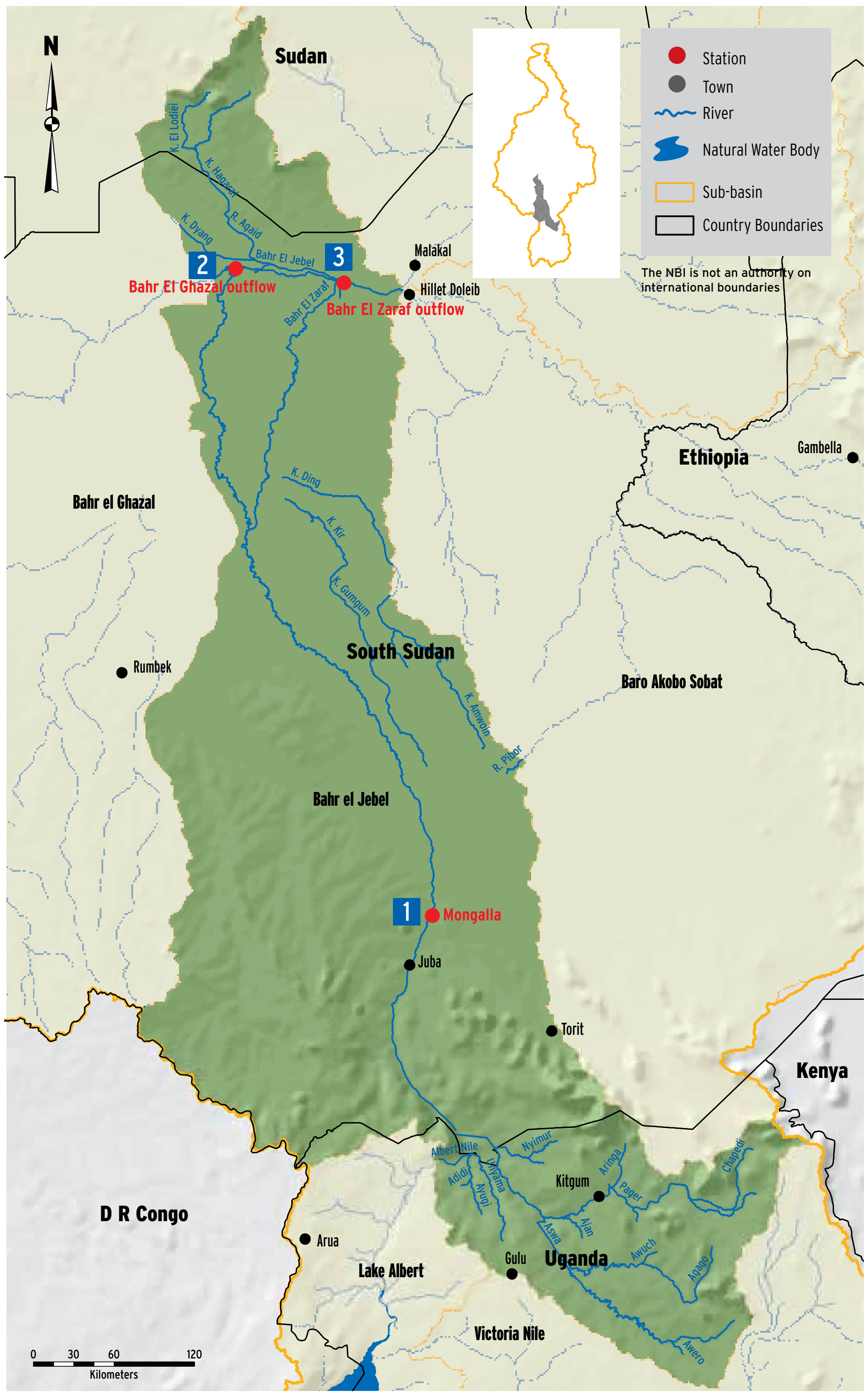
4 Monthly Flow Statistics - Nasser



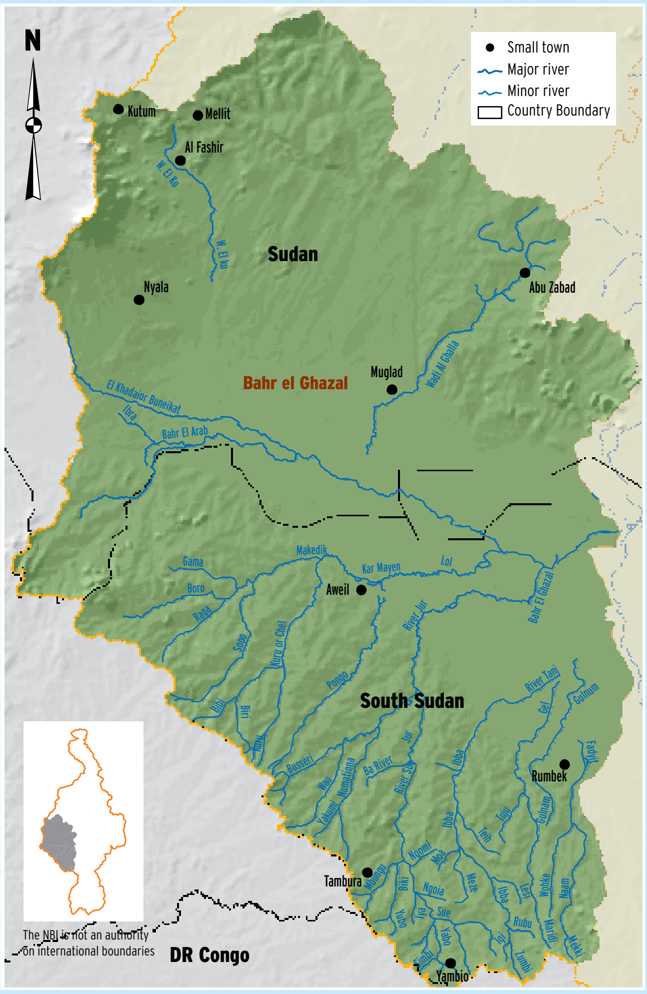
4 Flow Duration Curve - Nasser



Bahr el Jebel Sub-basin



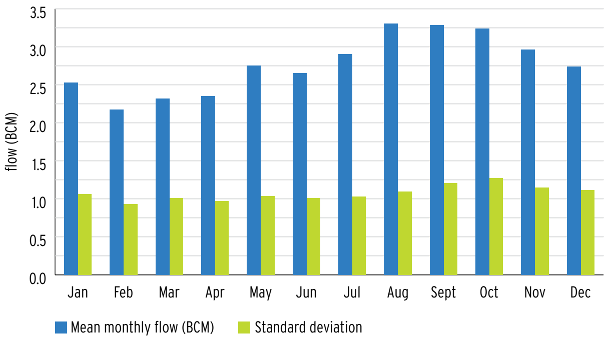
Bahr el Ghazal Sub-basin



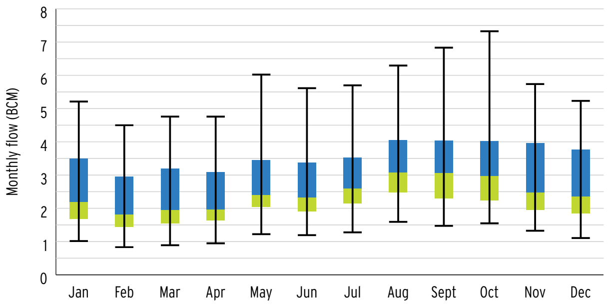
Bahr el Jebel and Bahr el Ghazal sub-basins are one of the least understood major sub-basins of the Nile and yet the existing hydro-met monitoring network is also very limited. The few available stream flow records exhibit substantial breaks and are of very poor quality

Seasonality the Bahr el Jebel Sub-basin is seen to have a single peak occurring between August and October as opposed to the two seasonal peaks in the upstream part of the Nile Basin. The standard deviation of the monthly flows is also seen to be high as gauged at Mongalla partly because of the steeper section with rapids and rock outcrops as flow enters into the sub-basin from the Albert Nile and the various torrential streams entering the Bahr el Jebel (with a single seasonal peak) before the gentle slope.

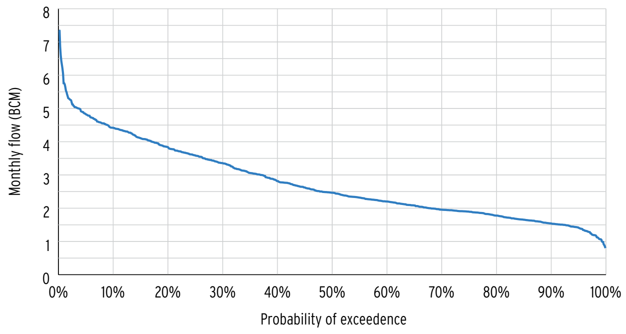
1 Monthly Flow Distribution - Mongalla



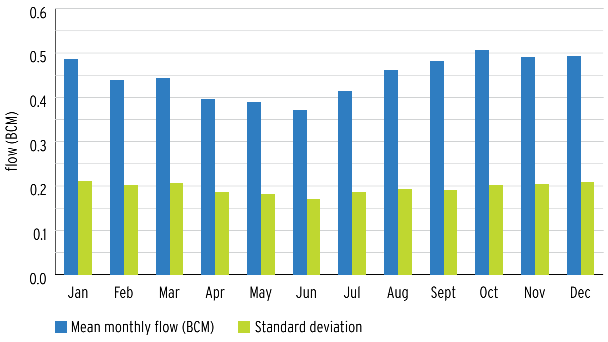
1 Monthly Flow Statistics - Mongalla



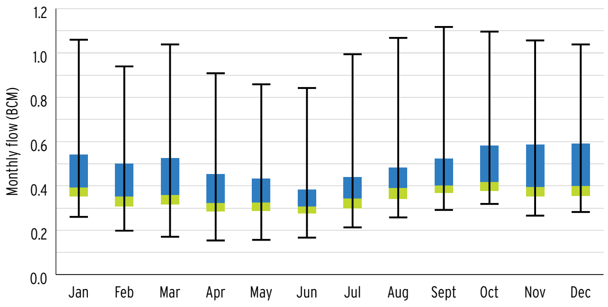
1 Flow Duration Curve - Mongalla



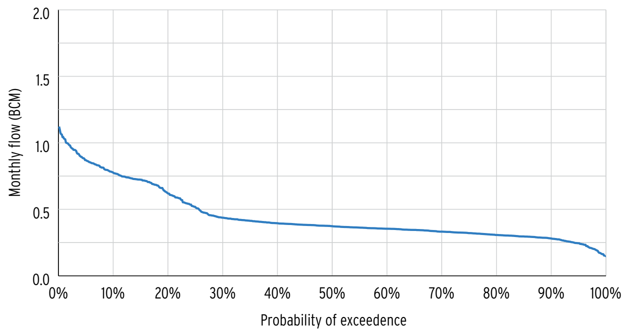
2 Monthly Flow Distribution - Bahr El Ghazal outflow



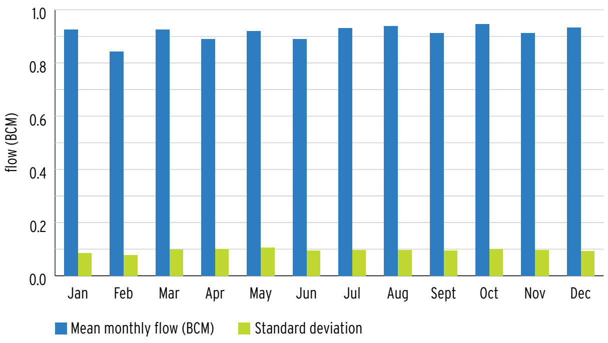
2 Monthly Flow Statistics - Bahr El Ghazal outflow



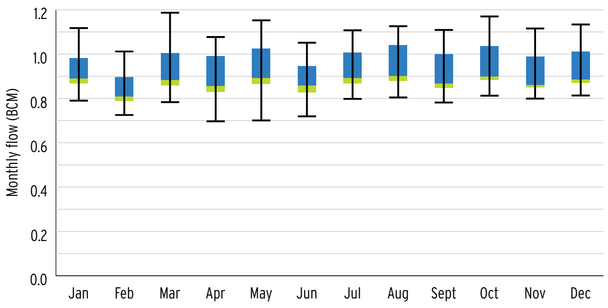
2 Flow Duration Curve - Bahr El Ghazal outflow



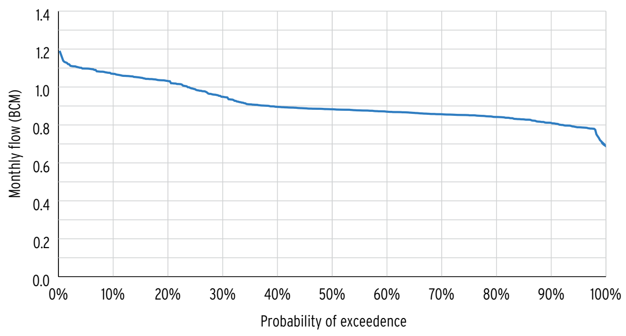
3 Monthly Flow Distribution - Bahr El Zaraf outflow



3 Monthly Flow Statistics - Bahr El Zaraf outflow



3 Flow Duration Curve - Bahr El Zaraf outflow



Lake Albert Sub-basin

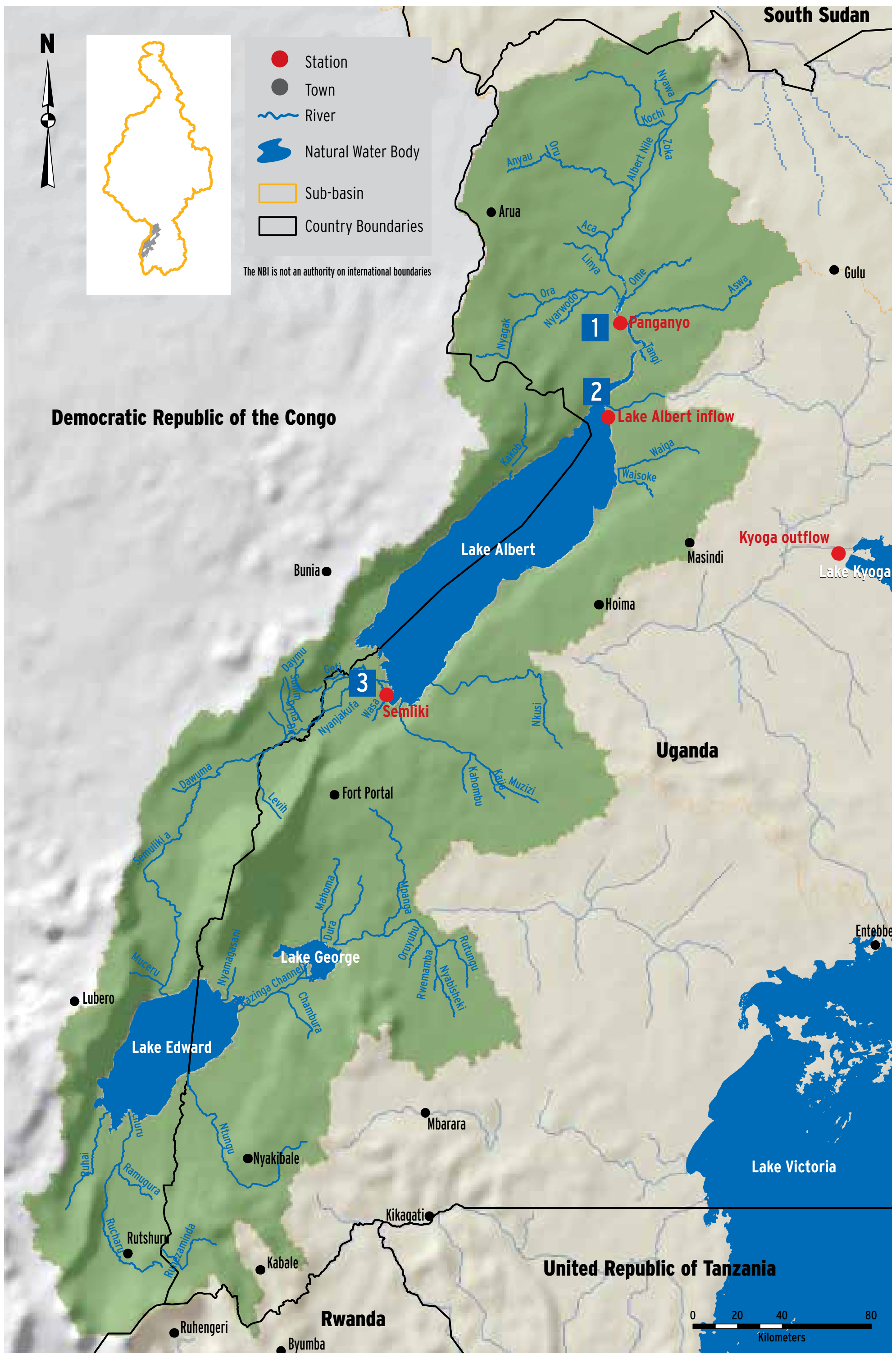



Photo: Noel Reynolds/flickr.com

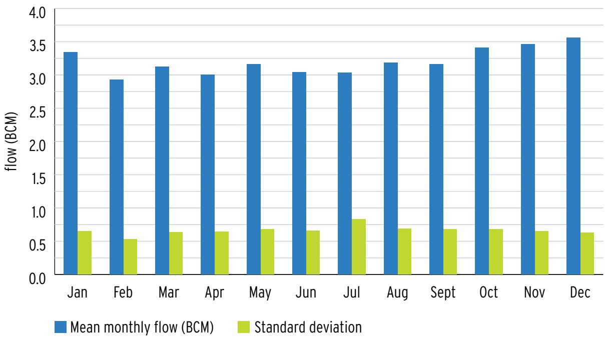
Murchison Falls


Photo: Monkey Boy/flickr.com

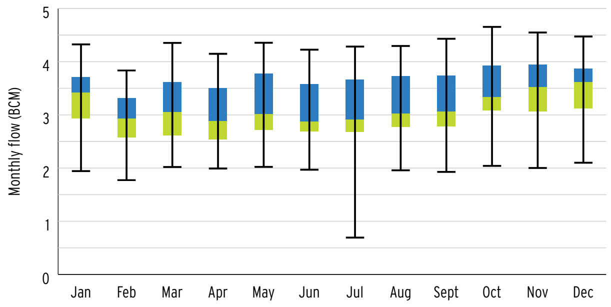
Kazinga Channel - The channel joins Lake Edward and Lake Albert and has one of the highest concentrations of wildlife in Africa.

There are two distinct seasons with high flows into Lake Albert, the peaks of which appear in May and November respectively. However, this is not reflected in the outflows partly because of the inflow from the Victoria Nile and water use and storage effect within the lake itself.

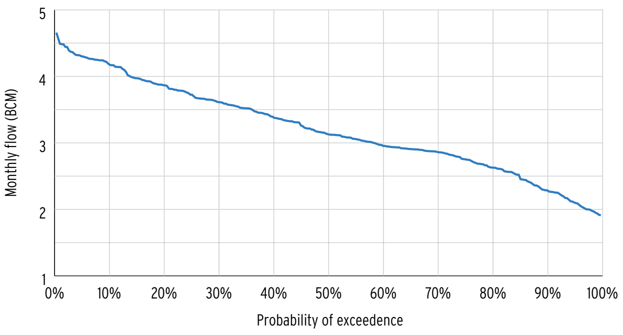
1 Monthly Flow Distribution - Panyango



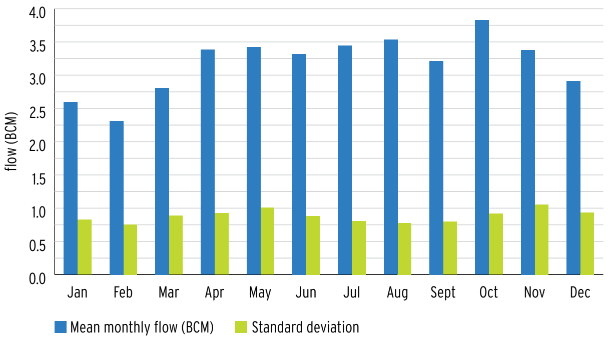
1 Monthly Flow Statistics - Panyango



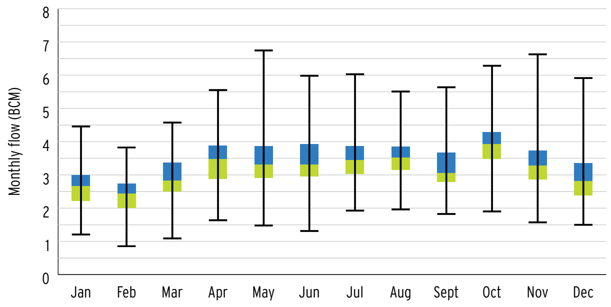
1 Flow Duration Curve - Panyango



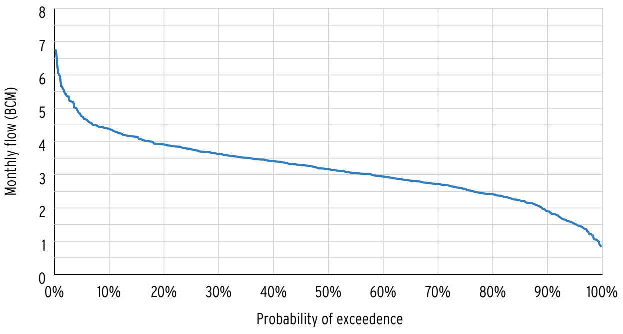
2 Monthly Flow Distribution - Lake Albert Inflow flow



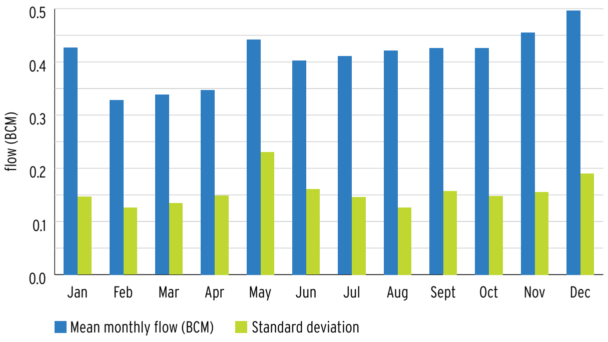
2 Monthly Flow Statistics - Lake Albert Inflow flow



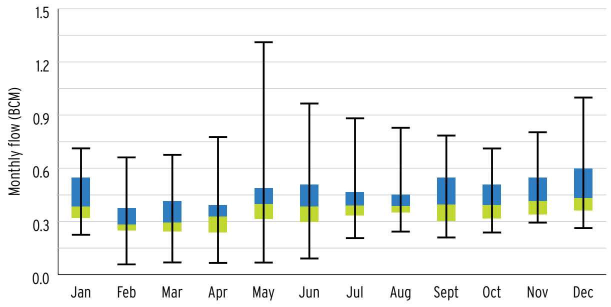
2 Flow Duration Curve - Lake Albert Inflow flow



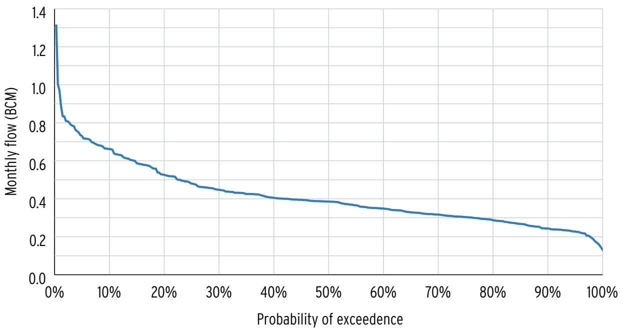
3 Monthly Flow Distribution - Semliki



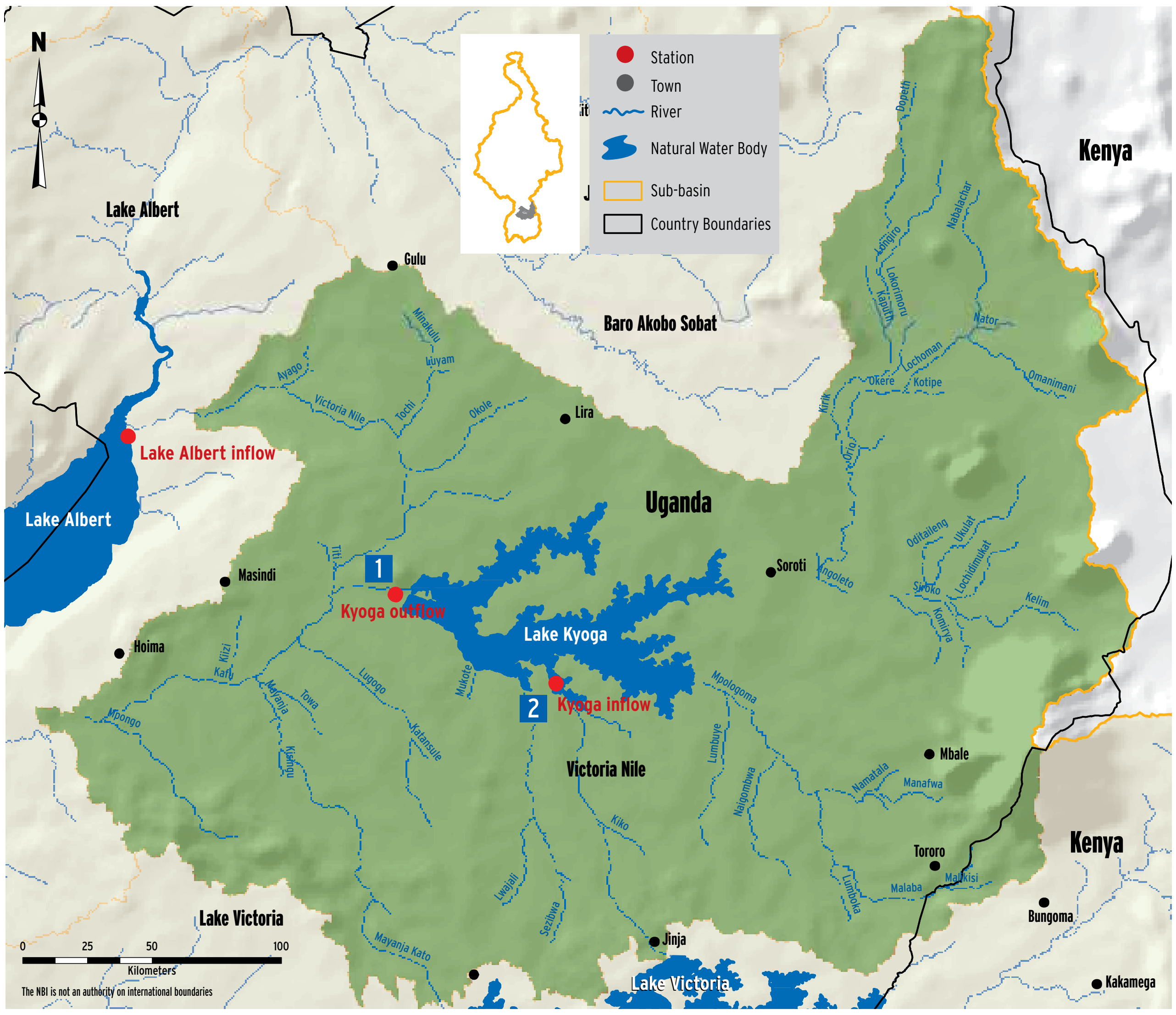
3 Monthly Flow Statistics - Semliki



3 Flow Duration Curve - Semliki



Victoria Nile Sub-basin



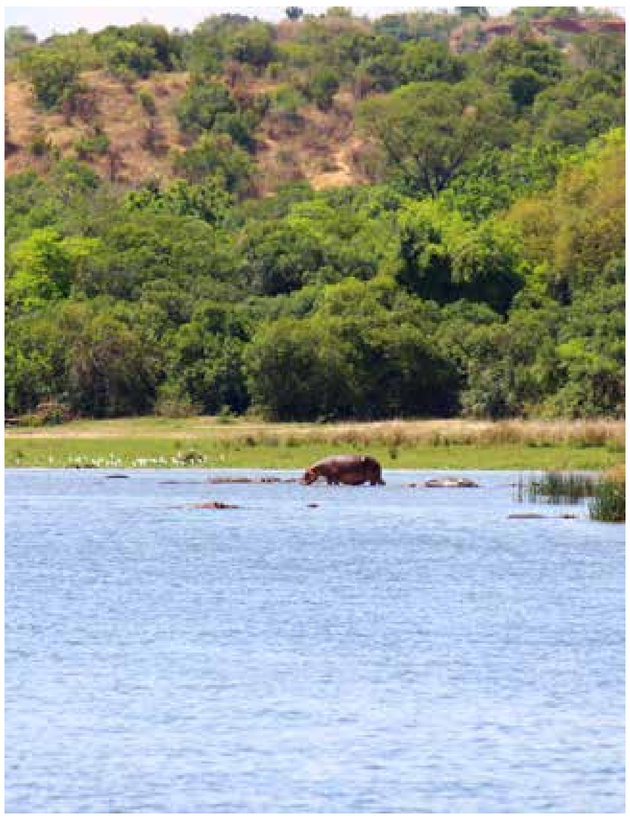
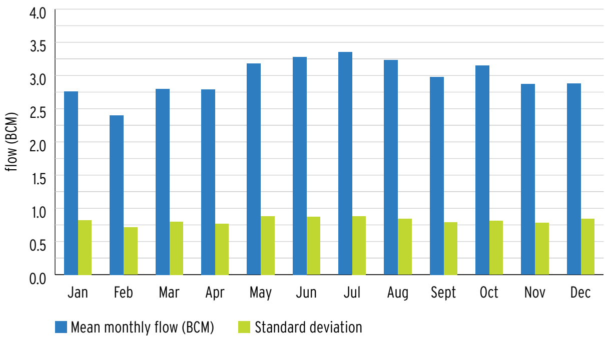


Photo: Vivek Bahukhandi

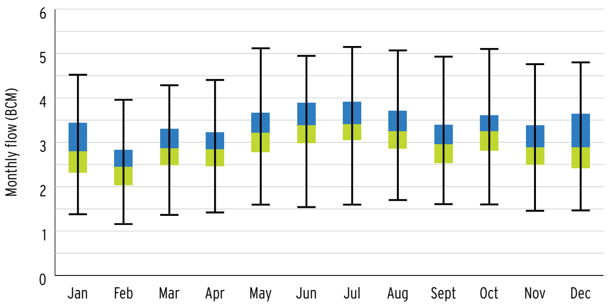
Albert Nile in Uganda

The outflow from the lake seems to indicate that the lake has minimal effect on inflow from the Victoria Nile since the major patterns are maintained both in the inflow and outflow.

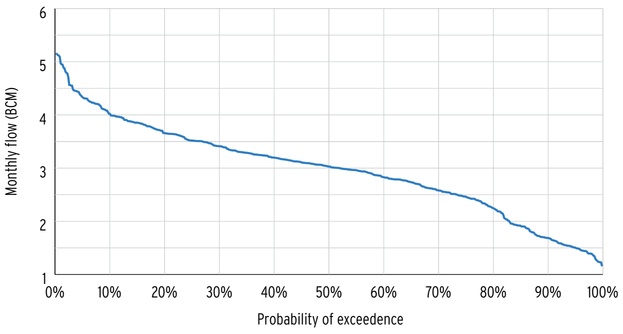
1 Monthly Flow Distribution - Kyoga outflow flow



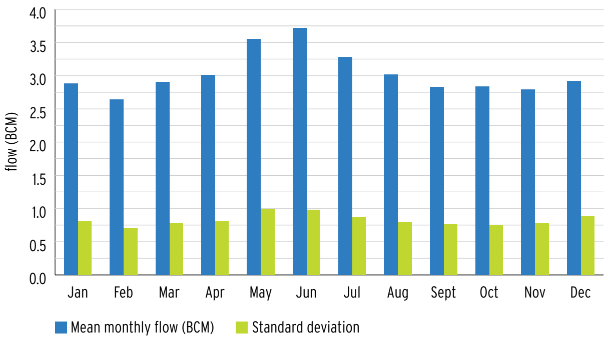
1 Monthly Flow Statistics - Kyoga outflow flow



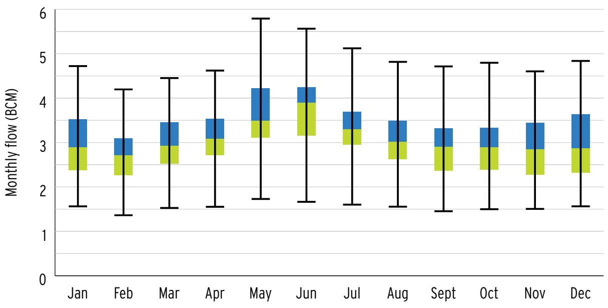
1 Flow Duration Curve - Kyoga outflow flow



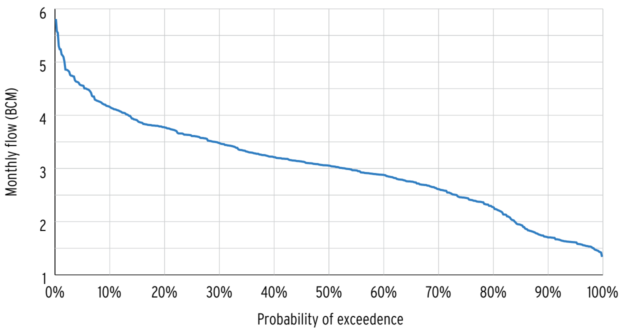
2 Monthly Flow Distribution - Kyoga inflow flow



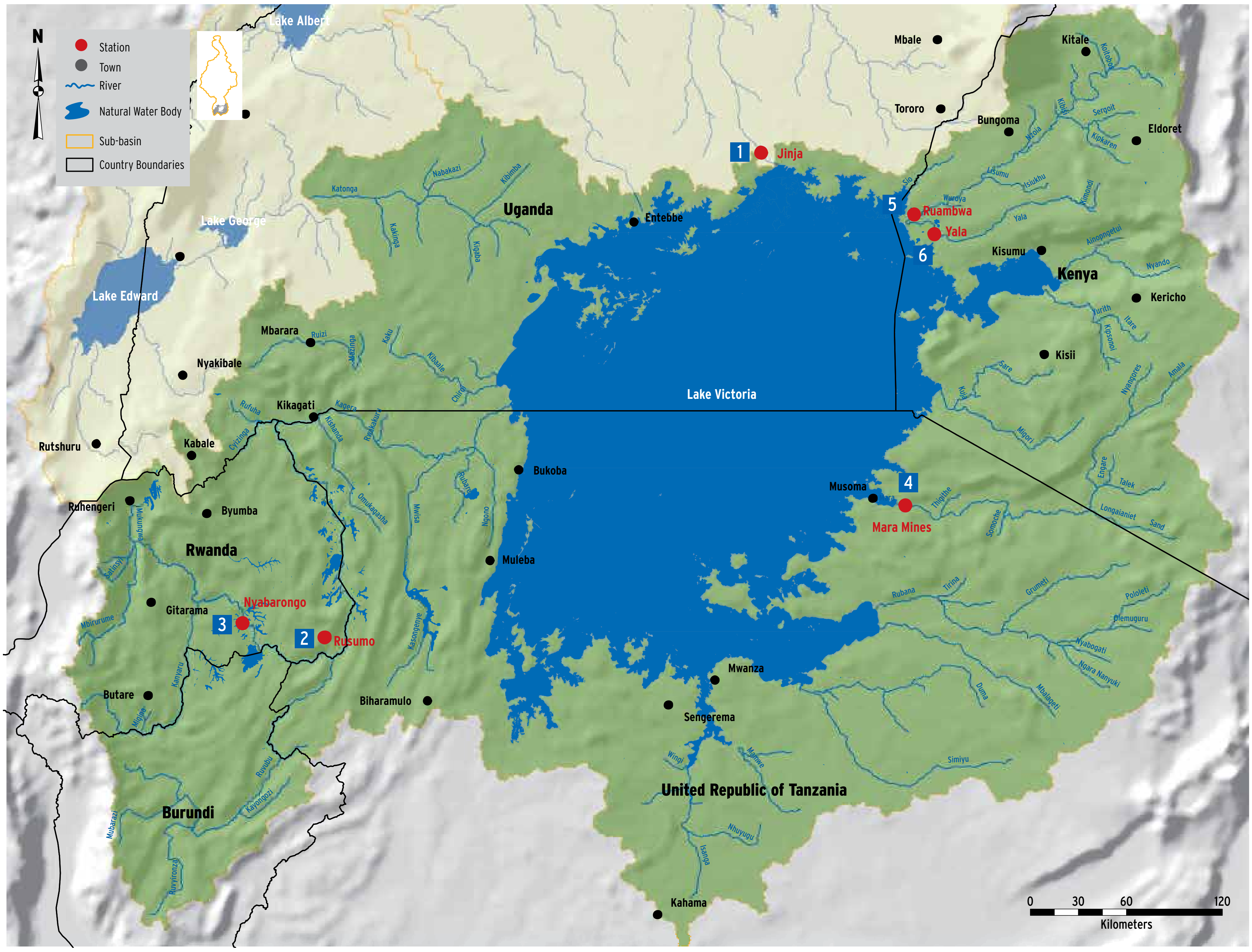
2 Monthly Flow Statistics - Kyoga inflow flow



2 Flow Duration Curve - Kyoga inflow flow

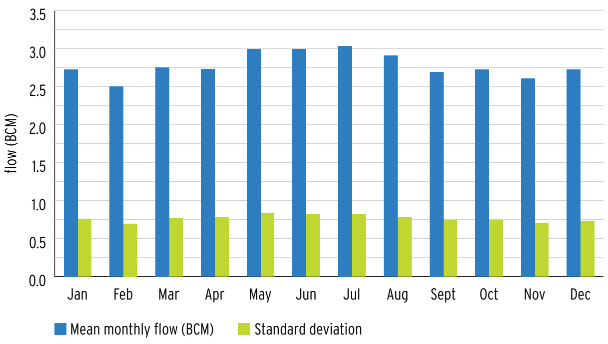


Lake Victoria Sub-basin

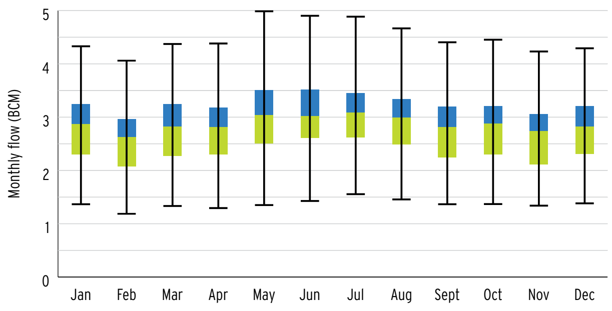


Lake Victoria within the Lake Victoria Sub-basin is a large buffer zone that not only allows for inter-annual storage but also regulates outflows. As seen, inflows from the upstream catchments depict seasonality but this variability is damped as the Victoria Nile outflows from Lake Victoria due to this regulation.

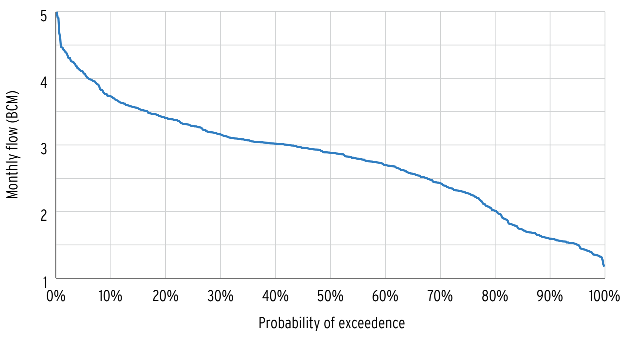
1 Monthly Flow Distribution - Jinja



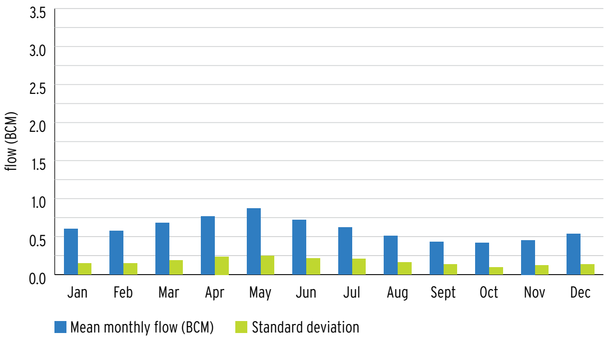
1 Monthly Flow Statistics - Jinja



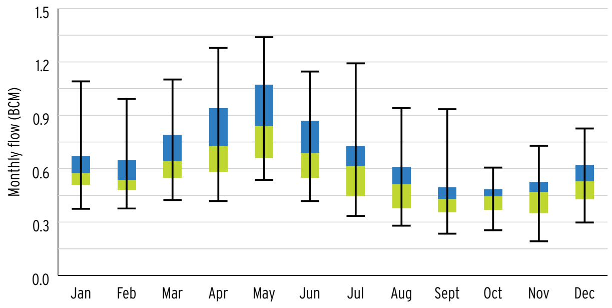
1 Flow Duration Curve - Jinja



2 Monthly Flow Distribution - Rusumo



2 Monthly Flow Statistics - Rusumo



2 Flow Duration Curve - Rusumo

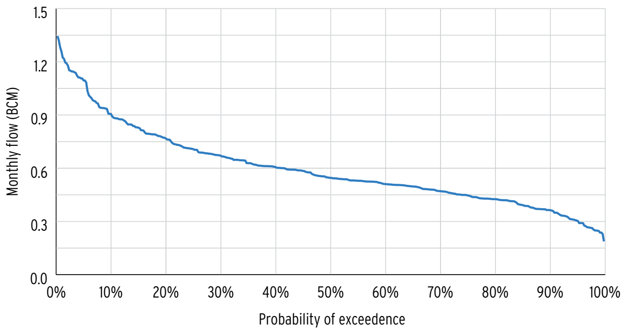
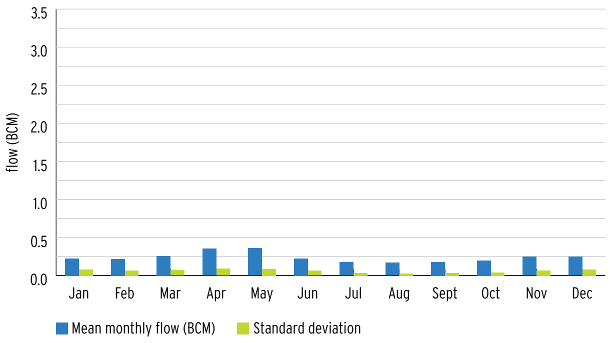


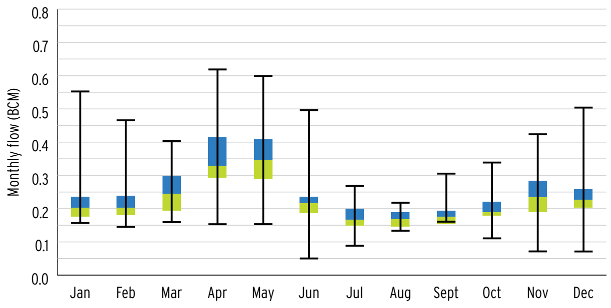
Photo: LM TP/flickr.com

Lake Victoria: The source of the Nile river

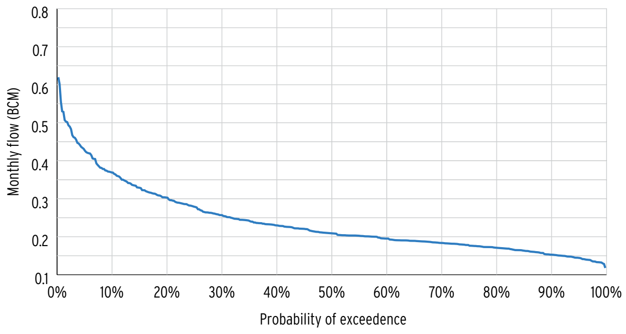
3 Monthly Flow Distribution - Nyabarongo



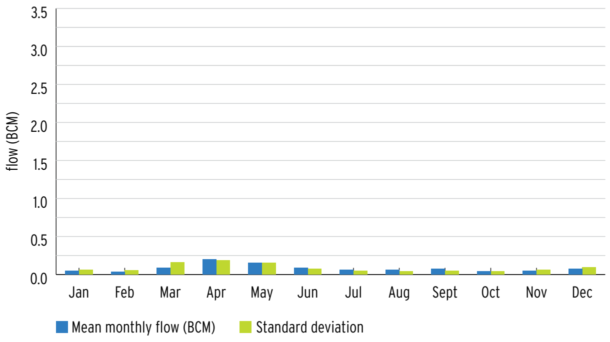
3 Monthly Flow Statistics - Nyabarongo



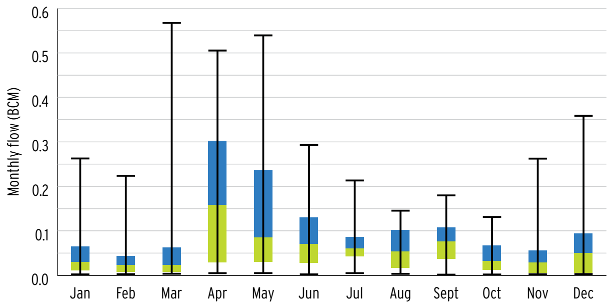
3 Flow Duration Curve - Nyabarongo



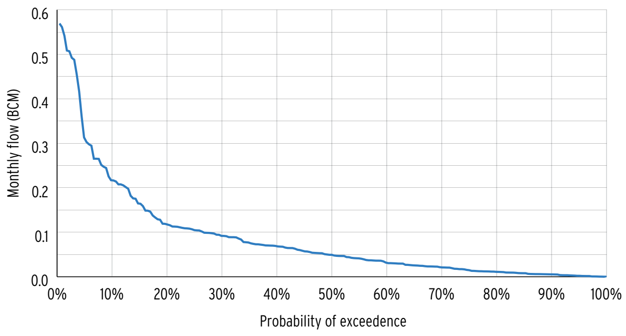
4 Monthly Flow Distribution - Mara Mines



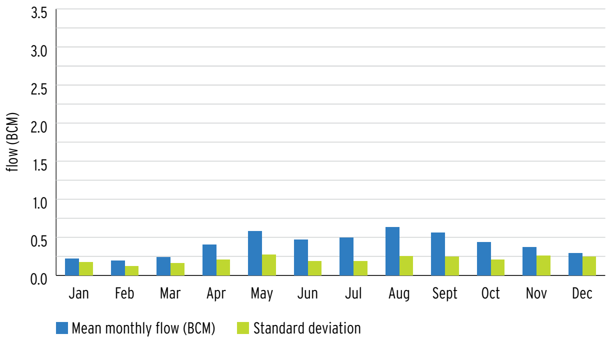
4 Monthly Flow Statistics - Mara Mines



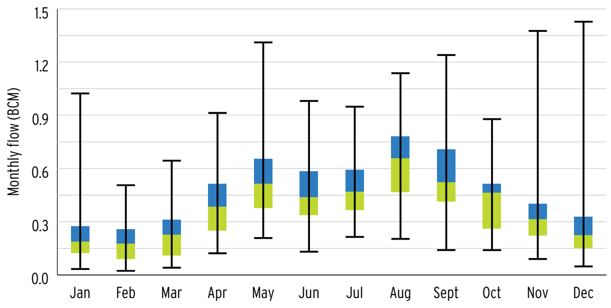
4 Flow Duration Curve - Mara Mines



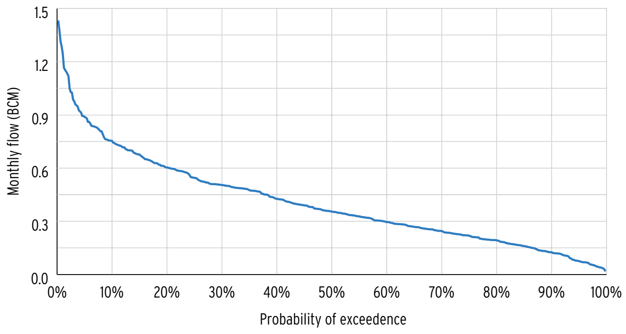
5 Monthly Flow Distribution - Ruambwa



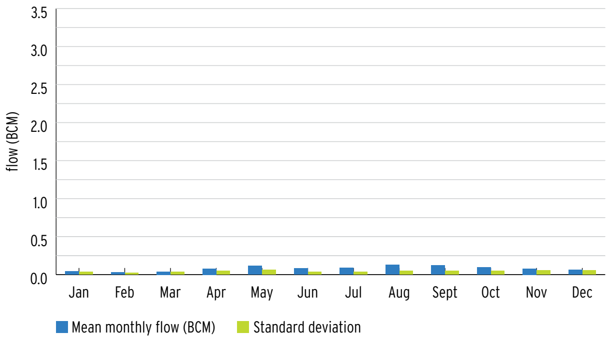
5 Monthly Flow Statistics - Ruambwa



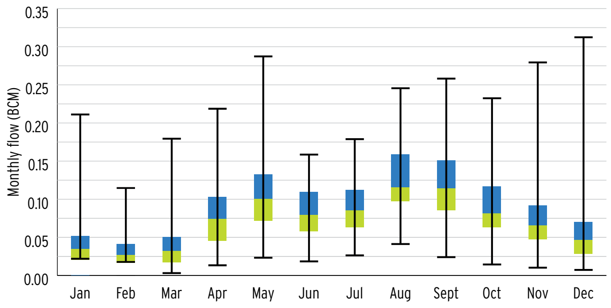
5 Flow Duration Curve - Ruambwa



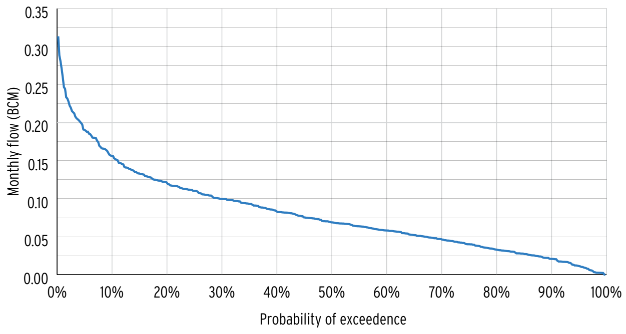
6 Monthly Flow Distribution - Yala



6 Monthly Flow Statistics - Yala

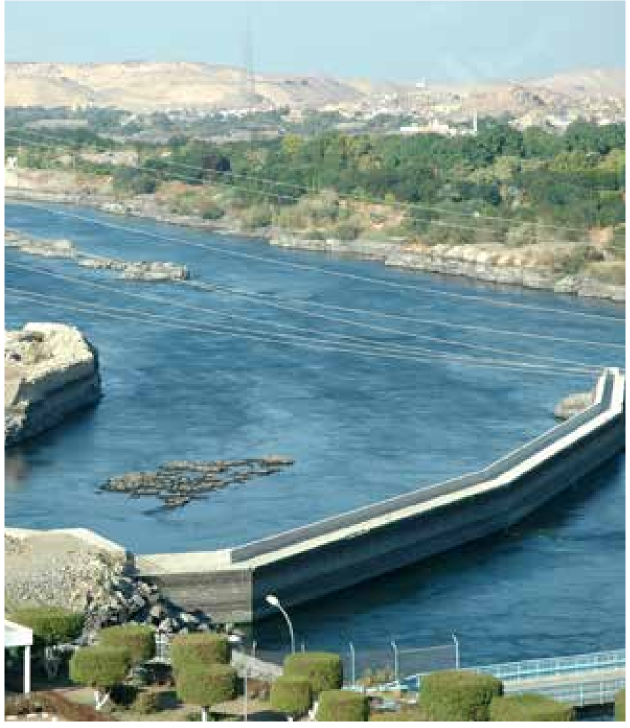


6 Flow Duration Curve - Yala



ANNUAL FLOW PATTERNS

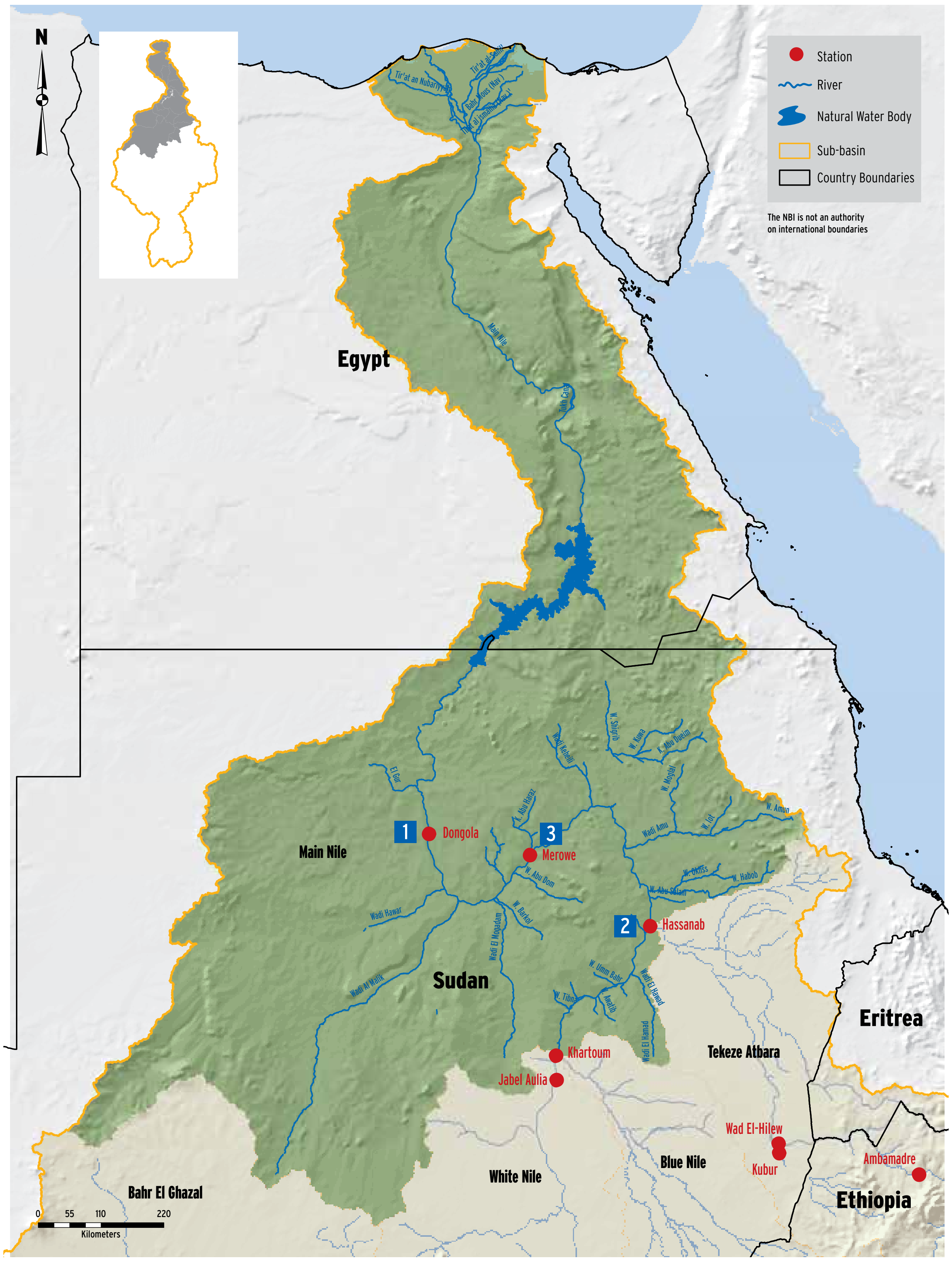
This sub section presents the annual flow patterns together with the long term mean annual flow for selected stations within the Nile. Again this has been presented per Sub-basin and it follows the Sub-basin presentation sequence similar to the previous section.



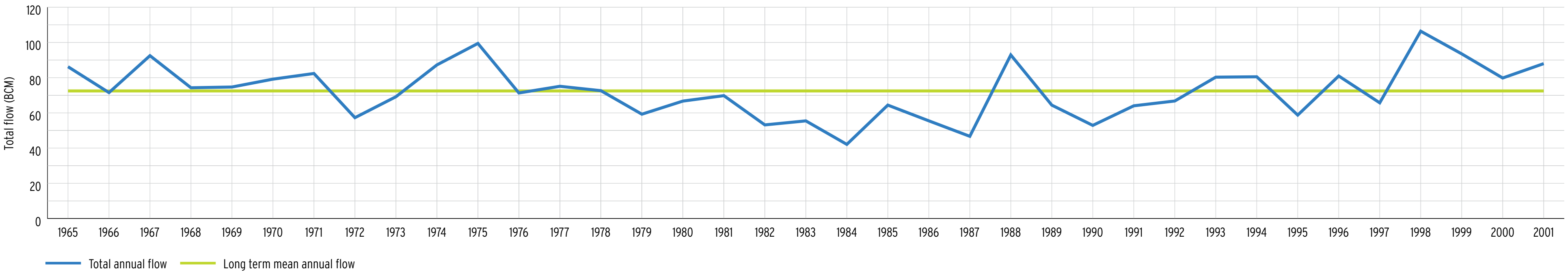
Aswan high dam

The long-term annual flows are shown in the charts. The part of the Main Nile downstream of the High Aswan Dam is fully regulated and, therefore, the flows there are controlled releases for various uses in Egypt. The part of the Nile upstream of the High Aswan Dam is partially regulated by the dams in Sudan. The Nile in this sub-basin is highly altered in its flows due to the abstractions of water for various uses and the flow records no longer represent natural flow conditions. The long-term flow at the Dongola station is about 72 BCM. The average discharge of the Nile into the Mediterranean Sea through its two branches in Egypt is estimated as 10 – 12 BCM per year.

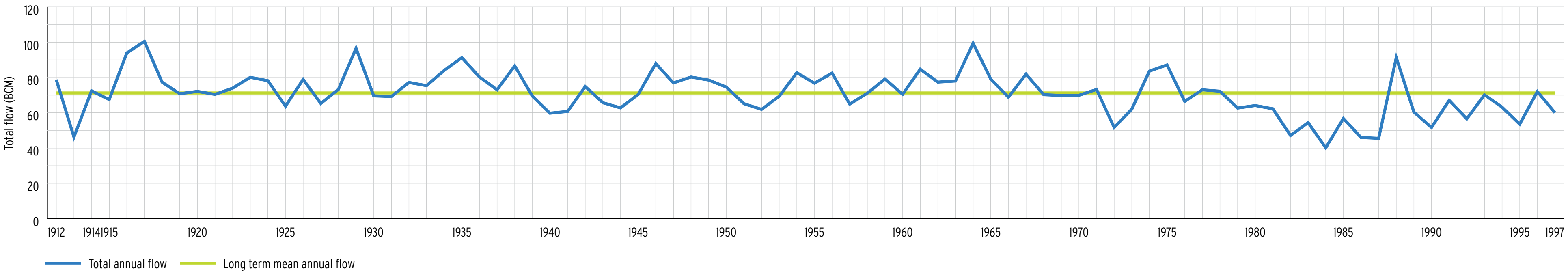
Main Nile Sub-basin



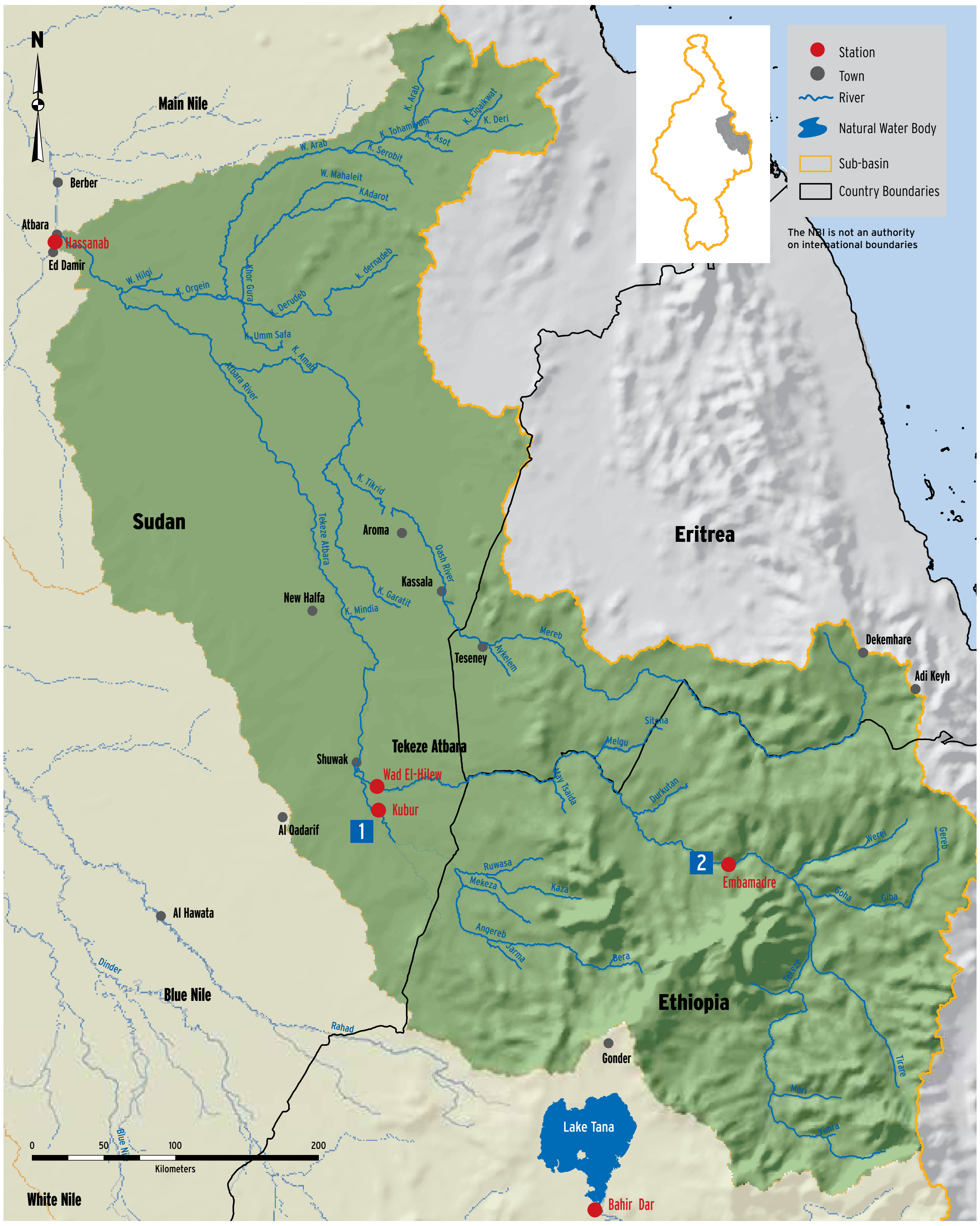
1 Annual flow volume - Dongola



2 Annual flow volume - Hassanab



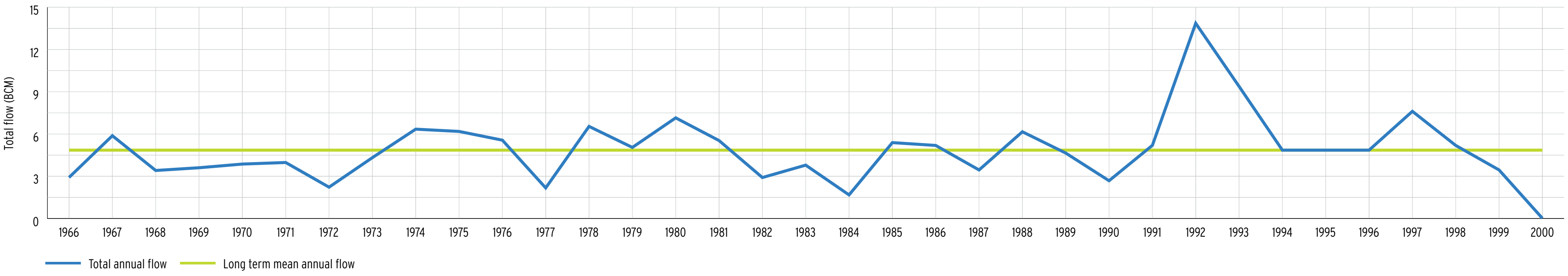
Tekeze Atbara Sub-basin



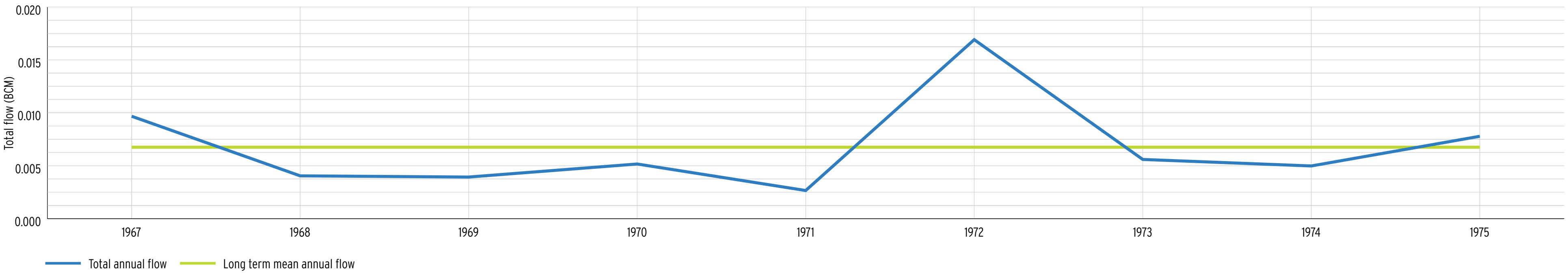
Simien Mountains, Ethiopia

The long-term annual yield of the Atbara catchment is estimated at 11.4 BCM. The inter-annual variability is very high and in its lower reaches, the river flow is very low.

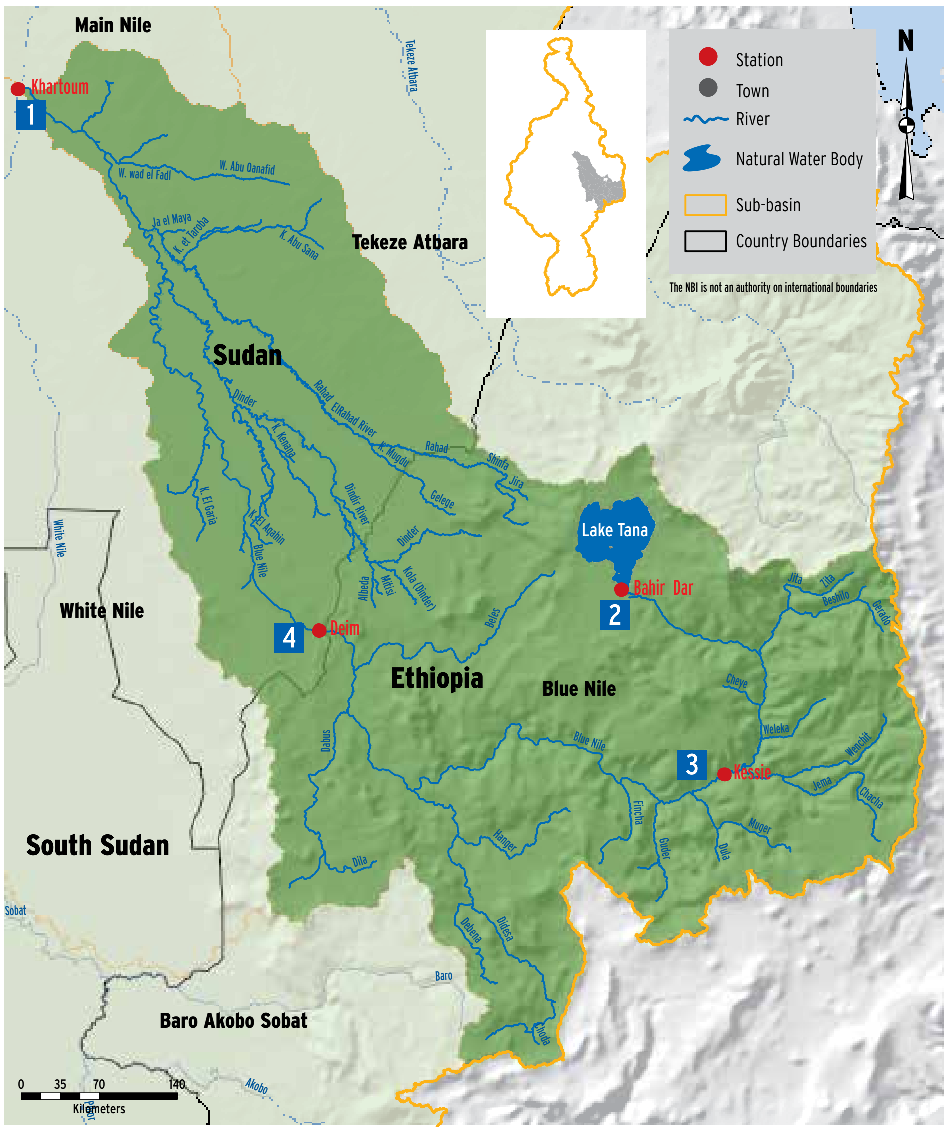
1 Annual flow volume - Kubur

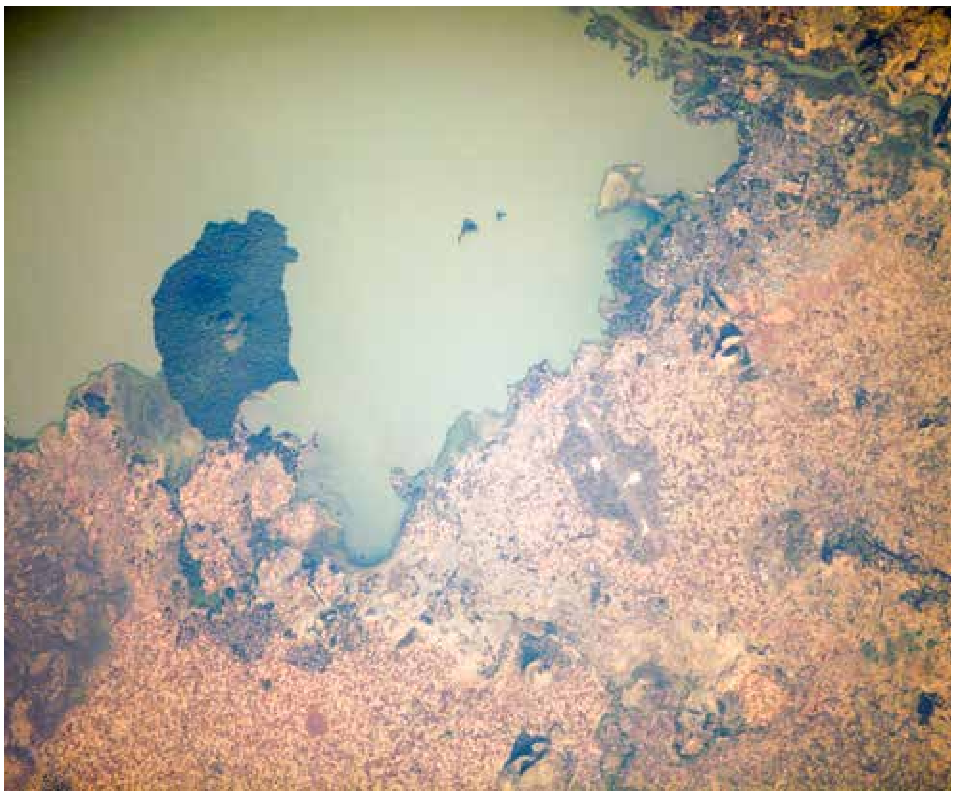


2 Annual flow volume - Embemadre



Blue Nile Sub-basin

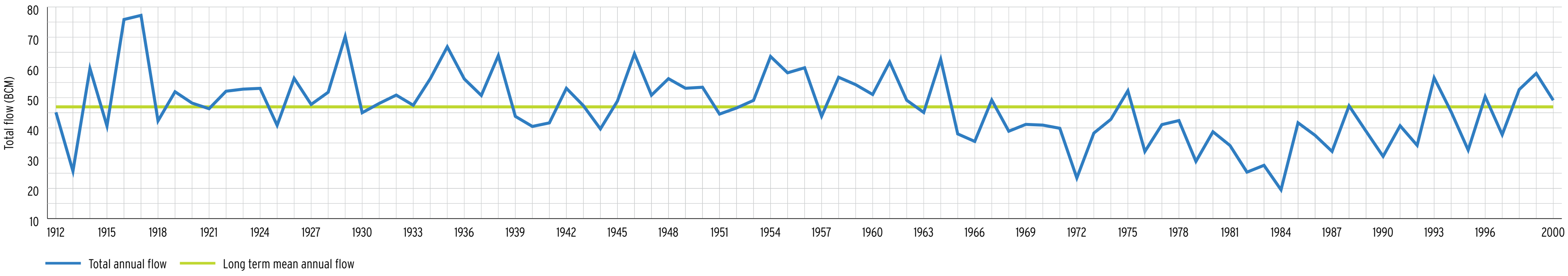




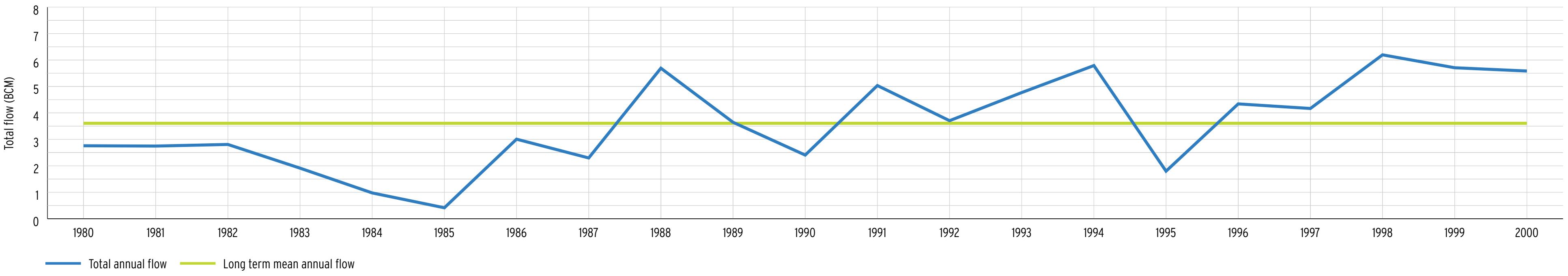
Lake T'ana, Bahir Dar, Ethiopia (NASA, International Space Station, 12/29/07

The long term (1915 – 2014) average annual flow at Diem station is about 50 BCM. However, the annual flows of the Blue Nile show strong inter-annual variability. The 1980's have been particularly dry period. Known years of low flow are: 1978 (annual flow: 26 BCM), 1979 (38 BCM), 1982 (28.8 BCM) and 1984 (29.7 BCM). Years of high flows were: 1961 (63.8 BCM), 1964 (60.9 BCM), 1988 (63 BCM), 1998 (65.9 BCM), and 2014 (63.6 BCM). Due to these high fluctuations in the flow, any meaningful use of the river requires storage dams to regulate the flow and thereby provide reliable water supply.

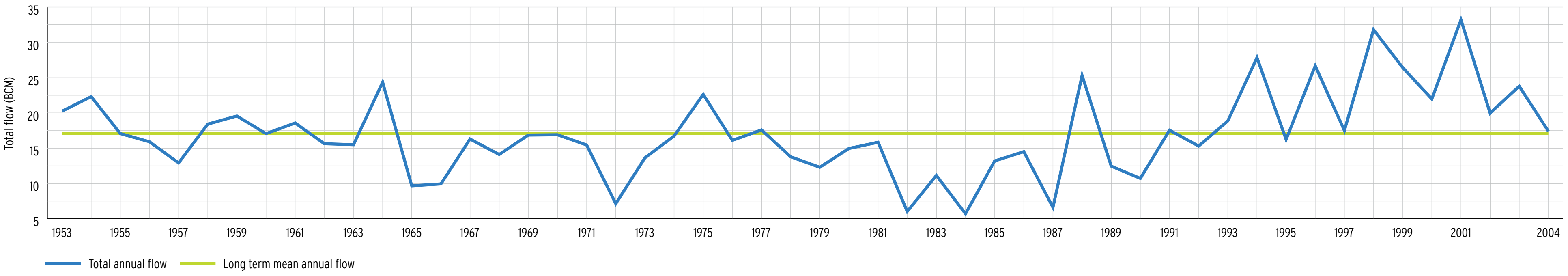
1 Annual flow volume - Khartoum



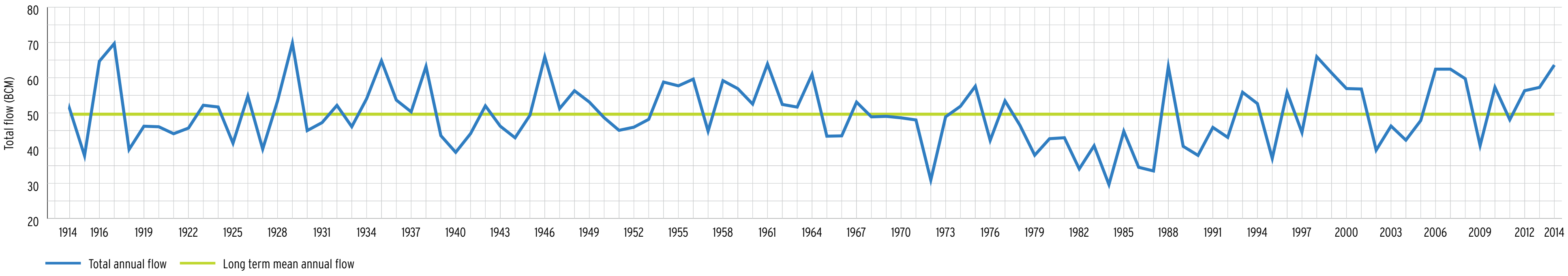
2 Annual flow volume - Bahir Dar



3 Annual flow volume - Kessie



3 Annual flow volume - Diem



White Nile Sub-basin


Photo: David Stanley/flickr.com

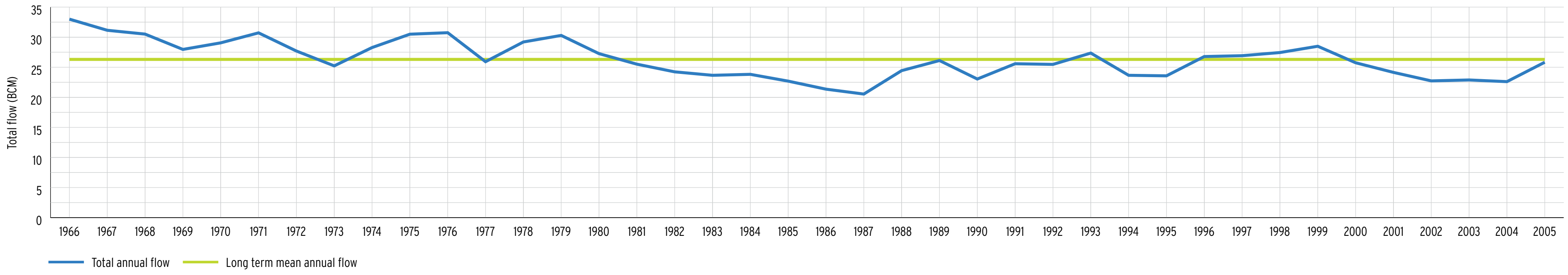
White Nile Bridge Khartoum


Photo: Arne Hoel/The World Bank

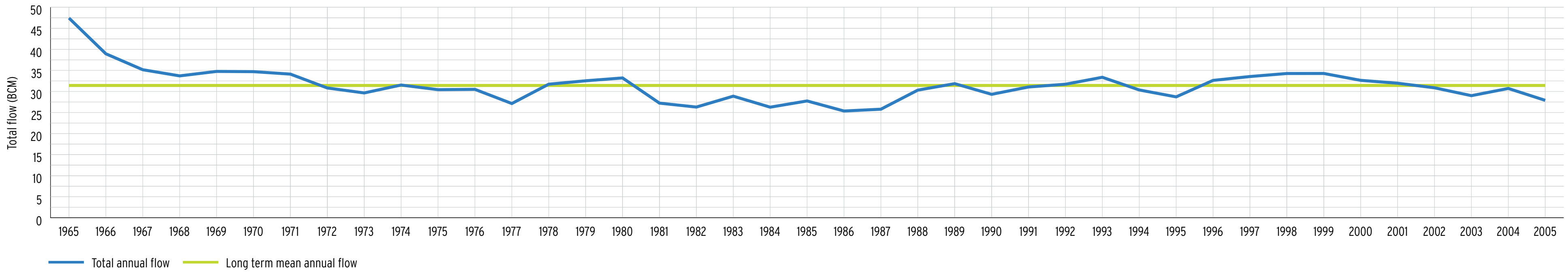
Sudan

The long-term average annual flow of the White Nile measured at Malakal is about 31 BCM. This value is reduced to about 26 BCM at Mogren in Khartoum. Major changes between Malakal and Mogren are the abstractions for irrigation and the evaporation from the Gebel Awlia dam, which is estimated to be approximately 2.25 BCM per year.

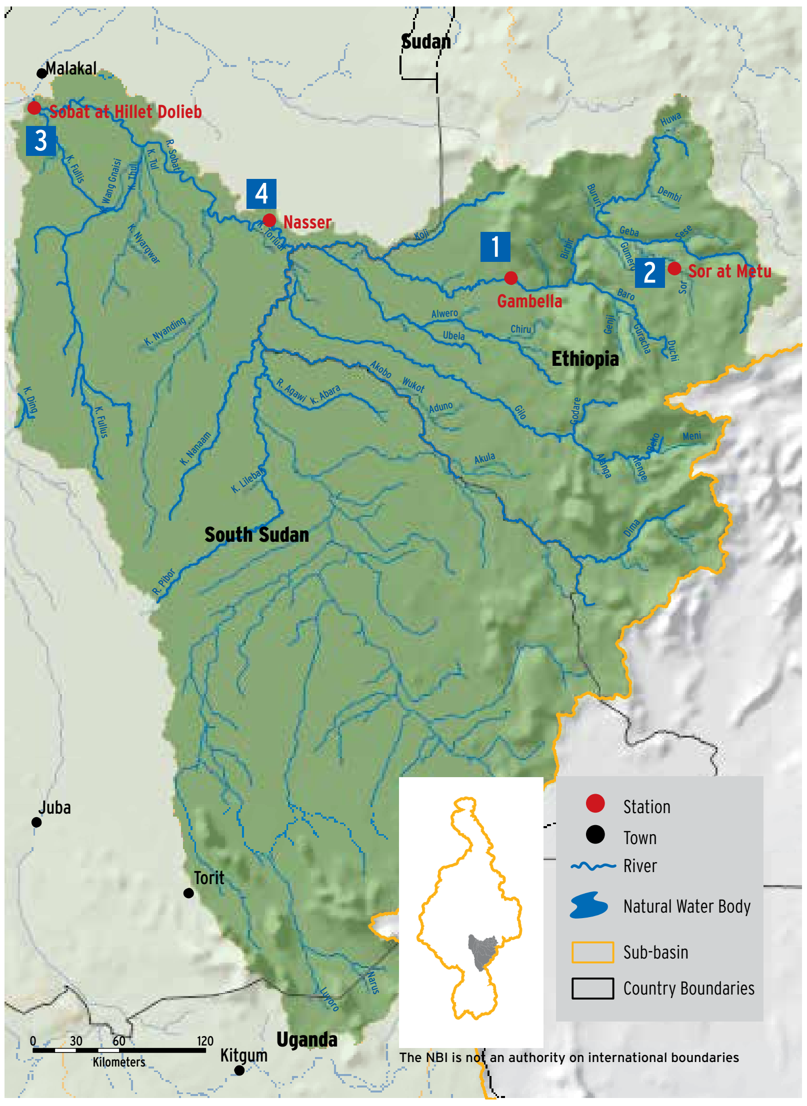
1 Annual flow volume - Jebel Aulia



2 Annual flow volume - Malakal



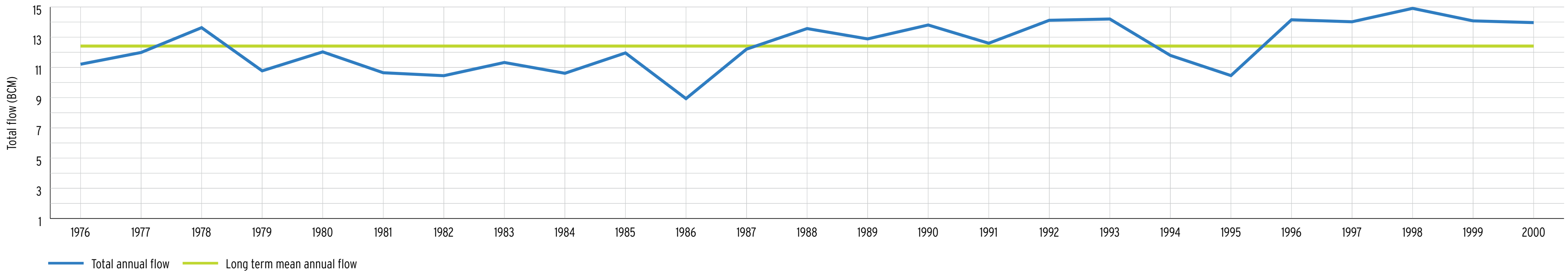
Baro Akobo Sobat Sub-basin



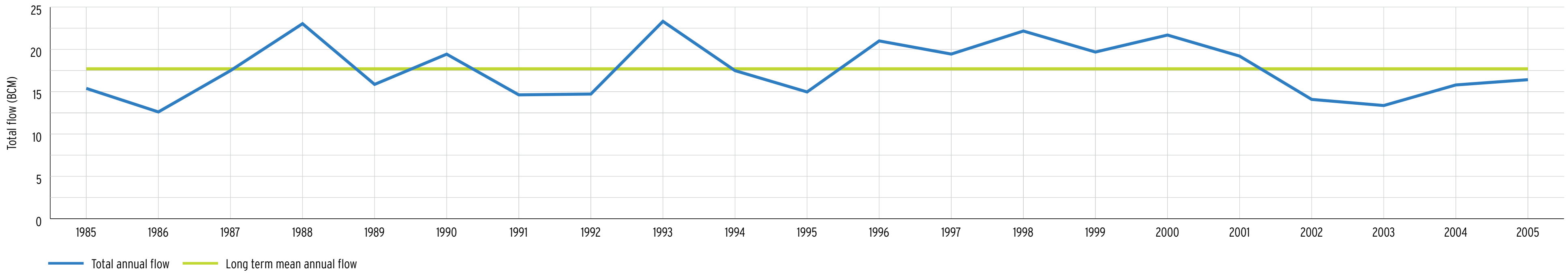
The Sobat River on the edge of Nasir, South Sudan

The long-term average annual flow of the White Nile measured at Malakal is about 31 BCM. This value is reduced to about 26 BCM at Mogren in Khartoum. Major changes between Malakal and Mogren are the abstractions for irrigation and the evaporation from the Gebel Awlia dam, which is estimated to be approximately 2.25 BCM per year.

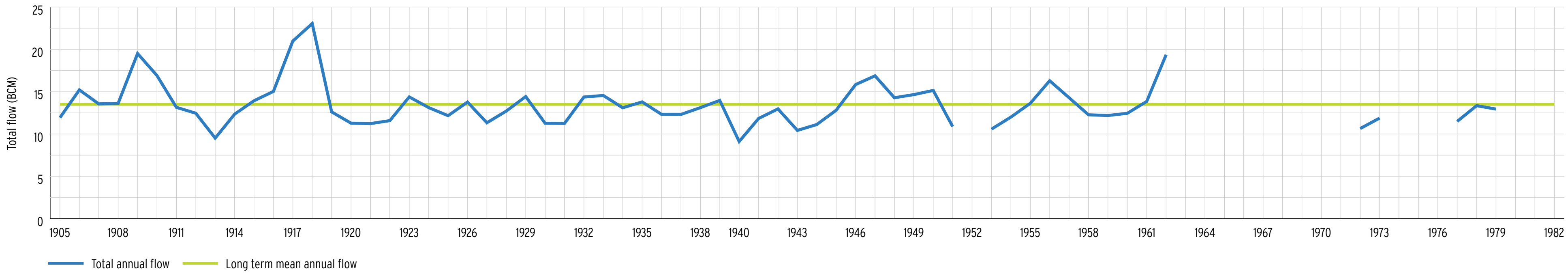
1 Annual flow volume - Gambela



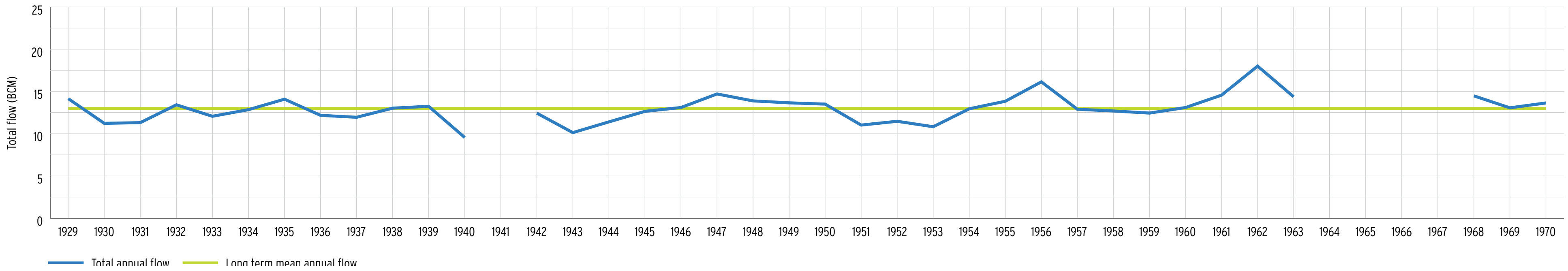
2 Annual flow volume - Sor near Metu



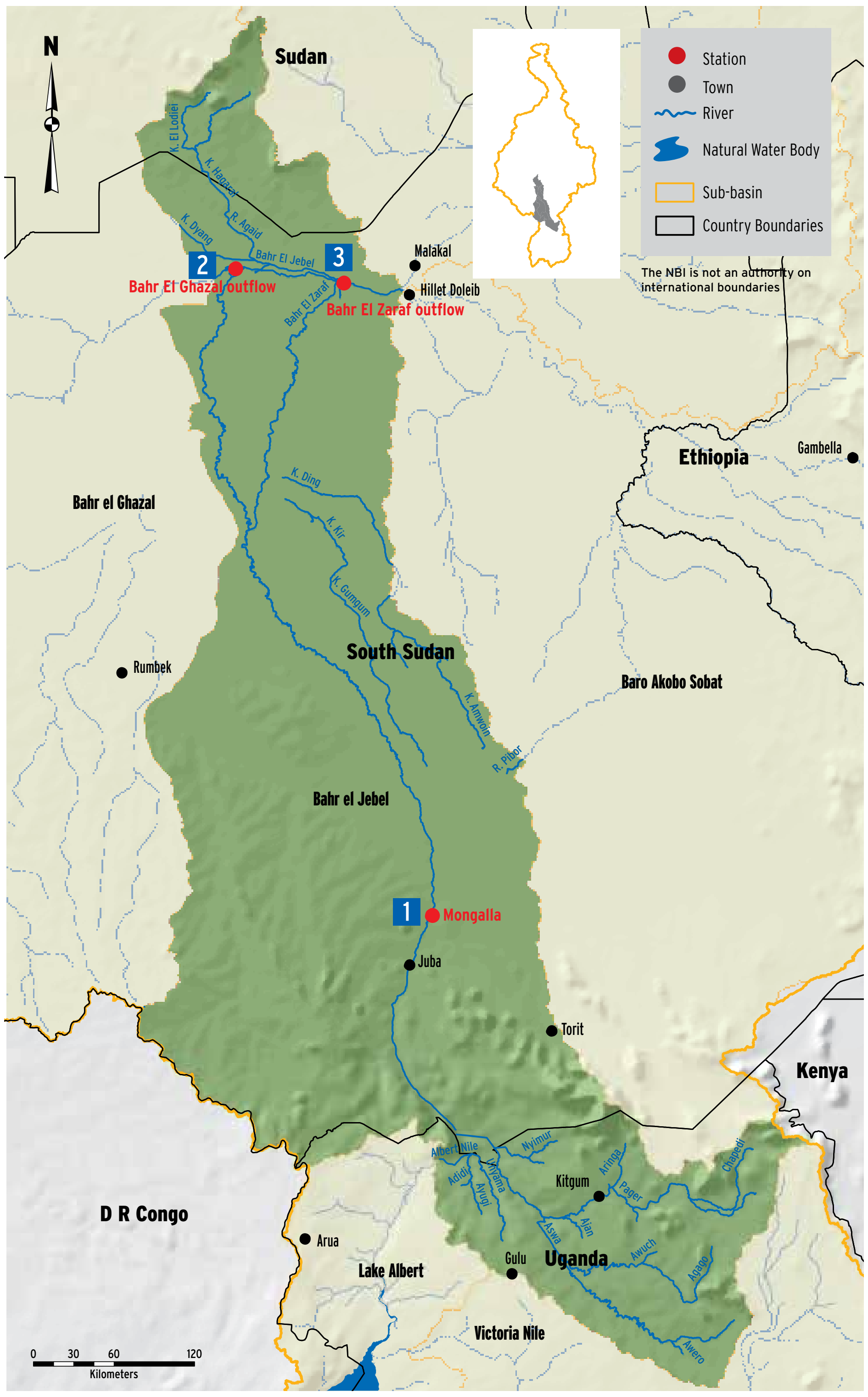
3 Annual flow volume - Sobat at Hillet Dolieb



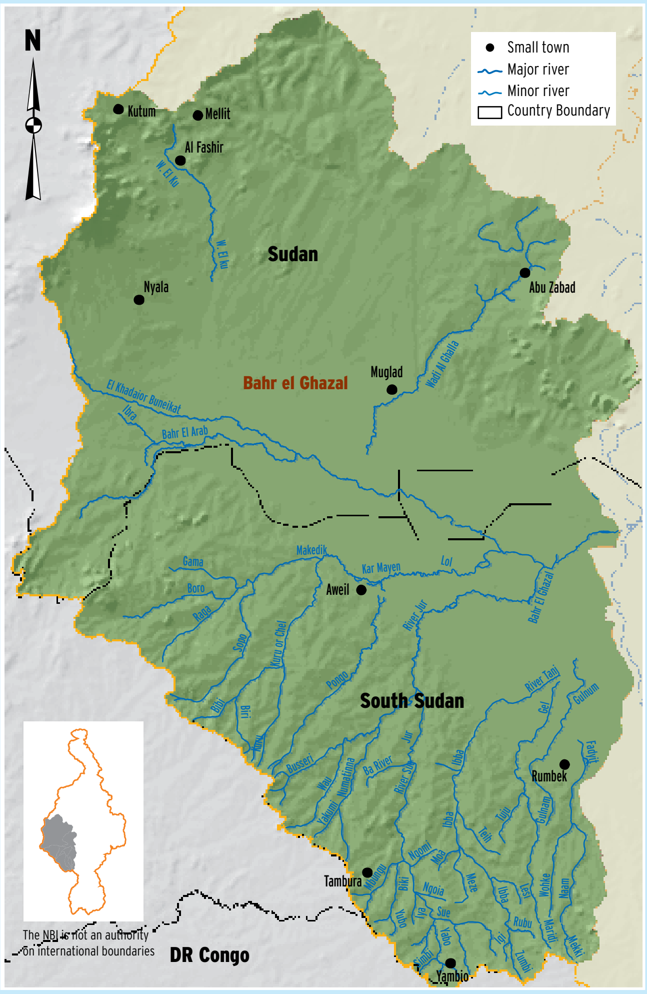
4 Annual flow volume - Nasser



Bahr el Jebel Sub-basin



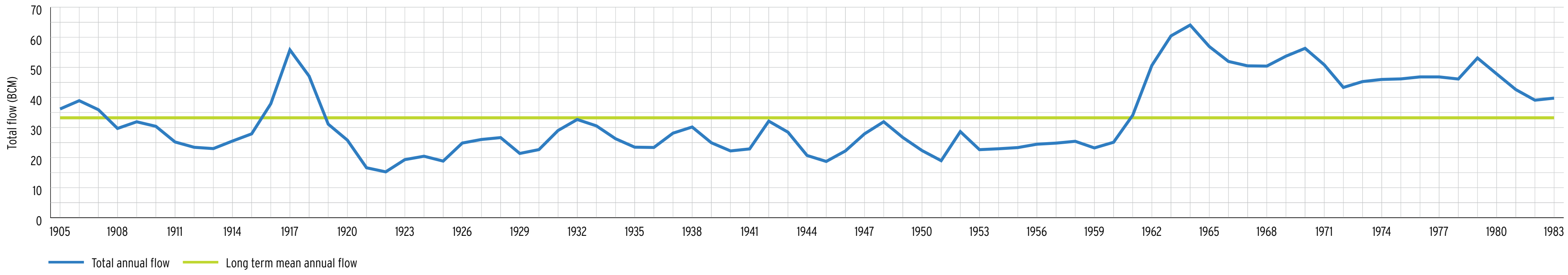
Bahr el Ghazal Sub-basin



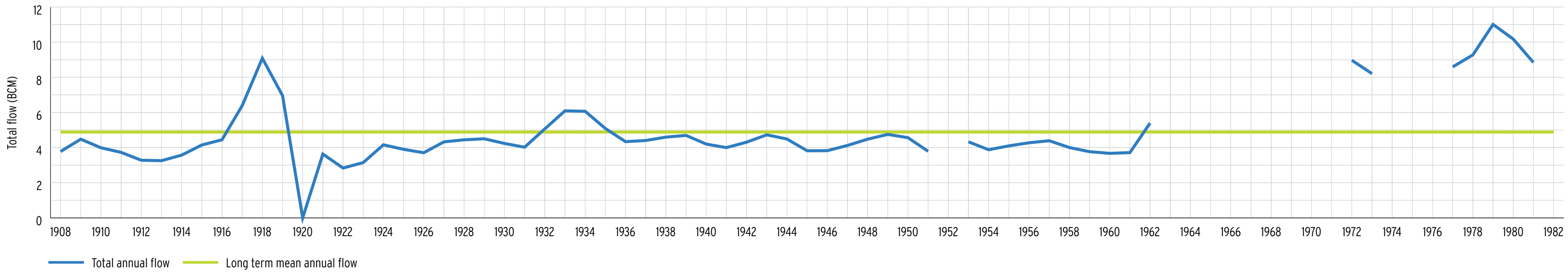
Bahr el Jebel and Bahr el Ghazal sub-basins are one of the least understood major sub-basins of the Nile and yet the existing hydro-met monitoring network is also very limited. The few available stream flow records exhibit substantial breaks and are of very poor quality.

This sub-basin is dominated by a system of wetlands that have substantial effect on river flow. The Sudd wetland, the second largest freshwater wetland in the world, is a major feature of this sub-basin. Nearly half of the river flow that enters the Sudd evaporates (or is transpired through plants). The mean annual flow at Mongala for the period 1905 – 1983 is estimated at 32 BCM. There is no flow measuring station at the outflow of Bahr el Jebel from the Sudd. However, estimates based on the flow of the White Nile at Malakal and the Sobat contribution (measured at Hillet Duleib) shows that the Sudd outflow is about 17 BCM.

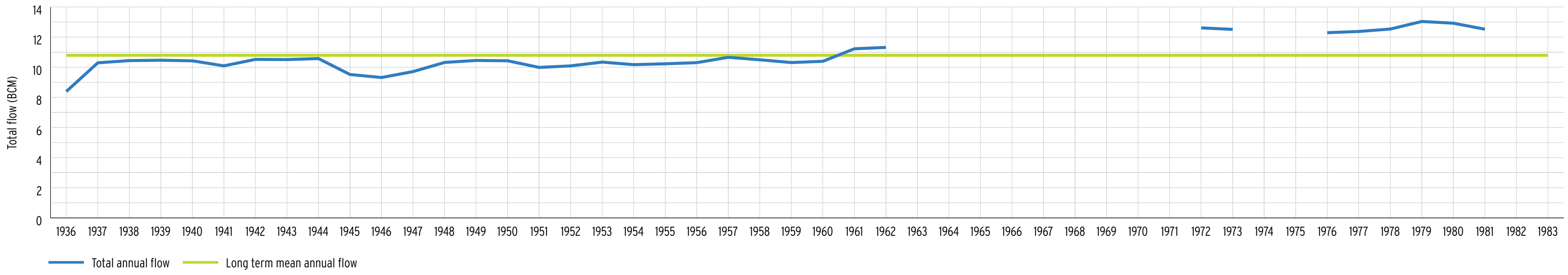
1 Annual flow volume - Mongalla



2 Annual flow volume - Bahr El Ghazal outflow



3 Annual flow volume - Bahr El Zaraf outflow



Lake Albert Sub-basin

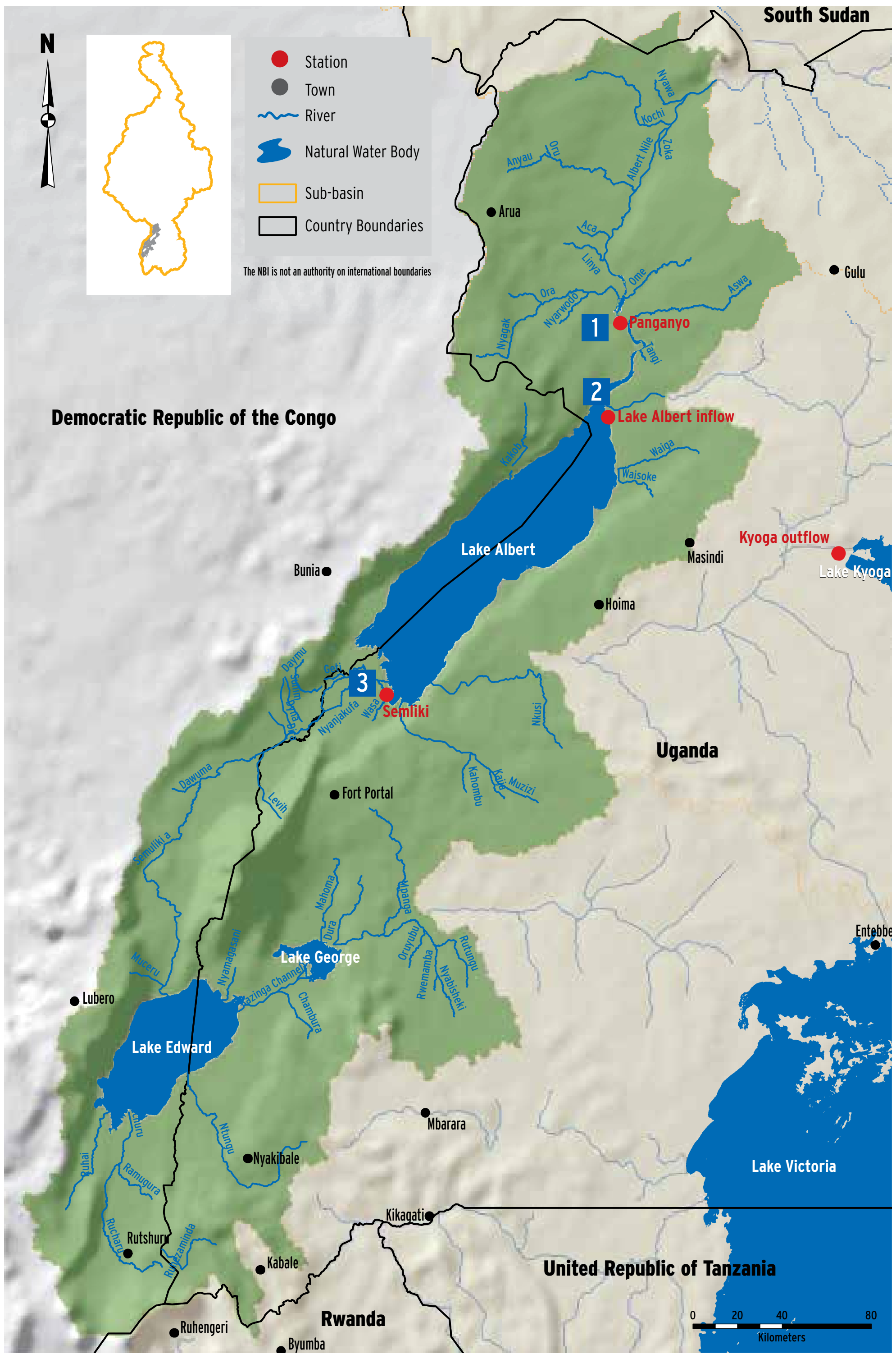



Photo: Vivek Bahukhandi

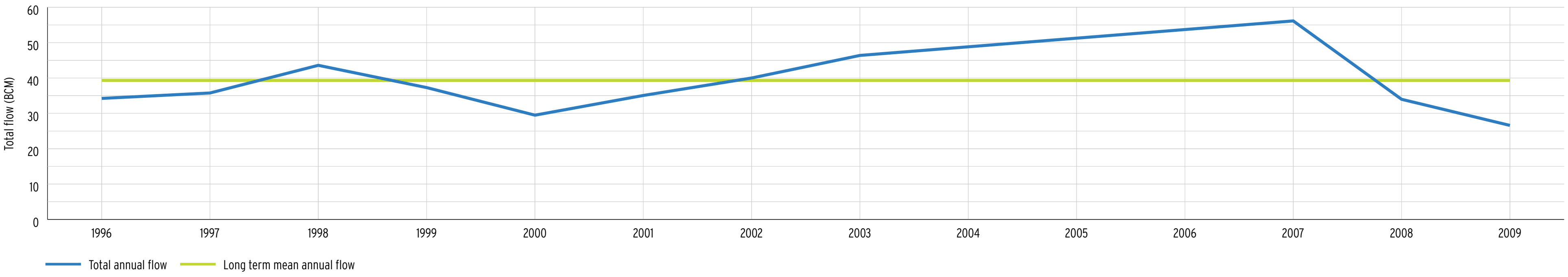
Ishasha River


Photo: Vivek Bahukhandi

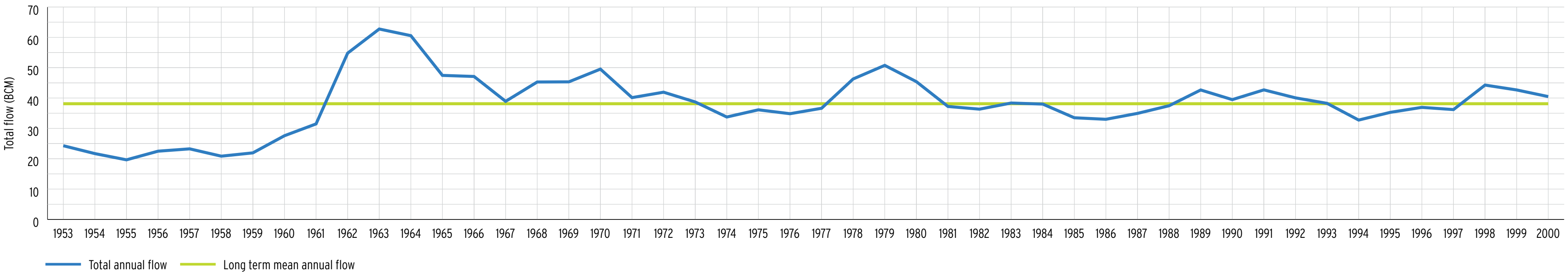
Virunga mountain range

The long term mean annual flow indicates an increment of about 2 BCM between the inflow and outflow of Lake Albert, which is mainly from the Lake Albert Sub-basin.

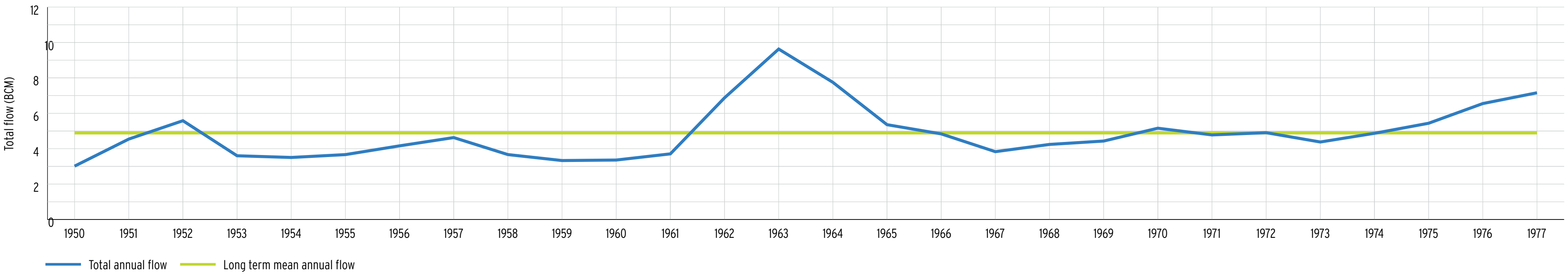
1 Annual flow volume - Panyango



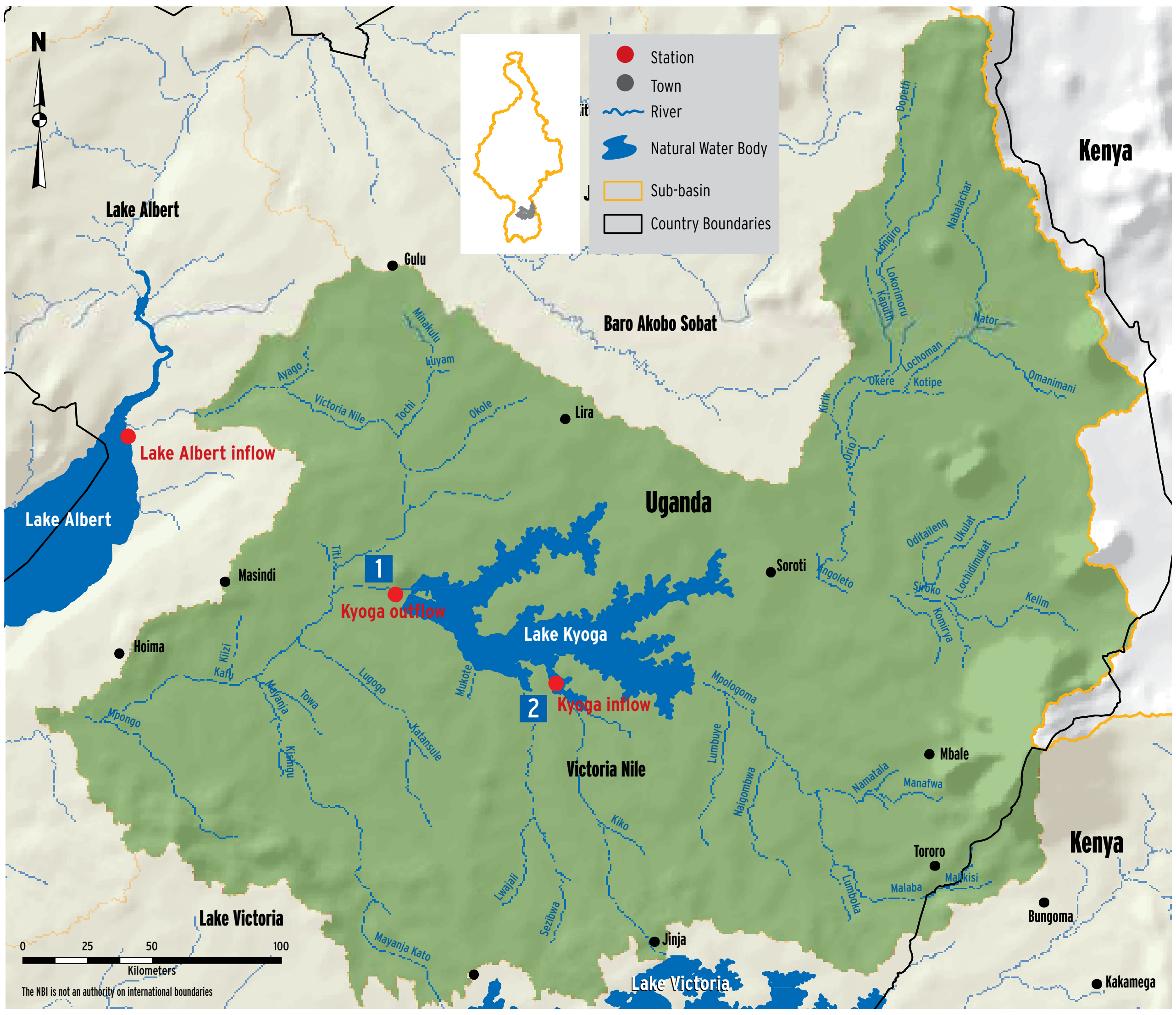
2 Annual flow volume - Albert inlet from Victoria Nile



2 Annual flow volume - Semliki



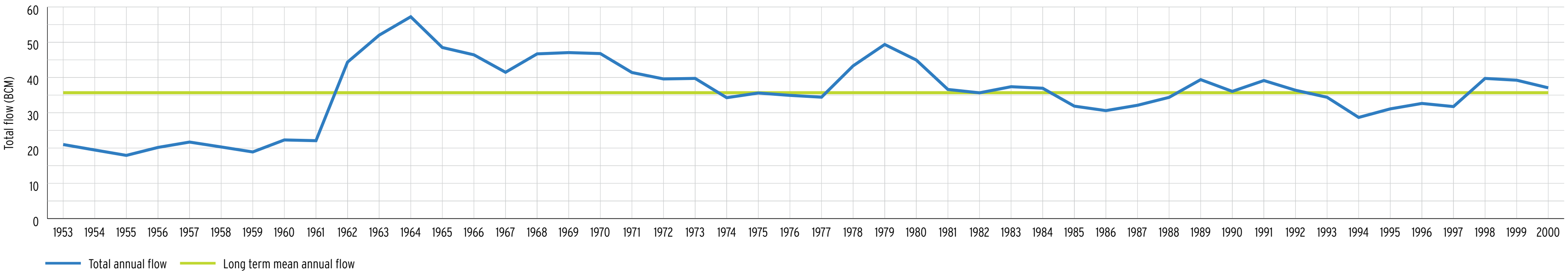
Victoria Nile Sub-basin



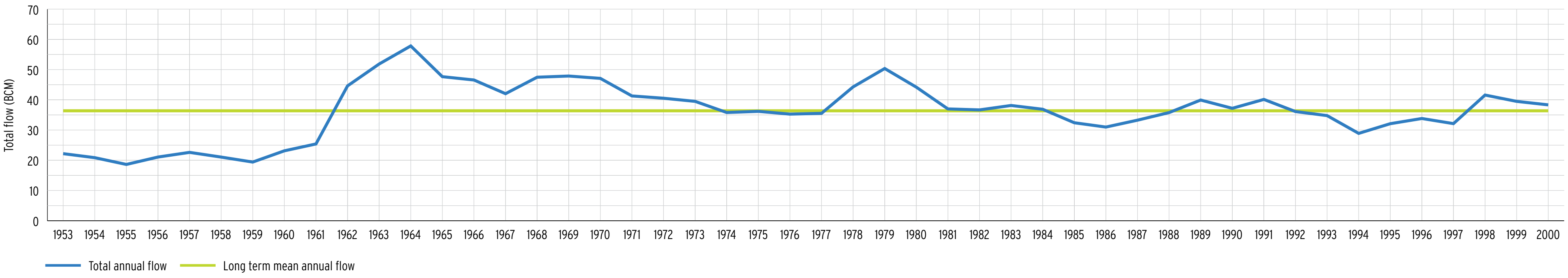
Sipi falls, Mount Elgon

The annual flow pattern of the inflow into Lake Kyoga from the Victoria Nile and the outflow from the lake is similar with a small increment of about 0.68 BCM which could be flow from the other contributing upstream catchments of Lake Kyoga other than from the Victoria Nile

1 Annual flow volume - Kyoga outflow flow volume

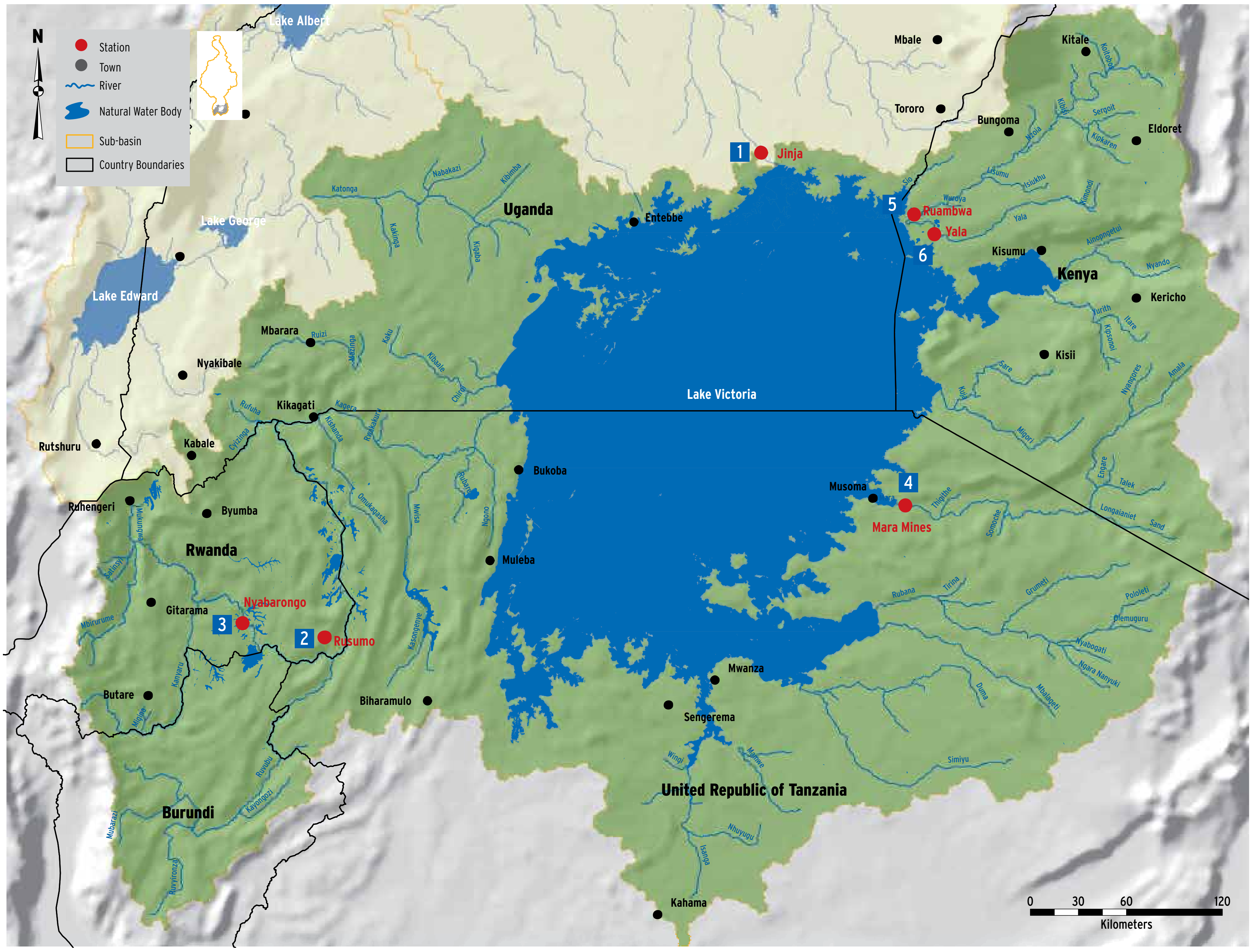


2 Annual flow volume - Kyoga inflow flow volume



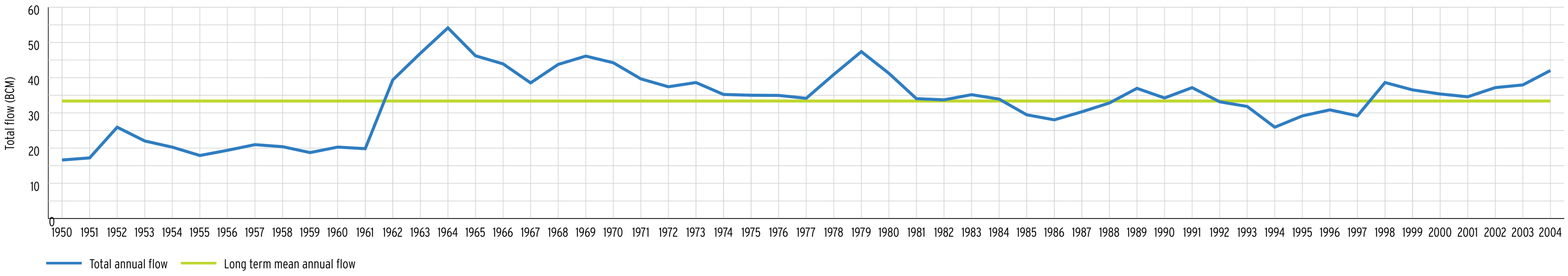
Norera Damsite on Mara river in Kenya

Lake Victoria Sub-basin

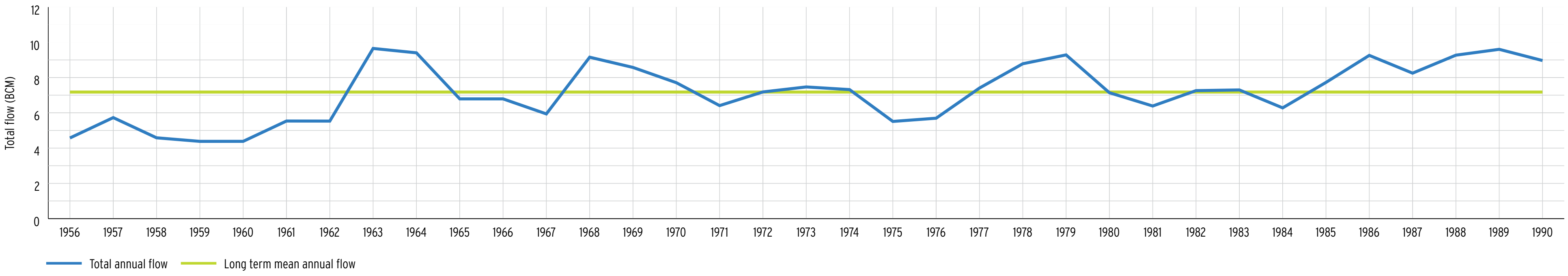


The Lake Victoria has many tributaries from the countries of Rwanda, Tanzania, Kenya, and Uganda with River Kagera as the main tributary. The lake which covers about a third of the basin area greatly influences the outflow due to storage and regulation with the average annual outflow of 33BCM. There is not much variation of the flow from the mean since there is high regulation of the lake. Rainfall and Evaporation over the lake plays an important role in the water balance of the lake and also has an impact on the outflow from the lake.

1 Annual flow volume - Jinja



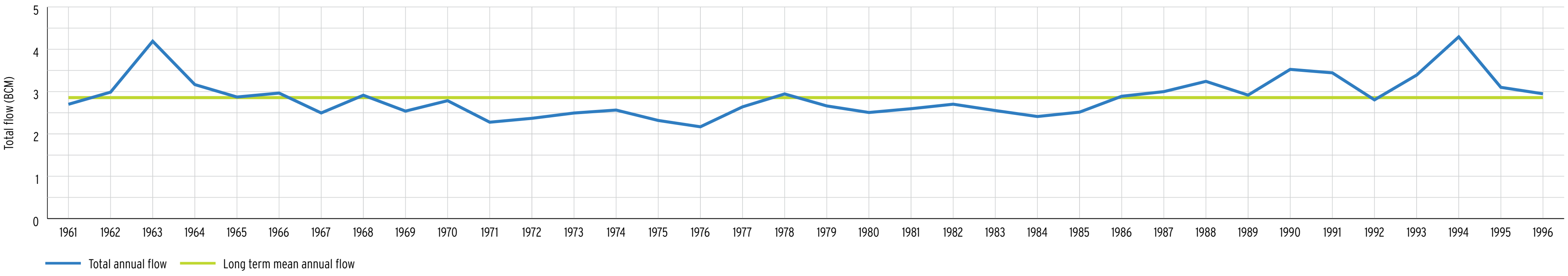
2 Annual flow volume - Rusumo



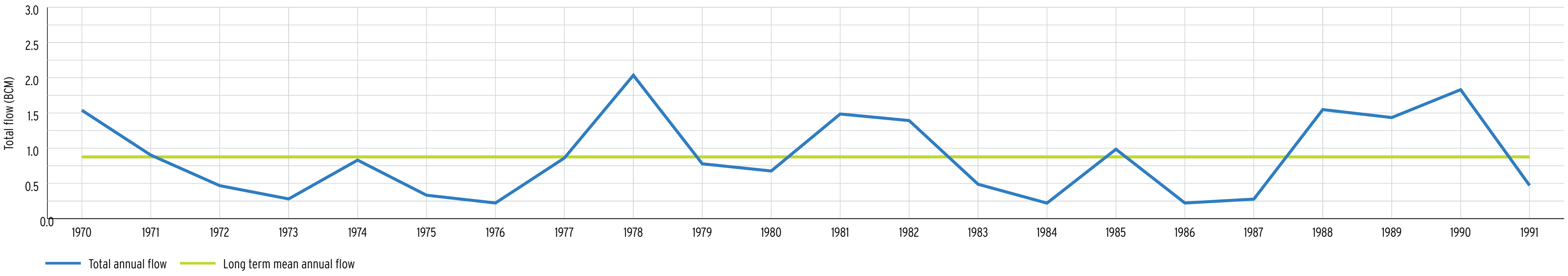
Jinja, Uganda

Photo: Vivek Bahukhandi

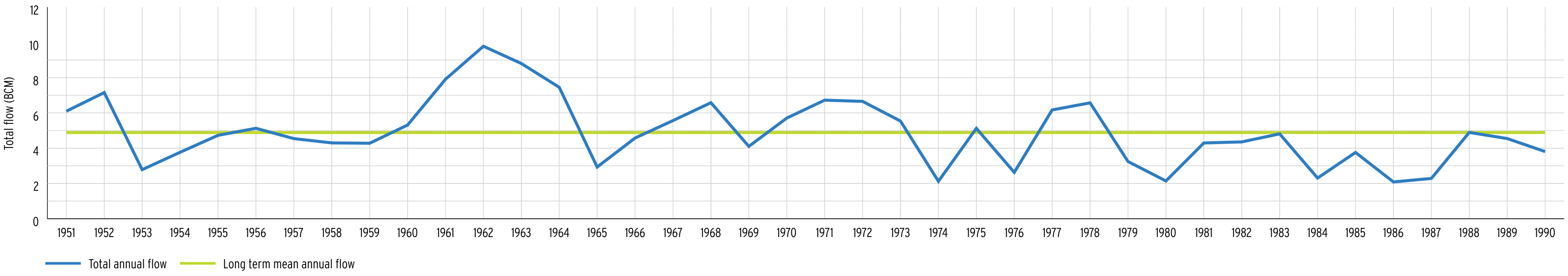
3 Annual flow volume - Nyabarongo



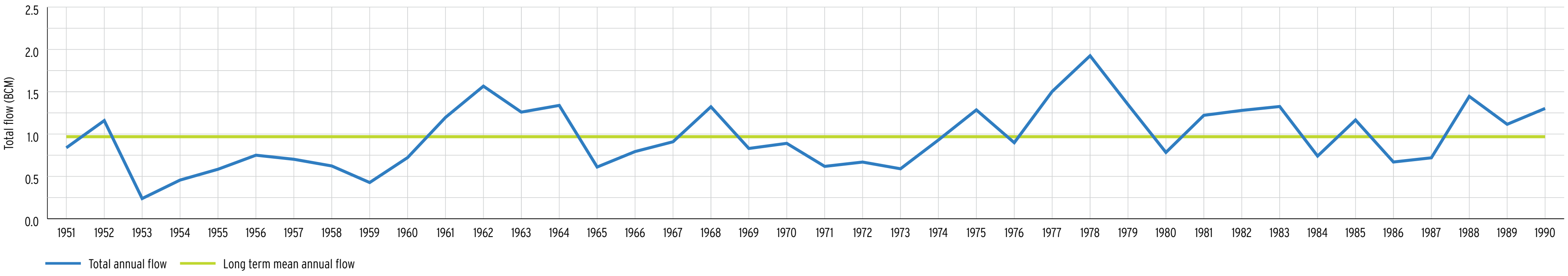
4 Annual flow volume - Mara Mines



5 Annual flow volume - Rwambwa



6 Annual flow volume - Yala



NILE LAKES AND WATER FLOW REGULATION

Storage and retention of water in the various lakes and wetlands in the Nile basin are of particular importance as they regulate and dampen the flows which results in an important role for local rainfalls as well as evaporation resulting in large water losses. The River Nile basin has numerous lakes, and water bodies, including some of the biggest freshwater lakes and man-made reservoirs in the world. Although the total area of open water in the Nile basin is vast, about 90 000 km², it represents less than 3% of the basin's total area (NIS 2013). The major lakes of the basin are found in the equatorial region, apart from Lake Tana which is to be found in the Ethiopian highlands. A summary of the Key characteristics of the Lakes is shown in the table.

Photo: Vivek Bahukhandi

Lake Victoria at Jinja, Uganda

Key facts about the major lakes in the Nile basin

Lake	Surface Area (km^2)	Volume (km^3)	Maximum depth (m)	Mean Depth (m)	Shoreline length (m)	catchment Area (km^2)	Altitude (m)	Country location
Tana	3600	28	14	9	385	10000	1788	Ethiopia
Edward	2200	39.2	112	17		12000	912	Uganda, DRC
Albert	5300			58		17000	615	Uganda, DRC
George	250	0.8	4.5	2.4		9705	914	Uganda
Kyoga	1720		5.7			75000		Uganda
Victoria	68800	2750	84	40	3440	184000	1134	Uganda, Kenya, Tanzania

Lake Victoria

Lake Victoria, the largest lake in the Nile basin, is shared by Kenya, Uganda and the Tanzania; although Burundi and Rwanda are also part of its catchment area which covers 184 000 km² (ILEC 1999). Annual average rainfall on the lake is 1 500 mm, which represents about 85 per cent of the water entering the lake; the balance comes from the rivers that drain the catchment. The annual evaporation rate from the lake surface is about 1 260 mm (Fahmy 2006). The main outlet for Lake Victoria is the White Nile at Jinja linking to Lake Kyoga.

Lake Albert

Lake Albert lies along the shared border of Uganda and the DRC. It is about 160 km long and 30 km wide, with a maximum depth of 58 m and a surface elevation of 615 masl (ILEC 1999). Evaporation over the lake is estimated at 1 200 mm per annum and rainfall is 710 mm (Fahmy 2006).

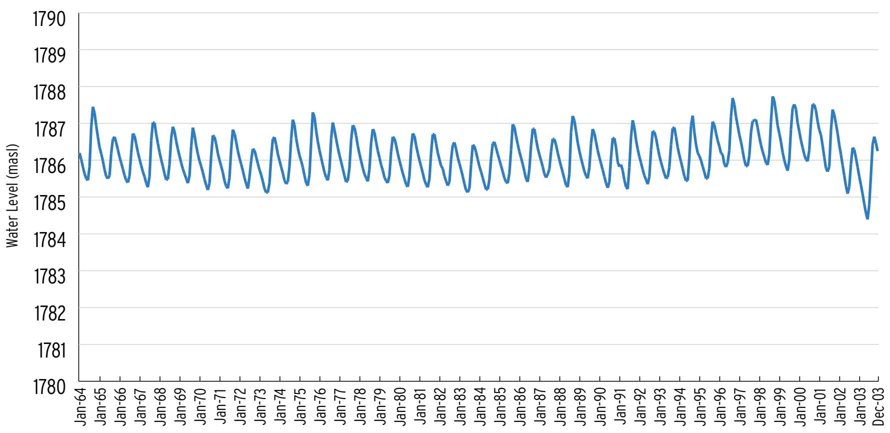
Lake George and Lake Edward

Lake George has a surface area of 250 km² and a catchment area of 9 705 km². Lake Edward has a surface area of 2 325 km² and its catchment's basin area is 12 906 km² (ILEC 1999). Lake George empties into Lake Edward via the Kazinga Channel. Queen Elizabeth National Park in Uganda extends from the eastern shores of Lake George and together with the adjacent Virunga National Park in the DRC completely surrounds Lake Edward. River Semliki receives flows from these two lakes and with runoff from its own catchment sends about 4 BCM of water to Lake Albert every year (Fahmy 2006).

Lake Tana

Lake Tana, found in the Amhara region in the north-western Ethiopian highlands, is the largest freshwater lake in Ethiopia. It is sited in a wide depression and has a surface area ranging between 3 000 and 3 600 km² depending on the season. It is about 84 km in length and 66 km wide, with a maximum depth of 14 m and an elevation of 1 788 m (Wale 2008, ILEC 1999). Lake Tana is fed by four main rivers: the Gilgel Abay, Ribb, Gumara and Magech; and discharges at Bahir Dar through the Blue Nile. The four inflowing rivers contribute 93 per cent of the lake's inflow (Anbah and Siccardi 1991). The average flow from Lake Tana was estimated at 3.8 BCM/year swelling to 54 BCM by the time it reaches Khartoum as a result of contributions from the Rivers Dinder and Rahed (Fahmy 2006).

Lake Tana WS Elevation



Inter-annual flow variability

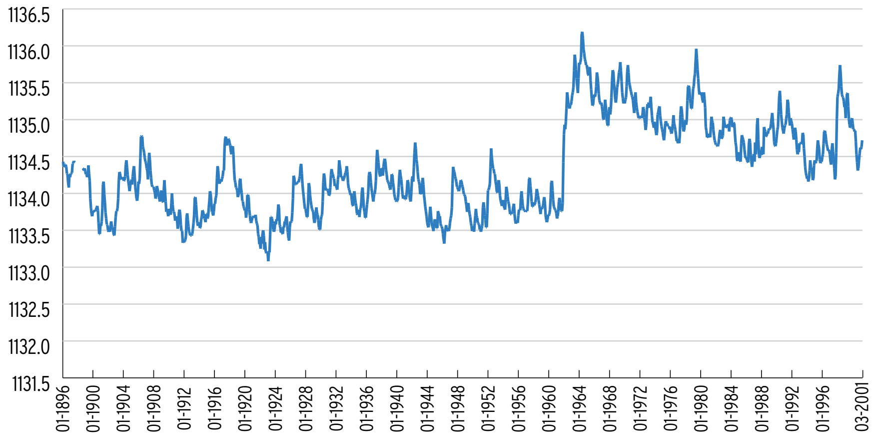
Over the last decades, the Nile Equatorial Lakes water system has experienced important inter-annual variability with sudden changes (rise or drop of water levels and flows) which would persist for some years because of storage. Regulation of Lake Victoria's outflow at Jinja, Uganda, has a clear effect on the lake's water levels (Sutcliffe and Petersen 2007) and less direct impacts on many of the lake's other ecosystem functions. These effects are also experienced by Tanzania and Kenya, who share the lake with Uganda, and to a lesser extent by all of the downstream countries in the basin.

Regulation of Lake Victoria

The quantity of water released from Lake Victoria through the Nalubale/Kiira power plants is constrained by an international

Observed water levels and discharge from the Lake Victoria from 1895 to 1998

Lake Victoria Elevation=Jinja+1122.86



Lake Victoria outflow (MCM)

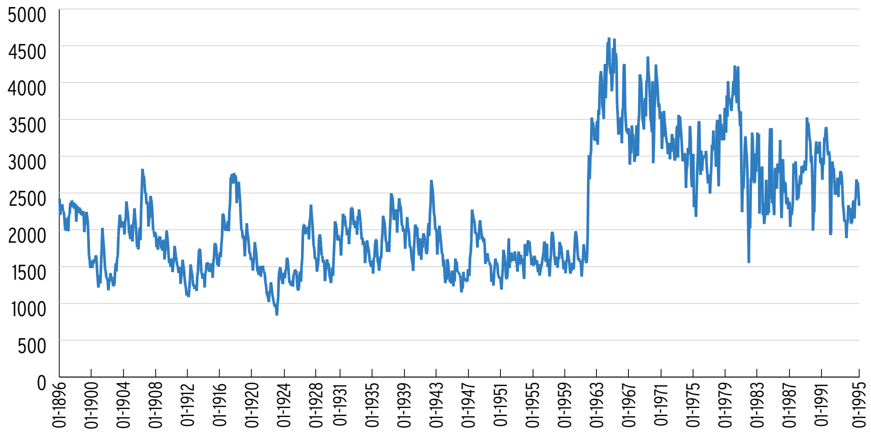


Photo: Vivek Bahukhandi

Swamps at Queen Elisabeth National park in Uganda

treaty which stipulates that the outflow should simulate the natural flow of the Victoria Nile, based on a ten-day average flow, as a function of lake level. This so-called 'agreed curve' safeguards the environmental integrity of the lake and guarantees water supplies to downstream users. However, a more flexible interpretation of the agreed curve - e.g. annual releases that follow the annual agreed curve release volumes - might make it possible to increase power production without serious impacts on the lake or the river downstream

The Agreed Curve allows for a release of 693 m^3/s at a gauge level of 1,134 m while the discharge would increase to 2,400 m^3/s at a gauge level of 1,137 m. The installed generation capacity of the two plants at Jinja (387 MW) cannot be achieved until a level of 1,137 m is reached. Levels above 1,137 m should be avoided since this could damage the dam and power plants, while technical considerations related to cavitation restrict operations at the Kiira facility when the lake level falls below 1,134 m. The effective range of lake level fluctuation for power production is therefore around 3 m. Because greater volumes can be released and more power generated when lake levels are high it is important to keep the lake level as high as possible and avoid a drawdown to low levels .

Recent investigations have found dramatic and sometimes rapid changes in the lake's level over the past two centuries (Sutcliffe and Peterson 2007, Nicholson and Yin 2000). The level of Lake Victoria remained fairly stable around 1,134 m up to 1960 but it rose rapidly thereafter to reach 1,136 m in the mid-1960s. Since then the level of the lake gradually declined, but heavy rains during the 1997 El Niño raised the level by more than 1 m, followed by a sudden drop around 2004. The lake level rise in the early 1960s was a result of abnormally heavy rains; in the last six months of 1961, 2323 mm of rain were recorded, nearly 100% higher than its average value. Very high rainfall was recorded during the first six months of 1962 (1884 mm/year, about 50-60% above average), and 1963 (1739 mm), and 1964 (1739 mm). As a result the lake rose by 2.5 m during those years.

The fall in lake level in the first decade of the 21 century was the result of poor rains and excessive releases of water at Owen Falls. After this sudden rise that changed the base flow downstream of the lake for years, the flows decreased steadily with gradually falling lake levels until in 2005, caused probably by over-release from the Nalubaale/Kiira dam hydropower stations, the lake levels dropped considerably leading to a now decreased flow after the increased flows that resulted from the increased hydropower operation. During these hydrological changes Lake Victoria as well as the consecutive lakes and swamps have functioned as a buffer so that the strong changes in upstream hydrological regime have less impact downstream.

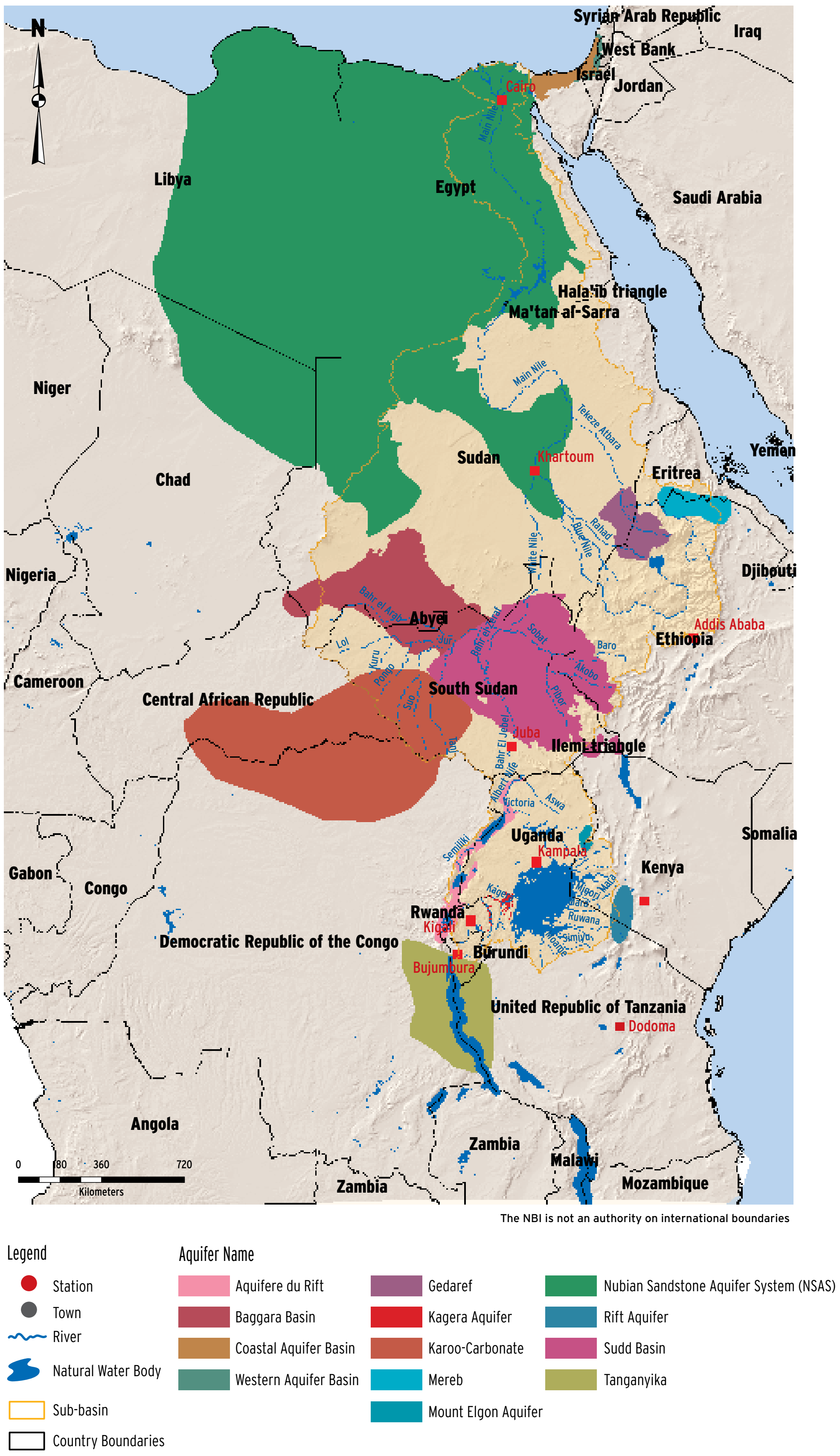
The basic determinants of Lake Victoria's water regime, direct rainfall on the lake and evaporation, are difficult to measure and not yet fully understood. The average difference between rainfall and evaporation over its 69,000 km^2 surface area is quite narrow, and its hydrological regime is therefore very sensitive to changes in climate. This is demonstrated by the considerable fluctuation in net basin supply. The water balance of the lake is also affected by inflow from the basin and irrigation developments could reduce this inflow and contribute to falling lake levels.

Assumptions about future water levels are necessary in planning Nile dams and their current and future operation. The future viability of hydropower from the Victoria Nile is generally as uncertain and variable as the climate. The lake's water level may also affect other ecosystem services, such as fisheries, wetlands, invasive species, water quality (Kiwango and Wolanski 2008) and malarial mosquito habitat (Minakawa and others 2008).

GROUNDWATER IN THE NILE BASIN

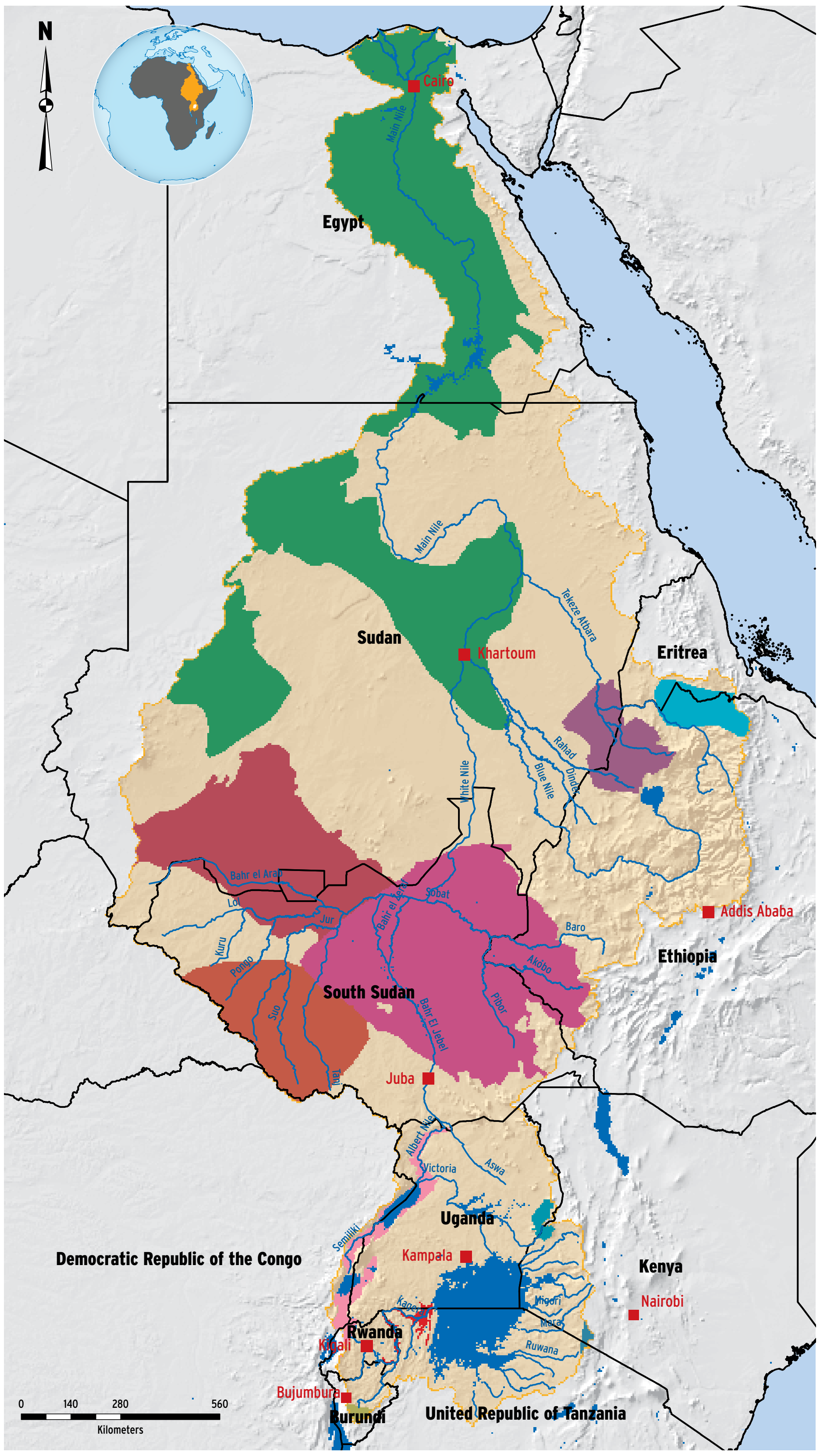
Basin ground water has not been adequately studied and so, information in this area is still scanty. An inventory of trans-boundary aquifers was obtained from International Groundwater Resources Assessment Centre (IGRAC), an organization which facilitates and promotes international sharing of information and knowledge required for sustainable groundwater resources development and management worldwide. The layer provided by IGRAC, identifies twelve (12) trans-boundary aquifers within the Nile basin, the largest being the Nubian Sandstone Aquifer System covering an area of about 567,344 Km² in the Nile basin.

Extents of transboundary aquifers shared in the Nile Basin



The NBI is not an authority on international boundaries

Transboundary aquifers in the Nile Basin



The NBI is not an authority on international boundaries

FID	Aquifer Name	Countries	Total Aquifer Area (Km²)	Aquifer Area in the Nile Basin (Km²)	% area within Nile Basin
1	Mount Elgon Aquifer	Uganda, Kenya	5,398.32	4,579.49	85%
2	Gedaref	Ethiopia, Sudan	57,830.51	51,369.10	89%
3	Mereb	Ethiopia, Eritrea	38,752.68	27,210.24	70%
4	Rift Aquifer	Kenya, Tanzania	21,145.08	1,780.24	8%
5	Kagera Aquifer	Tanzania, Rwanda, Uganda	5,778.95	5,218.10	90%
6	Baggara Basin	Central African Republic, South Sudan, Sudan	239,876.71	196,127.11	82%
7	Coastal Aquifer Basin	Egypt, Israel, Palestinian Territory	23,338.14	11.72521552	0%
8	Karoo-Carbonate	Central African Republic, Congo, South Sudan	604,596.15	120,947.00	20%
9	Tanganyika	Burundi, Democratic Republic of the Congo, Tanzania	184,594.89	2,279.49	1%
10	Nubian Sandstone Aquifer System (NSAS)	Chad, Egypt, Libya, Sudan	2,892,867.48	567,344.75	20%
11	Aquifere du Rift	Democratic Republic of the Congo, South Sudan, Uganda	44,632.12	30,023.07	67%
12	Sudd Basin	Ethiopia, Kenya, South Sudan	370,647.62	324,287.18	87%

Agricultural runoff, industrial waste and untreated municipal and domestic waste have led to seriously degraded water quality in Lake Victoria over the past few decades (Scheren and others 2000, USAID 2009). While industrial waste is generally confined to urban areas (Kampala, Mwanza, and Kisumu among others), untreated sewage and agricultural runoff occur all along the heavily populated shoreline. Phosphorous, and to a lesser extent nitrogen from untreated waste, put excessive nutrients into the water driving algae blooms and contributing to the water-hyacinth invasion seen in the mid-1990s (Scheren and others 2000, Williams and others 2005, Albright and others 2004).

In addition, accelerated erosion from deforestation and agricultural conversion of natural areas has led to greatly increased sediment loads being carried into the lake (Machiwa 2003).

As the river flows through Sudan it also picks up substantial non-point source agricultural and urban runoff (NBI 2005a). While water quality has generally been found to be within World Health Organization standards (NBI 2005a) there are some localised high chemical pollution concentrations especially in the Khartoum area (NBI 2005a). In Egypt, water quality is under pressure from intense population and accompanying agricultural and industrial activity concentrated along the banks of the Nile. In Upper Egypt, this comes primarily from agro-industries particularly sugar cane (NBI 2005b,Wahaab 2004). Downstream, where populations are more concentrated, a wide range of industrial pollution and wastewater enter the river from Cairo and Lower Egypt's other urban centres (NBI 2005b, Wahaab 2004). While Egypt has made significant efforts to construct additional wastewater treatment capacity, population growth has outstripped capacity and considerable domestic wastewater enters the Nile with no treatment (NBI 2005b). Intense agriculture and some mixing of industrial and domestic wastewater in irrigation-drainage canals make a source of multiple contaminants in Lower Egypt (NBI 2005b).

Relative Magnitude of Loading Sources to Lake Victoria

It has been recognized by most of the scientific community that Lake Victoria is enriched with nutrients. There are, however, conflicting reports on the magnitude of nutrients received from different sources and the dynamics of nutrients in the Lake. Lake nutrient balance is essential for understanding primary productivity and ecosystem function and for planning nutrient management strategies. The Water quality and Ecosystems study under LVEMP I identifies major point and non-point sources of nutrients and estimated the rates of sedimentation into Lake Victoria. The determination of pollution loads from point sources was limited to the Biochemical Oxygen Demand (BOD5), Total-Nitrogen (TN), and Total-Phosphorus (TP). For the non-point pollution sources emphasis is given to Total Nitrogen (TN), Total Phosphorus (TP) and Total Suspended Solids (TSS), the loads from rivers and atmospheric deposition are also estimated both due to their relevance as quality indicators and their contribution to eutrophication of the Lake. For the purpose of determining the nutrient balance of the lake, the sedimentation rates in the lake are also calculated as both fluxes per unit area and total lake bottom accumulation.

The annual increase in lake TN is estimated using a TN: TP ratio for the current lake and assuming it applied in 1960.

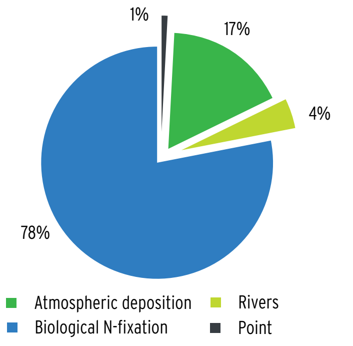
Variability in Lake Victoria river yields and chemical composition

The river basins have different physiographic characteristics such as altitude, rainfall, basin slope, vegetation cover, soils, and runoff coefficients that impose different yields of nutrients and sediments even under natural conditions. Agricultural use can alter those physical characteristics as well as add nitrogen and phosphorus as fertilizers and accelerate soil erosion. The resulting differences among the catchments in yields and composition of loads can be appreciated from the graph below which gives the yields per unit area of catchment and the ratios between the TN, TP and TSS yields which normalize the annual loads by the catchment area of the rivers

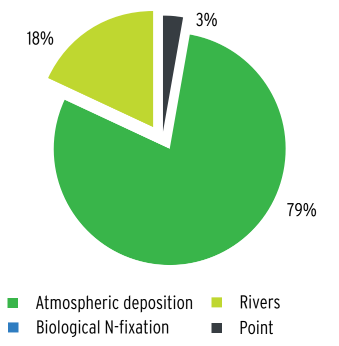
The annual increase in Lake TN is estimated using a TN: TP ratio for the current lake and assuming it applied in 1960.

Source	TN (t/y)	TP (t/y)
External loading	967700	50920
Annual Increase in Lake (1960-2000)	30360	2760
Permanent Burial	107000	24000
Outflow through Nile	56200	3410
Balance	774140	20750

Relative magnitude of loading sources to Lake Victoria % Nitrogen



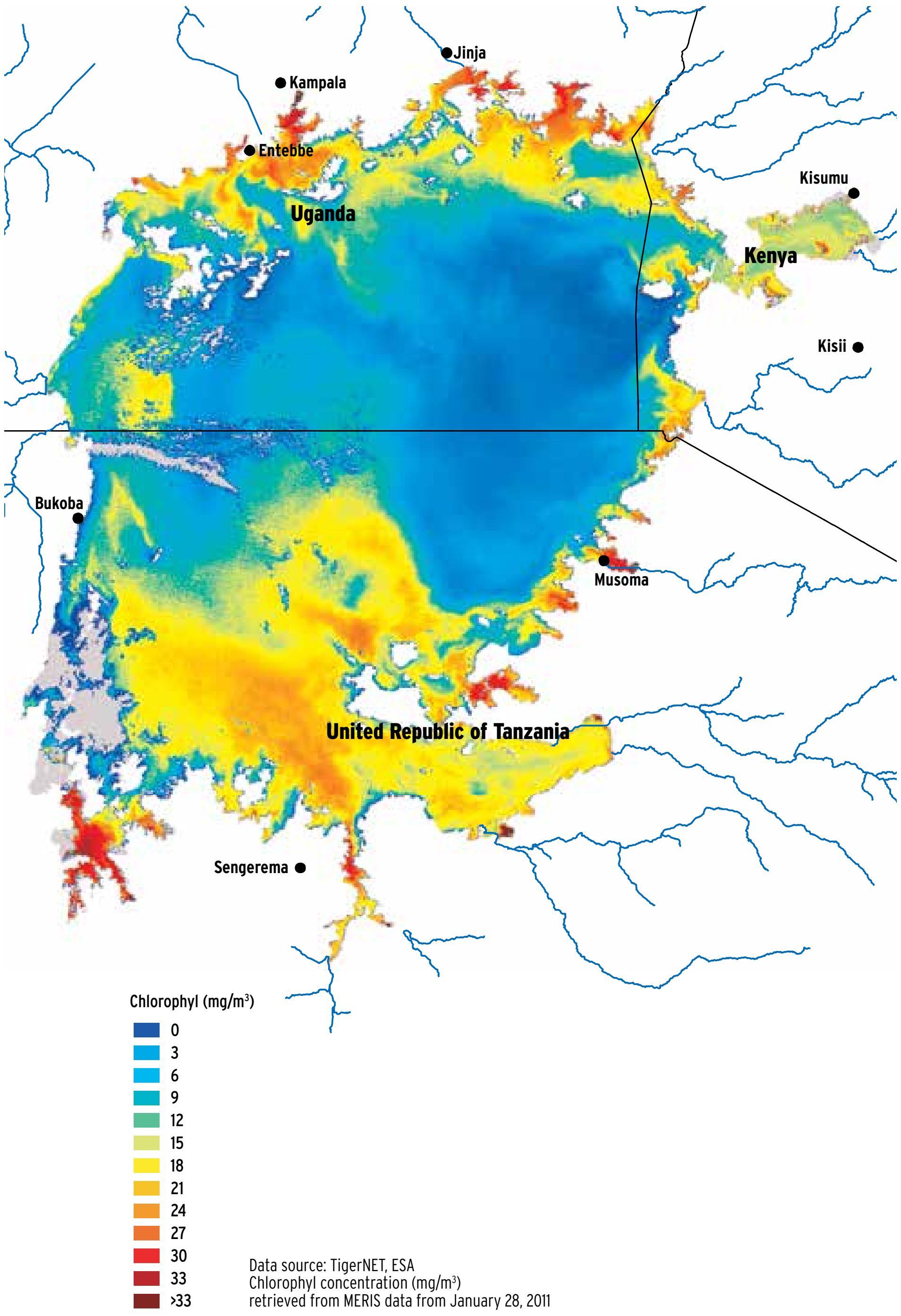
Relative magnitude of loading sources to Lake Victoria % Total Phosphorus



Summary of yields of sediments (TSS), TN and TP and ratios of TN to TP and the nutrients to sediment yields for the tributary rivers in the Lake Victoria Basin

River	Area Km^2	Discharge (m^3/s)	TSS (t/km^2/y)	TN (kg/Km^2/y)	TP (Kg/Km^2/y)	TN:TSS (Kg/Ton)	TP:TSS (kg/ton)	TN:TP (w/w)
Tanzania								
Kagera	59682	279.5	21.5	274	38	12.8	1.8	7.2
Mara	13393	41.7	22	123	17	5.6	0.8	7.2
Grumeti	13363	13	13.4	38	35	2.8	2.6	1.1
Simiyu	11577	43	179.2	146	164	0.8	0.9	0.9
South Shore Streams	8681	24.6	21.2	53	20	2.5	0.9	2.7
Isanga	6812	29.8	32.6	81	31	2.5	1	2.6
East Shore Streams	6644	20.2	42	120	135	2.9	3.2	0.9
Magogo-Moame	5207	8.9	12.8	32	12	2.5	0.9	2.7
Mbalageti	3591	5.3	20.3	58	53	2.9	2.6	1.1
Biharamulo	1928	18.4	57.3	367	73	6.4	1.3	5
Nyashishi	1565	1.7	7.9	20	16	2.5	2	1.3
West Shore Streams	733	21.3	175.1	1121	222	6.4	1.3	5
Kenya								
Nzoia	12842	115.3	52.8	422	66	8	1.2	6.4
Gucha Migori	6600	59.1	70.6	468	128	6.6	1.8	3.7
Nyando	3652	18	6.3	442	93	69.8	14.7	4.8
Yala	3357	35	52.2	479	41	9.2	0.8	11.8
Sondu-Miriu	3508	42.2	41.4	519	52	12.5	1.3	9.9
South Awach	3156	6	9.5	140	14	14.8	1.5	10.1
North Awach	1985	3.8	3.5	24	4	7	1.1	6.4
Sio	1437	11.4	22	241	37	11	1.7	6.5
Uganda								
Katonga	15244	2.3	0.2	28	2	127.6	8.3	15.4
Bukora	8392	7	5.6	41	13	7.3	2.3	3.2

Water quality Lake Victoria



Data source: TigerNET, ESA
Chlorophyl concentration (mg/m³)
retrieved from MERIS data from January 28, 2011

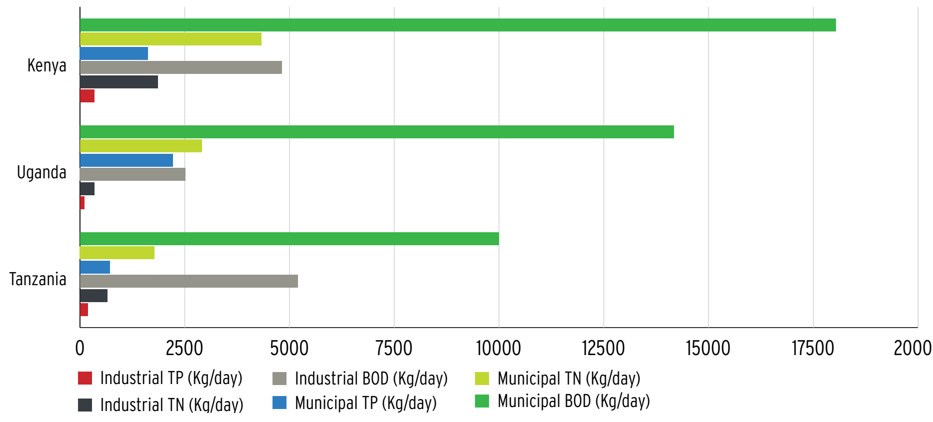
Eutrophication

The mean concentrations of macro-nutrients in Lake Victoria surpass the concentrations that have been recorded in other lakes and oceans, and the high mean concetrations of chlorophyll makes it one of the most eutrophide lakes in the world. Eutrophication has been identified as a greater threat to the value of the lake than other factors like fishing pressure. Eutrophication is associated with increase in chlorophyll concentration by x4 for offshore and x8 for inshore parts of the lake; and the algal community that is composed of different algae species with a distinct seasonal succession is presently predominated by cyanobacteria through-out the years. The increased alga biomass has been accompanied by reduced water transparency both inshore and off shore , increased rates of material decomposition have depressed dissolved oxygen to less than 1 mg/L over as much as the 30% of the water column8

Mean Daily Industrial and Municipal Loads into Lake Victoria

Municipal effluent load are higher than industrial loads but both represent a threat to the community downstream the discharge point and the littoral zone of the lake. Municipal loads for BOD dominate over the industrial loads. Furthermore Kenya leads in municipal pollution loading followed by Uganda, while Kenya and Tanzania contribute industrial loads of the same magnitude. In Kenya and Uganda some industries are connected to the municipal sewer, hence they are captured as municipal loads. Cane sugar processing, soft drinks manufacturing, fish processing, vegetable oil processing, breweries and distillery industries are the major categories of polluters to the lake in a descending order.

Regional Summary of Municipal and Industrial Loads (LVEMP I)



Summary of yields of sediments (TSS) yields for the National rivers

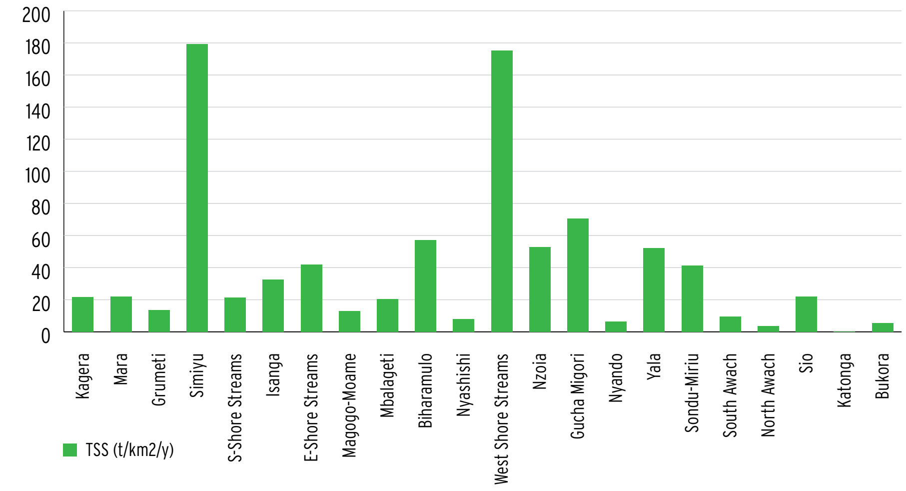


Photo: Milly Mbuliro

Kagera river

Sediment yields in the Rivers flowing to lake Victoria

The Simiyu stands out for its high yield of sediments while the remaining rivers have sediment yields that are characterized as lightly to moderately disturbed by agriculture (Hecky et al 2003). The sediment yield of the Simiyu would place it among the highest disturbed catchments of the Lake Victoria. Simiyu is densely populated in its lower reaches and the flood plain has been occupied for agriculture. The Ugandan rivers and especially the low gradient Katonga River that is choked with papyrus have very low yields of sediments and nutrients. Among the Kenyan rivers the Gucha Migori has the highest yields of sediments. The upper catchment of Gucha Migori is hilly, steep, densely populated, with intensive agriculture characterized by simple farming practices and excessive rates of soil erosion.; while in the lower reaches the river flows through dry rangelands.

Total Non-Point Loads in Lake Victoria

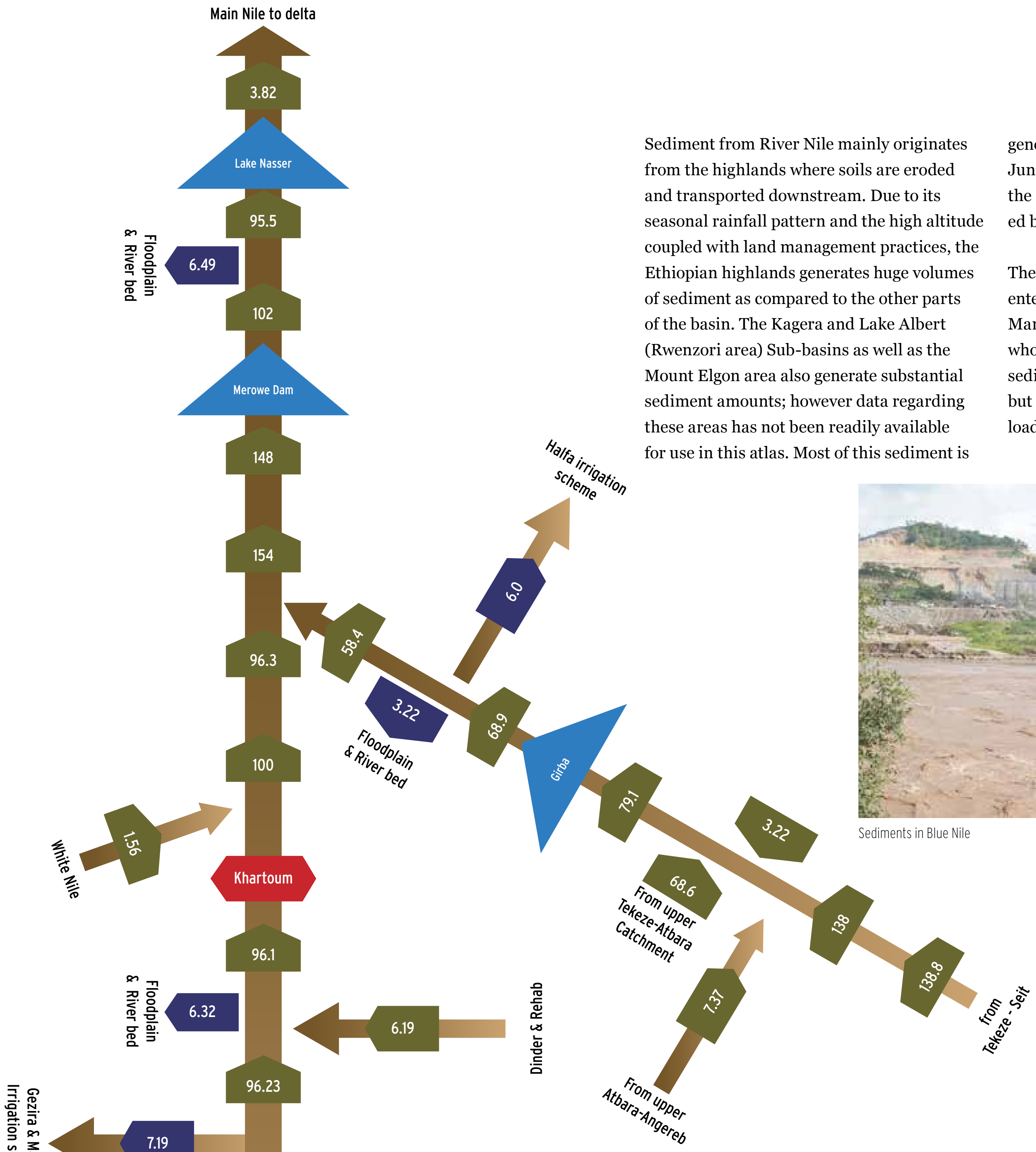
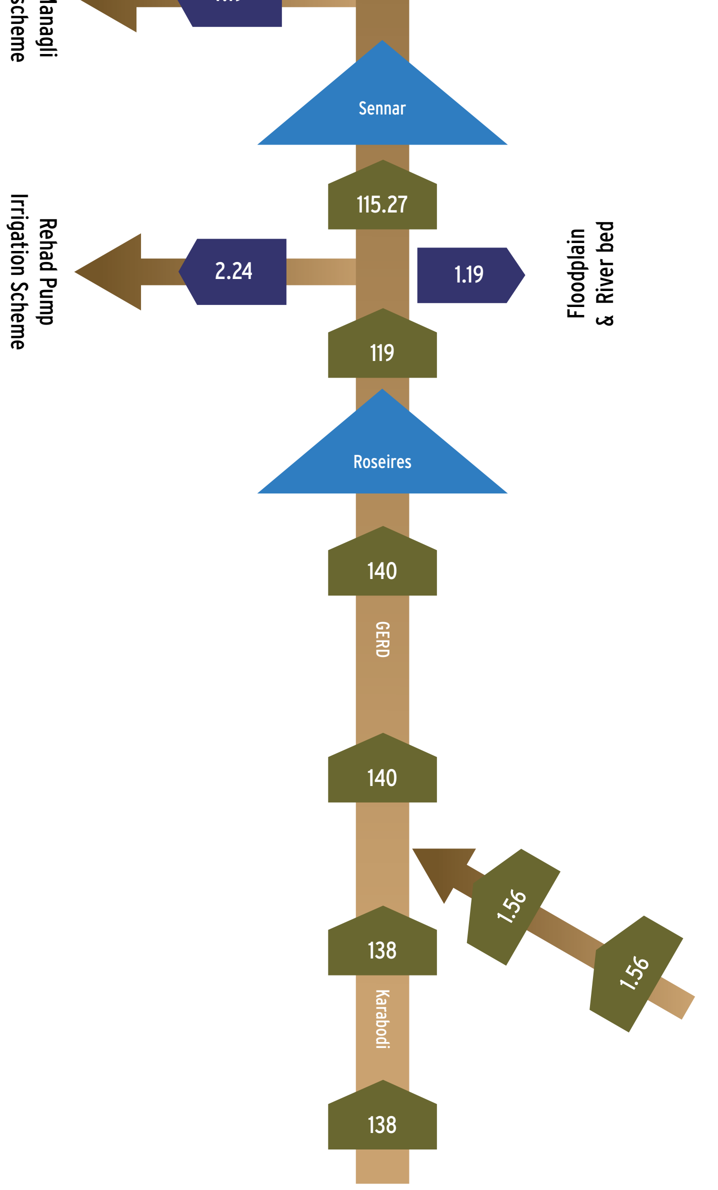
The riverine loads are estimated at 9,270 of TP and 38,828 tons/y of TN respectively, and represented in both cases 80% of the total non-point load. Atmospheric deposition is estimated as the overall dominant source contributing about 39,978 and 167,650 tons of TP and TN respectively to the lake annually. The current non-point loadings whether from the atmosphere or rivers represent major losses of soils and nutrients from the agro-ecosystems and are symptomatic of degrading soil fertility in the lake Victoria catchment. Atmospheric deposition dominates the non-point loadings with some of the highest rates of deposition known globally. Although not widely appreciated as vector for nutrient loss, biomass burning does mobilize nutrients into the atmosphere and has likely been a major source of increased nutrient loading to Lake Victoria. Improved land management would be necessary to reduce the current loadings, but it will also preserve soil fertility by retaining nutrient on the land.

Estimates of total N, P and Suspended Sediment loads from the catchment and atmosphere

Parameter	Catchment (tons/Yr)	Atmospheric (tons/yr)	Total Load (tons/Year)	% Atmospheric	% catchment
TP	9247.0	39978.0	49225.0	81.2	18.8
TN	38828.0	167650.0	206478.0	81.2	18.8
TSS	6511950.0	-	6511950.0	-	-

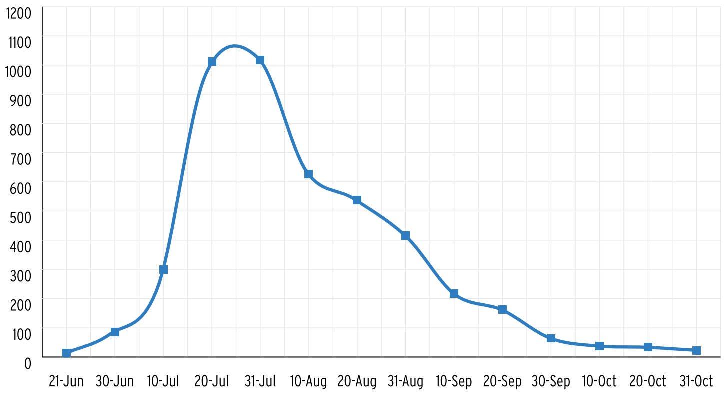
Sediment from River Nile mainly originates from the highlands where soils are eroded and transported downstream. Due to its seasonal rainfall pattern and the high altitude coupled with land management practices, the Ethiopian highlands generates huge volumes of sediment as compared to the other parts of the basin. The Kagera and Lake Albert (Rwenzori area) Sub-basins as well as the Mount Elgon area also generate substantial sediment amounts; however data regarding these areas has not been readily available for use in this atlas. Most of this sediment is generated within the wet season; mainly from June – September. The chart presented shows the Eastern Nile Sediment balance as provided by ENTRO.

The graphs below show the average sediment entering the Gezira main canal, that from the Managil canal and the total sediment into the whole scheme. It is clear from this graph that sediment loads accumulate in the wet season, but also the fact that overtime the sediment loading is on an increasing trend.

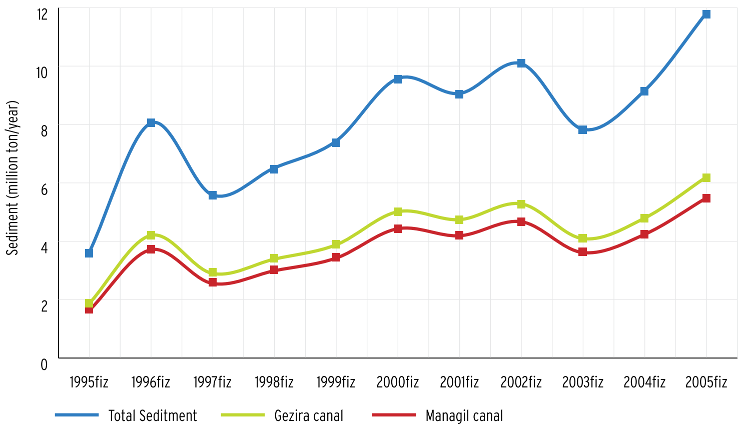



Sediments in Blue Nile

Average sediment entering Gezira main canals in 1000 tons/decade (years 1995 - 2004)



Total annual sediment into Gezira, 1995 - 2005

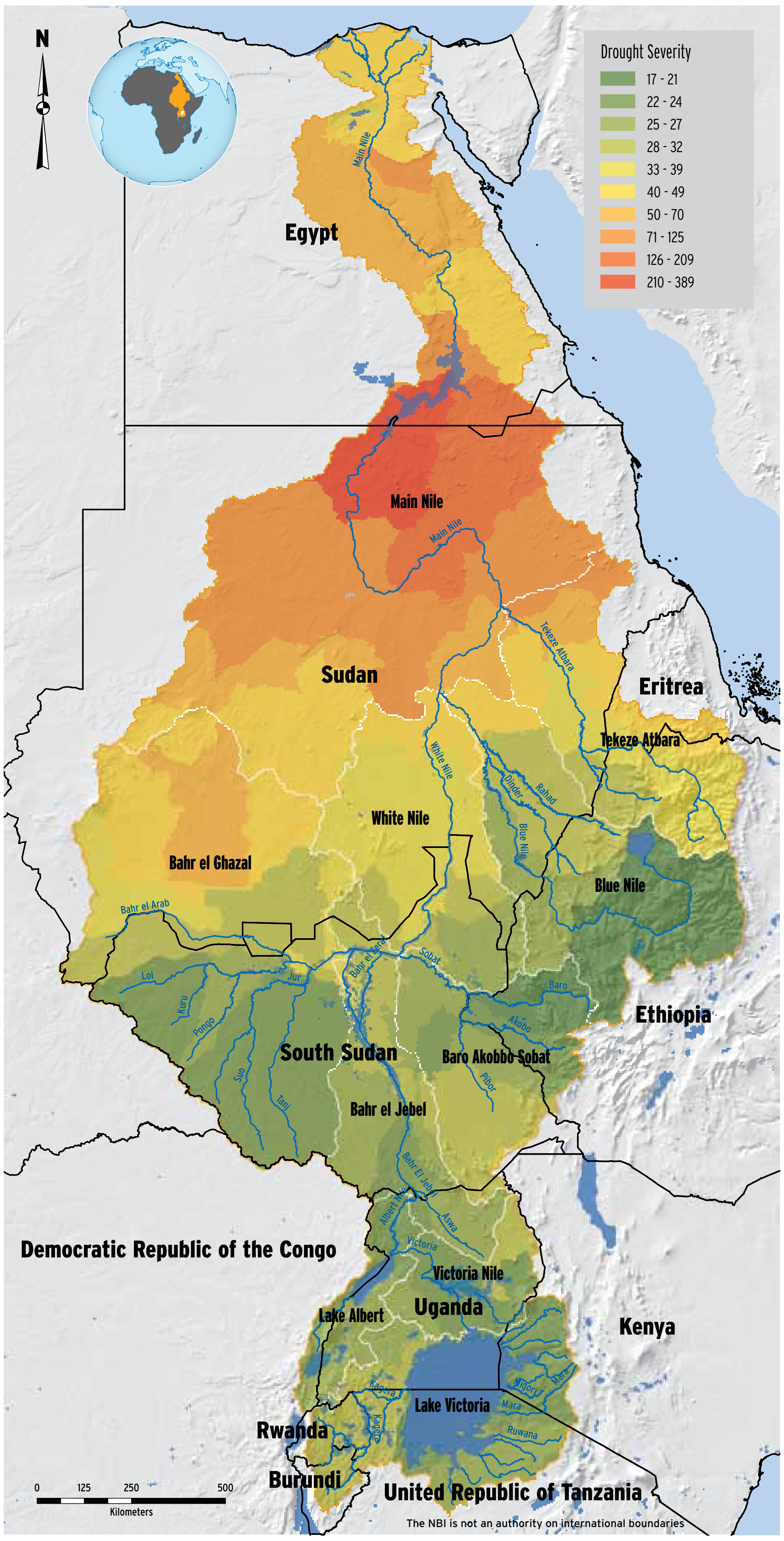


Source: ENTRO Sediment Tool

HYDROLOGIC EXTREMES

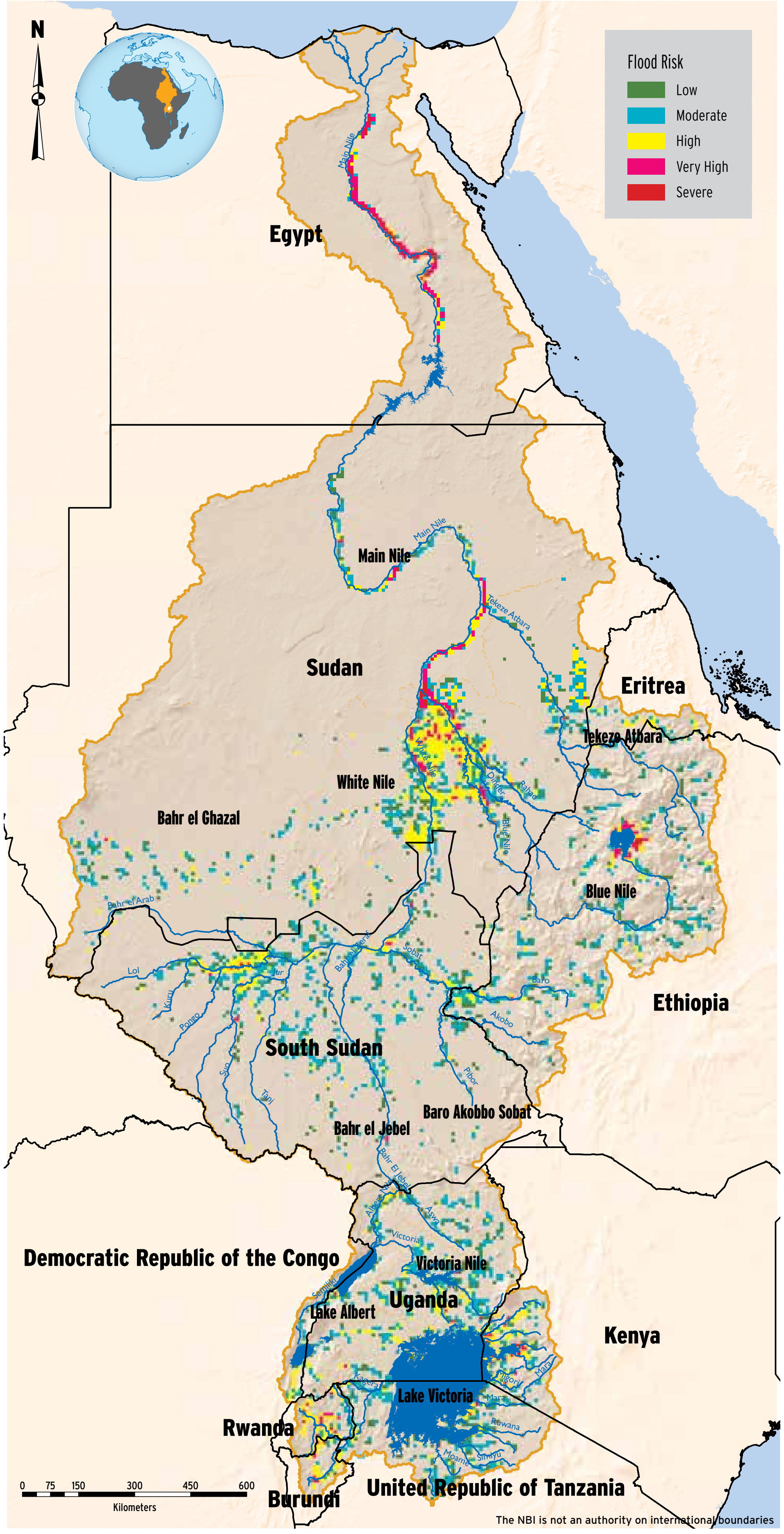
The Nile Basin, like any other part of the world experiences extreme events including droughts, floods, landslides, heat waves, e.t.c. The Equatorial lakes region and the Blue Nile including Khartoum experience flooding. The Darthmouth Flood Observatory had compiled an archive of the flooding events in the world; the "Global Flood Hazard Frequency and Distribution" and can be referred to for this information. In this atlas, we present the drought severity as a measure of the average length of drought times the dryness of the droughts from 1901 to 2008 as presented by aqueduct from Sheffield and Wood. Drought is defined as a contiguous period when soil moisture remains below the 20th percentile. Length is measured in month and dryness is the average number of percentage points by which soil moisture drops below the 20th percentile. The flood risk (estimate) map has also been presented clearly indicating areas which are at high risk of flooding with in the Nile basin. The flood risk index ranges from 1 (low) to 5 (extreme) as seen in the map. This product was designed by UNEP/GRID-Europe for the Global Assessment Report on Risk Reduction (GAR) and was modeled using global data.

DROUGHT SEVERITY IN THE NILE BASIN



Source: World Resources Institute, Aqueduct Global Maps 2.1 Data; http://www.wri.org/resources/data-sets/aqueduct-global-maps-21-data

FLOOD RISK IN THE NILE BASIN



Source: http://preview.grid.unep.ch/index.php?preview=data&events=floods&evcat=5&lang=eng accessed through http://www.preventionweb.net/english/maps/

Hydrologic extremes in Kenya

In Kenya, high inter-annual and intra-annual rainfall variability results in frequent and severe droughts and floods, negatively affecting the country's economic performance. Agriculture and animal husbandry, which together account for 28% of Kenya's national GDP and employ 70% of the total population, are particularly sensitive to climatic variations and have been adversely affected by the frequent occurrence of water shocks in recent years.

Droughts in Kenya

Kenya's droughts can have devastating consequences. Arid and semi-arid lands (ASAL) account for 80% of Kenya's land area, making the country poorly endowed with potential for rain-fed agriculture given the hydrologic variability that Kenya experiences. Since 2007, Kenya has suffered from two consecutive years of below average rains in most of the country, leading to one of the worst droughts in a decade. The devastating consequences included widespread famine as a result of severely depressed food production, with maize production alone down by 50% and up to 10 million people in need of food aid. The drought from 2007-2009 left Nairobi without water for a period of three weeks in November 2009.

Floods in Kenya

Although less well documented than the periods of drought, Kenya frequently experiences severe flooding about every three years. Kenya is affected by floods following torrential rain. Major floods occurred in 1937, 1947, 1951, 1957-1958, 1961, 1978, 1998, 2008 and 2010 with the largest flood having occurred in 1961 (UN-WATER 2005). Many parts of Kenya, particularly in the Rift Valley and Ewaso Ng'iro Basins, experience both floods and droughts on a regular basis. The floods between 1982 and 2008 affected more than 2.1 million people, mostly in Western and Nyanza provinces and in the Tana River district. While most parts of Kenya experience floods, severe floods regularly occur in most parts of the Kano plains (Nyando district, Nyanza Province), Nyatike (Migori district, Nyanza Province), Budalangi (Western Province, on the Nzoia River), and the lower parts of Tana River. People in informal settlements around Nairobi and other cities with homes near rivers are disproportionately affected. The most disastrous events occurred in 1997/98 when widespread floods throughout Kenya impacted about 1.5 million people. The 2008 floods affected 300,000 people (UN-WATER 2005). The areas that were affected by the various floods are shown in Table

Economic Implications of Hydrologic Extremes in Kenya

Climate variability negatively impacts national GDP and human development in Kenya. The World Bank estimated in 2004 that the losses from climate variability average about 2.4% of GDP per year with a further 0.5% loss from water resources degradation, constituting a serious impact on the country's competitiveness. For example, during the back-to-back floods (1997-98) drought (1998-2000) between 1997 and 2000, the World Bank estimated that water-related events caused GDP losses of 11%, 16%, and 16%, respectively, for each of the three years. Based on the GDP in those years, this is equivalent to an almost US$ 5 billion loss over those three years. Consequences included widespread famine as a result of severely depressed food production with millions of people in need of food aid, load shedding and extensive power rationing as a result of a near-halving of hydropower generation, and a decline in economic activities of all sectors (World Bank 2004a).

Heavy dependence on hydropower for electricity means that Kenya's economy is especially vulnerable to hydrologic variability. The droughts of 1999-2000 and 2007-2009 clearly illustrated this, when hydropower generation fell by almost half, resulting in massive load shedding, reliance on expensive emergency diesel, and large economic losses. The use of emergency diesel since 2006 has reached 14% of total generation (World Bank 2010c). Future growth will be dependent on better controlling existing hydrological variability, and putting in place policies and infrastructure to hedge against future climate uncertainty.

Year	Affected Areas	Number of Affected People
2008	Mandera, Budalangi, Coast Province, Nyando,Migori, Wajir, Siaya, Nyatike, Trans Nzoia, Meru/Tharaka-Tigania, Pokot Central	300000
2003	Nyanza, Busia, Tana River	170000
2002	Nyanza, Busia, Tana River	150000
1997-1998	Widespread	1500000
1985	Nyanza, Western Province, Tana River	10000
1982	Nyanza	4000

Cycle of poverty, droughts, floods in Sudan and South Sudan

Sudan and South Sudan like other countries of the Sahel, have long suffered from lengthy, devastating droughts. The most severe droughts of recent decades occurred in 1980–1984, 1989, 1990, 1997 and 2000, causing widespread population displacement and famine. In addition, floods in Sudan cause extensive damage, especially around the Nile and its main tributary, the Blue Nile.

Severe floods on the latter river in 1988 and 1998 caused property losses estimated at hundreds of millions of dollars. Flooding of the Nile proper in 2007 affected over 500,000 people and destroyed thousands of homes (WHO, 2008a). Seasonal rivers can also cause serious flood damage. In 2003, for example, heavy flooding along the Gash River affected 79% of the city of Kassala, leaving 80% of the population homeless, and inflicted heavy losses on agriculture in the region (NASA, 2008).

It is estimated that 85% of the two countries rural population lives on less than US$1 per day. Overall, some 20 million people were living in extreme poverty in 2002 (IFAD, 2008). The incidence of poverty varies considerably because economic growth is geographically uneven and conflict has devastated parts of the country. Severe regional inequalities exist in access to even the most basic services, such as education, sanitation, safe drinking water and job opportunities. For example, health services in South Sudan reach only about 25% of the population. People living in areas that have been or continue to be affected by drought and conflict –– are the most vulnerable to poverty (IFAD, 2008)

Photo: Salahaldeen Nadir / World Bank

Water point to allow people and their animals to access clean drinkning water as they move in search of pasture

CONCLUSION

Photo: istock

The hydrologic regime of the Nile River, in particular the discharge regime, is distinctly influenced by the south and eastern highlands precipitation patterns. The hydrology of the Nile is mainly characterized and influenced by high variations in climate and altitude/topography which have a great bearing on flow magnitudes and patterns in the different parts of the basin. The Nile receives its flow from a network of various hydraulic systems, draining the Ethiopian Plateau and the Equatorial Lake Plateau. The network within the basin is of diverse hydrological processes, e.g. tributaries ad streams, wetlands, open water, man-made infrastructures. The Atlas also identifies and presents the water towers of the basin, as the high altitude area (Rwenzori Mountains in western Uganda, Mount Elgon, and the Ethiopian highlands) with registered rainfall in excess of 1,500 mm, they also usually lose less water to evapotranspiration because temperatures are lower.

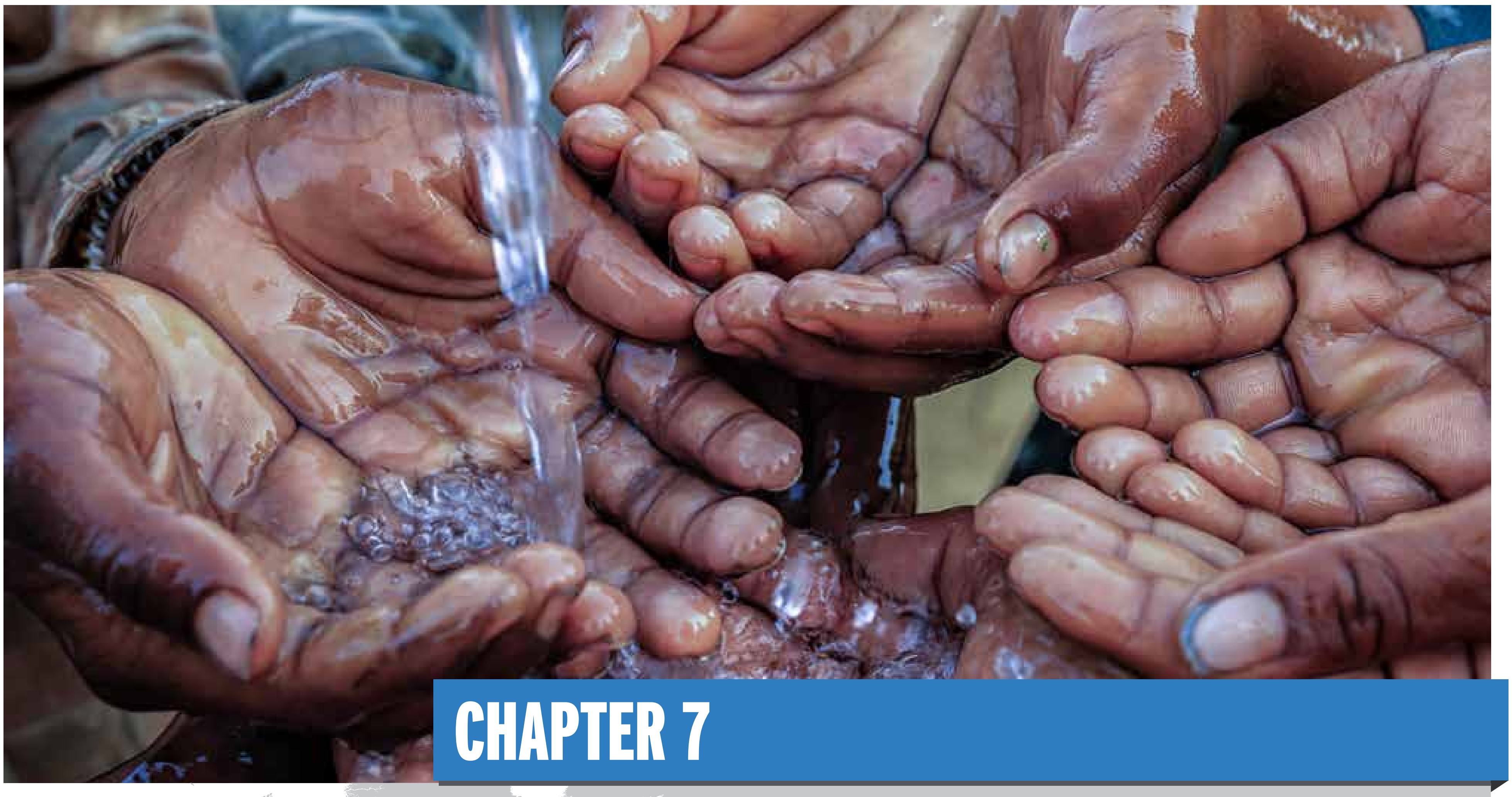
Presentation of the hydrology of the Nile in this Atlas focused on key stations within the sub-basins of the Nile starting from downstream to upstream; Main Nile, Tekeze Atbara, Blue Nile, Baro Akobo Sobat, White Nile, Bahr el Jebel, Bahr el Ghazal, Lake Albert, Victoria Nile, and ends with Lake Victoria sub-basin. There are also swamps and wetlands in the Nile basin which play and influence the hydrology of the Nile mainly the Sudd, Bahr el Ghazal swamps, and the Machar marshes.

The Ethiopian highlands through the main tributaries (the Blue Nile, Atbara River, Baro-Akobo) are contributing most of the annual flow to the Nile (85%), but its contribution is highly seasonal - highest flows in four months (July – October). The discharges of the Equatorial watersheds into the White Nile are of low magnitude compared to the Ethiopian highlands. However the Equatorial sub-basins contribute more consistent and steady year-round flow. The Nile River course north of Atbara in Sudan receives no tributary and insignificant rainfall contribution. Thereafter, the Nile River flows through dry areas featured by extended desert, storage and the hydrology is dominated by management for multiple uses (irrigation, hydropower, navigation, tourism, etc.) - infrastructures and regulations influence the downstream flow. Further downstream, the Nile discharge into the Mediterranean Sea through its two branches in Egypt (Rosetta and Damietta).

Since the early years of the 20th century, records have been kept of the discharge at key stations of the Nile and its main tributaries. However, due to the fact that the stations records were for different time spans, they can be used to provide a good picture of the seasonal variation and quantify the relative contribution of the respective tributaries to the total Nile flow. The mean annual flow at Dongola station (immediate station upstream Aswan) is about 72 BCM. Inter-annual variability is very high for the long-term annual yield of the Blue Nile and Atbara rivers. While Atbara contributes an average flow of 11.4 BCM, the Blue Nile considered as the major Nile River yields an average of 50 BCM at Ed Deim station (spare its Dinder and Rahad downstream tributaries). Further upstream, the flow at Malakal averages 31 BCM (at the outlet of Baro-Akobo-Sobat, Bahr El Jebel, Bahr El Ghazal sub-basins), compared to an averages of 32 BCM at Mongola (upstream station of Bahr El Jebel sub-basin), which is close to the outflow from Lake Victoria averages 33 BCM. With average annual flow at Gambella of about 11.4 BCM, the Sudd outflow can be computed as 17 BCM. The outflow from the Bahr El Jebel varies little throughout the year because of the regulatory effect of swamps and lagoons of the Sudd region, about half of its water is lost in evaporation (or transpiration through plants), and seepage. Also, the flow duration curve depicts storage characteristics of the Southern stations (e.g. Malakal) compared to the Eastern tributaries.

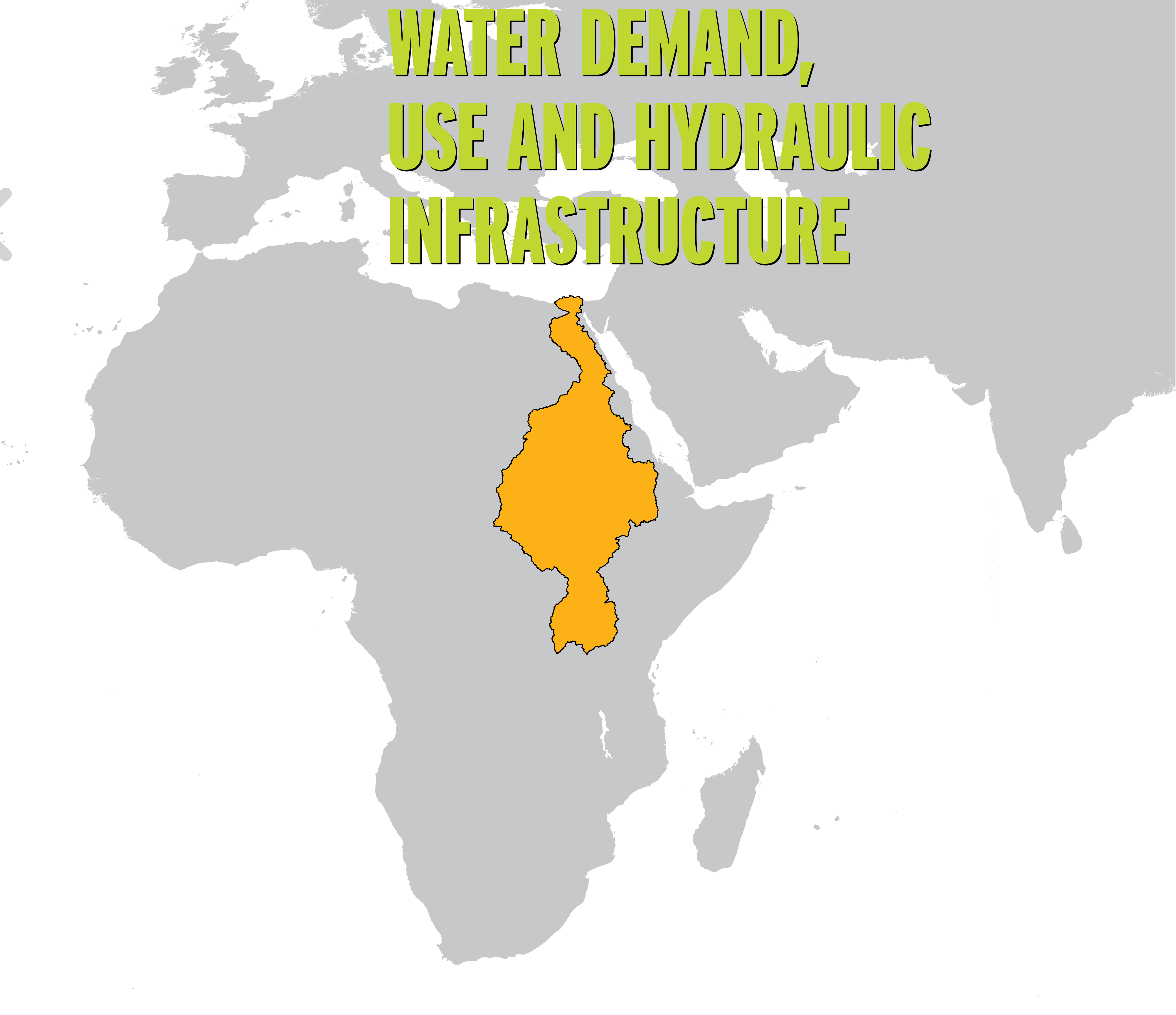
References

- Ssebiyonga, Nicolausi1; Erga, Svein, Rune2; Frette, Øyvind1; Stamnes, Jakob1; Measurement of Instantaneous Phytoplankton Photosynthetic Parameters in Lake Victoria (Uganda) Using A Fluorescence Technique
- Directorate of Water Resources Management, Ministry of Water and Environment, Uganda (2013), National Water Resources Assessment
- World Water Assessment Programme. 2009. The United Nations World Water Development Report 3: Water in a Changing World. Paris: UNESCO, and London: Earthscan
- Hezron Mogaka, Samuel Gichere, Richard Davis, Rafik Hirji, World Bank, Climate Variability and Water Resources Degradation in Kenya Improving Water Resources Development and Management
- Prof. F.L. Mwanuzi, Dr J.O.Z. Abuodha, Dr. F.J. Muyodi and Prof. R.E. Hecky. Lake Victoria Environment Management Project (LVEMP II) Water Quality And Ecosystem Status. Lake Victoria Regional Water Quality Synthesis Report
- UNEP (2010), "Africa Water Atlas" Division of Early Warning and Assessment (DEWA); United Nations Environment Programme (UNEP); P.O. Box 30552; Nairobi 00100, Kenya



CHAPTER 7

WATER DEMAND, USE AND HYDRAULIC INFRASTRUCTURE



KEY MESSAGES

Photo: istock

Agriculture is a major livelihood strategy in the Nile Basin, sustaining tens of millions of people. It provides occupations for more than 75% of the total labour force and contributes to one-third of the GDP in the basin. An estimated 5.4 million hectares of land is under irrigation basin-wide, where over 97% of this area is in Egypt and Sudan. The actual area cultivated on average is approximately 6.4 million hectares. The total estimated annual irrigation water demand for irrigation is approximately 85 BCM; the actual basin-wide withdrawal of water from the Nile for irrigation is estimated as 82.2 BCM. In few irrigation schemes, due to mainly lack of sufficient water storage, all the irrigation water requirements are not met. Water scarcity in terms of both physical water scarcity and economic water scarcity remains the major limiting factor for agricultural development in the basin. Productivity is highly influenced by spatial variations of rainfall in the rain-fed system while in the irrigated areas scheme management is the main determining factor in the productivity variation

Energy is vital to the future growth of the Nile Basin riparian states. The per capita energy consumption in the Nile riparian states, except Egypt, is below the requirements for rural supply in sub Saharan Africa (250kWh/capita/year) which calls for increased production. Hydroelectric power is key in meeting the energy deficit in the partner states. The current installed capacity of hydropower on the Nile is estimated at 5660MW of which 40% is generated in Egypt. This is followed by Sudan (28%) and Ethiopia (18%). The topography of the Nile provides opportunities for power generation, especially Ethiopia. Hydropower is a major water user in the Nile, relying on water passing through turbines to generate electricity. Most power plants within the Nile are run of the river. However water can be consumed via seepage and evaporation from the reservoirs created for hydropower facilities. Factors determining the amount of consumed water – climate, reservoir design and allocations to other uses – are highly site-specific and variable.

The net evaporation from dams and reservoirs within the Nile basin is estimated at 17.6 BCM. Due to the size of the reservoir surface area and the climate, the evaporation from the High Aswan Dam is the highest.

Despite the power deficits in the Nile Partner states, power trade is low, and only restricted to limited exchange (Ethiopia-Sudan; Kenya-Uganda; Uganda-Rwanda and Rwanda-DRC-Burundi. The NBI in collaboration with the Eastern African Power Pool (EAPPP) promotes regional transmission interconnection. The regional interconnection backbone under development is

photo: istock


photo: istock

expected to add more than 4600 circuit kilometers of new transmission lines at various voltage levels in the riparian states of Ethiopia, Uganda, Kenya, Tanzania, Rwanda, Burundi, DRC, South Sudan, and Djibouti (outside NBI). Such interconnection projects allow utilities to share reserve margins across a wider operating area, thus reducing the need for costly installed capacity to meet reserve requirements. As example the 500 kV HVDC Eastern Electricity Highway Project under the Eastern Africa Power Integration Program will allow Kenya to purchase relatively cheaper hydropower energy from Ethiopia and support Ethiopia's system when water is scarce.

The per capita water availability among the Nile riparian states is decreasing, due to rapid population growth, urbanization and inadequate investment of riparian states in hydraulic infrastructure over the last four decades. The very low per capita water storage capacity available to the Riparian States, Kenya (103m^3/capita) and Ethiopia (38m^3/capita), clearly illustrates the risks the countries are facing due to the high seasonality of the Nile and its tributaries, especially those in the Eastern Nile. This exposes Nile basin riparian states to flood and drought risks. Even more difficult hydrology is in the Blue Nile system, where rainfall is markedly seasonal – a short season of torrential rain followed by a long dry season which requires the storage of water. Perhaps most difficult of all is a combination of extreme seasonality (intra-annual) and variability (inter-annual) – characteristics of many of the Nile riparian states which affects the Nile riparian state economies.

The total water demand for Municipal and Industrial uses has been estimated at 12,900 MCM per year for the whole Nile Basin. Nearly 97% of this demand occurs in Egypt. Nearly 97% of this demand occurs in Egypt. While population in the Nile basin riparian states is estimated to nearly double by 2030, domestic water demand is expected to grow five-fold to five to six-fold during the same period.


photo: istock

Although fisheries are usually non consumptive users of water, they require particular quantities and seasonal timing of flows in rivers and their dependent wetlands, lakes, and estuaries. Freshwater fish resources in the Nile basin are probably among the most resilient harvestable natural resources, provided their habitat, including the quantity, timing, and variability of river flow, is maintained. The Nile Basin annual fresh fish production is estimated at three million tons of which 57% is apportioned to capture fisheries in the lakes and rivers. The total fisheries capture is estimated at three million tons annually in the Nile riparian states (WDI, 2016). Egypt has the greatest yield in fisheries production at 50%, followed by Uganda 19% and Tanzania 12%.

There has been a long history of water transport on Lake Victoria, contributing to domestic and international trade within the lake basin. However, deterioration of train service severely affected rail networks and the rail-dependant lake transport. Most cargo and passengers are now moving by road around the lake, whose economic life decreased. As for South Sudan, navigation is also a long established practice, although it suffered during the South/North political conflict. Cheaper and safer than roads, it now represents a mode of considerable importance for the country developing transport sector.

INTRODUCTION

photo: istock

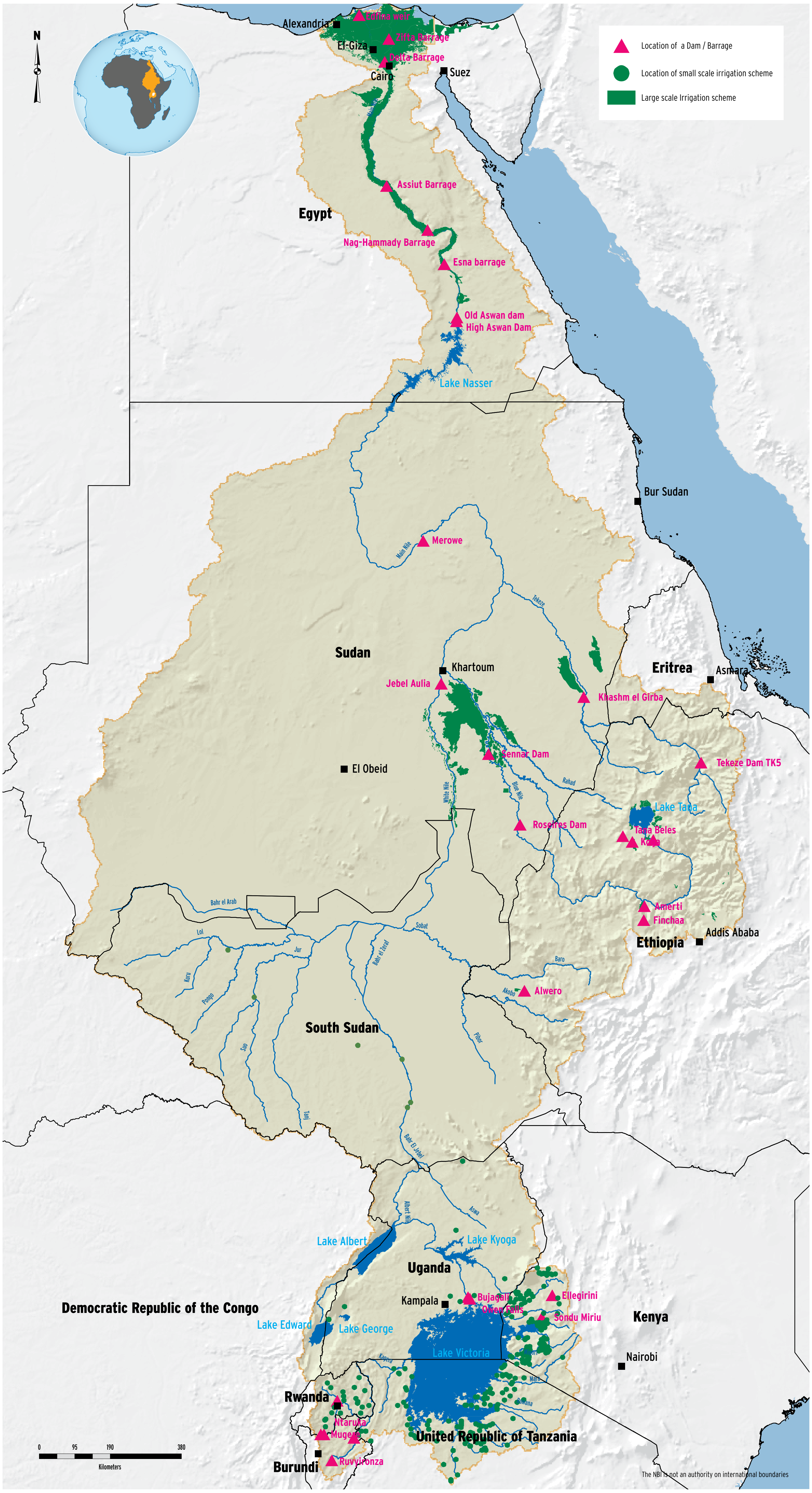
Water use is simply the amount of water used by a country or other lower entity such as a household. Some of the varied uses in the Nile basin riparian states include hydro-electricity generation, Municipal and Industrial water supply, agriculture, fishing, recreation, transport, tourism and waste disposal.

Water use includes consumptive as well as non-consumptive uses. The water use sectors that have been included in the Nile Basin water Resources Atlas are: Irrigated agriculture; Hydropower, Municipal and Industrial (M and I) uses for large urban centers. Evaporation from dams is also considered as water use. Water demands for other uses are not included due to lack of information.

Together, the countries of the Nile basin use almost 90% of the region's renewable water resources. Egypt and Sudan, which need water from outside their borders, account for the largest water withdrawals at 57 and 31 per cent of the total renewable water withdrawals, respectively. The per capita withdrawals for these two countries are almost 10 to 15 times the amounts withdrawn by other countries in the basin (FAO Aquastat 2005).

Recent strategic analysis by the Nile Basin Initiative secretariat supports this fact indicating that most of the stream flow of the Nile is allocated - used for industrial, domestic, agricultural and ecological water supply. Each year, on the average, 12 – 14 BCM reaches the Mediterranean.

HYDRAULIC INFRASTRUCTURE IN THE NILE



Jebel Aulia dam

Photo: Milly Mbuliro

Tekeze dam in Ethiopia

Photo: ENTRO

Kira power station Jinja, Uganda

Photo: A'Melody Lee/ World Bank

High Aswan dam

Photo: istock

GERD dam under construction

Photo: NBI

Storage dams in the Nile Basin

Photo: Milly Mbuliro

Storage dam in Ethiopia

Data obtained from NBI member states show that as of 2014, there are 14 storage dams basin-wide with a total storage capacity of about 203 BCM. The growth in aggregate storage capacities of all dams in the basin is shown in the adjacent figure.

It is interesting to note that, after a period of four decades of near stagnation in dam construction during 1968 – 2007, the basin is witnessing more and more storage dams added to the system. In addition, the Owens Fall (Nalubalee) dam built at the outlet of Lake Victoria in Uganda provides an additional 200 BCM of live storage to the Lake. Dams on the Nile conserve water and provide sustained supply for meeting demands. Lake Nasser, in Egypt was formed after the construction of the Aswan High Dam in 1970. The total capacity of the Aswan reservoir (162 BCM) consists of dead storage of 31.6 BCM, active storage of 90.7 BCM and emergency storage for flood protection of 41 BCM. After the construction of the High Aswan Dam, completed in 1970, no storage was added to the Nile Basin till 2009 when the Tekezze dam with capacity of 9.29 BCM was built. Other storage dams constructed since then include, the Merowe dam (12.39 BCM capacities) and Roseries heightening (to 5.9 BCM) completed in 2009 and 2012 respectively. Bujjagali dam with capacity of 0.75 BCM was built in Uganda. In Sudan, the main reservoirs are the Jebel Aulia reservoir on the White Nile, Senar and Roseries storage reservoirs on the Blue Nile, Merowe reservoir on the Main Nile and Khashm El Girba reservoir on Atbara.
In 2012, work began on Ethiopia's Grand Renaissance Dam, which has become the key project in the nation's plan to increase its electricity supply fivefold by 2015. It will have an estimated installed capacity of 6000 MW, and a reservoir capacity (74 BCM). The dam together with its power house, when finished, will be Africa's largest hydroelectric power plant.

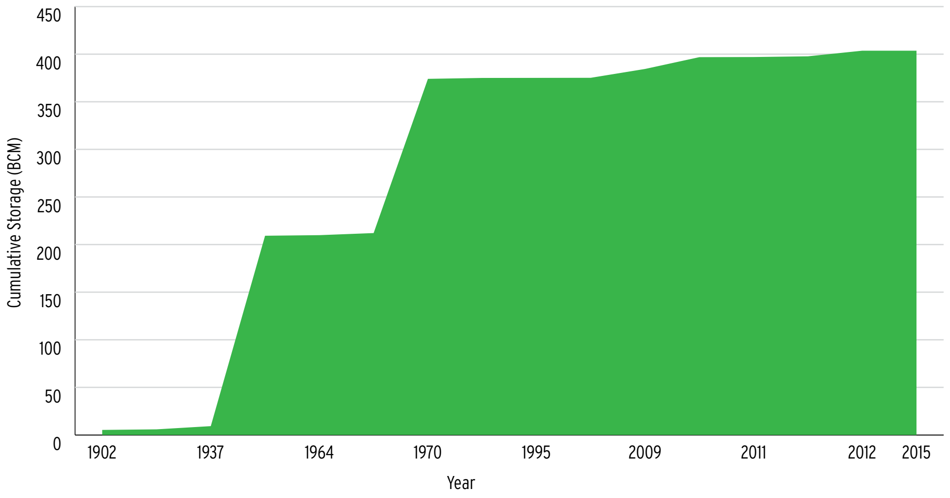
Per Capita Water Availability in the Nile Partner States

Population growth, urbanization and socio-economic growth are the major reasons for the decreasing per capita water availability in the Nile Basin states. With per capita internal water resources availability less than 1000 m³, Sudan, Rwanda, Kenya, Egypt and Burundi can be categorized as water scarce. The per capita storage capacity of the partner states is low. These trends call for improved storage in these Nile Basin States.

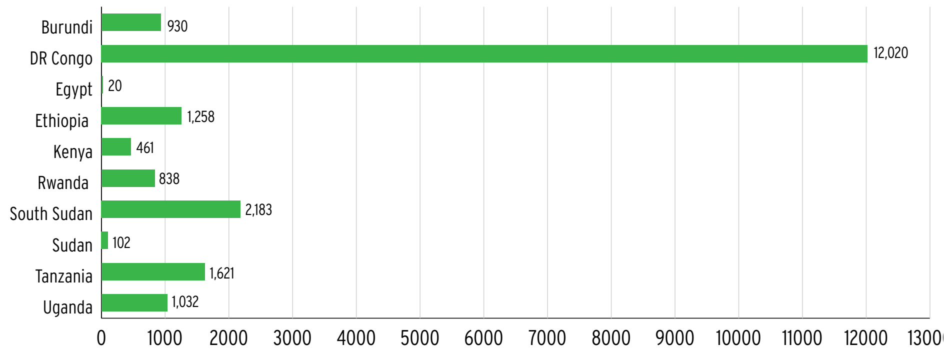
With an aggregate basin-wide storage capacity of just over 200 BCM (excluding the Nalubaale dam), most of the Nile Basin countries have the least per capita water storage by world standards. In a region with severe seasonal and intra-annual variability and anticipated climate change, absence of adequate storage capacity means more vulnerability to impacts of climate shocks.

There is a trend between a country's Human Development Index (HDI) and per capita water storage. Water storage in countries with a high HDI (>0.85) tends to be in the range of 2,500 and 3,000 m³/capita. Countries with HDI of 0.55 tend to have has a storage of about 173 m³ per capita.

Growth in Cummulative Storage of Dams in the Nile Basin

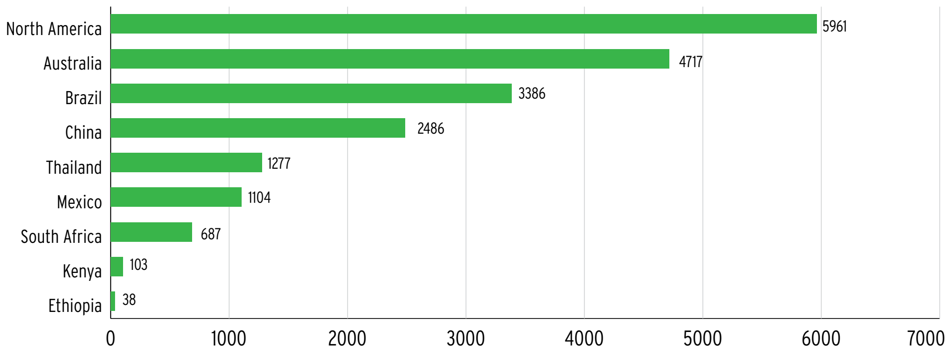


Renewable internal fresh water resources per capita (m³)



Source: WDI 2016

Water storage per capita in selected countries (m³/capita)



Source: FAO-Aquastat 2008

Storage and Economic Performance in Kenya

Water storage has been positively correlated with performance of Nile economies. Where economic performance is closely linked to rainfall and runoff, growth becomes hostage to hydrology. Kenya's limited water storage capacity leaves the country vulnerable to climate and hydrologic variability. Kenya's total water storage capacity is 4.1 bcm, or 103 m³ per capita, which is very low. Of the estimated 103 m³ per capita, 100 m³ per capita is single-purpose storage for hydropower production only. This means that only 3 m³ per capita of storage is available for water supply and other uses such as irrigated agriculture and livestock. No major dams have been constructed since Ndakaini dam in the mid-1990s, which supplies water to Nairobi. Kenya also experiences significant hydrologic variability throughout and between years. Without sufficient water storage to lessen the effects of variability, frequent and severe floods and droughts have been resulting in devastating economic and livelihood consequences. Kenya, with a HDI of 0.548 in 2015, has a per capita storage of 103 m³, which is low (adapted from UNDP, 2015)

Photo: Flore de Preneuf / World Bank

Siltation threatens hydropower,
an important source of electricity in Kenya

Storage and Economic performance in Ethiopia

Hydrological variability seriously undermines growth and perpetuates poverty in Ethiopia. The economic cost of hydrological variability is estimated at over one third of the nation's average annual growth potential, and these diminished rates are compounded over time. Yet, with much greater hydrological variability than North America, Ethiopia has less than 1% of the artificial water storage capacity per capita to manage that variability. Economy-wide models that incorporate hydrological variability in Ethiopia show that projections of average annual GDP growth rates drop by as much as 38% as a consequence of this variability. In Ethiopia, so sensitive is economic growth to hydrological variability that even a single drought event within a twelve year period (the historical average is every 3-5 years) will diminish average growth rates across the entire 12-year period by 10%. During the 1984–5 drought, for example, GDP declined by 9.7%, agriculture output declined by 21%, and gross domestic savings declined by 58.6%. Drought also severely undermines hydropower generation, Ethiopia's main source of electricity. If rains fail, or simply come too early or too late, the entire agricultural cycle can be disrupted, because there is inadequate water storage capacity to smooth and schedule water delivery. Flooding meanwhile causes significant damage to settlements and infrastructure, and the inundation and water-logging of productive land undermines agriculture by delaying planting, reducing yields, and compromising the quality of crops, especially if the rains occur around harvest time


Photo: NBI

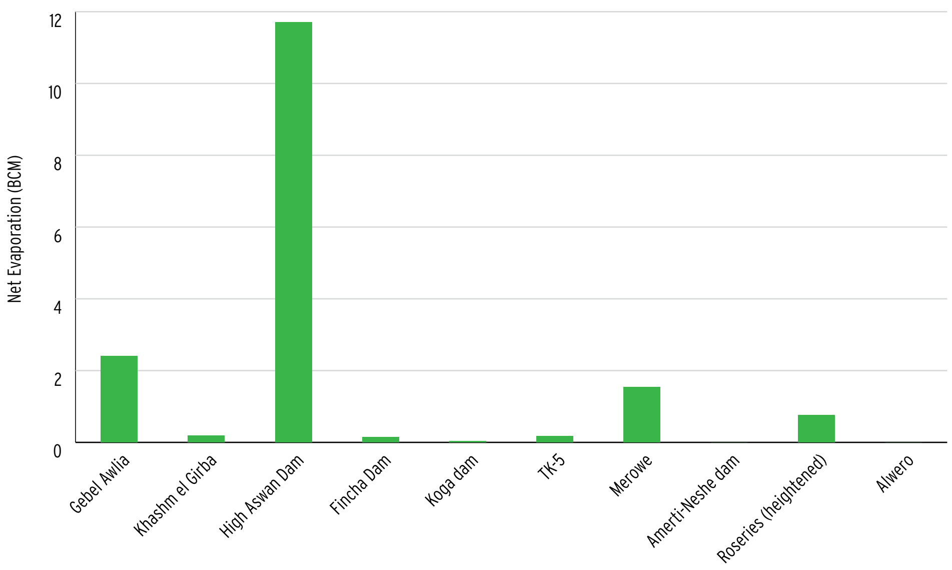
GERD dam under construction

Evaporation from Dams along the Nile

On the average an estimated 17.6 BCM of water evaporates from major dams in the Nile Basin. Net evaporation from dams is defined as the year total of evaporation from the dams reduced by the annual total of precipitation on the reservoir surface. As example, an estimated 10 – 12 BCM are lost through evaporation each year from the High Aswan Dam (HAD).

Due to its large reservoir surface area and the hot climate, the High Aswan Dam has the biggest net annual evaporation followed by Jebel Aulia dam. In most upstream dams, the net evaporation is very small due to partly the relatively cool/temperate climate and high rainfall. This is the case, for instance, for most Ethiopian dams.

Net Evaporation from Dams (BCM/year)



Net Evaporation from selected dams on the Nile

Dam	Period	Net Evaporation (BCM)
Gebel Awlia	1950 - 2014	2.4
Khashm el Girba	1964 - 2014	0.19
High Aswan Dam	1970 - 2014	12.35
Fincha Dam	1973 - 2014	0.14
Koga dam	2007 - 2014	0.04
TK-5	2009 - 2014	0.18
Merowe	2009 - 2014	1.54
Amerti-Neshe dam	2011-2014	0
Roseries (heightened)	2012 - 2014	0.75
Alwero	1995 - 2014	0

Hydro-electricity Power Generation in the Nile Basin Member States

Hydropower is one of the purposes most dams in the Nile Basin serve. The aggregate installed capacities of 22 hydropower plants basin-wide is approximately 5660 MW. The distribution of the existing hydropower installed capacity and annual generation capacity as of 2014 is shown in the figures below.

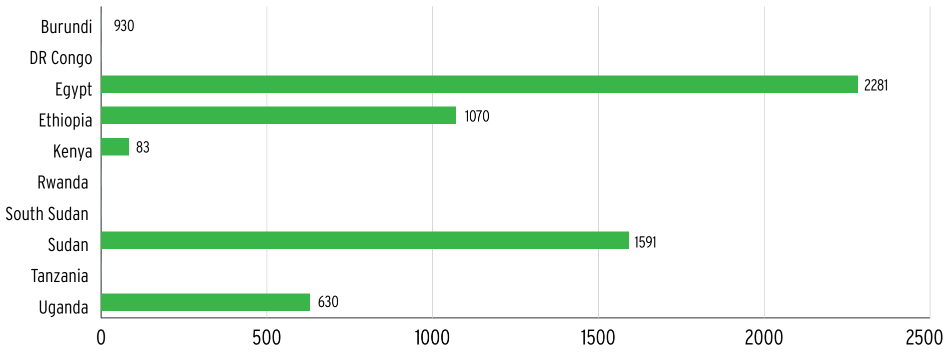
Hydropower offers an important low-carbon energy solution to meet the massive unmet demand and provides reliable base-load power in the Nile Basin states. Hydropower options remain the preferred source of energy in the region because they have long economic life which translates to very low per unit cost of energy and a renewable source of energy at that and with proper preparation of the reservoir, are pollution free and could be eligible for carbon credits

In the next section, details will be given on selected hydropower generation potential for the sub-basins of the Nile.

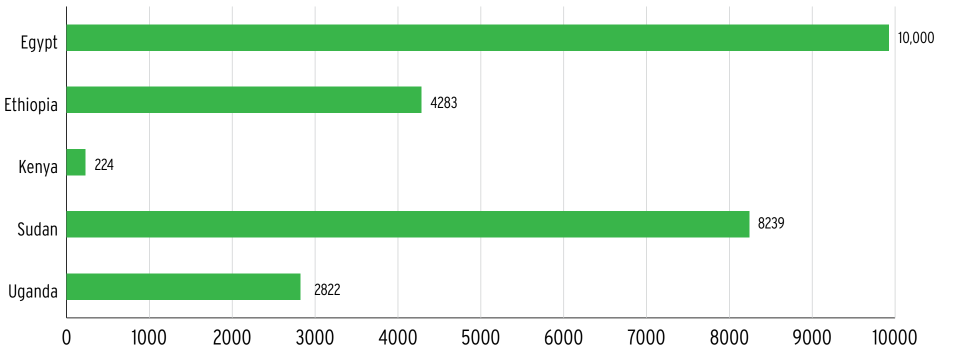

Photo: istock

Hydroelectric power plant in Aswan dam (Egypt).

Baseline Installed capacity (Hydropower) by Country (MW)



Energy generation by selected member states (GWH/year)



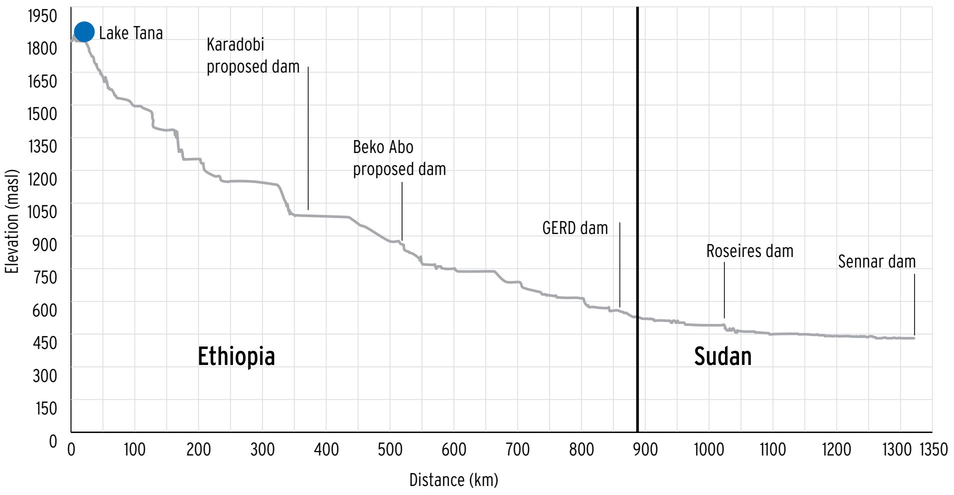
HYDROPOWER GENERATION POTENTIAL

Nile Basin's potential for hydroelectric power is quite substantial. The Blue Nile drops some 1,360-m between Lake Tana and its exit point into Sudan. Coupled with its substantial discharge, the Blue Nile has the largest hydropower potential in the Nile Basin. A number of sites with high hydropower potential have been studied in the past.

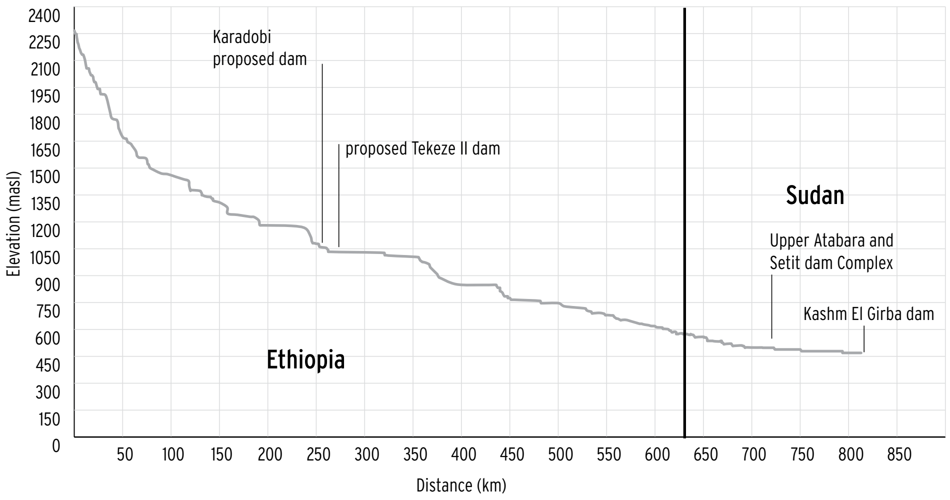
Photo: istock

Owen falls dam, Jinja Uganda

Blue Nile River Longitudinal Profile

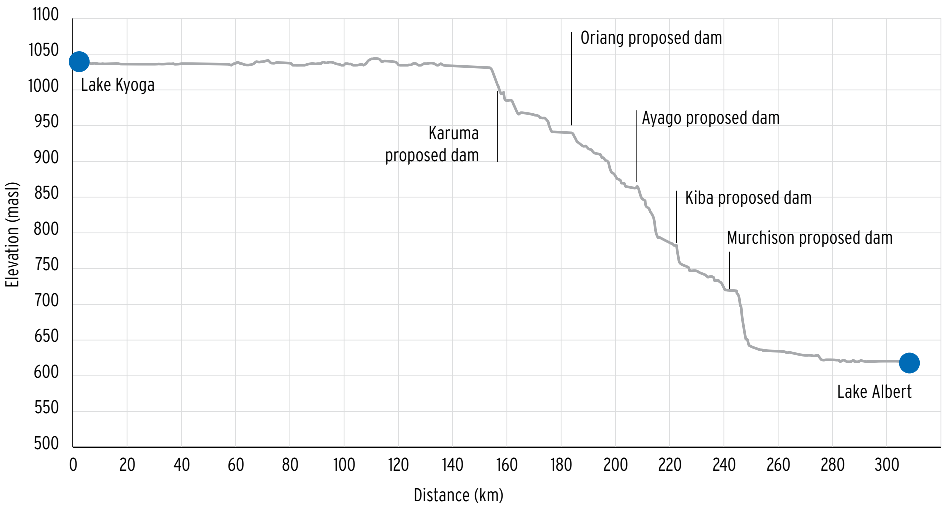


Tekeze-Atbara River Longitudinal Profile



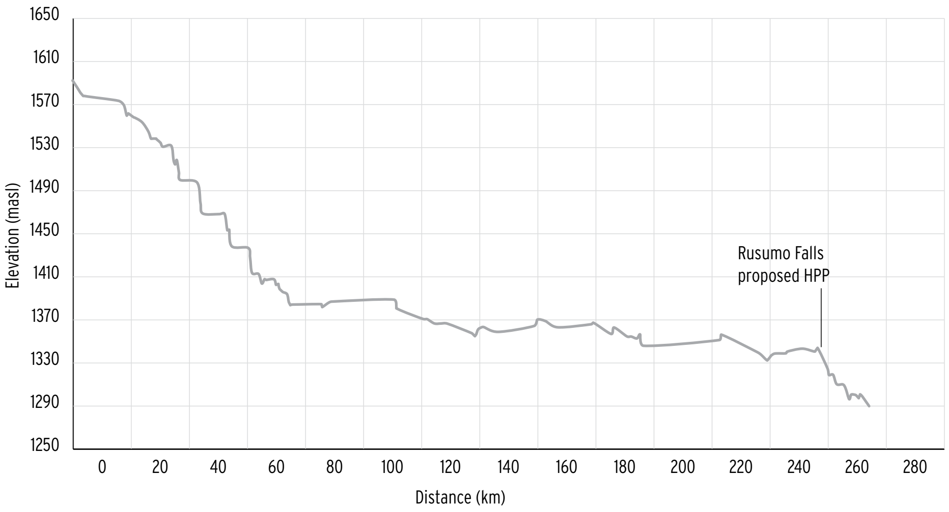
The Tekeze-Atbara river drops for about 1770-m between the Ethiopian highlands and Rumela-Burdana (Atbara Complex) dam on Atbara river. The identified potential hydropower site in the reach is Tekeze II (450 MW).

Victoria Nile Longitudinal Profile



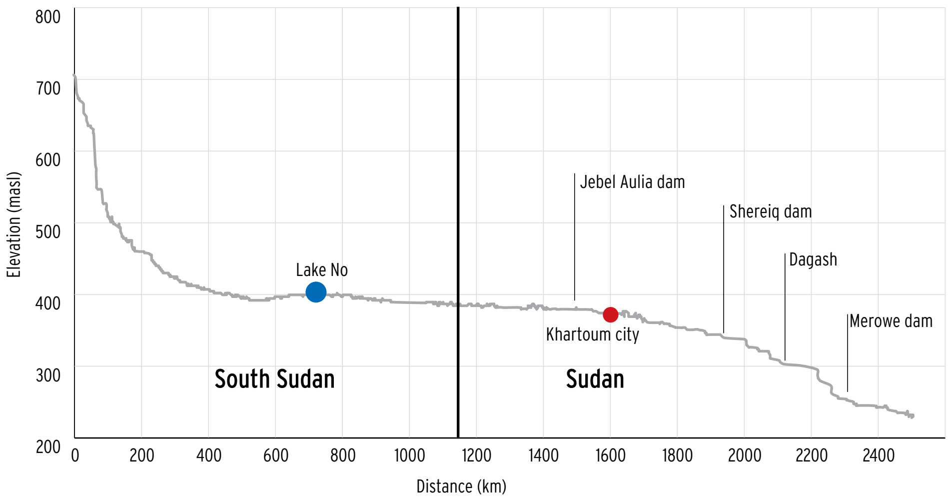
In the Nile Equatorial Lake Sub-basin, the Victoria Nile drops for about 415-m between Lake Kyoga and Lake Albert. The identified potential hydropower sites in the reach include Karuma (576 MW), Oriang (392 MW), Ayago (582 MW), Kiba (288 MW) and Murchison Falls (648 MW).

Ruvubu River Longitudinal Profile



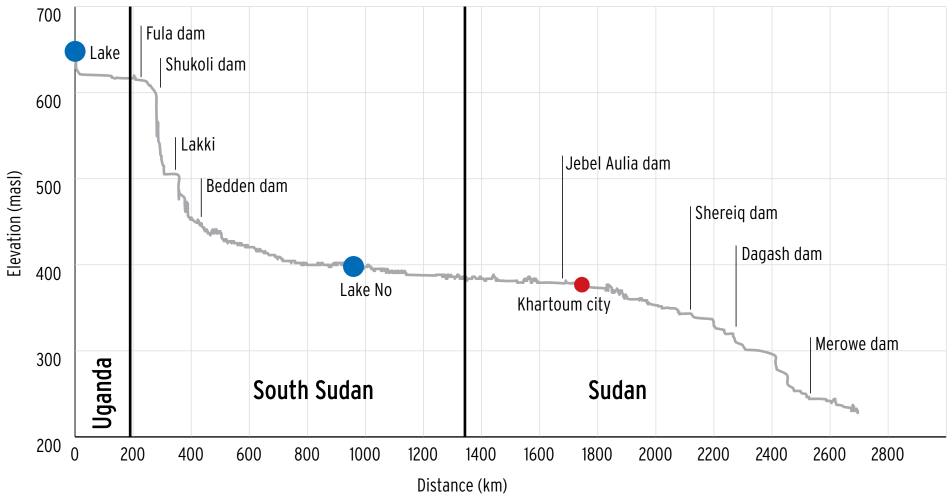
The Ruvubu river drops for about 300-m from upper Kagera mountains to the junction with the Nyabarongo river at Rusumo falls

Bahr El Ghazal river profile (originating Lol River to Lake No)



The Bahr El Ghazal is formed by a number of poorly defined streams. Many of these streams originate from the Nile Congo divide. The streams are Bahr El Arab, Lol, Jur, Gel, Tonj, Yei and Naam. Lol stream originates from the highlands at an altitude of about 700 masl and drops to about 400 masl before it joins other streams and forms Bahr El Ghazal river with confluence at Lake No with Bahr El Jebel. Lake No is a large shallow lagoon, where the sluggish Bahr el Ghazal joins the Bahr el Jebel.

Bahr El Jebel River Profile and downstream part of main Nile



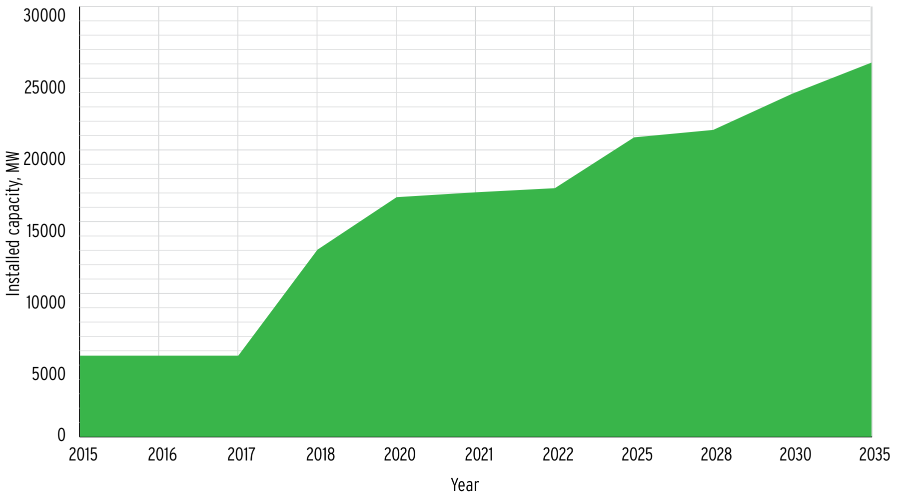
Bahr El Jebel River stretches a distance of about 1,000 km from the outlet of Lake Albert to the inlet of Lake No. The stretch has a drop of about 250m and has several potential hydropower sites such as Fula I, Shukoli, Lakki, and Bedden.

Projected increment in installed capacity

Looking into the future, existing national plans indicate a substantial increase in installed capacity in the period 2017 – 2050. Projected growth in aggregate installed capacity in the Nile Basin is shown in the adjacent chart. The total increase in installed capacity by about 2050 will be over 20,000 MW bringing the total installed capacity to about 26,000 MW.

Most of the increase is expected to be in the Blue Nile sub-basin. The GERD will inject 6000 MW of installed capacity. The Rusumo falls project, which is the first hydro-electric power project cooperatively implemented by Burundi, Rwanda and Tanzania with the facilitation of NBI will produce 81 MW.

Projected growth in total installed capacity of hp plants, MW



Power Plants in the Basin

Uganda's Bujagali Hydroelectric Power Plant Financing through Public-Private Partnerships[1]


Photo: www.akdn.org

Aerial view of the Bujagali plant

The project which was regionally identified through the NELSAP SSEA, will enhance power trade with neighboring Kenya, through the Nile Basin Planned Kenya-Uganda Interconnector.

Despite being one of Africa's fastest growing economies, Uganda had one of the lowest electrification rates in the world. Only 2% of its rural population had access to electricity, and the country suffered from frequent rolling blackouts - requiring expensive emergency generation, costing USD 9 million per month. In 2007, to meet these shortfalls, the government decided the least cost option - a USD 860 million hydroelectric power plant in Bujagali, 8 km down the Nile from Lake Victoria. However, it needed financiers and large hydropower developers to implement the project. The government established a public-private partnership called Bujagali Energy Limited, which would own the plant for a 30-year concessionary period before transferring it to Uganda.

The project which was regionally identified through the NELSAP SSEA, will enhance power trade with neighboring Kenya, through the Nile Basin Initiative Planned Kenya-Uganda Interconnector Multilateral lenders including the World Bank, the European Investment Bank, and the African Development Bank joined in with private financiers, such as South Africa's ABSA Capital and Standard Chartered Bank. Commissioning of the dam took place in August 2012. Today the 250 MW hydropower plant meets half of Uganda's energy needs. The project's construction created over 3,000 local jobs. Bujagali was registered in 2012 as a Clean Development Mechanism project, making it the largest ever registered in a Least Developed Country.

[1] International Renewable Energy Agency (IRENA)

Power Plants in the Basin- The Tekeze Hydroelectric Power Plant


Photo: ENTRO

The Tekeze Dam

The dam is located on the Tekeze River, a tributary of the Nile, in a mountainous region of Ethiopia. At 188m high, the Tekeze Arch Dam ranks as the highest dam in Africa, eclipsing the previous record height for an African dam of 185m held by the Katse Arch Dam in Lesotho. It generates 300 MW adding 40% energy to the 683 MW previously generated for the entire country. The dam impounds a 70-km-long reservoir. An underground powerhouse, containing four 75 MW Francis Turbines, is located 500 mm downstream from the dam and fed by a 75-m-high intake structure connected by a 500-meter-long concrete-lined power tunnel. A 105-km-long 230 kV double-circuit transmission line was constructed through rugged, mountainous terrain with minimal environmental impact to connect to the Ethiopian national grid.

REGIONAL INTERCONNECTION BACKBONE


Photo: istock

Panorama across Cairo skyline at night

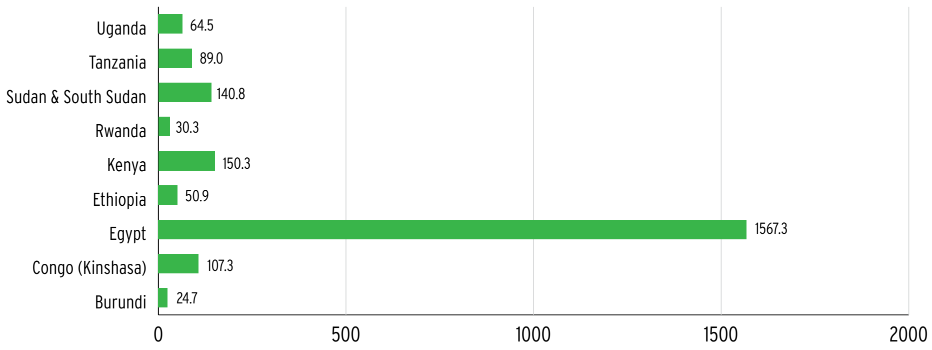
The Nile Basin Initiative promotes regional transmission interconnection projects in partnership with the Eastern Africa Power Pool. Such interconnection projects allow utilities to share reserve margins across a wider operating area, thus reducing the need for installed capacity to meet reserve requirements. Regional interconnection becomes even more important as the penetration of variable renewable energy grows. As example, the 500 kV HVDC Eastern Electricity Highway Project under the First Phase of the Eastern Africa Power Integration Program will allow Kenya to purchase relatively cheaper hydropower energy from Ethiopia and support Ethiopia's system when water is scarce.

Electricity Consumption

Electricity demand in much of the Nile Basin is constrained by available supply, resulting in people either not having any access or not being able to consume as much as they would like. Such unmet demand is not captured in electricity data and makes it difficult to measure electricity demand in a holistic sense.

Except Egypt, the Nile Basin member states all have a per capita electricity consumption which is lower than the initial threshold level of electricity consumption for rural households (250 kilowatt-hours per year). Investments are required in hydropower and transmission interconnectors, to raise the threshold to at 500 kWh per year (recommended for urban households).

Electricity net consumption (KWh/c), 2010



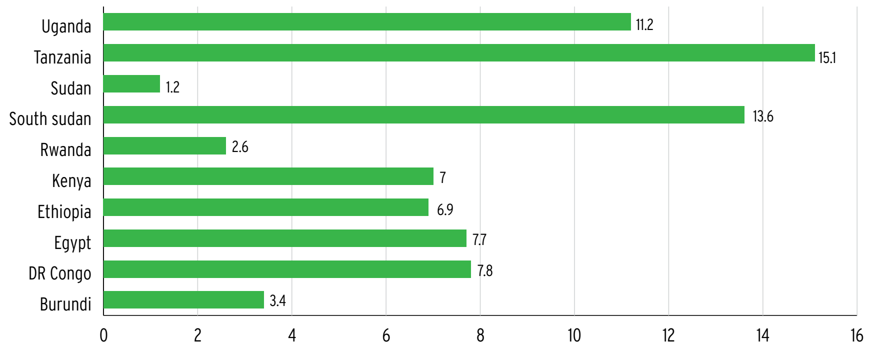
Source: US Energy Information Administration

Cost of Electrical Outages

Today, unreliable power services mean that businesses and factories are frequently interrupted, reducing profits and requiring an array of back-up sources. These often come in the form of diesel generators, which are polluting and require costly fuel inputs. The economic costs of power outages are substantial in the Nile basin partner states.

The immediate economic cost of power shortages can be gauged by looking at the cost of running backup generators and forgoing production during power shortages. As an example, the use of backup generators as a hedge against unreliable supply is estimated to cost the East African Economies of Kenya, Uganda and Tanzania, 2 %, 5% and 4% of GDP each year (AICD, 2012). Through Interconnectors, the distributed nature of renewable power generation can also help to alleviate the problem of power service unreliability.

Losses due to electrical outages as percentage of annual sales 2012



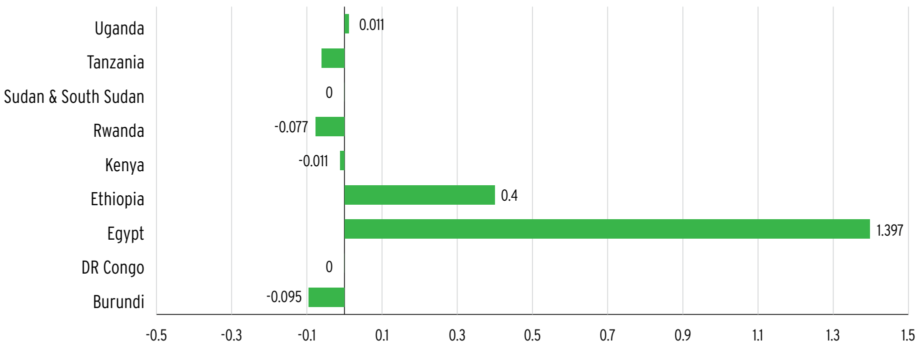
Source: US Energy Information Administration

Electricity Trade

The remote location of many Hydro Electric Power (HEP) plants (Victoria Nile, Bahr el Jebel or the Baro Akobo Sobat and Blue Nile systems) require new transmission infrastructure to connect power plants to load centers. Until recently, Nile Basin states developed their power systems largely independently of one another, focusing on domestic resources and markets, but there has been progress towards regional co-operation to permit concentrated resources, such as large hydropower, to serve larger markets. As shown in the adjacent chart, power trade within the Nile Basin is limited.

The transmission lines in the Ethiopia Power Trade project and the NEL Interconnector Project are being designed and built with a view to creating a backbone for enhanced future trade within the NBI region and with power blocks outside of it (such as SAPP to the south and the Maghreb to the north).

Net power trade (GWh), 2012



Source: US Energy Information Administration


Photo: istock

Electricity substation


Photo: Milly Mbuliro

Troder Bugoye Hydropower plant in western Uganda

Eastern Nile Power Export Project

The Ethiopia Power Export Project (formerly called the Ethiopia-Sudan Interconnection Project) connects the power grids of Ethiopia and Sudan and facilitates cross-border energy trade and optimizes existing and planned generation capacity. This is needed in order to overcome the severe electricity shortage in both countries, which is a major constraint to poverty reduction and economic growth. It is considered a first step toward greater regional power trade. Other Interconnectors promoted by the NBI include:

- Ethiopia and Kenya 500 kV HVDC interconnection transfer capacity 3.200 MW
- Ethiopia to Djibouti 220 kV (282km) interconnection
- Ethiopia to Sudan 230 kV transmission line (335 km) from Gambela in Ethiopia to Malakal in South Sudan
- Ethiopia – Kenya 500 kV HVAC (1045km)


Photo: Milly Mbuliro

Mpaga Hydropower plant

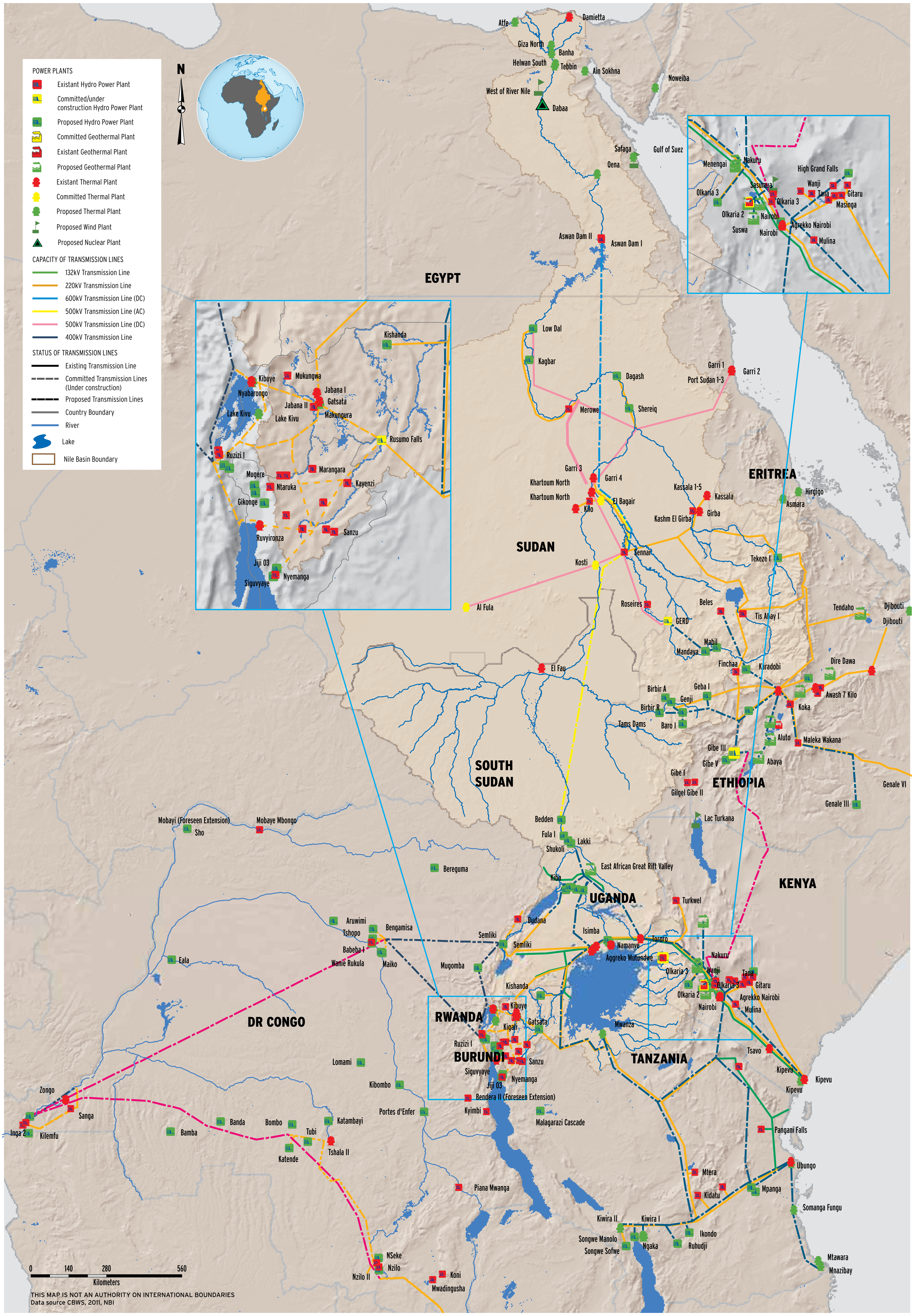
Nile Equatorial Lakes Power Export Project

Ethiopia has plans to increase electricity exports to Eastern Africa, based on new hydropower generation, and construction is underway to boost interconnections with Kenya. Rwanda –Burundi and eastern DRC. The present facilitated investments are expected to add more than 4600 circuit kilometers of new transmission lines at various voltage levels in the partner states of Ethiopia, Uganda, Kenya, Tanzania, Rwanda, Burundi, DRC, South Sudan, and Djibouti (outside NBI). The regional transmission network backbone for Victoria Lake countries includes:

- Kenya (400kV) - Uganda (220 kV) interconnections (260.5km)
- Uganda - DR Congo 220 kV interconnection (352km)
- Uganda - Rwanda 220 kV interconnection (164km)
- Rwanda – Burundi-DRC 220 kV interconnection (400km)
- Kenya - Tanzania 400 kV interconnection (507.5km)
- Tanzania (Iringa-Mbeya)- Zambia (Kabwe) 400kV Interconnector to SAPP (1247km)

Longer-term NBI ambitions for significant electricity trade are predicated on developing the substantial hydropower resources of the DR Congo (particularly Inga with 40,000 MW of potential in a single site) and of Ethiopia and Sudan.

REGIONAL POWER TRANSMISSION IN THE NILE BASIN



THIS MAP IS NOT AN AUTHORITY ON INTERNATIONAL BOUNDARIES
Data source CBWS, 2011, NBI

IRRIGATION IN THE NILE BASIN

Overall, agriculture dominates all other water uses in the basin, accounting for more than 80% of water withdrawals (Timmerman 2005, Karyabwite 2000, FAO 2011b). The total equipped area in the Nile Basin is estimated at 5.4 million hectares. Actual cropped area is estimated at 6.4 Million hectares. The cropped area is variable depending on what percentage of the irrigation equipped areas is covered by crops in any given year and whether more than one crop is planted. In most Nile Basin countries, the cropped area is much less than the area equipped for irrigation.

Egypt has the highest cropping intensity (cropped area divided by equipped area). Due to higher cropping intensity, approximately 79% of the total cropped area under irrigated agriculture in the Nile Basin lies in Egypt. The equipped irrigated area is dominated by the large schemes in Egypt (3.45 million ha) and Sudan (1.764 million ha), while in the remaining parts, only relatively small areas of irrigation have so far been developed. In Egypt, the use of double cropping means that the effective area in production is greater than the total area of land under irrigation. The vast majority of the irrigation water requirements are supplied from surface water. The table below shows estimated equipped and crop areas across the Nile riparian states.

The Growing agricultural production will further increase pressure on land and water resources. A realistic assessment of future food requirements is therefore essential for Nile Basin governments to take informed decisions about agricultural planning and water resource use. In most of the Nile Basin countries, irrigation systems use surface gravity method of water application where water is conveyed through open canals and finally distributed over the irrigation fields by gravity. However, some pressurized irrigation is practiced in Egypt, Sudan and in some schemes in Ethiopia, Kenya and Uganda. In all countries except Egypt and, to some extent in Sudan, there are no drainage systems whereby excess water is removed from the irrigation fields.

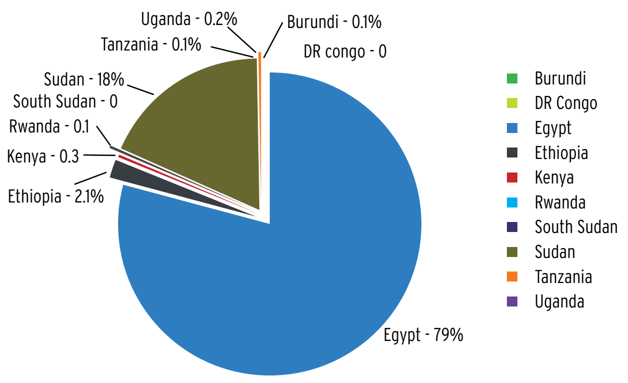

Photo: istock

Tea Plantation

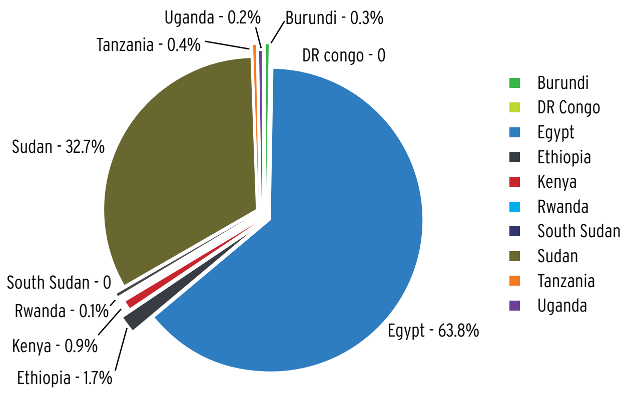
Estimated equipped and crop areas across the Nile riparian states

Country	Equipped Area ('000 ha)	Equipped Area (% of total)	Cropped Area ('000 ha)	Cropped Area (% of total)
Burundi	15.3	0%	8.7	0%
Dr Congo	0	0%	0	0%
Egypt	3447	64%	5021	79%
Ethiopia	91	2%	134	2%
Kenya	47.8	1%	20	0%
Rwanda	7	0%	7	0%
South Sudan	0.5	0%	0.15	0%
Sudan	1764.63	33%	1146.7	18%
Tanzania	19.753	0%	6.464	0%
Uganda	9.7	0%	9.7	0%
Total	5402.683	100%	6353.714	100%

Cropped Area (% of total)



Equipped Area (% of total)



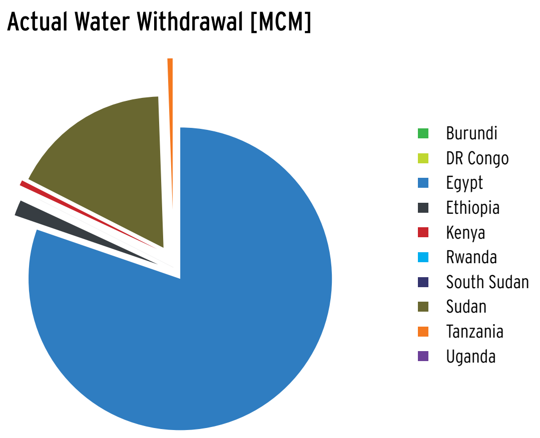
Water Withdrawal for Irrigation in the Nile Basin

On average 82 Billion Cubic Meter (BCM) of water is withdrawn from Nile waters every year for irrigation where approximately 8.6 BCM is re-used drainage water in Egypt. An estimated 80% of the irrigation water abstraction in the Nile Basin occurs in Egypt followed by Sudan (about 17% of the total basin-wide abstraction for irrigation). The total abstraction for irrigation in the rest of the Nile Basin countries is estimated at 3%. In most countries, there are no appreciable deficits in meeting the total annual irrigation requirements. In few upstream countries, due to lack of adequate water storage facility, lower irrigation water demand satisfaction rate have been estimated.

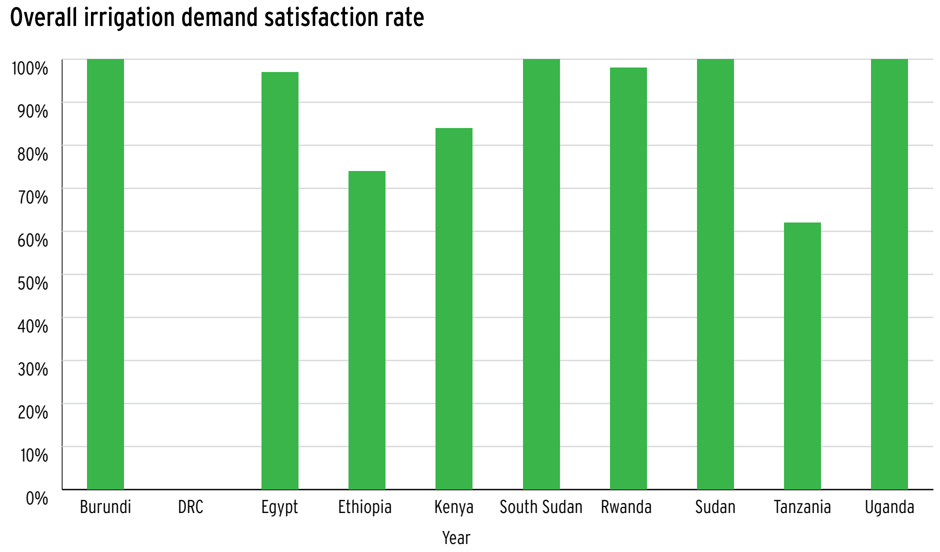
In the next section, details will be provided on irrigation practices in the Nile Basin countries

Water withdrawals (MCM)

Country	Withdrawal requirement	Actual Withdrawal
Burundi	28.9	28.7
DRC	0.0	0.0
Egypt	66551.5	66054.0
Ethiopia	2018.2	1500.9
Kenya	367.4	307.5
South Sudan	3.4	3.2
Rwanda	58.6	57.4
Sudan	13959.8	13921.6
Tanzania	102.2	63.4
Uganda	260.4	260.3
Total	83350.4	82197.0



Country	Unmet Demand [MCM]
Burundi	0.132
DRC	0.000
Egypt	499.379
Ethiopia	517.336
Kenya	59.874
South Sudan	0.000
Rwanda	0.853
Sudan	38.258
Tanzania	38.821
Uganda	0.054
Total	1154.708



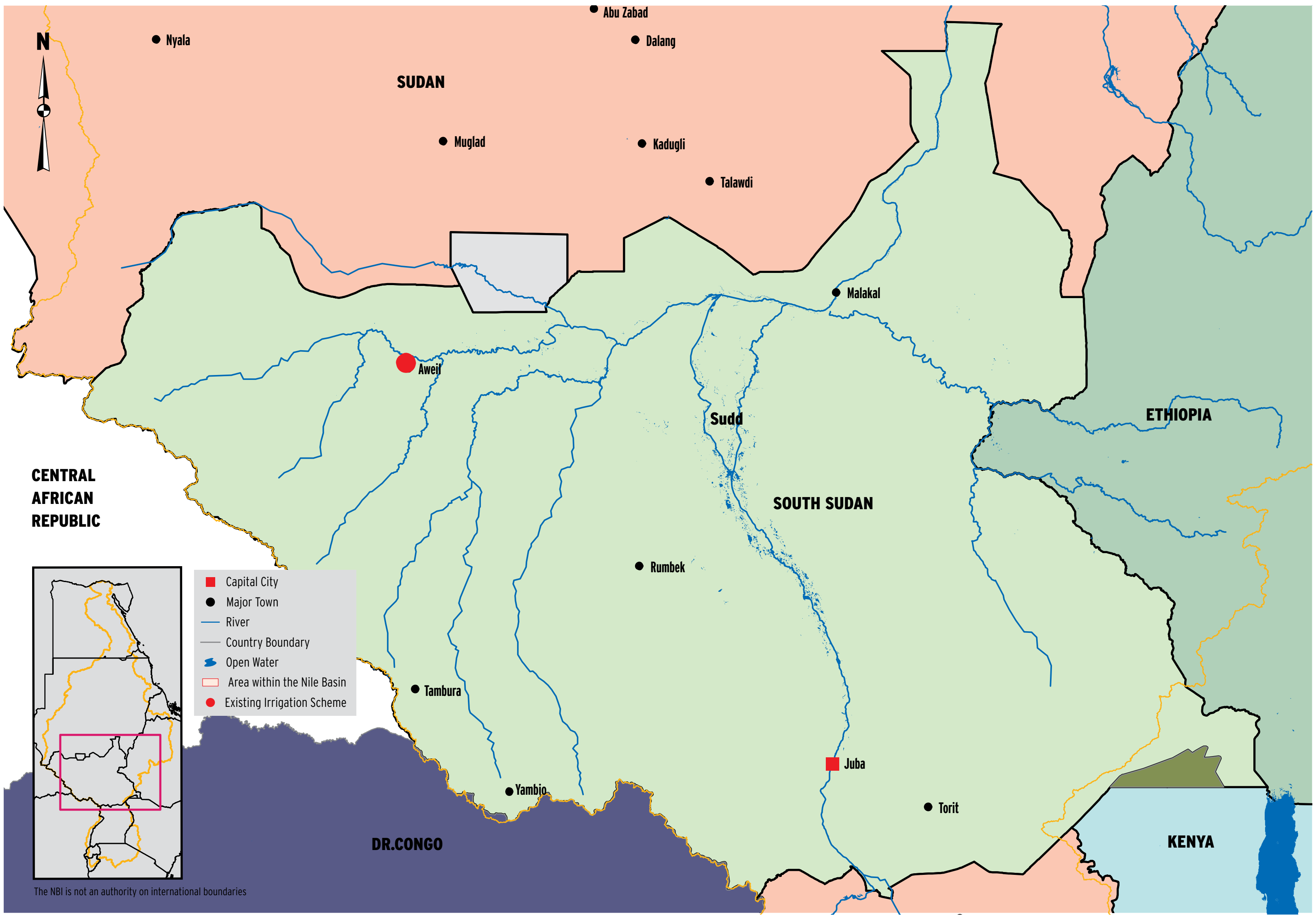
Irrigation areas in South Sudan

Infrastructure for irrigated agriculture in South Sudan is yet to develop. Currently, there is one irrigation scheme, the Aweil scheme located in the southern bank of the Lol river, with a total equipped area of 500 ha and an estimated cropping intensity of 30%. The main crop cultivated is rice. The total annual water demand is estimated to be 3.4 MCM with all the water coming from Lol River.

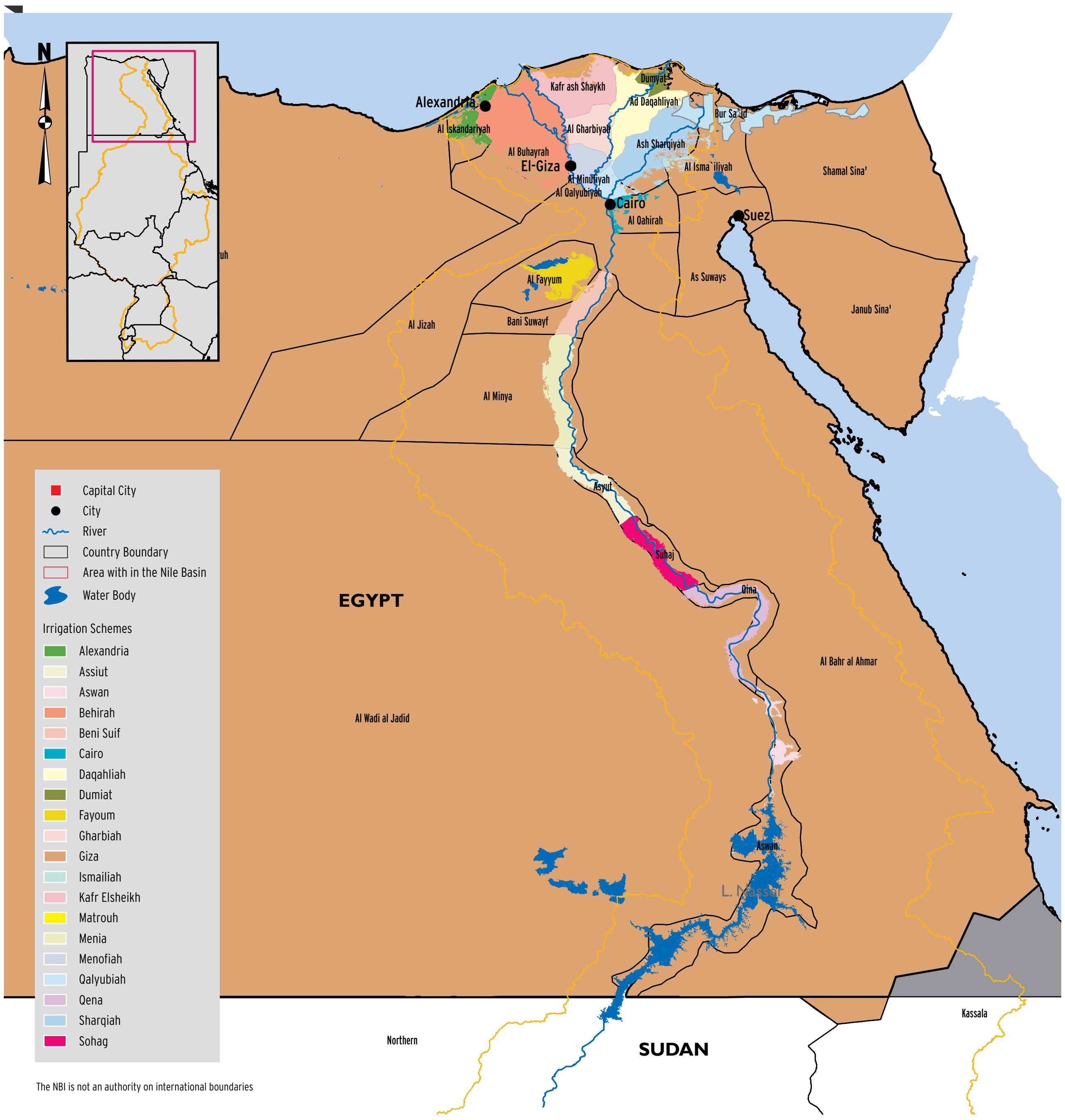

Photo: Robert Zakayo

Main canal in Aweil rice scheme during dry season


Secondary canal in Aweil rice scheme during dry season



Irrigation areas in Egypt



The NBI is not an authority on international boundaries

Area equipped for irrigation by governorate

S.No.	Governorate	% of total irrigation area
1	Janub Sina (South Sinai)	0.1%
2	As Suways (Suez)	0.2%
3	Al Qahirah (Cairo)	0.2%
4	Bur Said (Port Said)	0.3%
5	Al Jizah (Giza), West	0.3%
6	Dumyat (Damietta)	1.3%
7	Al Wadi/Al Jadid	1.5%
8	Shamal Sina (North Sinai)	1.7%
9	Aswan	1.8%
10	Al Iskandariyah (Alexandria)	1.9%
11	Al Jizah (Giza), East	2.2%
12	Al Qalyubiyah (Kalyoubia)	2.3%
13	As Ismailiyah (Ismailia)	2.6%
14	Beni Suwayf (Beni-Suef)	3.4%
15	Suhaj	3.8%
16	Al Minufiyah (Menoufia)	3.9%
17	Matruh	4.0%
18	Asyiut	4.1%
19	Qina	4.6%
20	Al Gharbiyah (Gharbia)	4.8%
21	Al Fayyum (Fayoum)	5.3%
22	Al Minya (Menia)	5.9%
23	Kafr-El-Sheikh	7.8%
24	Al Daqahliyah (Dakahlia)	7.8%
25	Ash Sharqiyah (Sharkia)	9.8%
26	Al Buhayrah (Behera)	18.2%

Photo: Terry Feurborn

Nile Valley, Egypt

The data on irrigated agriculture in Egypt has been compiled from NBI projects and global data sources notably from FAOSTAT (FAO). These values haven't been validated with ground observation as this was not available at the time of preparing the Atlas. Egypt has the largest irrigation area among Nile Basin countries. The total area equipped for irrigation in Egypt is estimated at 3.45 million hectares (3.4% of the total area of the country) and a cropped area estimated at about 5 million hectares. 85% of this is in the Nile Valley and Delta. The estimated cropping intensity is 146%. The irrigation system in the old land of the Nile Valley is a combined gravity and water lifting system (lift: about 0.5-1.5 m).

Most of the water used in irrigation in Egypt is surface water with some water taken from groundwater sources. Estimates of water used for irrigation by NB states based on globally available data sources show that an average of 66 BCM per year is used for irrigation where 57 BCM per annum is supplied from the Nile while the remaining 8.5 BCM supplied from groundwater and re-use of drainage water from agricultural fields.

The irrigation system in the new lands (reclaimed areas) is based on a cascade of pumping stations from the main canals to the fields, with a total lift of up to 50 m. Surface irrigation is banned by law in the new reclaimed areas, which are located at the end of the systems, and are more at risk of water shortage. Farmers have to use sprinkler or drip irrigation, which are more suitable for the mostly sandy soil of those areas. Egypt's irrigation system extends some 1,200 km. from Aswan to the Mediterranean Sea and includes 2 storage dams at Aswan (the Low and High Aswan Dams), 7 major barrages on the Nile that divert river water into an extensive network of irrigation canals. This includes 13,000 km of main public canals, 19,000 km of secondary public (Branch) and 100,000 km of tertiary private watercourses (mesqas) that form the main distributaries to farmer's fields. Complimentary drainage networks cover about 272,000 km with 17,500 km of main drains, 4,500 km of open secondary drains and 250,000 km of covered secondary & tile drains. Holdings average less than 1.9 fed (0.8 ha) one of the lowest in the world. The most limiting resource for Egyptian agriculture is irrigation water. Management of its water resources has always been a central feature of the country's development strategy.

Irrigation areas in Burundi

A total of about 8737 hectares of land is equipped for irrigation in Burundi. Nearly all areas are cultivated rice. The total annual estimated water use for irrigation for all schemes is estimated at 29 Million cubic meters per annum.

District	Equipped (ha)
Gitega	1186.47
Karusi	1857
Kyanza	1200.4
Kirundo	1413
Muramya	185.4
Muyinga	731.5
Mwaro	20
Ngozi	2144
	8737.77

Irrigation areas in Ethiopia

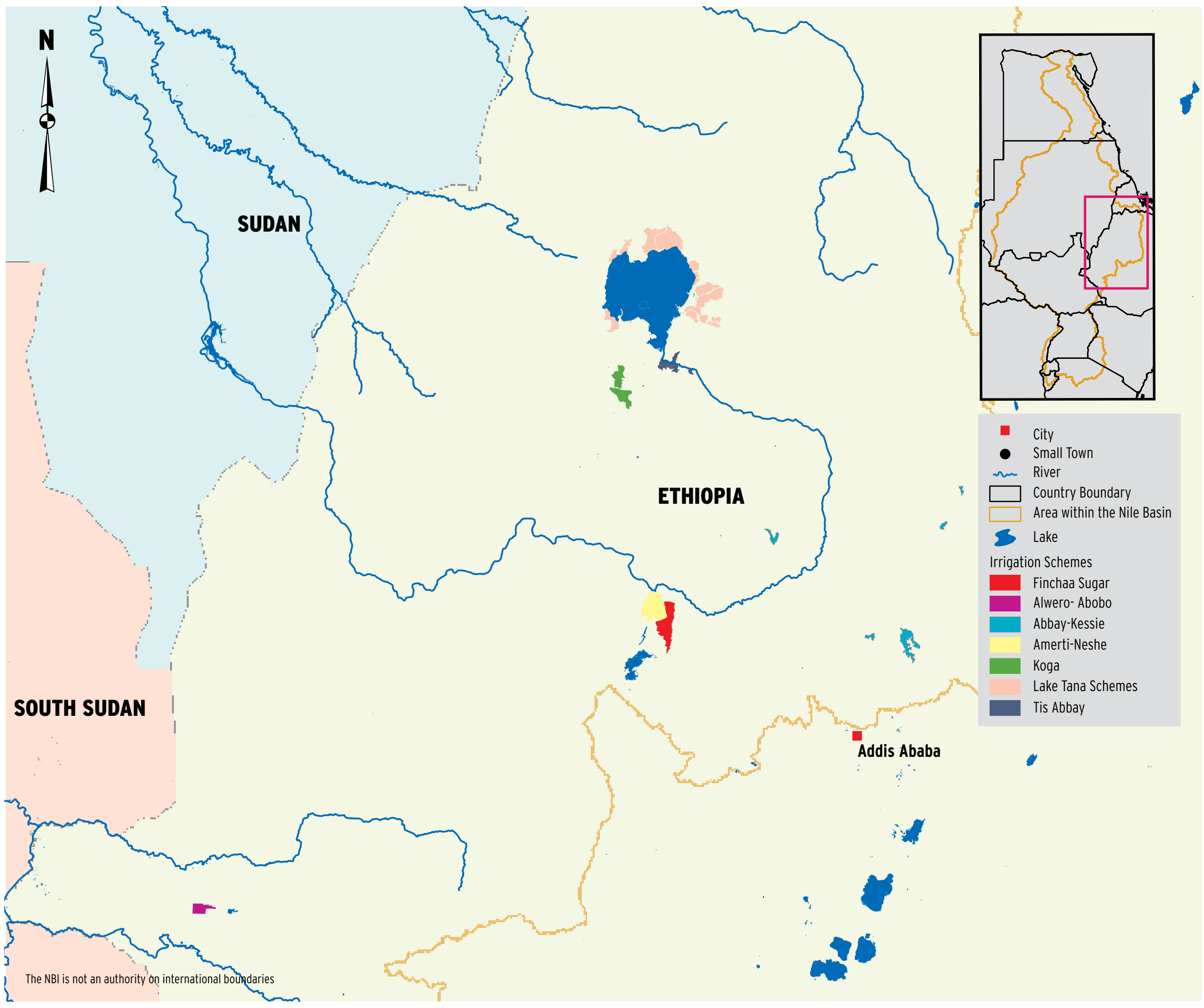
While small-scale individual farmer managed irrigation in Ethiopia has a relatively long history, large scale irrigation started in the 1970s as part of the government owned state farms. Broadly, irrigation schemes in Ethiopia can be of any of the following four types:

- traditional small-scale schemes of up to 100 ha in area, built and operated by farmers in local communities
- modern communal schemes of up to 200 ha, built by Government agencies with farmer participation
- modern private schemes of up to 2,000 ha, owned and operated by private investors individually,
- in partnership, or as corporations
- public schemes of over 3,000 ha, owned and operated by public enterprises as state farms

The total area equipped for irrigation in Ethiopia in the Nile Basin is about 91,000 ha. All except one scheme lie in the Blue Nile sub-basin. Lying in relatively high rainfall area, irrigation of these areas is supplemental where the rainfall is expected not to meet the crop water requirements. Nearly half (46%) of the irrigation area depends on the flow of the Blue Nile without a storage facility that would regulate the highly seasonal flows of the river. As a result, the schemes face shortage of water during the dry season. With the exception of the Fincha irrigation scheme, which uses sprinkler system, all irrigation in Ethiopia in the Nile Basin relies on surface – gravity method for water conveyance and application.

Both irrigated and rain fed agriculture are important in the Ethiopian economy but virtually all food crops are rain fed with irrigation accounting for only about 3%. Export crops such as coffee, oilseed and pulses are mostly rain fed but industrial crops such as sugar cane, cotton and fruit are irrigated. Other irrigated crops include vegetables, fruit trees, maize, wheat, potatoes, sweet potatoes and bananas. Sugarcane is mainly cultivated as part of the Fincha sugar estate that also includes the Amerti-Neshe scheme. Overall, pulses make most of the crop cultivated in the irrigated systems

There is a marked value added in irrigated agriculture. The total estimated annual water use for irrigation in Ethiopia is estimated at 1.5 BCM. Growing population pressure in the highland areas of rainfed agriculture on a rapidly declining natural resource base has secured irrigated agriculture a prominent position on the country's development agenda.



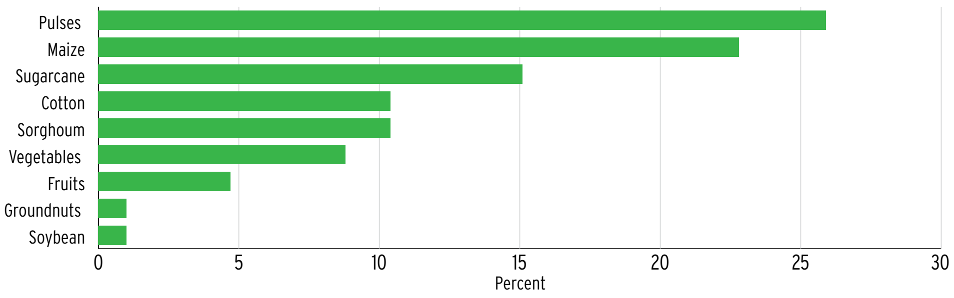
Irrigation Schemes

Scheme Name	District (Level 3)	Water Source	
		Type	Name
Koga	Merawi	Dam	Koga
Neshe	Abay Chomen	Dam	Amerti
Fincha Sugar	Abay Chomen/Guduru	Dam	Fincha
Lake Tana	Several	Lake	Lake Tana
Tis Abbay	Bahir Dar Zuria	River	Blue Nile
Us/ Abbay@Kessie	Several	River	Blue Nile
Abobo	Abobo	Dam	Alwero

Cropped Area

Crop	Area (Ha)
Groundnuts	1261.848
Soybean	1261.848
Fruits	5878.85
Vegetables	11011.848
Cotton	13000
Sorghum	13000
Sugarcane	19009.6
Maize	28628.85
Pulses	32500
Total	125552.844

Percentage area per crop



Irrigation areas in Kenya

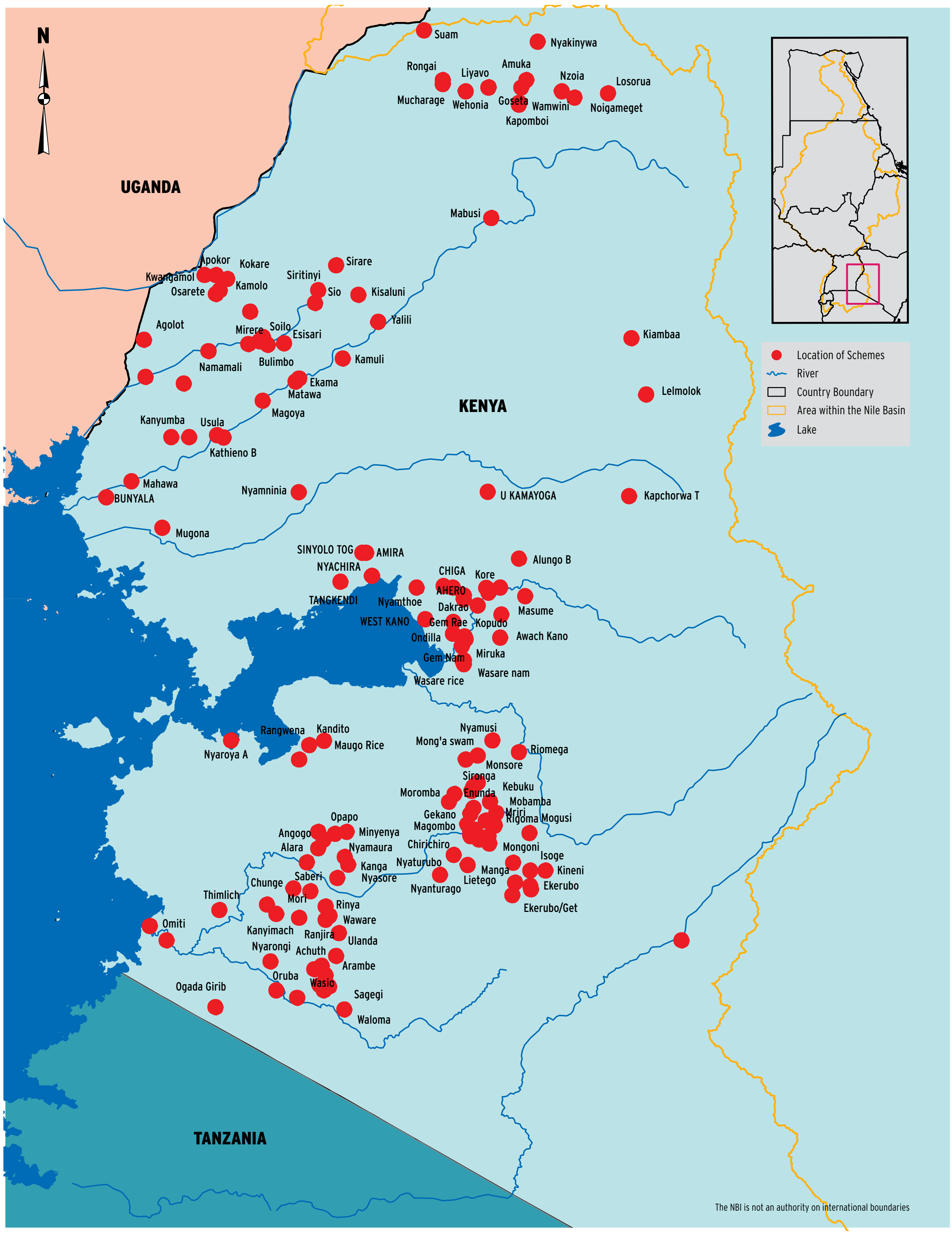
The total area equipped for irrigation in the Nile Basin parts of Kenya (Lake Victoria North and Lake Victoria South Catchments) is about 47500 hectares while the cropped area is on the average 20000 hectares. Most of these schemes are less than 300 ha in size. In 1957 some 1,691 hectares of this were under irrigation and by 2003, this had risen to 10,700 ha but this still represents only 5% of the irrigation potential in the Kenyan part of the Lake Victoria basin.

Public and Private Irrigation schemes in the Kenyan Nile basin include West Kano, Ahero and Bunyala irrigation schemes. Yala swamp development is being undertaken by a private investor called Dominion Farms Limited. The total annual average irrigation demand is estimated at about 367 MCM. The actual water use is estimated to be 307 MCM. The scheme level water supply reliability ranges from 66% for Sare to 100% for Nzoia downstream scheme.

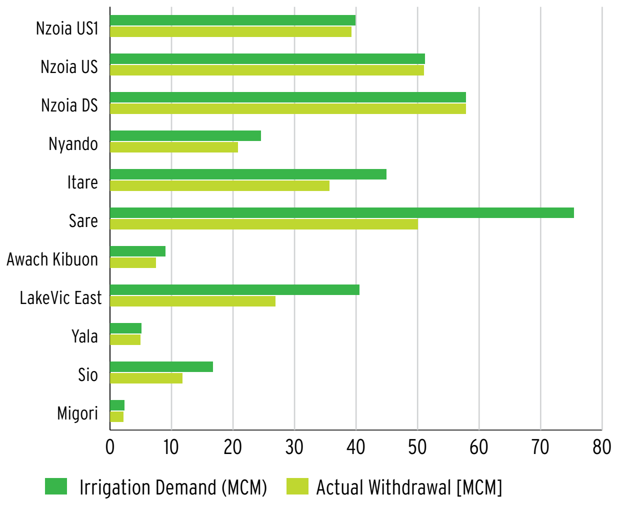
Almost all irrigation is achieved through run of river developments although water pans and small dams have been built the former being located in the medium potential zones. Basin, furrow and flood irrigation methods are used in most community irrigation schemes with sprinkler and drip being used on some private farms especially for the cultivation of flowers and horticulture crops. Greenhouses are used by commercial flower growers and also by some small-scale farmers in Kericho and Eldoret. The simple greenhouses are constructed from clear plastic material and are built on to timber structures. They cover on average ¼ acre and are irrigated by drip.

The total estimated irrigation water demand for all schemes is about 367 MCM and actual abstraction estimates lie at 307.5 MCM, which indicates a volumetric demand satisfaction rate of about nearly 84%.

The major constraints and challenges to accelerated irrigation and drainage development in Kenya include: (i) Inadequate Public and Private sector Investment in the sector; (ii) Inadequate development of irrigation infrastructure and water storage facilities; (iii) Weak Irrigation Water Users' Associations (IWUAs); and (iv) Inadequate support services.



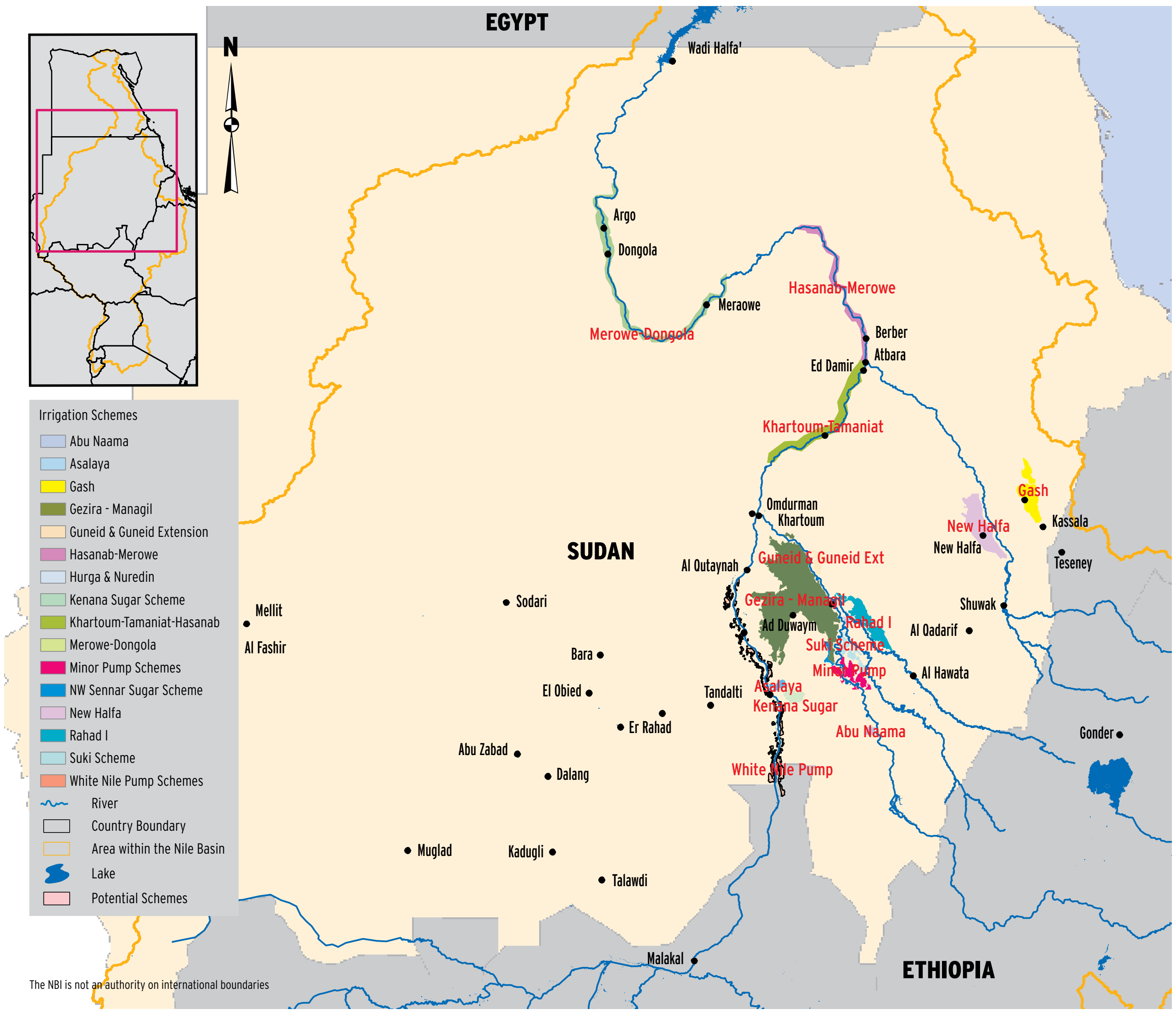
Irrigation Demand and estimated actual water use



Irrigation Water Demand, Kenya

Scheme	Net Irrigation Requirement	Irrigation Demand (MCM)
Nzoia US1	20	40
Nzoia US	25	51
Nzoia DS	28	58
Nyando	12	24
Itare	22	45
Sare	37	75
Awach Kibuon	4	9
LakeVic East	20	41
Yala	2	5
Sio	8	17
Migori	1	2
Total	180	367

Irrigation areas in Sudan



The NBI is not an authority on international boundaries

Scheme Name	Cropped (Ha)	Equipped (Ha)
Blue Nile System	9,09,652	13,19,176
Abu Naama	0	12,600
Pump schemes u/s of Sennar (inlcuding Shashena)	56,700	75,600
Hurga and nour-el-deen (Pump schemes as part of gezira)	9,352	42,000
Genaid (Sugar)	16,800	22,400
Seleit	6,300	12,600
Small Private Pump Schemes (through out blue nile)	75,000	1,00,000
Waha (Blue Nile)	9,450	12,600
Gezira - Managil (Al Jazira); c	5,88,000	8,46,720
Rahad I	98,700	1,26,000
Suki Scheme (Old and new)	28,350	37,800
NW Sennar Sugar Scheme	14,700	22,456
Guneid Extension (haddaf/wadel faddul)	6,300	8,400
White Nile System	79,413	1,40,259
Kenana Sugar Scheme	29,988	39,984
Kenana - mixed crop	4,725	6,300
Asalaya (sugar)	14,700	18,375
White Nile Pump Schemes	30,000	75,600
Atbara System	88,200	2,10,000
New Halfa	75,600	1,94,250
New Halfa Sugar	12,600	15,750
Main Nile System	71,400	95,200
Merowe - Dongola; Main Nile Pump schemes	31,500	42,000
Hasanab - Merowe	8,400	11,200
Khartoum_Tamaniat_Hasanab	31,500	42,000
Total	11,48,665	17,64,635

Sudan has the largest irrigated area in sub-Saharan Africa and the second largest in all Africa, after Egypt. The total estimated area fully equipped for irrigation is 1,764,635 ha and an estimated cropped area of 1,148,665 ha, i.e. an estimated cropping intensity of 65%. The irrigated sub-sector contributes more than 50% of the total volume of the agricultural production although the irrigated area constitutes only about 11% of the total cultivated land. It has become more and more important over the past few decades as a result of drought and rainfall variability and uncertainty.

The irrigated sector produces 95% of the long stable high quality cotton produced, 100% of sugar production, 36% of sorghum and 32% of groundnuts. Other main irrigated crops are fodder, wheat and vegetables with other crops comprising maize, sunflower, potatoes, roots and tubers and rice.

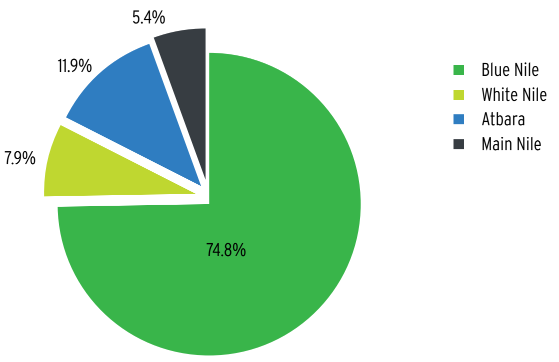
Irrigated agriculture falls into two broad categories: traditional and modern schemes. Traditional irrigation is practiced on the floodplains of the main Nile downstream of Khartoum and on substantial areas along the Blue and White Nile, and the Atbara river as well as on the Gash and Tokar deltas. Many schemes are fully equipped with infrastructure but have low cropping intensity due to scarcity of water during the long dry season.

Large-scale gravity irrigation started more than 100 years ago and was characterized by the promotion of cotton production in the Nile Basin. Irrigation by pumping water began at the beginning of the 20th Century, substituting traditional flood irrigation and water wheel techniques.

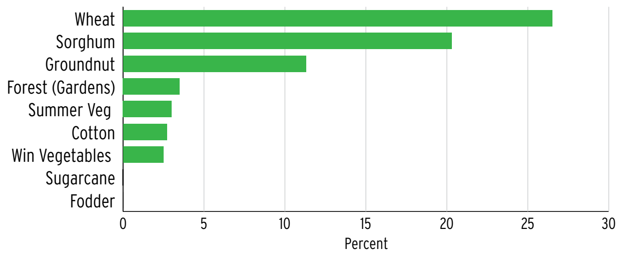
The Gezira Scheme is Sudan's oldest and largest gravity irrigation system, located between the Blue Nile and the White Nile. The scheme together with its extension of Managil scheme with a total equipped area of 846,772 ha is the largest single scheme in Sudan and one of largest irrigation schemes in the world. Nearly 75% of the total irrigation area is in the Blue Nile sub-basin in Sudan. Started in 1925 and progressively expanded thereafter, it receives water from the Sennar Dam on the Blue Nile and is divided into some 114 000 tenancies.

The total net abstraction of water for irrigation from the Nile system is estimated at 13.3 BCM per year. The lion's share of this amount is taken by the Gezira – Managil scheme with an estimated withdrawal of nearly 6.5 BCM followed by the New Halfa scheme with annual net abstraction of about 1.5 BCM.

Percentage equipped area by sub-basin



Distribution of area equipped for irrigation - kenya



Irrigation areas in Tanzania

There are approximately 64 schemes of irrigation with a total area of 19,753 ha in the Nile Basin parts of Tanzania. Most of the schemes are less than 200 ha and only 7 schemes have areas 1000 ha or greater. Main crops in most irrigation areas are maize, beans, rice and vegetables.

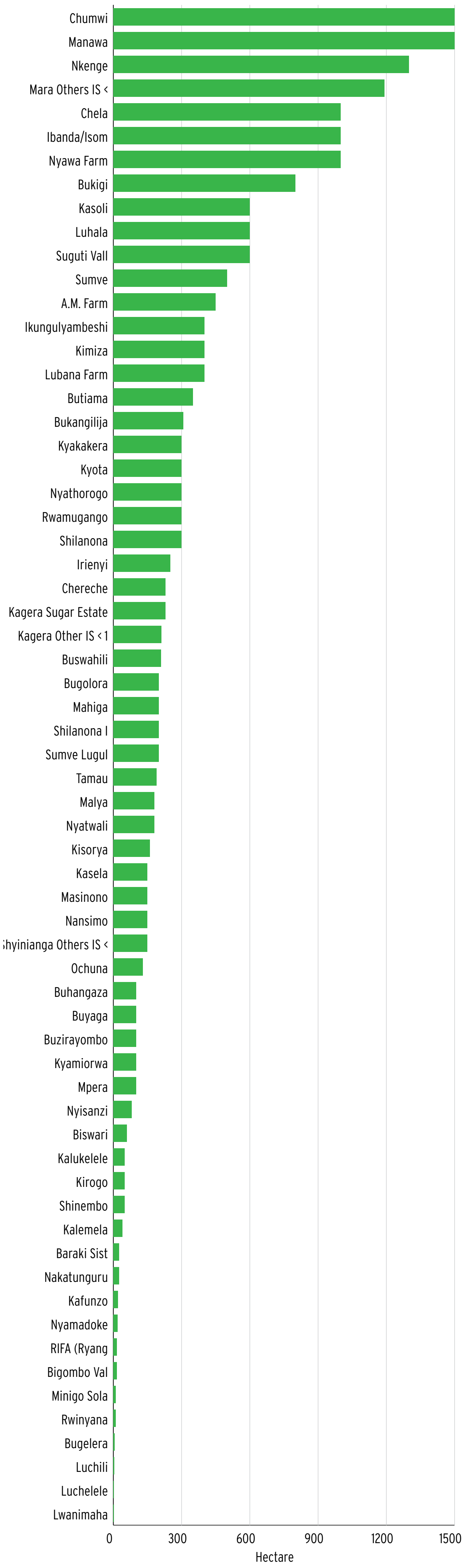
Almost all schemes are gravity-fed (99%) from surface sources with the remainder using pumps for water abstraction. Surface irrigation is practiced widely using furrows and basins with conveyance by both lined and unlined canals. Sprinkler irrigation is used by a few large-scale commercial farms with drip rarely used except on pilot schemes run by Government or in small-scale water harvesting.

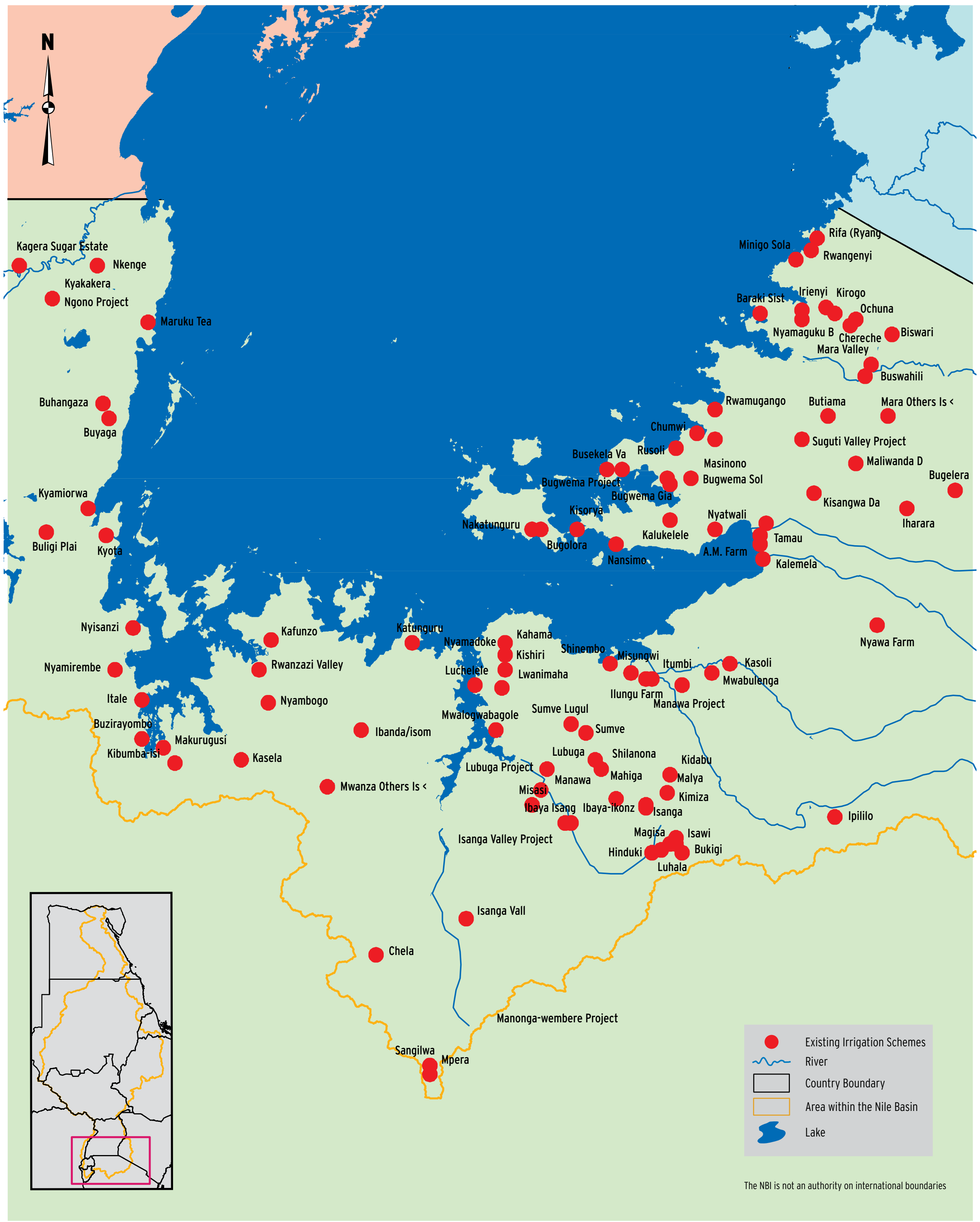
The main irrigated crops are paddy and maize, accounting for about 48% and 31% respectively of the irrigated areas in 2002. Other irrigated crops account for 44% of irrigated areas with an average cropping intensity of 123%. More recently government has been implementing irrigation schemes based on traditional rainwater harvesting technologies together with storage dams.

The average annual irrigation water demand is estimated at 102 MCM. The estimated annual volume of water used for irrigation is 63 MCM, which is about 62 percent of the annual irrigation water demand.

The major challenges to improved agricultural growth through irrigation as identified by the Ministry of Agriculture in the 2012 include (i) developing new sources of growth in response to markets, (ii) increasing farm productivity, (iii) improving agribusiness and processing to enhance rural employment, (iv) establishing producer incentives for export and food crops, (v) fostering the participation of the rural poor in agricultural growth and development, (vi) enhancing the sector investment climate, and (vii) improving public expenditures in the sector.

Distribution of Areas Equipped for Irrigation by Scheme



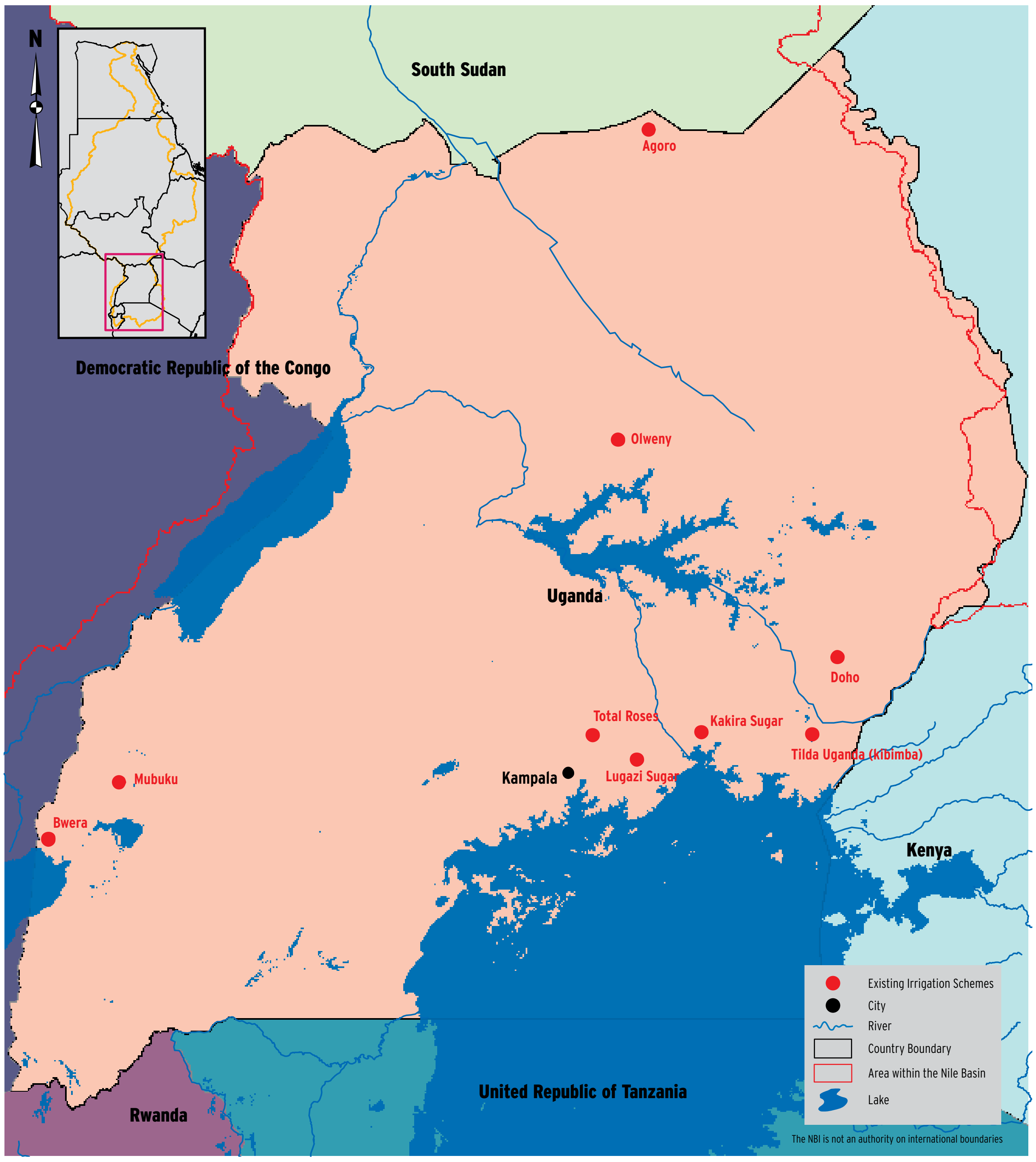


Irrigation areas in Uganda

Agriculture dominates the Ugandan economy. The average cropped area in a given year is estimated at 9,700 ha with a cropping intensity of about 80%t. Over 80% of the irrigation area gets water from Victoria Nile. Main crops cultivated are sugarcane, rice and vegetables. The total estimated total annual irrigation water demand is 260 MCM. Irrigation is a relatively new as rainfall has been more or less sufficient in the past. Most parts of the country experience at least one long rainy season and this has been sufficient for farmers to produce at least one crop a year. In the past, irrigation was only practiced during the dry season at small-scale informal level with most of this located on the fringes of swamps. Nowadays rainfall has become less reliable with supplementary irrigation needed in rain season at times and much of this has been developed by smallholders without planning and with little or no technical assistance. The technology used is basic and approaches are sometimes inappropriate.

Most smallholder schemes grow rice and vegetables, with the larger commercial estates cultivating rice and sugarcane. Most irrigation developments use surface methods although the more recent developments involving greenhouse irrigated flower farms that started in 1990s utilized drip and micro sprinkler.

Some work has started on the water for production component (WfP) for Uganda, but this has still a long way to go. An irrigation policy is in place. There is a strong need to clearly establish the needs for irrigation and drainage and the process by which it can be realized. This needs to go hand in hand with the training of technical staff to support any proposed interventions.



Sr. No	Scheme Name	District	Equipped area Ha
1	Nyamugasani	Kasese	360
2	Mubuku	Kasese	516
3	Olweny	Lira	500
4	Lugazi Sugar	Jinja	2000
5	Agoro	Kitgum	130
6	Kakira Sugar	Mukono	6800
7	Tilda Uganda (kibimba)	Iganga	600
8	Doho	Tororo	830
9	Total Roses	Wakiso /Mukono	280
Total			12,016


Photo: flickr.com

Drip irrigation in a flower farm in a green house in Entebbe, Uganda


Main water division canal from river Sebwe-Mubuku Irrigation Scheme


Water division box at secondary canal-Mubuku Irrigation Scheme


Photo: Albert Water Management Zone, Uganda

field ditches filled with water during irrigation-Mubuku irrigation Scheme

Irrigated Areas in Democratic Republic of Congo

The Nile basin in DRC covers less than 1% of the area of the country. The area is hilly and does not really lend itself to irrigation. This area is rather densely populated with most people engaged in cattle rearing and fishery activities around Lake Albert. It is considered that about 10,000 ha could be developed for irrigation (FAO, 1997).

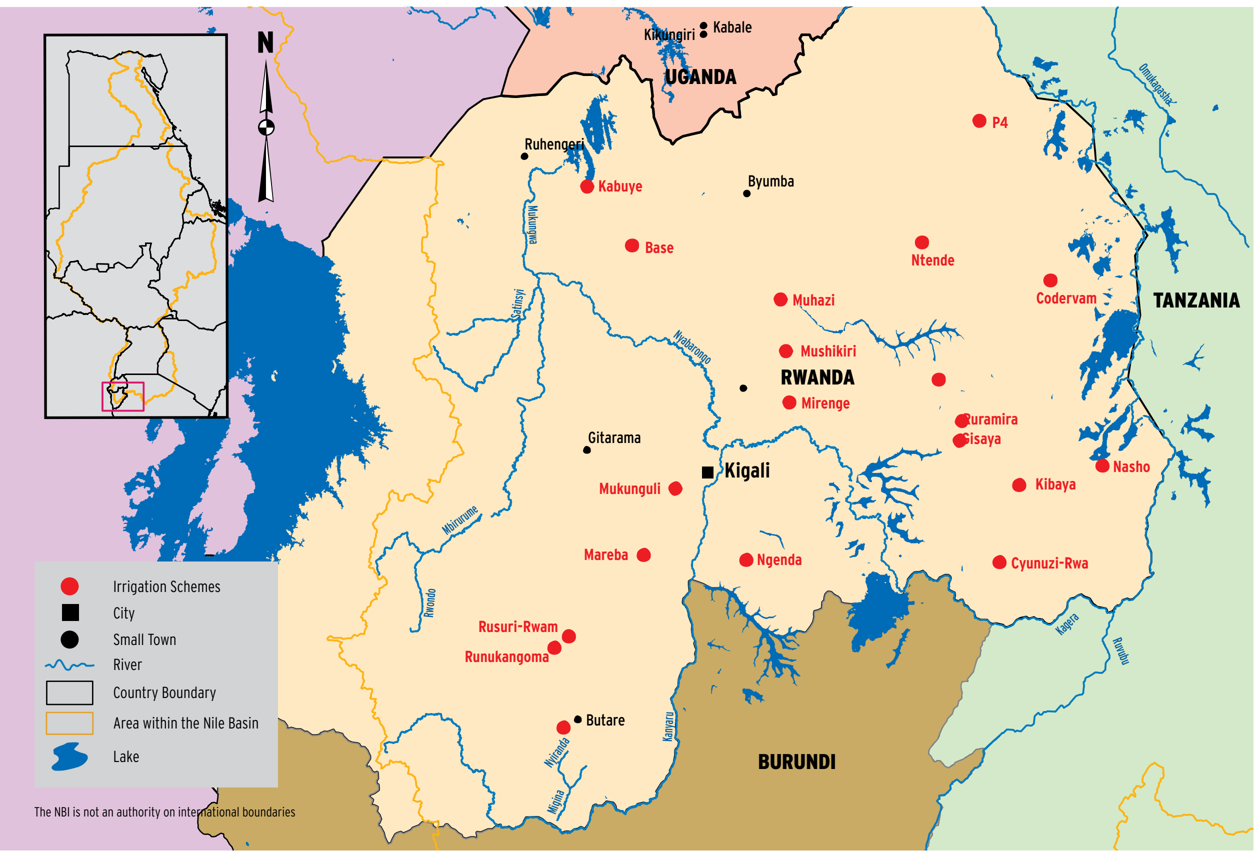
Major crops grown include Cereals (rice, maize), Tubers, Cash crops (coffee, cocoa) and Sugarcane. In the past, the national program for rice production (PNR) has managed 80 ha including the reparation of irrigation canals and drainage and the distribution of pumping material. It has also managed a total of 300 ha of valley bottoms in the Kikwit region, the Ruzizi valley in the south of Kivu, Lodja in East Kasai, Mbandaka-Bikoro, Gemena-Karawa and Bumba in the Equator Province. The total irrigated water withdrawal for the Nile basin part has been estimated at 600,000 m³ per year (FAO, 2010)

Irrigation areas in Rwanda

The total area equipped for irrigation in Rwanda is estimated at 11467 ha. With an estimated cropped area of 7000 ha, the overall cropping intensity is 61%. Main crop planted in most irrigation schemes is rice. The total estimated irrigation water demand for all schemes is about 58 MCM and actual abstraction estimates lie at 57.4 MCM, which indicates a volumetric demand satisfaction rate of about nearly 99.%

Irrigation in Rwanda dates back to 1945 when the Belgians built the main Ntaruko – Rubengera canal with 8 km of length to irrigate a small farm. From 1962 to 1994, the total cultivated and irrigated lands were estimated to be 4000 ha. The major part of irrigated lands (8.3% of the estimated potential) are located is in the marsh lands that cover 164,947 ha with around 57% already cultivated with an estimated 11,467 ha currently managed with moderate irrigation structures (regulators, diversions, head works, etc.).

Rice is an important crop and approximately 62,000 tons are produced annually on about 12,000 ha. Due to the retention of flood flows, the marshlands are important to downstream users as they maintain relatively continuous flow rates in the dry season.



The NBI is not an authority on international boundaries

Ser No	Scheme Name	District	Equipped area (ha)
1	Base	Gitarama	170
2	Codervam	Umutara	460
3	Gisaya	Kibungo	300
4	Kabuye	Kigali-Ngali	344
5	Mareba	Kibungo	200
6	Mirenge	Kibungo	600
7	Muhazi	Kibungo	96
8	Mukunguli	Gitarama	440
9	Ntende	Umutara	120
10	Mushikiri	Kibungo	160
11	Ngenda	Kigali-Ngali	756
12	P4	Umutara	460
13	Cyunuzi-Rwa	Kibungo	400
14	Kibaya	Kibungo	240
15	Nasho	Kibungo	160
16	PRB (8 schemes)	Butare	4358
17	Runukangoma	Butare	170
18	Ruramira	Kibungo	90
19	Rusuri-Rwam	Butare	600
20	Rwamagana (5 schemes)	Kibungo	1343

Rice paddles in Rwanda

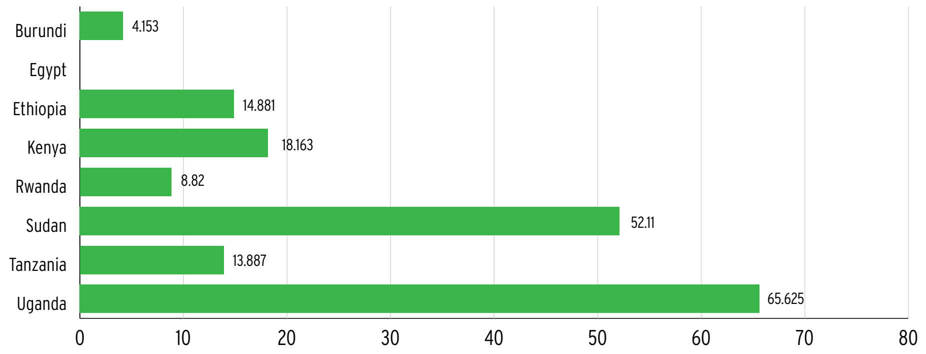
Photo: Adam Cohn

RAIN-FED AGRICULTURE


Photo: Simone D. McCourtie / World Bank

Rain fed agriculture

Evapotranspiration for rainfed production for selected Countries (km^3)



Source: FAO, 2010

Rain-fed farming, covering 33.2 Million ha, is the dominant agricultural system in the Nile Basin. Over 70% of the basin population depends on rain-fed agriculture (Seleshi et at., 2010). Sudan, with 14.7 million ha accounts for 45% of the total rain-fed lands, followed by Uganda, Ethiopia, Tanzania, Kenya, Rwanda and Burundi. Low rainfall does not allow rain-fed farming in Egypt, and rain-fed areas of Eritrea that fall within the Nile boundary are almost negligible. The main rain-fed crop in the Nile Basin in terms of cultivated area is sorghum, followed by sesame, maize, pulses and millet, covering 7.39, 3.68, 3.35, 2.94 and 2.86 million ha, respectively. Rain-fed agriculture in the Nile Basin is characterized by low yields with the majority of crops having an average yield of less than 1ton /ha. Different sets of reasons have been proposed for the low yields in rain-fed systems from natural causes such as poor soils and drought-prone rainfall regimes to distance from urban markets (Allan, 2009). However, the opportunity of favorable rainfall in many rain-fed areas of the basin provides a high potential for yields to increase by improved farm water management techniques such as rainwater harvesting.

While the proportion of (evapotranspiration) ET from rain-fed crops remains relatively stable between years, the absolute amount varies very significantly, from 180 to 256 km^3, representing a large difference in potential crop production between years and at the same time illustrating the risks associated with rain-fed agriculture in the region. The variability is in low rainfall areas: the ratio of rain-fed crop ET between the driest and the wettest years is around 0.7- 0.9 in the humid uplands, but falls to around 0.5 in the semi-arid catchments of central Sudan and the Atbara basin. In terms of food security, this annual variability is exacerbated by the occurrence of multi-year droughts.

Under these conditions, opportunistic cropping in wet years may be a viable strategy commercially, although it is difficult to reconcile it with the need for subsistent smallholders to produce crop every year to ensure food security. Much of the additional food demand in the Nile partner states is expected to be met through improvements in rain fed agriculture. The vast untapped potential of rain fed agriculture could be unlocked through knowledge-based management of land and water resources, bridging the yield gaps (a factor of two to four) between the current farmers' yield and the researcher-managed or commercial plot yields (Rockström et al. 2007).

Small-scale agricultural water management techniques, such as rainwater harvesting and groundwater within a watershed management approach have important potential roles in securing rain-fed crops in these regions. Araya and Stroosnijder (2011) found that in northern Ethiopia, where crops failed in more than a third of years in the period 1978-2008, one month of supplementary irrigation at the end of the wet season could avoid 80 per cent of crop yield losses and 50 per cent of crop failures. Other strategies used in the area to manage erratic rainfall include supplementary irrigation to establish crops (to avoid false starts to the wet season), postponement of sowing until adequate soil moisture is available, and growing quickly maturing cash crops such as chickpea at the end of the growing period, to utilize unused soil water reserves.

CROP WATER PRODUCTIVITY IN THE NILE


Photo: Arne Hoel/World Bank

Dina farms, Egypt

Large gaps between actual and potential crop yields reflect the presence of socio-environmental conditions that limit production. In much of the Nile, lack of farmers' access to available water is the prime constraint to crop production. With increasing numbers of people and their growing demand for food, combined with little opportunity to access new water sources, great need exists to make more productive use of agricultural water. Based on Crop Water Productivity, the spatial distribution of the basin can be divided into three zones: the high productivity zone, the average productivity zone and the low productivity zone. The WP index serves as a useful indicator of the performance of rain-fed and irrigated farming in water-scarce area

High productivity zone

The high productivity zone includes the delta and irrigated areas along the Nile River in the northern part of the basin. This zone is characterized by intensive irrigation, high yields and high-value crops. These characteristics collaboratively contribute to the high level of the WP attained and art' in fact correlated. Access to irrigation results in higher yields; higher yield results in higher incomes; and higher incomes result in higher investment in from inputs by farmers.

Average productivity zone

The average productivity zone consists of two major areas, one in the eastern part (Ethiopia mainly) and the other in the southern part (areas around the Lake Victoria). Despite the fact that most of the areas in this zone receive relatively good amounts of rainfall, the predominantly rain fed agriculture has rather low yields and, therefore, relatively low Water Productivity. The fact that rainfall is sufficient to grow crops in this zone opens a wide prospect for improvement in this region. Two parallel strategies that could be applied are, first, improving farm water management and, second, promoting irrigated agriculture. The main obstacle for irrigated agriculture in this zone is accessibility to water rather than its availability. For example, in Ethiopia, due to lack of storage infrastructure the majority of generated run-off leaves the country without being utilized. Controlling these flows and diverting the water to farms can drastically improve both land and water productivity

Low productivity zone

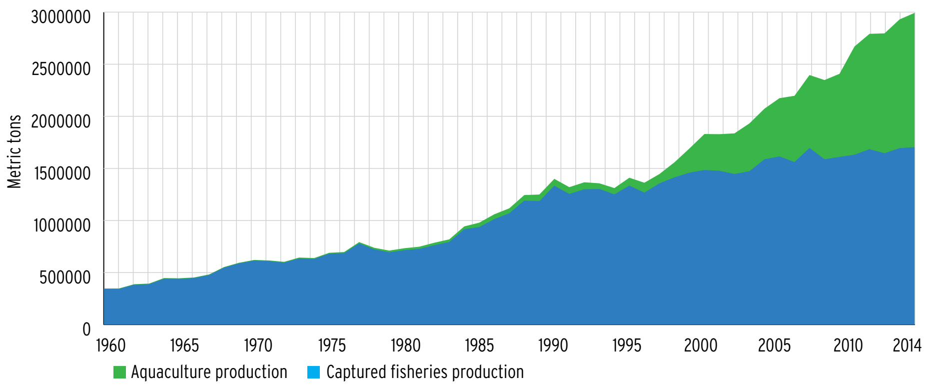
The low productivity zone covers the central and western part of the basin. Agriculture in this zone is rain-fed and it receives a low amount of rainfall in most areas rainfall amounts received cannot meet the crop water demands and therefore crops suffer from high water stress. As a result, yields are extremely low. In this zone improving water and land productivity is contingent upon expanding irrigated agriculture. A good example that shows how irrigation can bring improvements is the Gezira scheme in Sudan.

This scheme is located in the same zone (geographically) but irrigation has resulted in significantly higher WP in the scheme compared to its surrounding rain-ted areas. However, due to poor water management, WP in the Gezira scheme is much lower than in irrigated areas in northern parts of the basin (i,e. in the delta).

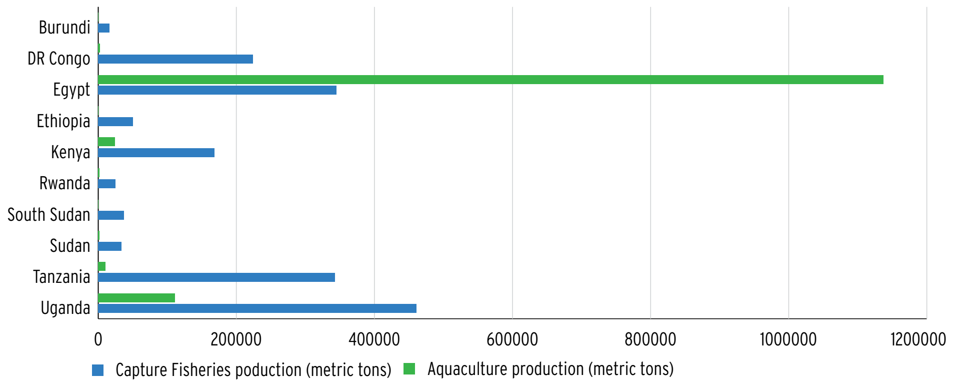
INLAND FISHERIES MANAGEMENT AND DEVELOPMENT

Fisheries and aquaculture are important components of agricultural production and productivity in the Nile. Nile Basin fisheries are mainly freshwater lakes, rivers and marsh sources and human-derived aquaculture. Freshwater fisheries have a large potential to enhance income opportunities for many thousands of people and contribute towards food and nutritional security of millions in Kenya, southern Sudan, Tanzania and Uganda. Fisheries are non-consumptive users of water, but require particular qualities, quantities and seasonal timing of flows in rivers and dependent wetlands, lakes, and rivers.

Fisheries production in the Basin



Total Fish Production by Country



Source: WDI, 2016

Fish being washed

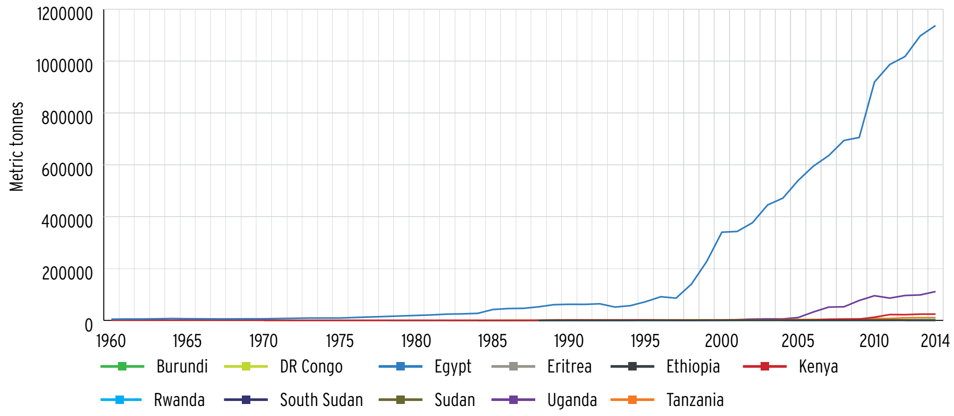
Aquaculture production (metric tons)

Aquaculture is understood to mean the farming of aquatic organisms including fish, mollusks, crustaceans and aquatic plants. Aquaculture production specifically refers to output from aquaculture activities, which are designated for final harvest for consumption.

In 2014, aquaculture production in the Nile Basin countries reached 1,289,234 tons, 88% of which is farmed in Egypt. Egypt is the main producer of farmed fish; since the mid-1990s it has rapidly expanded its aquaculture. Aquaculture expansion has contributed to increasing the total fisheries production in Egypt. Aquaculture activities in Egypt are more concentrated in sub-regions of the Nile Delta, where the water resources are available. Most of the aqua culture production is derived from farmers' use of earthen ponds in production systems. Uganda is a distant second of the total basin aquaculture production. Kenya, Rwanda and Sudan are developing fisheries with the help of foreign aid to boost production which, together with other basin countries, represents 1 per cent of the farmed fish in the basin.

Uganda's aquaculture export market, regional use and employment have risen dramatically over the past 10 years. Aquaculture production is still negligible in most of the sampled countries, although in countries such as Kenya,– in addition to Tanzania which mostly cultivate seaweed - aquaculture is developing and its contribution to GDP is rising. Most aquaculture is conducted in earthen ponds, but at a wide range of intensities. At the low end are small ponds of less than 500 square meters, which contribute to the stability and durability of small-scale farming systems in Africa. When regularly stocked and fertilized, these units produce 1,000–2,000 kg per hectare per year of fish for household consumption and sale or barter. However, aquaculture has also contributed to serious water pollution when not well managed, a problem that is likely to intensify with increased aquaculture activities.

Aquaculture production (metric tonnes)



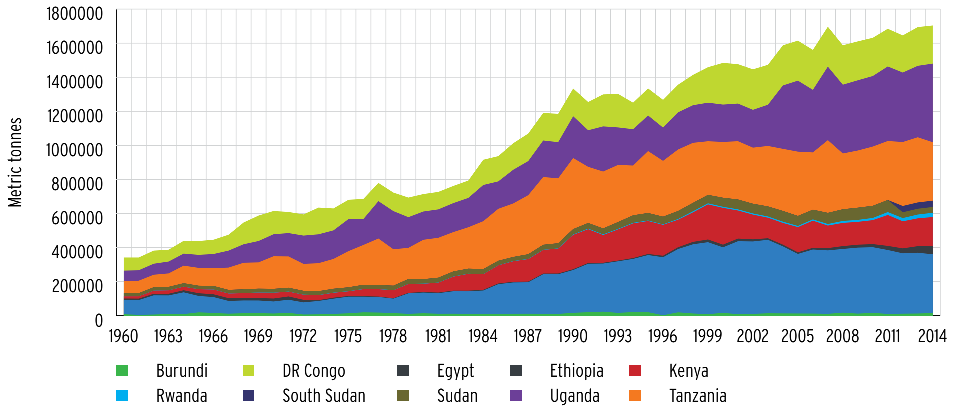
Source: World Development Index

Capture fisheries production (metric tons)

Capture fisheries production measures the volume of fish catches landed by a country for all commercial, industrial, recreational and subsistence purposes.

Diminishing water level, and pollution have acute consequences for several economic sectors that depend on the basin lakes, It greatly affects the fishery by changing water levels. Water-level variations affect shallow waters and coastal areas which are of particular importance for numerous fish species, at least in certain stages of their lives. Pollution also poses a problem for fishery productivity in the Nile Basin. Some of the rivers feeding the lake and the shoreline are particularly polluted by municipal and industrial discharges. Cooperation between all concerned authorities is necessary to search for coherent solutions to ensure the sustainability of the fisheries.

Captured fisheries production (metric tonnes)

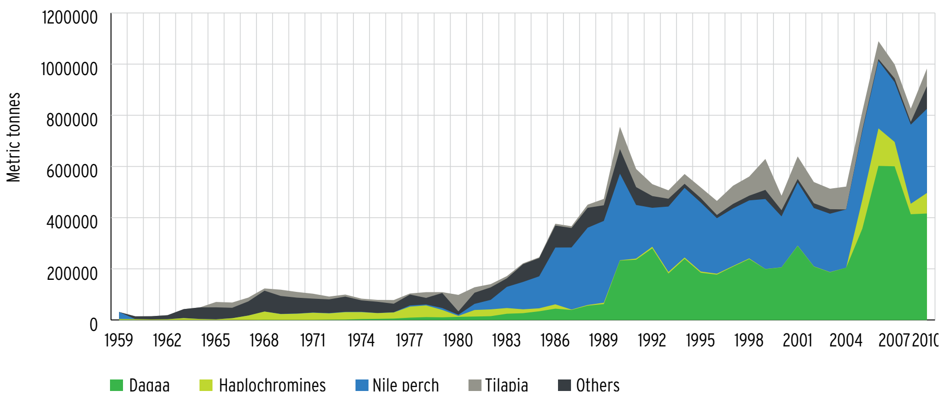


Source: FAO, 2016

Lake Victoria Fisheries Trends in the most important fish stocks

Lake Victoria is the second largest lake in the world, covering an area of 68,000 km^2 and surrounded by a dense and fast growing human population of at least 25 million people. In addition to its size, the lake is unique in several ways. It supports one of the world's biggest inland fisheries aimed at both domestic consumption and international export and it has experienced some of the most extreme ecological perturbations ever observed in a large freshwater environment. The total catch from Lake Victoria by species is shown in the adjacent chart. The most notable change in the demersal Lake Victoria fish community and fishery is the fundamental metamorphosis in the mid 1980's when it suddenly changed from being dominated by the diverse species flock of endemic haplochromines (contributing around 90% of the demersal biomass) to a much simpler fauna consisting of three primary species: Nile perch, Dagaa in the open waters and the introduced Nile tilapia along the shores.

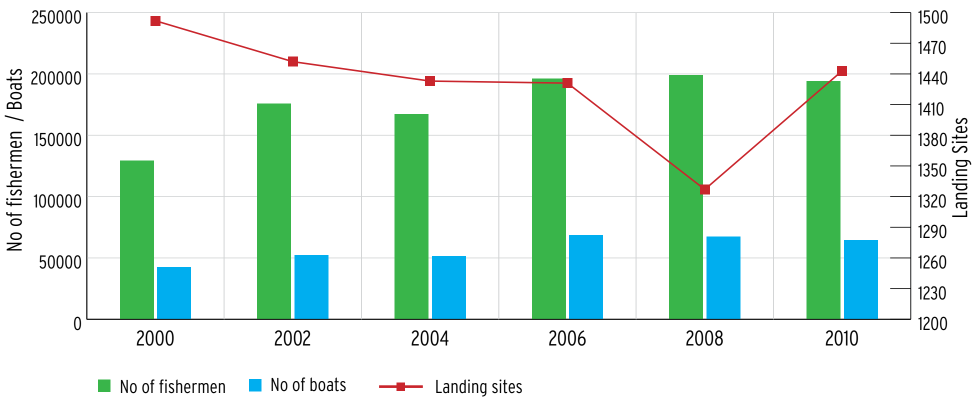
Lake Victoria: Total annual Catched by species or species groups



Trends in effort and estimated total catch rates

Effort statistics prior to 2000 are less reliable than the catch statistics, but the overall pattern largely mirrors the changes in overall catches. There have been three main periods intersected with periods of rapid growth: the mixed cichlid fishery from the 1950s to the 1980s; the fast growing Nile perch fishery during the 1980s; the relatively stable Nile perch/Dagaa fishery from 1990 to the turn of the century; a doubling of the Dagaa fishery 2003 - 2006 and a possible new stable phase since 2005/6. Water levels, flows modification, pollution, affects fisheries production. From late 2000 to 2005, L- Victoria level receded on the coastline by ~5m, reducing fish habitats and spawning grounds.

Indicators of fishing effort in the Lake Victoria Fishery

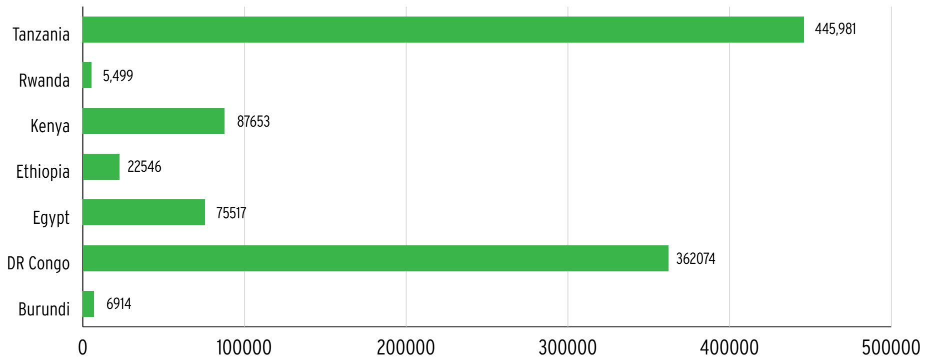


Benefits from Fisheries Management in the Nile

Based on current stock estimates, the lake has the potential to yield fish valued at over US$ 800 million annually on a sustainable basis. Further processing and marketing the fish in the local and export markets could provide opportunity to generate additional earnings. Currently, however, only about 500,000 tons of fish is landed annually, with an average landing value of approximately US$ 600 million. Further processing and marketing of this fish in the local and export markets can generate an additional value of about US$ 57 million.

Inland fisheries, and related export and regional trade, can play a significant role in the economy of regions and countries. The sector contributes 4% to GDP in DR Congo and 2.5% in Tanzania (2013). Inland fisheries provide employment and income for several million people (estimated employment population employed in the sector amounts to 445,981 people.

Employment in inland fisheries in sampled countries 2013



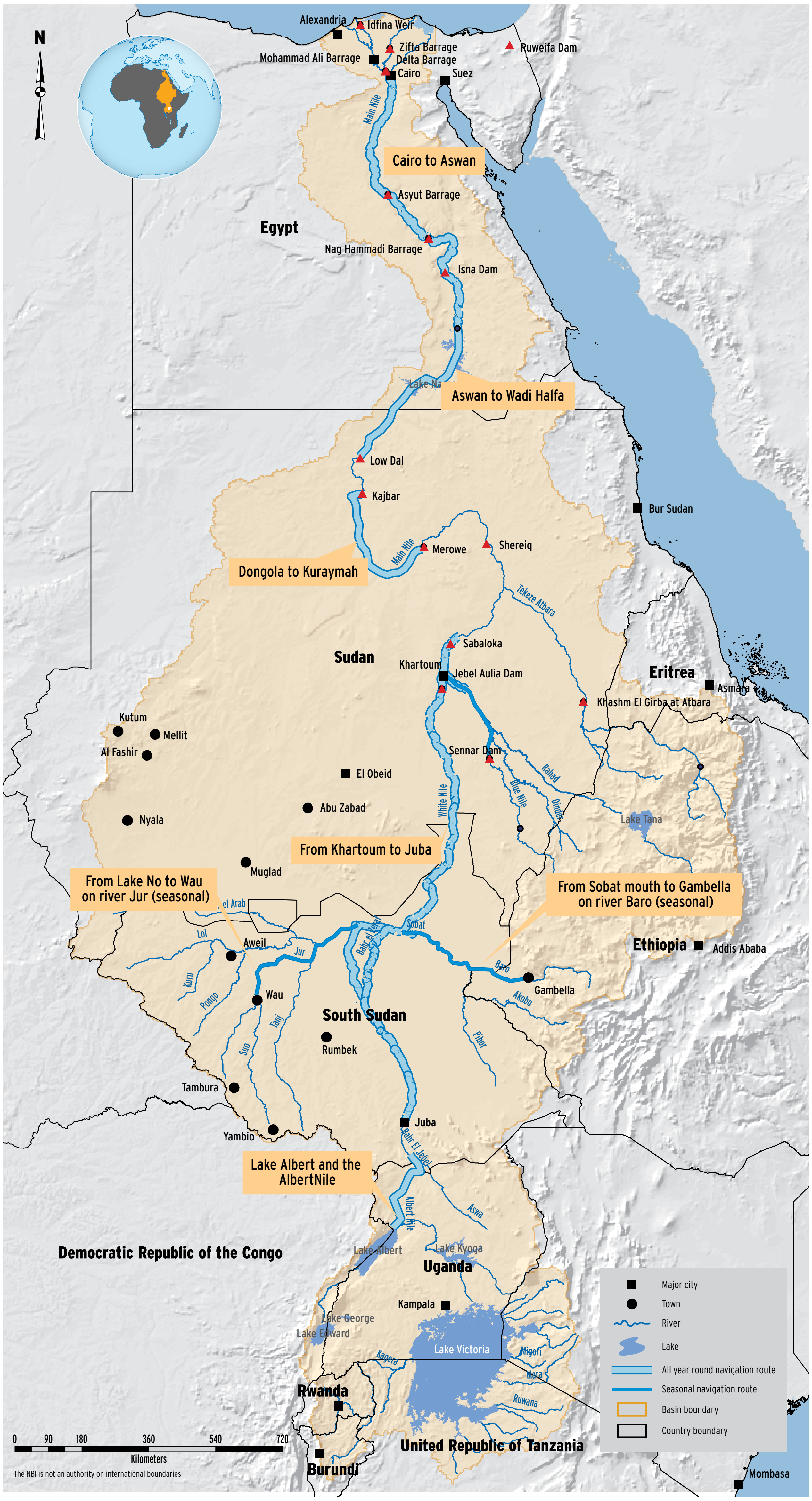
Industrial sector contribution to national water withdrawal, 2014

Types of benefit	Kenya	Uganda	Tanzania
Production (US$ Million)	115	156	180
Contribution to GDP	0.5%	1.5%	1.8%
Employment of fishermen (2002)	54163	41674	80053
Foreign Exchange Earnings (US$ Million)	50	88	112
Per Capita Fish Consumption (Kg/year)	5	12	12
Contribution to Animal Protein (1994-97)	10.6%	29.7%	32.6%
Balance of Trade	N/A	N/A	N/A


Photo: istock

Fisherman in Uganda

INLAND WATERWAY TRANSPORT



Inland navigation is often the most cost-effective and least polluting means of transport and, with improved trade and exchange, has contributed to the development of the Nile Basin riparian states economies. Inland waterways can efficiently convey large volumes of bulk commodities over long distances. However, inland shipping remains an underdeveloped sector on most waterways.

Nine of the 11 Nile riparian countries have navigable water bodies, and a total of 72 inland water ports between them, with Egypt and Uganda having the highest number. The main areas important for inland water transport are Lake Victoria which provides a vital transportation link for Kenya, Uganda and Tanzania with the main ports being Jinja and Port Bell in Uganda, Kisumu in Kenya, and Mwanza, Musoma and Bukoba in Tanzania; Sections of the White Nile in South Sudan, and the Main Nile in The Sudan and Egypt.

In Egypt, the Nile is navigable by sailing vessels and shallow-draft river steamers as far south as Aswan. In South Sudan, steamers still provide the only means of transport facilities, especially where road transport is not usually possible from May to November, during the flood season. The Blue Nile has an 800 km stretch that is navigable during high water times. The main types of goods and services transported comprise agricultural produce, livestock, fish, general merchandise, and passengers. Inland ports, linked to other modes of transport connecting to international markets, also handle export/import traffic of agricultural products and manufactured goods.

Navigation is a sector that does not consume water. It depends on the state of water resources in terms of quantity (a minimum depth is needed) and, quality (invasive aquatic plants or excessive solid waste in the water bodies would obstruct engines and waterways). It also brings the threat of potential hazards to water quality, such as oil spills from tankers operated on Lake Victoria, or ships degassing.

Inland waterway transport on Lake Victoria

Lake Victoria is the primary inland waterway servicing both the central and northern corridors. Lake Victoria acts as a principal waterway with commercial traffic. In conjunction with train services, Uganda and Tanzania operate train wagon ferries on the lake between railhead ports of the two countries and Kenya.

The three main lake ports are: (i) Kisumu for Kenya, located in the North Eastern corner of the Winam Gulf, fronting Kenya's third largest city, (ii) Mwanza South for Tanzania, located within a natural shallow bay on the Eastern shore of Mwanza Gulf, and (iii) Port Bell for Uganda, located at the end of Murchison Bay, South-East of Kampala. They are directly included in the regional multimodal trade routes, namely the Northern and Central Corridors

Traffic across all public ports on Lake Victoria is estimated at 500,000 tons a year. However, it should be noted that local traffic has increased since 2005 while international transit traffic has been decreasing (imports to Uganda estimated at 3,000 tons in Port Bell over the last years).

However, developing rivers for navigation often results in irreversible transformation of river courses, with negative impacts on vulnerable groups and ecosystems (such as fish mortality from propeller impact and larvae stranding due to drawdown).


Photo: Pierre Lesage

Ship on the Nile Egypt

Water use for Navigation

The hampering of port and navigation activities due to low water levels received much attention in the 2005/06 water level crisis on Lake Victoria. Lake Victoria transport system for passenger and goods suffered as well as its essential role for island connection. Declining water levels cause a decrease in draft and so ships cannot enter ports safely when the water depth is too shallow. During the water level crisis, various vessels had known difficulties to berth properly. Loading and offloading of passengers was severely affected in Tanzania. And several accidents involving their vessels found to be related to low lake levels. The minimum and maximum levels for days when accidents were reported are 10.76m and 11.05m (JJG) respectively.

Generally it may be concluded that the safety of marine navigation in Lake Victoria cannot be guaranteed below an elevation of 11.33 m, which corresponds to the highest level in 1957 when the lake was surveyed. The operation of vessels below this level is risky and if it has to be done, reassessment of the routes to ensure safety would be required. Low lake levels would also compromise most of the maintenance structures functioning, leading to a high operational cost of navigation.

In Kenya and Tanzania, maintaining the lake level between 11.5 and 12.5m (higher than the present 11m level) would rejuvenate navigational activities with positive effects to the livelihood and environmental sector. The opposite could be said of Uganda who heavily relies on power generation for livelihood at national scale. In general, it is envisaged that in all the five countries sharing Lake Victoria, the infrastructure, navigation risk and revenue will not be seriously affected while navigation and dredging cost may go up. These will in turn affect livelihoods and the environment.

CONCLUSIONS

Photo: Milly Mbuliro

River Nyamugasani

The water resources in the Nile Basin is serving multiple purposes and are essential for sustaining life, the economy and a healthy environment. Water is used off-stream (withdrawn e.g. for agriculture, municipal or industrial use), in-stream (e.g. hydropower, fisheries, environment) or on-stream (e.g. navigation, tourism and recreation). By far, the largest consumptive use is for agriculture/irrigation (roughly 2600 m³/s) although part of the abstraction is returned as drainage water. Egypt and Sudan are the largest users accounting for 96% of the total. Municipal and industrial consumption is estimated at over 400 m³/s. Population in the Nile Basin is forecasted to double by 2030 and municipal water demand will grow five-fold during the same period due to urbanization and increase in standard of living. Industrial demand will be likely to grow at a comparable rate. The largest municipal and industrial consumption is taking place in Egypt (close to 97%) followed by Sudan and Uganda. Drainage water from irrigation and sewage from urban areas and industries present pollution threats to the aquatic environment.

A survey made in 2014 showed the existence of 14 storage dams basin-wide. The existing dams are highly beneficial from a power generation point of view and are also helping equalizing flows. However, there is substantial evaporation from the reservoir surfaces causing loss of water. The loss reaches an estimated 540 m³/s with 70% occurring from the reservoir of the High Aswan Dam.

The total reservoir capacity per capita in the basin is very low compared to world benchmarks. In a region with severe seasonal and inter-annual variability and anticipated climate change, absence of adequate storage capacity adds to the vulnerability of the population as prudent reservoir operation can help reduce flood and drought impacts.

Hydropower is generated primarily in Uganda, Sudan, Ethiopia and Egypt but is only meeting a small part of the power demand. However, there is a large untapped potential for hydropower especially in the Blue Nile, where the Grand Ethiopian Renaissance Dam (GERD) is under development and will become Africa's largest hydroelectric power plant with an installed capacity of 6000 MW.

Fisheries and aquaculture are important users of water although not consumptive. Nile Basin fisheries are mainly seen in freshwater lakes, rivers and marsh sources as well as in human-derived aquaculture and has significant impact on the socio-economy. Fisheries require particular water qualities, quantities and seasonal timing of flows and water depths in lakes, rivers and wetlands.

The environment is another, though silent user. A sound aquatic environment is essential to maintain the productiveness of the water bodies and the wetlands and providing suitable habitats for diverse fauna and flora populations. Water pollution from urban and industrial sources endangers the soundness of the environment and the furthest downstream environment is at greatest risk.

Nine of the 11 Nile riparian nations have navigable water bodies and a total of 72 inland water ports with Egypt and Uganda having the highest numbers. Navigation is a sector that does not consume water. It depends on the water resources in terms of quantity (minimum water depths) and quality which can cause excessive amounts of, for instance the water hyacinth. Such plants can block harbors and prevent the launching of small crafts at landings.

In a not too distant future, the Nile Basin will be in a critical situation, where increases in consumptive use in one sub-basin will have to be covered by decreases in consumptive use in another sub-basin and reallocation of water will have to be negotiated. Changes in climate could very well aggravate the situation. These conditions require a very high degree of trust, cooperation and sharing of water and benefits between the riparian nations. The Nile Basin Initiative has a vital, strategic mission in facilitating the cooperation, promoting Integrated Water Resources Management, providing access to Decision Support Systems and reliable databases and raising awareness on known or innovative ways of demand management, water conservation and efficiency in water use.

References

- "Water for Growth and Development." David Grey and Claudia W. Sadoff in Thematic Documents of the IV World Water Forum. Commission Nacional del Agua: Mexico City. 2006.
- Northern Corridor Transit Transport Coordination Authority; Northern Corridor Infrastructure Master Plan: Final Report; Executive Summary (2011)
- Ethiopia: Managing Water Resources to Maximize Sustainable Growth A World Bank Water Resources Assistance Strategy for Ethiopia
- Water storage and hydropower: supporting growth, resilience and low carbon development; A DFID evidence-into-action paper
- Sutcliffe,]. (2009) The hydrology of the Nile Basin, in The Nile, H.j. Dumont (ed.), Monographiae Biologicae 89,335-364, Springer, Dordrecht, The Netherlands.
- Sutcliffe, J V and Parks, Y. E (1999) The Hydrology of the Nile, IAHS Special Publication 5, International Association of Hydrological Sciences, Wallingford, UK.
- Eastern Africa Power Pool (EAPP) and East African Community (EAC) Regional Power System Master Plan and Grid Code Study, May 2011, SNC Lavalin International Inc. In Association with Parsons Brinckerhoff
- Uganda Ministry of Energy and Mineral Development, The Development of A Power Sector Investment Plan For Uganda, Generation Plan, 20 October 2009
- Nile Basin Initiative Regional Power Trade Project; Comprehensive Basin-wide Study of Power Development Options and Trade Opportunities Final Report; RSWI/Fichtner JV, with the participation of Parsons Brinkerhoff
- Nile Basin Initiative; Efficient Water Use for Agricultural Production (EWUAP); Large Scale Irrigation Practices in the Nile Basin Best practices, weaknesses and opportunities; Wim Bastiaanssen, Wageningen, NL; Chris Perry, London, UK
- Nile Basin Initiative ; Efficient Water Use for Agricultural Production (EWUAP); Agricultural Water In The Nile Basin – An Overview; Final Report; Ian McAllister Anderson; April 2008
- NELSAP / NBI, December 2012. Nile Equatorial Lakes Multi Sector Investment Opportunity Analysis (NEL MSIOA). NEL indicative Investment strategy and action plan. Draft version. Report prepared by BRL Ingénierie. 111 pages
- Food and Agriculture Organization of the United Nations Rome, 2011. Agricultural Water Use Projections in the Nile Basin 2030: Comparison with the Food for Thought (F4T) Scenarios
- The Value of African Fisheries; Gertjan de Graaf FAO consultant Amsterdam, the Netherlands; Luca Garibaldi; Fisheries and Aquaculture Statistics and Information Branch FAO, Rome, Italy
- Availability of water for agriculture in the Nile Basin; Robyn Johnston

OVERALL CONCLUSION

The Nile Basin Initiative, established in 1999, has initiated the preparation of the Nile Basin Water Resources Atlas as part of their quest for basin-wide cooperation, enabling water resource management and water resource development. The primary objective of the Atlas is to support collaborative monitoring the water and related resources of the Nile Basin by Riparian States and thereby contribute towards achieving their shared vision objective "to achieve sustainable socio-economic development through the equitable utilization of, and benefit from, the common Nile Basin water resources".

The Atlas provides a snap-shot of the present water resources situation and aims to give overviews of the conditions and the huge variations in water resources parameters in the Nile Basin that is roughly 10% of the African continent and comprises eleven countries. In such a huge area with large variations the Atlas will give aggregated information. The Nile flows from its spring in the highlands southwest of Lake Victoria and join the Kagera River, which empties into Lake Victoria. Totally the Nile flows roughly 6700 km to the north before reaching the delta and eventually the Mediterranean Sea.

The physiography of the basin represents the result of the processes, which have formed the landscape over millions of years. In historical time, humans have started influencing erosion and sedimentation, land cover, soils and the wetlands. The physiography divides the Nile Basin into two broad sub-systems. The Equatorial Nile sub-system comprises the sub-basins of Lake Victoria, Lake Albert, Victoria Nile, Bahr el Jebel, White Nile and Bahr el Ghazal. The Eastern Nile sub-system comprising the Main Nile sub-basin and the sub-basins of Tekeze-Atbara, Blue Nile and Baro-Akobo-Sobat. Totally, there are ten sub-basins with large variations in characteristics.

The Nile and its tributaries is the lifeline for a population of 257 million or more than 10% of the population of the African continent. The Nile and the socio-economy of the 11 riparian countries are intimately connected. Agriculture, hydropower production, wetlands, water supply, navigation, fisheries and tourism are among the many sectors depending on water resources and providing livelihoods for the riparian population.

The settlement patterns also reflect the availability of water, which seems to overshadow other factors such as social and economic infrastructure. In the downstream countries, population is concentrated along the course of the Nile and in the Nile Delta. Upstream population densities are highest in the Equatorial Lakes region and in the Ethiopian Highlands, both being regions of high rainfall and abundant water resources. The trend in migration is from rural areas to urban areas. For the Nile Basin as a whole, the rural population is larger than the urban population. Projections for 2050 shows that the urban population will reach above 60% of the total population in 4 of the 11 Nile Basin riparian nations. In the remaining seven nations the urban population will increase but stay well below 40%. Urbanization will increase the pressure on urban services and facilities as well as on the natural resources and the environment. Water pollution will be one of the serious challenges for the water resources management.

The Human development index (HDI) is an aggregation of the average achievement in the key dimensions, a long and healthy life, being knowledgeable and having a decent standard of living. All Nile Basin countries fall into the Low Human Development category with the exception of Egypt, which is in the middle category. However, all basin countries show improvements compared to year 2000. The higher the HDI, the higher the potential for involvement of the broad population in the stewardship of the environment, the water resources and the battle against water pollution. Poverty is widespread and by income, around 40% of the population of the basin countries live below a poverty line of USD 1.25 per day.

The full dependence of the socio-economy on shared basin water resources makes a fact based management and development essential. Monitoring of water resources is therefore done by all countries and close to 1,000 meteorological stations for rainfall and temperature recording exists. Almost 450 hydrometric stations for gauging of streamflow were registered. Technical and financial resources to operate the networks of stations have been dwindling in most countries and station densities can become inadequate. The need for improvements have been realized by the Nile Basin Initiative, which has completed a design of a Nile Basin Regional Hydromet System based primarily on upgrading of existing stations adding water quality monitoring and laboratory strengthening. Groundwater monitoring is generally very sparse. Automated water level registrations and telemetric transfer of data are still underused. Calibration of hydrometric stations is often not adequate and data reliability suffers.

Climatically, the Nile Basin has large variations ranging from the tropical climate in the Equatorial Lake region to the Mediterranean climate of the Nile Delta. This is brought about by the latitude range (4o S to 32o N) and the variation from sea level to an altitude of around 3,000 m. Regarding rainfall, the Equatorial Lakes region and the Ethiopian Highlands receive an average annual rainfall above 1,000 mm, while the high altitude areas (Rwenzori mountains, Mount Elgon and the Ethiopian Highlands receive an average annual rainfall in excess of 1,500 mm. The northern part of Sudan and Egypt receives less than 50 mm and there are years, which are completely dry. This accentuates Egypt's and Sudan's full dependence on a steady flow of the Nile as very little surface runoff is generated there.

Temperature is a significant factor in for instance evapotranspiration and is, together with water, essential for plant growth. In the Equatorial Lakes region and the Ethiopian Highlands, maximum temperatures are recorded in the range of 30oC while parts of the Blue Nile, Tekeze-Atbara and the White Nile in Sudan are measuring maximum temperatures of 45oC. High temperatures entail large evaporation losses from water surfaces like lakes and reservoirs.

Climate change as a result of global warming, is a challenge for water resources management and development. Adaptation is the immediate response to climate change and trends and statistics have to be closely monitored as they are no longer stable. Even small changes in temperature averages or extremes can have serious consequences for water resources availability, floods and droughts, agriculture, power and transportation systems, the natural environment and even health and safety.

The Nile Basin streamflow patterns are influenced by the variations in meteorological parameters such as rainfall and evaporation as well as by the physiography in terms of among others, topography, land cover, soils and geology. This is evident when comparing the White Nile and the Blue Nile being key tributaries to the Main Nile. The Blue Nile is highly seasonal with most of its flow occurring between July and September, while the White Nile flow is almost stable over the year mainly due to the regulating effect of Lake Victoria, Lake Kyoga, Lake Albert and the Sudd (a huge wetland in South Sudan). The Blue Nile contributes almost 160 percent of the annual flow of the White Nile and has a large potential for development of dams and reservoirs, among others, for hydropower production. Seasonality is a dominant hydrologic feature in the Nile riparian nations. This exposes the countries to floods and droughts with a devastating effect on the national economies and the affected communities.

Kagera River is the southernmost river discharging into Lake Victoria. The reservoir effect of Lake Victoria makes the outflow almost constant and Jinja Dam is operated to simulate the natural outflow of roughly 900 m^3/s as an annual average. The Nile continues through Lake Kyoga and the surrounding wetlands and run through a stretch with a good hydropower potential before it joins Lake Albert at Murchison Falls. The Nile continues through South Sudan and enters the Sudd, one of the largest wetlands in the world. A huge amount (approx. 50%) of the Nile inflow is lost to evaporation when passing the Sudd. The Nile proceeds towards Khartoum, where it is joined by the Blue Nile and now, combined flows of close to 2300 m^3/s are recorded. The last significant contribution to the Nile flow comes from the Tekeze-Atbara Sub-basin where about 350 m^3/s is received on the average. The Nile enters the reservoir created by High Aswan Dam. The reservoir, Lake Nasser, has capacity to regulate Nile flows on an inter-annual basis, but causes a huge water loss by evaporation estimated at roughly 10 – 12 BCM on the average. The Nile ends its 6700 km journey at the two branches at the Delta and close to 12BCM reaches the Mediterranean Sea – with a good proportion of this volume being drainage water from irrigation fields in Egypt. Surface water quality is mainly influenced by human activities relative to urban areas and industrial activities. Sediment production takes place in the upland areas with the Ethiopian Highlands as the main source compared to other parts of the Nile Basin.

Another source of water is groundwater, which is, however, not well studied and inadequately exploited. The most significant groundwater aquifer is the Nubian Sandstone underlying part of Egypt, Sudan, Chad and a part of Libya.

The water resources in the basin are essential for sustaining life, the economy and a healthy environment. Water is used off-stream (withdrawn e.g. for agriculture or domestic use), in-stream (e.g. hydropower, fisheries, environment) or on-stream (e.g. transport, tourism). The total area under irrigated agriculture in the Basin is estimated at 5.4 million hectares – over 97percent of the area lie in Egypt and Sudan.

By far, the largest consumptive use is for irrigation, which has been estimated at 82 BCM per year with over 96 percent of this occurring in Egypt and Sudan. In a region that is beset with strong seasonal and inter-annual variation of climate, storage dams provide one way of reducing vulnerabilities of water use sectors to climate shocks. The total storage capacity of dams in the Nile Basin is estimated at about 200 BCM. Water demand for municipal and industrial use, estimated at 12.9 BCM per year is rapidly increasing from the present estimates of roughly 400 m^3/s. Forecasts for 2030 are expecting a five-fold increase and the Nile Basin population seen as a whole, will become unable to meet the water demand.

The Nile Basin is expected to undergo substantial changes as more and more hydraulic infrastructure is realized to meet the growing water demands the riparian states. According to consulted national planning documents, the total storage capacity of dams in the Basin is expected to double by around 2040 – 2050; total area under irrigation can grow to 8.7 Million Hectares – an increase of some 60 percent of current size of irrigated areas; aggregate installed capacity of hydropower plants is expected to grow from a current value of 5600 MW to over 25,000 MW.

Unless actions are taken to enhance the water supply and manage the growth of consumptive demands, in a not too distant future, the Nile Basin will thus be in a critical situation, where increases in consumptive use in one sub-basin will have to be covered by decreases in consumptive use in another sub-basin and reallocation of water will have to be negotiated. Changes in climate could very well aggravate the situation. These conditions require a very high degree of trust, cooperation and sharing of water and benefits between the riparian nations. The Nile Basin Initiative has a vital, strategic mission in facilitating the cooperation, promoting Integrated Water Resources Management, providing access to Decision Support Systems and reliable databases and raising awareness on known or innovative ways of demand management, water conservation and efficiency in water use.

INDEX

ONE RIVER ONE PEOPLE ONE VISION

NILE BASIN INITIATIVE
INITIATIVE DU BASSIN DU NIL

Burundi DR Congo Egypt Ethiopia Kenya Rwanda South Sudan The Sudan Tanzania Uganda

Nile Basin Initiative Secretariat

P.O. Box 192
Entebbe – Uganda
Tel: +256 414 321 424
+256 414 321 329
+256 417 705 000
Fax: +256 414 320 971
Email: nbisec@nilebasin.org
Website www.nilebasin.org

Eastern Nile Technical Regional Office

Dessie Road
P.O. Box 27173-1000
Addis Ababa – Ethiopia
Tel: +251 116 461 130/32
Fax: +251 116 459 407
Email: entro@nilebasin.org
Website: http://ensap.nilebasin.org

Nile Equatorial Lakes Subsidiary Action

Program Coordination Unit
Kigali City Tower
KCT, KN 2 St, Kigali
P.O. Box 6759, Kigali Rwanda
Tel: +250 788 307 334
Fax: +250 252 580 100
Email: nelcu@nilebasin.org
Website: http://nelsap.nilebasin.org

Nile Basin Initiative

@nbiweb

ISBN 978-9970-444-02-1