Cuando State of the Basin Report

Knowledge Creation and Capacity Building

Compiled by John Pallett, Inonge Mukumbuta-Guillemin, John Mendelsohn
Published by the Namibia Nature Foundation, Windhoek, and WWF Zambia, Lusaka

Cuando State of the Basin Report

Knowledge Creation and Capacity Building

Namibia Nature Foundation

Compiled and edited by: John Pallett, Inonge Mukumbuta-Guillemin, John Mendelsohn

2022

Published by the Namibia Nature Foundation, Windhoek, and WWF Zambia, Lusaka

Suggested citation: Pallett J, Mukumbuta-Guillemin I, Mendelsohn J, 2022. Cuando State of the Basin Report. Namibia Nature Foundation, Windhoek, and WWF Zambia, Lusaka. 96 pp.

Design & layout: Carmen Begley

Acronyms

CBNRM	Community Based Natural Resource Management.
IRDNC	Integrated Rural Development and Nature Conservation
IWRM	Integrated Water Resource Management
KAZA	Okavango-Zambezi (Transfrontier Conservation Area)
MEFT	Ministry of Environment,Forestry & Tourism
MFMR	Ministry of Fisheries and Marine Resources
NASC	
NGO	Non-Governmental Organization
NGOWP	National Geographic Okavango Wilderness Project
NNF	Namibia Nature Foundation
SBR	State of the Basin Report
SCP	Sustainable Communities Partnership
TOR	Terms of Reference
UNDP	United Nations Development Program
WB	World Bank
WWF	World Wildlife Fund

The name Cuando (rather than Kwando) River is used here, following international practice that names used in the catchments should follow their rivers downstream.

Joint WWF, ZAMCOM and KAZA foreword

The Cuando River Basin is one of the thirteen Sub basins of the Zambezi Watercourse. The Cuando River provides critical water resources to the heart of the Kavango-Zambezi Transfrontier Conservation Area (KAZA TFCA), the largest terrestrial trans-frontier conservation area on the planet. The KAZA region, where Angola, Namibia, Botswana, Zambia, and Zimbabwe converge is home to 2.5 million people, shelters half of Africa's remaining savannah elephant population, and is critical for many other important wildlife species. The Cuando Basin has remained largely undeveloped, with a population of less than 200,000 people, but in recent years is seeing increasing pressure due to climate changes and unsustainable use of natural resources such as water, forests and land.

Without a shared transboundary vision that balances the needs of people and the environment, these pressures could result in negative impacts to the basin and the people who live within it. At the core of such a shared vision is inclusive and sustainable integrated water resource management (IWRM) and increased water security for the benefit of people and ecosystems in the Cuando River Basin, and downstream in the Zambezi Watercourse. Attaining the shared vision in turn requires effective management of water resources, transboundary water governance forums and innovative partnerships.

The State of the Cuando River Basin Report is part of the outputs of a larger project entitled "Transboundary Governance of the Cuando; Protecting the Heart of Southern Africa" funded by the United States Department of State (USDOS) and supported by the World Wildlife Fund for Nature (WWF); the Zambezi Watercourse Commission (ZAMCOM); and the Kavango-Zambezi Transfrontier Conservation Area (KAZA) Secretariat. Preparations of the report began with a multi sectoral stakeholder workshop that took place from 9–11 March 2020 in Kasane, Botswana. More than 35 diverse stakeholders from 19 institutions met to conceptualize the report, together with the team of consultants. The purpose of this report is to:

- profile the hydrology of the Cuando River Basin, including all aspects of the hydrological cycle, namely surface and groundwater, and the climate that governs the precipitation and evaporation of water;
- documentation of the basin's key ecological features and processes, such as topography and soils, vegetation, wildlife populations, fire dynamics and trophic interactions;
- collate information on the socio-economic circumstances, including traditional natural resource practices, and future potential & opportunities;
- compile current levels of water use, and existing and planned developments in the Basin;
- identify threats to the economic conditions and the natural resources in the Basin; and
- provide a record of the relevant actors in the Cuando River Basin, including investors/cooperating partners, local and international Non-Governmental Organizations (NGOs).

The State of the Basin Shows that the Cuando River is mostly pristine. Conservation is the dominant land use, and is increasing in importance while at the same time, poverty reduction and addressing environmental degradation are key concerns.

The partnership behind this report shall therefore continue to support efforts to strengthen transboundary water governance and inclusive decision-making mechanisms across the four Riparian Countries (implementing states) that the Basin traverses: The Re-

publics of Angola, Botswana, Namibia, and Zambia. Through the Kwando Joint Action Group (KJAG) a public and non-state actors' collaborative platform was specifically established to support dialogue processes during the preparation of the State of the Basin Report, collective action and visioning for the Cuando River Basin was advanced. There are strong indications of appreciation of the CJAG as a platform for dialogue and cooperation supporting sustainable utilization, development, protection, and science based decision making for transboundary water resources management should be sustained beyond this project's timelines.

Sincere gratitude therefore goes to United States Department of State who funded the project. The contributions of the (KJAG) and the ZAMCOM Technical Committee (ZAMTEC) are highly appreciated. Special thanks are due to the Ministries and multi sectoral stakeholders that form the country National Multi Stakeholder Committees (NAMSCs) in the Republics of Angola, Botswana, Namibia and Zambia for their participation, technical reviews and guidance on the reports from the consultants. Appreciation is due to supporting organizations that include Namibia Nature Foundation, Global Water Partnership Southern Africa (GWPSA), International Water Management Institute (IWMI), the World Bank in Zambia and civil society organizations (CSOs) that participated in the various activities leading to this important report.

Ms. Nachilala Nkombo
WWF Zambia Country Director

Mr. Felix M. Ngamlagosi
ZAMCOM Executive Secretary

Dr. Nyambe Nyambe
Executive Director KAZA TFCA

Table of contents

Table of figures

Table of figures (cont.)

Acknowledgements

We appreciate the time and inputs given by the client, WWF Zambia, towards making this report clear and concise; particularly Brian Chilambe, Faith Chivava, Obrian Mwanza and Beauty Shamboko-Mbale. Also, valuable feedback was given during meetings of Zamcom and the Kwando Joint Action Group, including interactions with the country focal points of the four basin states.

Various government departments, NGOs and other organisations and individuals have shared their data and expertise, including:
Antonio Chipita
Robin Clanahan, retired engineer
Competence Center Environment and Sustainability, African Dams Project (ADAPT): Lucas Beck and Thomas Bernauer
Department of Water Affairs, Ministry of Agriculture, Water and Land Reform, Namibia: Geraldine Diergaardt
Retha-Louise Hofmeyr
International Water Management Institute, Southern Africa office: John Lindle and Karen Villholth
Kwando Carnivore Project: Lise Hanssen
Namibia Nature Foundation projects: fish life in the Zambezi and Cuando River systems - Clinton Hay and Charles Hocutt; vegetation - Frances Chase; forestry and conservancies - Juliette Perche
Namibia University of Science and Technology: Marina Coetzee
Panthera: Paul Funston, Lisanne Petracca
South African Institute for Aquatic Biodiversity: Denis Tweddle
Southern African Institute for Environmental Assessment: Peter Tarr
Stellenbosch University, Centre for Invasion Biology: Brian van Wilgen
Ben van der Waal, retired fish biologist
Stefan van Wyk
University of Cape Town, Climate System Analysis Group: Piotr Wolski
WWF KAZA Secretariat: Mike Knight

Our sincere thanks go to Katharina Dierkes for her painstaking care with the GIS information and providing clear maps.

This report has benefited from numerous photos and data from the National Geographic Okavango Water Project (NGOWP), which undertook expeditions down various Angolan tributaries of the Okavango, Cuando and Zambezi Rivers in 2018-2019. The Cuando and Kembo River expeditions were staffed with biodiversity experts, and travelled in 18-foot fibreglass replicas of the traditional dugout canoes, equipped with solar panels and electrical gadgetry to record and make readily available the wide array of studies.

1. Introduction

The Cuando River is one of the few remaining undisturbed, naturally connected rivers on Earth today. The river originates out of a remote and wild area in Central and Southern Angola, flows alongside the Zambian border for about 220 kilometres, and then crosses Namibia's Zambezi Region before ending in the Linyanti Swamps on the border with Botswana. Along much of its passage and with its relatively stable flows year-round, the Cuando is a linear oasis for wildlife and people and is the only water within the thousands of square kilometres of dry sandy woodlands that flank the river.

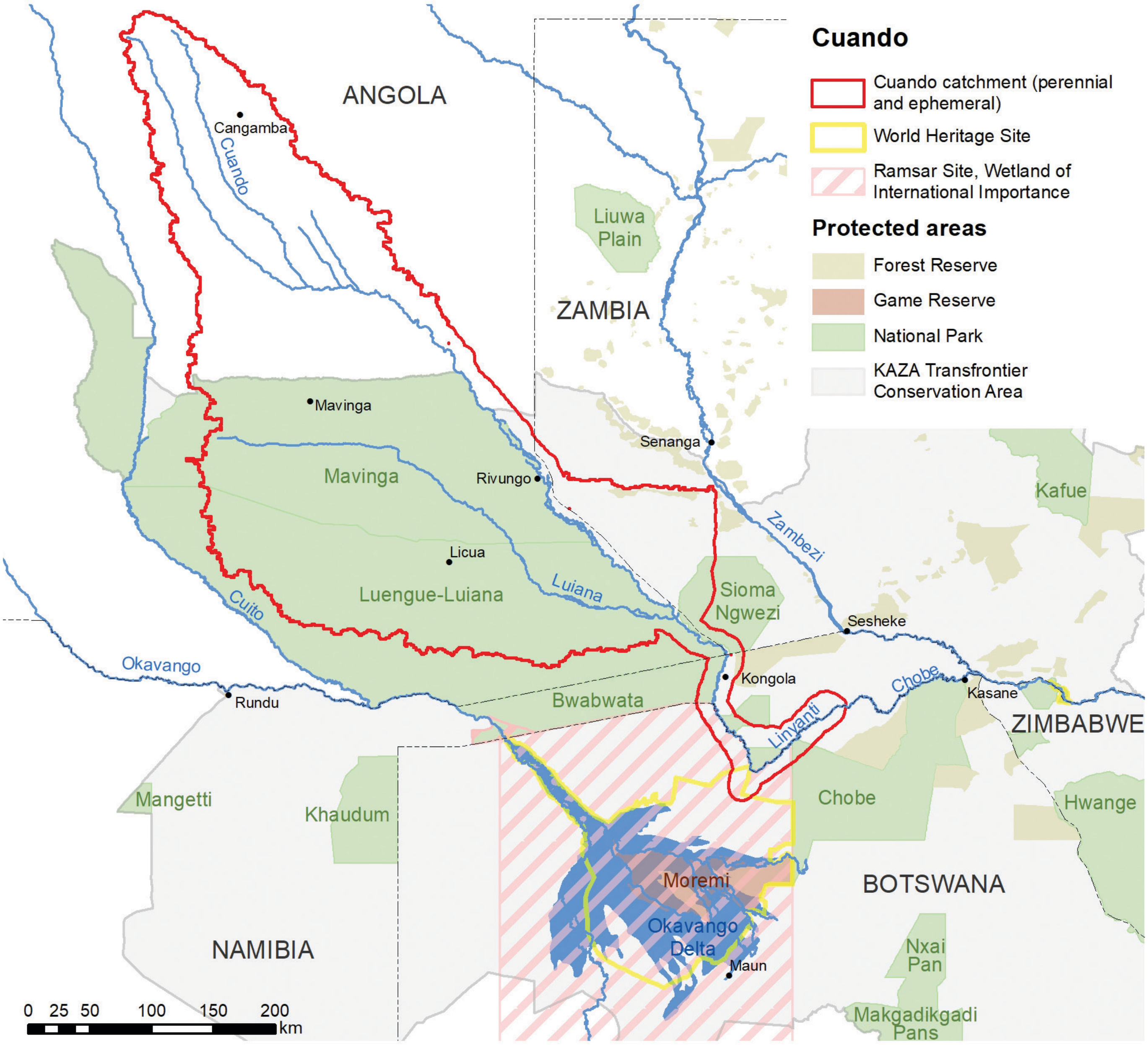


Figure 1: The Cuando River Basin.

Probably the most unusual aspect of the Cuando is its hydrological functioning. Arising in an area of relatively high rainfall, the river channel is surprisingly small but its floodplains are wide and extensive, caused by the flat and sandy terrain that it crosses in southern Angola. The water is slowed down as it follows a sinuous path with many oxbows and cut-off channels in a wide marshy bed of reeds and grasses. This finally makes its way into Namibia and the border with Botswana, where past geological forces have caused it to makce a right-angled turn into the Linyanti Swamps. Under certain conditions that are still poorly understood, Cuando water may connect with its neighbouring river basins, the Okavango and Zambezi. These connections are both intriguing and influential, as they demand shared and transboundary management.

This State of the Basin Report attempts to explain the complexity of the Cuando. It has been compiled through research and an inclusive consultative process with stakeholders in the basin, to strengthen transboundary water resources management and decision-making. The report aims to build the knowledge and understanding of the basin, as a contribution to attainment of the Sustainable Development Goals.

1.1 Purpose of this State of the Basin Report

A core requirement of the Sustainable Development Goals is to enhance global partnerships amongst stakeholders, to mobilize and share knowledge, expertise and technology for sustainable development. This transboundary knowledge creation and capacity development assessment is necessary in integrating water resource management and governance at all levels, including through transboundary cooperation, to protect and restore water-related systems.

There are several competing pressures over resources in and around the Cuando. These include land and water competition between wildlife reserves and pastoral economies, changing socio-economic circumstances for the local residents, and climate change and variability, which is expected to exacerbate the occurrence of floods and droughts.

To address these challenges, this report provides the information and context for preparing relevant policy actions at the local, national and transboundary levels. Integrated water resources management in transboundary basins calls for objective information. This has been gathered from relevant reports, data and descriptions of the natural, physical and social resources of the basin. Specifically, the maps have accumulated geographic information from many sources and present the current state of knowledge of the resources.

The State of the Basin Report (SBR) aims to provide social, political, economic and environmental information, with recommendations for policy action on transboundary natural resource management.

The second aim of the SBR is to provide a better understanding of how conservation and community-based livelihood development can be structured to benefit the basin and downstream ecosystems. This aim integrates the primary linkages to the SDGs which are:

i. Goal 6: Clean water and sanitation;
ii. Goal 2: Zero hunger;
iii. Goal 7: Affordable and clean energy;
iv. Goal 11: sustainable cities and communities
v. Goal 13: Climate action;
vi. Goal 14: Life below water; and
vii. Goal 15: Life on land.

Finally, the last aim is to complement other scientific work that is being undertaken in the area (such as the 'Lishima Watershed Partnership') to establish and support effective management of newly proposed conservation areas in the Okavango-Zambezi Water Tower. This aligns with SDG Goal 17: partnerships.

In summary, this SBR presents:

- A profile of the hydrology of the Cuando, including all aspects of the hydrological cycle, namely surface and groundwater, and the climate that governs the precipitation and evaporation of water;
- Documentation of the basin's key ecological features and processes, such as topography and soils, vegetation, wildlife populations, fire dynamics and trophic interactions;
- Information on the socio-economic circumstances, including traditional natural resource practices, and future potential & opportunities;
- A compilation of current levels of water use, and existing and planned developments in the basin;
- Identified threats to the economic conditions and the natural resources in the basin;
- A record of the relevant actors in the Cuando River Basin, including investors/donors, local and international NGOs, and partners.

This will provide the information for a Policy Brief for Cuando Basin Management, which will be developed in consultation with members of the NASC.

2. Hydrology

The Cuando is the smallest of the rivers that rise in the 'Okavango-Zambezi Water Tower' or *Lisima Lya Mwono* (meaning 'the source of life'), the hilly area of south-eastern Angola where these rivers originate. To get an idea of its relative size: the flow rate of the Cuando measured at Kongola is just over 1 billion cubic metres per year; compare this to the Zambezi which is about 40 billion at Victoria Falls[1], and the Okavango at 9 billion at its inflow into the Delta[2] (Figure 2).

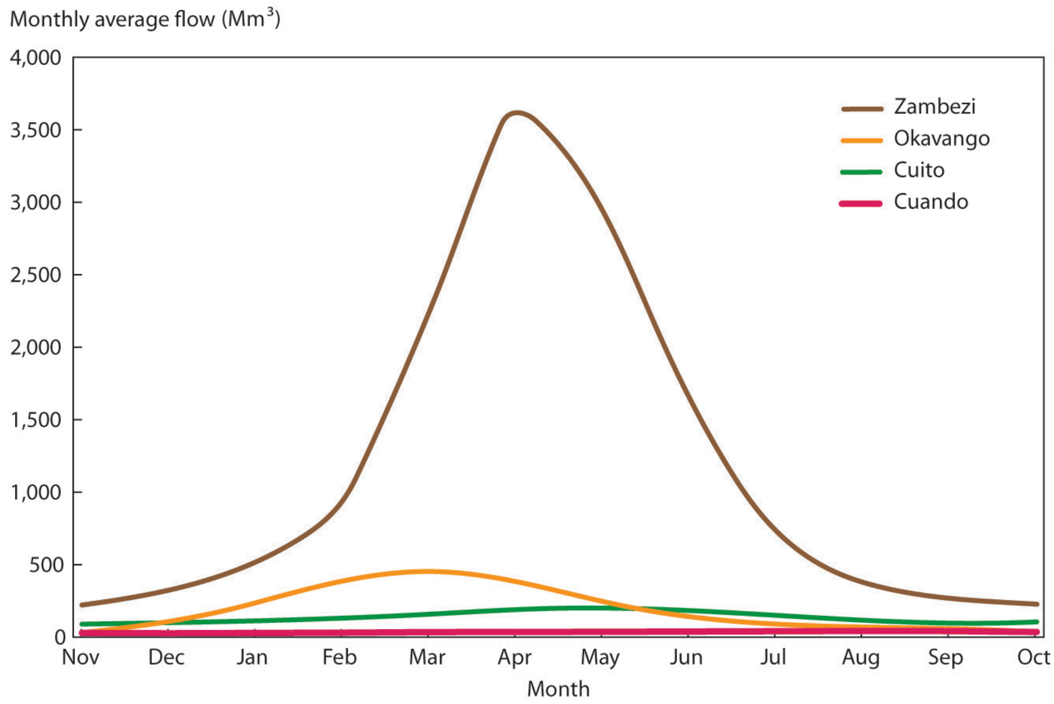


Figure 2: Average discharges in millions of cubic metres per second each month in 2001 to 2019 at Katima Mulilo (Zambezi), Rundu (Okavango), Dirico (Cuito) and Kongola (Cuando) The data are from DWA, Namibia

2.1 Parts of the Cuando River Basin

Any study of the functioning of the Cuando wetland system must distinguish between the 'wet' and the 'dry' or dormant parts of the Basin. The southern part of the basin contributes no surface water to the main stem of the river, making the Cuando a linear oasis through an area of dry sandy woodland that extends for more than a hundred kilometres on either side of the river. Life along the Cuando is therefore different from elsewhere, both in its diversity and abundance.

Using the criterion of surface flow, the Cuando River Basin can be categorised into perennial, ephemeral, dormant and shared sections, as shown in Figure 3 on the following page. The perennial and ephemeral parts correspond roughly with what are called the upper and lower parts of the river basin in Angola.

1 Schlettwein CHG, Simmons RE, MacDonald A & Grobler HJW. 1990. Flora, fauna and conservation of East Caprivi wetlands. Madoqua 17(2): 67-76.
2 Mendelsohn JM, vanderPost C, Ramberg L, Murray-Hudson M, Wolski P, & Mosepele K. 2010. *Okavango Delta: Floods of Life*. RAISON (Windhoek, Namibia).

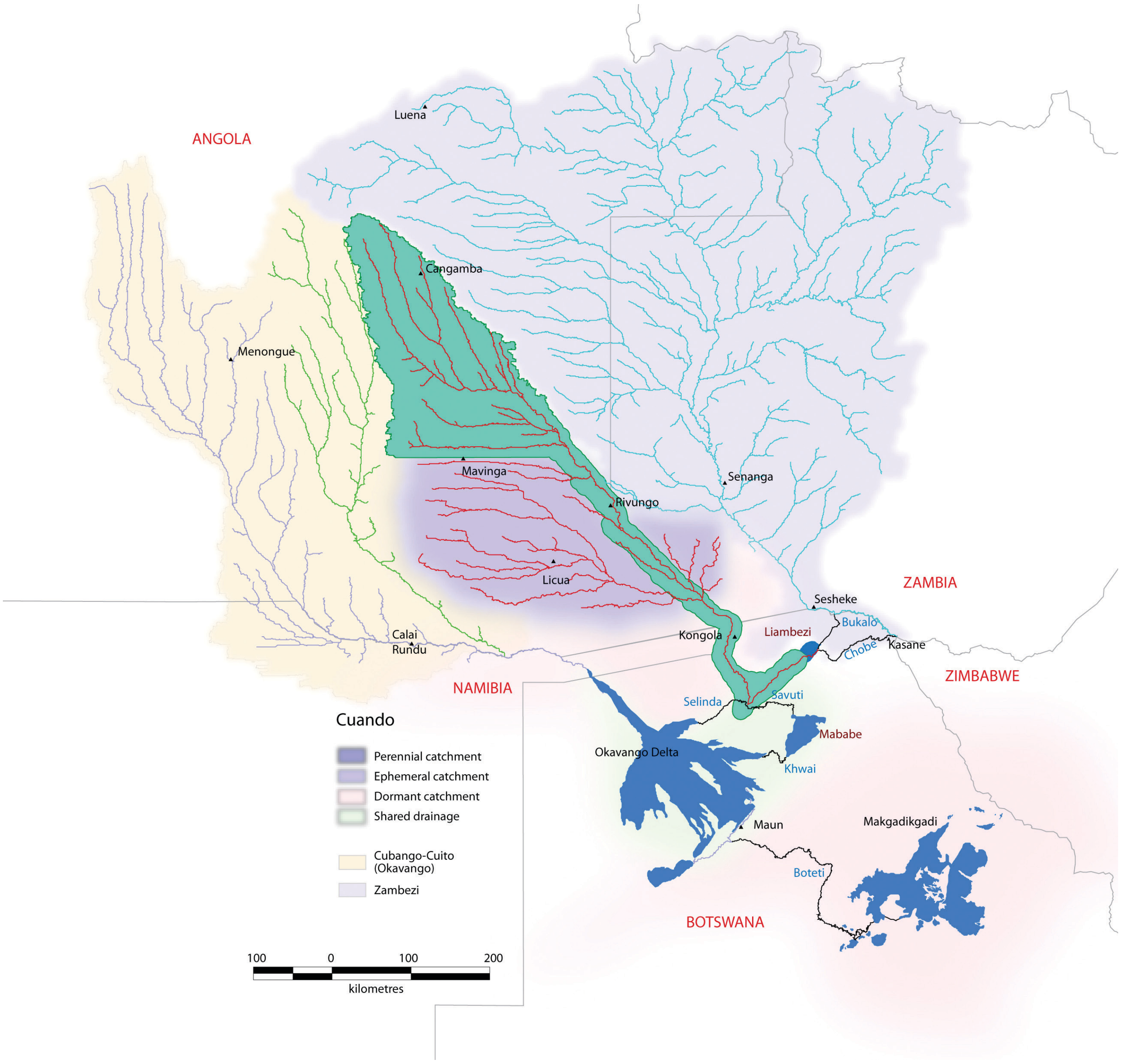


Figure 3: Perennial, ephemeral, dormant and shared sections of the Cuando River Basin.

2.1.1 The perennial part of the Cuando

All of the Cuando's surface water originates in Angola; in fact, most of it from only the northernmost third of the basin within that country. The main tributaries named Kembo, Cuando, Cubangui, Cussivi, Cueio and Lomba make up the upper Cuando Basin and send their flows south-eastwards along the main stem of the river. The Kembo rises from Lake Saliakembo, a relatively large (0.17 km2) and deep (15 m) lake that appears to have been created by a landslide that obstructed subsurface flow in marshy ground and forced the water to the surface[3]. The Cuando has no source lake.

The rolling hills in the north deliver the great majority of the Cuando's surface flows. Here, rainwater per-

3 NGOWP (2017). Report 1: Initial Findings from exploration of upper catchments of the Cuito, Cuanavale and Cuando Rivers in Central and South-Eastern Angola. NGOWP annual report 2015-2016. 347pp.

colates into the deep porous sand, and at least some water is forced by hard layers of rock or sediments to move horizontally out of the hill slopes. From there, the water feeds small bogs and streams, which later aggregate to form the Cuando's main tributaries. The waters are clear and uncontaminated. The channels have sloped, grassy sides, and are occasionally filled with riparian trees.

Figure 4: Semi-submerged aquatic vegetation alonbg the upper Cuando River. (Photo: NGOWP)

Figure 5: The upper reaches of the Cuando and Kembo Rivers have many tree plockages which generally consist of fig and water-berry trees. (Photo: NGOWP)

Figure 6: Screen shot of the 360 degree picture transects down the Kembo and Cuando Rivers. Images like this were taken every minute on the Okavango Wilderness Project trips to provide a virtual journey down the rivers

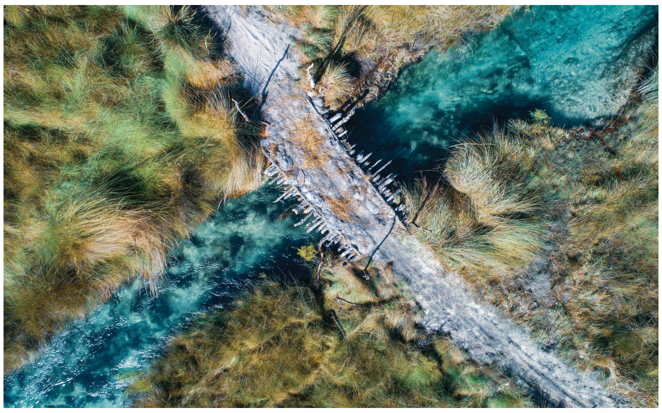


Figure 7: Motorbike bridge crossing the upper Cuando River. Note the fast-flowing, sparklingly clear water. (Photo: NGOWP)

This part of the river is barely known to the outside world but can be glimpsed from the photographic record of the National Geographic expedition down the Kembo and Cuando Rivers in 2018. Their 360° photos can be found at
https://arcgis.earthviews.com/public/cuando#0
https://arcgis.earthviews.com/public/kembo-2018#0

2.1.2 The ephemeral part of the Cuando

From physical observation and satellite imagery, it is clear that south of the confluence with the Lomba, there are very few further tributaries that contribute any more water to the main flow, and this happens only occasionally. The main ephemeral tributaries are the Cubia, Luengue, Utembo and Luiana Rivers. These channels in the ephemeral zone flow only intermittently after substantial rains have fallen (see the Luiana River example on the following page).

In the lower two-thirds of the Cuando Basin the river widens out into a *Phragmites*-dominated marsh between

10 and 15 kilometres wide over the next 360 kilometres of its straight-line course. The water spreads out as it percolates through the reeds with its channel slowly flowing along hundreds of meanders. Much of the water is lost through evaporation and transpiration as it heads downstream. Small islands are scattered in the broad expanse of reedbeds and meanders.

The small contribution of water from the lower tributaries is demonstrated in the time-lapse photos of an unusual ephemeral flow in the Luiana (figure 8). The image shows the Cuando floodplain upstream of the Luiana confluence to be 4-6 km wide; think of the losses of water from that breadth of floodplain under the tropical sun, and with all those reeds and grasses transpiring water into the dry air. The image also shows the comparatively tiny contribution of Luiana water that eventually makes it into the Cuando. The wide floodplain explains why the total discharge of the Cuando is so much less than its neighbouring river to the west, the Cuito, which arises from much the same part of Angola. Floodplains in the lower Cuito are much narrower and less vegetated than in the Cuando, so that river loses less of its water.

A rare flow in the ephemeral Luiana River

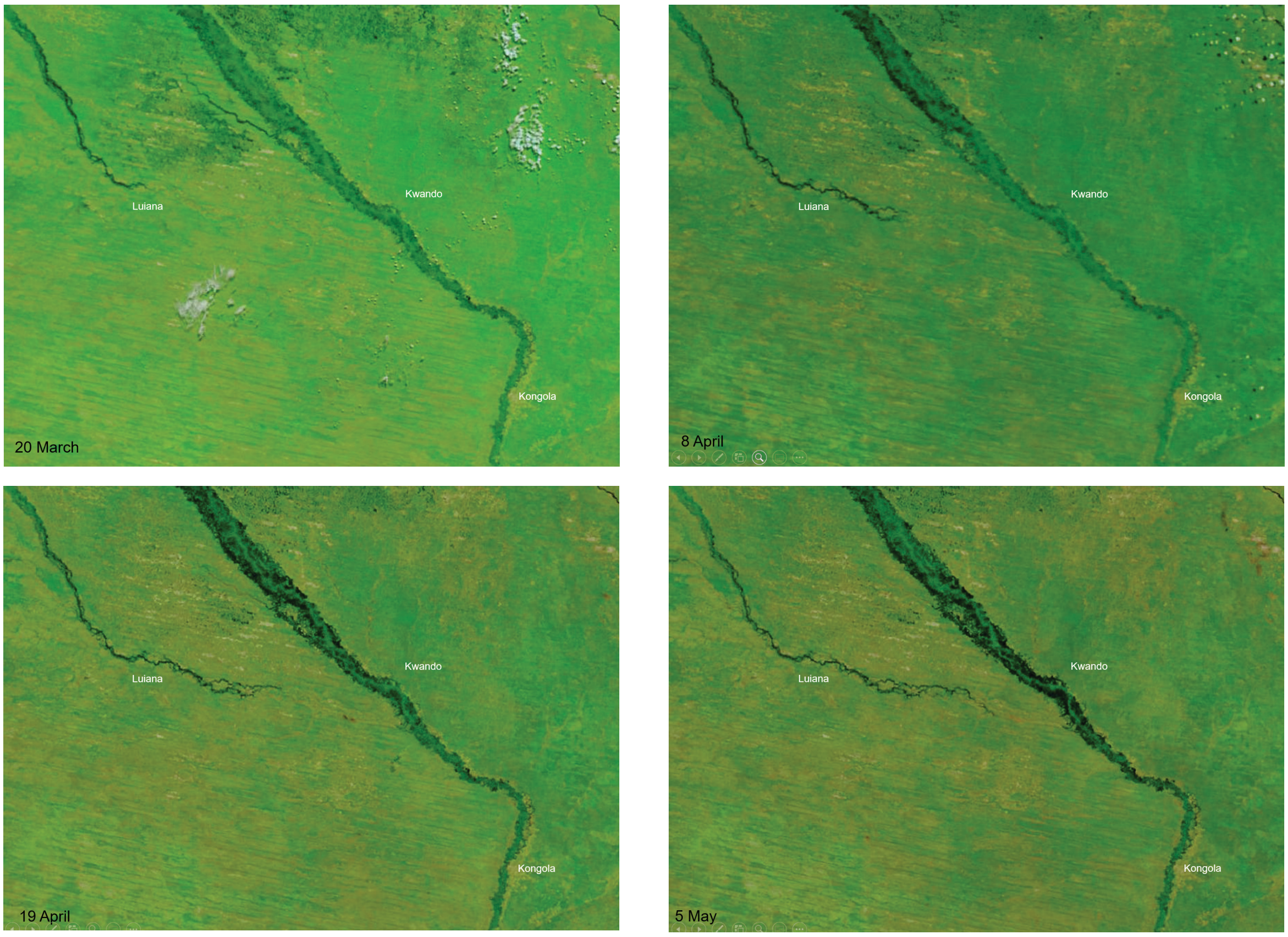


Figure 8: Satellite images of water flow in the ephemeral Luiana River

These Modis images taken on 20 March, 8 and 19 April and 5 May 2009 record a rare significant flow of water in the ephemeral Luiana River. Note the surface water in the Luiana steadily approaching its confluence with the Cuando, and the increasing flow of surface water south along the Cuando. The expanse of dark, surface water in the Cuando is between 4 and 6 kilometres wide.

The dark line of surface water in the Luiana has a width of 500 to 1,000 metres.

2.1.3 The dry part of the Cuando

The lack of surface channels in the southern dormant zone of the basin is associated with somewhat less rain falling there than to the north. But even during heavy rains here and in the ephemeral zone, the great majority of rainwater seeps into and disappears in the deep, porous sands that characterise the entire Basin. Bear in mind that the entire southern and ephemeral zone is extremely flat, thus affording no slope across which even the heaviest rain might wash or flow. It is indeed worth investigating what is the fate of the water that infiltrates into the sand, possibly accumulating in deep aquifers of a type that has recently been detected (see section 2.3 Groundwater).

The Cuando River is a single channel in a wide floodplain where it crosses into Namibia and then passes the town of Kongola. The river meanders strongly across the breadth of the floodplain, and the water slowly follows a path which is more than three times longer than the straight-line distance between points[4]. As these twists and turns get cut off over time they become oxbow lakes that are separated from the main channel.

That describes the river and its broad reedbeds. On either side, there are no tributaries or other drainage features. This dry and dormant part of the basin has probably been like this for hundreds of years.

Figure 9: The large population of elephants along the Cuando in Namibia makes up part of the wildlife experience in Bwabwata National Park. (Photo: Helge Denker)

Figure 10: Aerial image of the Cuando floodplain showing the meandering nature of the main channel, numerous curved relicts of past meanders, and oxbow lakes that have become pinched off from the main flow. Note the greener reedbeds near the channel, a consequence of these plants having the best access to the sypply of nutrients delivered by the incoming flow. (Photo: John Mendelsohn)

Figure 11: The Trans-Zambezi Highway crosses the Cuando River near Kongola. (Photo: Peter Tarr)

4 National Geographic Okavango Wilderness Project, 2020. Final Report: Scientific Exploration in Angola During 2018. Pp 70

2.1.4 The shared part of the Cuando

In their Angolan catchments the Cubango/Cuito, Cuando and Zambezi are discrete bodies of water. But downstream they can connect with each other when water levels are high in the three river systems. This makes it impossible to accurately define the watersheds that separate these systems in the area covered by Namibia's Zambezi Region (previously known as Caprivi), and the adjoining areas of Botswana.

The Cuando is spelled as Kwando in Namibia, and is called the Linyanti River from where it makes a right-angle turn to the north-east, at the inlet of the Selinda or Magweqgana Spillway. The river then winds through a swampy area – the Linyanti Swamp – with small side channels, oxbows and forested islands. Here the channels are clogged with reed beds which slow down any flow and cause the water to spread out. The southern bank is slightly raised, making that a sharply defined boundary. But the northern side slopes very gradually, allowing the Swamp to reach a width up to 6 km near the village of Linyanti. Rarely, the Linyanti River may reach a large shallow depression, Lake Liambezi, which is an ephemeral feature. The Lake obtains most of its water from the Zambezi River via the Bukalo Channel and Chobe River, and is thus an ephemeral backwater of the Zambezi River.

The Chobe River is permanently connected to the Zambezi River, but occasionally pushes back to Lake Liambezi where its waters could mix with water from the Cubango/Cuito and Cuando Rivers. The direction of flow in the Chobe is therefore sometimes towards the Zambezi, and sometimes towards the Lake Liambezi, determined by the relative height of the water in the different areas.

To add to the complications, Cubango/Cuito water in the Okavango Delta may reach the Cuando and Linyanti Swamps via the Selinda Spillway. When high, water in both the Cuando and Okavango Delta can flow into the Mababe Depression, the former via the Savuti Channel and the latter along the Khwai River. Thus, water collected from across the broad Angolan catchments can later be spread across other broad areas in northern Botswana.

Interestingly, a new channel south of Kongola, lying in Botswana to the west of the existing channel, has recently been reported[5]. This is a clearly defined and navigable channel, 11-12 metres wide and up to 2 metres deep. It appears to have originated after 1985 with natural diversion of water into a small lagoon which gradually increased in size and then carved its own channel through the floodplains, growing wide in several places and forming marshy areas along its way. It appears that this channel spills into the Selinda Spillway, which may mean that very much less water will flow into the Linyanti in future.

This unusual mixing of basins has been known for some time but the details of each river's contributions have relied only on sporadic studies, usually sparked by high floods when the extent of the water has been most impressive[6]. Until now, there has been no systematic long-term study, through drier and wetter periods, of river flows in the greater area where the basins meet. For this study, satellite images going back to 1972 were closely inspected for the presence/absence of surface water, giving a much clearer picture of the nature of these links.

5 Kurugundla CN, Morongwane BK, Bombo T. 2018. Kwando New Channel - Development and evolution of New Channel parallel to Kwando River in Botswana. Unpublished Report, Ministry Of Land Management, Water And Sanitation Services, Department Of Water Affairs, Botswana.

6 Van Langenhove G. 2004. Hydrology of Zambezi floodplains: 2004 Flood in Caprivi Region. Unpublished report, Hydrology Division, Ministry of Agriculture, Water and Forestry, Windhoek.

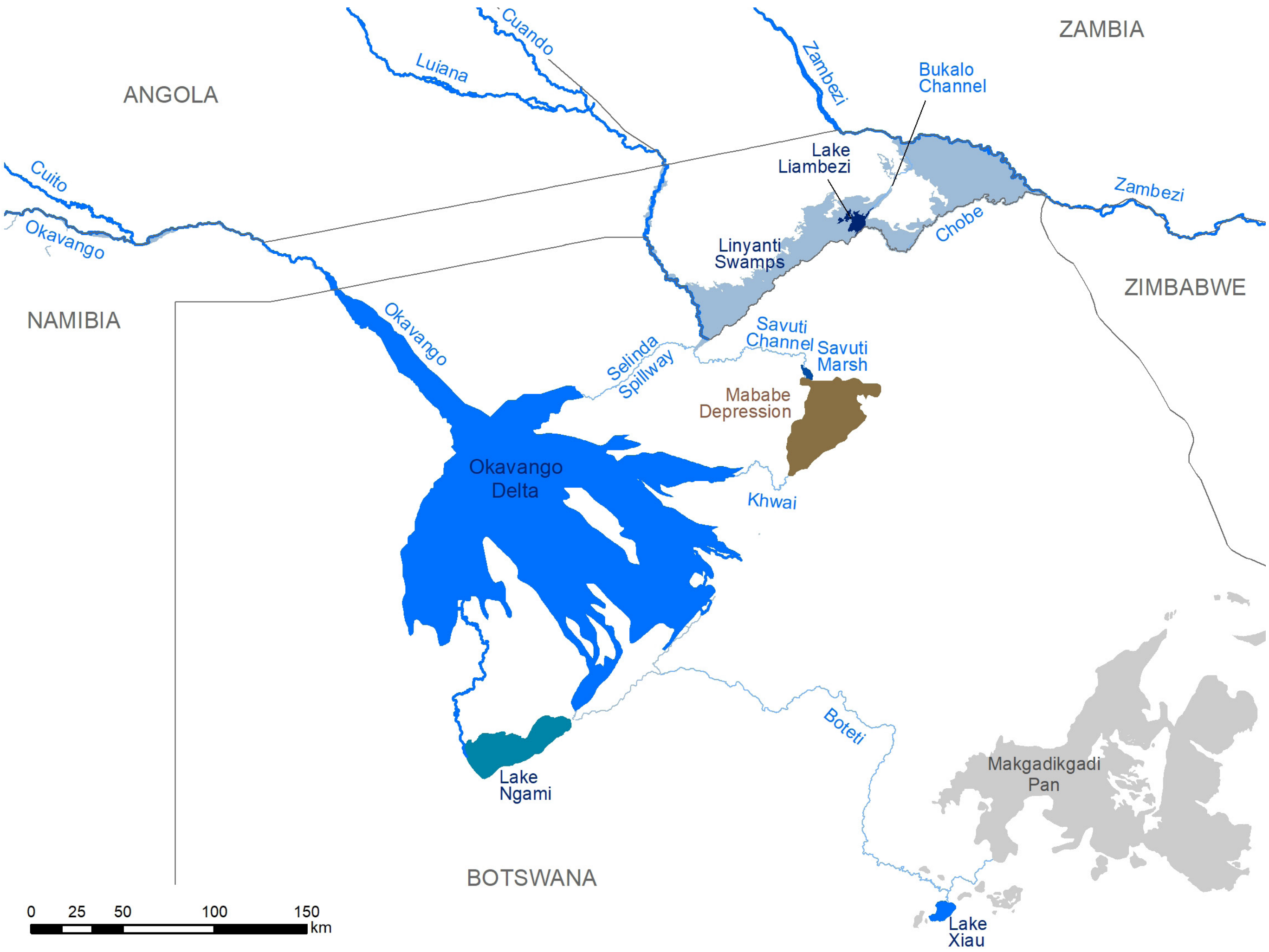


Figure 12: Hydrological features of the southern part of the Cuando River Basin and its occasional links to the Zambezi and Okavango River Basins

2.1.5 The key connection - Linyanti Swamp and Lake Liambezi nexus

Lake Liambezi[7] is a backwater the Zambezi River with a history of long periods of being dry alternating with periods of holding water up to several metres deep. During dry times it is an expanse of open grassland and fields, often with fires that burn from combustion of the thick organic layer of peat that builds up during periods of inundation. These dramatic variations depend on the water levels in the surrounding rivers, with flows coming in from a few possible sources, namely from the Zambezi down the Bukalo Channel (the predominant source), or by water backing up the Chobe River, or from the Cuando River via the Linyanti Swamps. Local rainfall also contributes water inputs.

When full, the lake and the surrounding area of temporarily inundated floodplains covers an area of about 300 km^2, although open water makes up about 150 km^2.

7 Information drawn from the following sources: (i) Mutelo MA. 2013. An understanding of variations in the area extent of Lake Lyambezi: Perspective for water resources management. MSc thesis, University of Zimbabwe, Harare. (ii) Peel RA, Tweddle D, Simasiku EK, Martin GD, Lubanda J, Hay CJ, Weyl OLF. 2015. Ecology, fish and fishery of Lake Liambezi, a recently refilled floodplain lake in the Zambezi Region, Namibia. African Journal of Aquatic Science 40(4): 417-424. http://dx.doi.org/10.2989/ 16085914.2015.1105779 (iii) Peel RA, Hill JM, Taylor GC, Tweddle D, Weyl OLF. 2019. Species succession and the development of a lacustrine fish community in an ephemeral lake. J Fish Biol. 95:855–869. https://doi.org/10.1111/ jfb.14081 (iv) Seaman MT, Scott WE, Walmsley RD, van der Waal BCW, Toerien DF. 1978. A limnological investigation of Lake Liambezi, Caprivi. *Journal of the Limnological Society of Southern Africa* 4: 129–144. (v) Van der Waal. 1990. Aspects of the fishery of the Eastern Caprivi. Madoqua 17(1): 1-16. (vi) MAWRD. 2003. Environmental Assessment of the Caprivi Agriculture Project and Lake Liambezi Rehabilitation. Compiled by AfriDev Associates (Pty) Ltd, South Africa, and SIAPAC Namibia. Unpublished report, Ministry of Agriculture, Water and Rural Development, Windhoek.

It can reach a depth of seven metres when full, as was measured in a peak in 2010. Reed beds grow around the perimeter, particularly in the south-western margin.

It is difficult to piece together the history of filling and drying of the lake, because there has been very little, and only discontinuous, recording of its levels. However, LandSat and Sentinel satellite images provide a more thorough record from 1972 to the present[8], which help to place into context some of the other information available from scientists who were mainly interested in the fish, and from environmental assessment reports dealing with proposed developments in the lake.

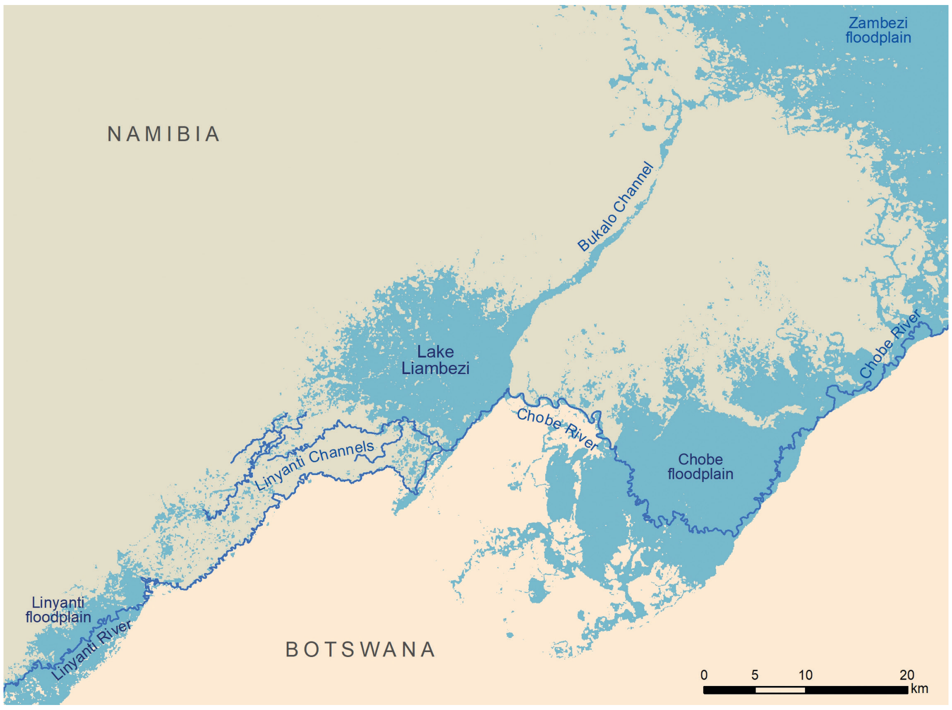


Figure 13: Lake Liambezi and its connections to the surrounding channels that feed it and/or drain it

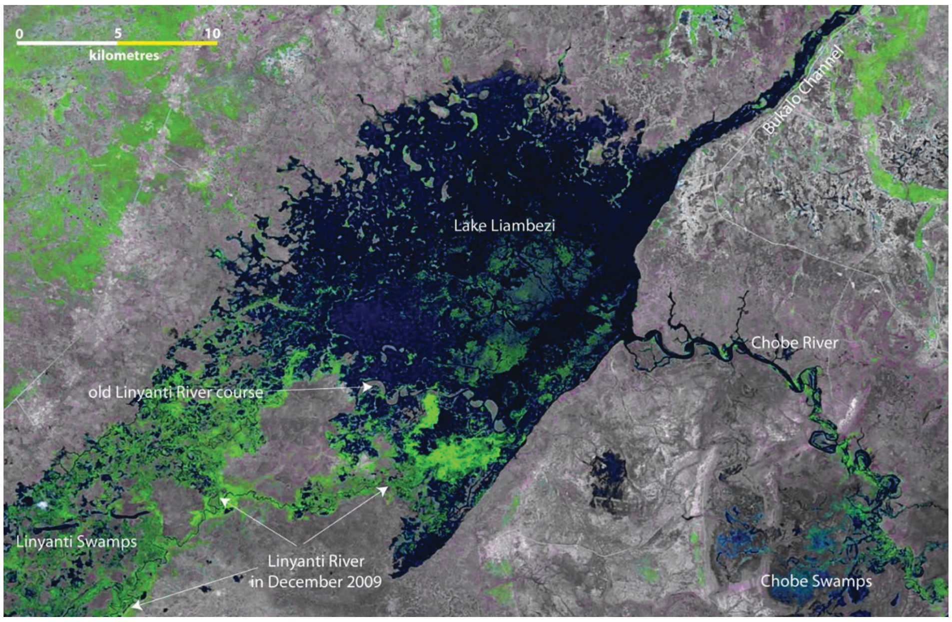


Figure 14: Satellite image of Lake Liambezi in September 2009 when the Linyanti River probably supplied water to the Lake. A broad, old channel of the Linyanti River is indicated. Floodwaters in the Chobe Swamps had subsided. Surface water is black or blue-black in the image.

8 Mendelsohn J. 2021. Water flows in the Cuando River, and in and out of Lake Liambezi. Summary results. Unpublished report.

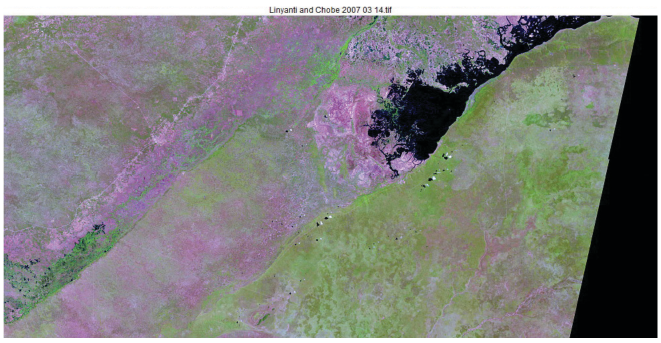
From the 50-year record of satellite images, three periods were identified:

A wet phase of 12 years from 1972 to 1983. Lake Liambezi was flooded during all six of the years with images in this phase, the Savuti Marsh was flooded during all five years with images, and the Selinda (Magweqgana) Channel reached or almost reached the Cuando River in three of the four years with images in this period. Written records not verified by satellite images indicate that this wet phase began in about 1952. If this is true, the wet phase lasted 30 years.

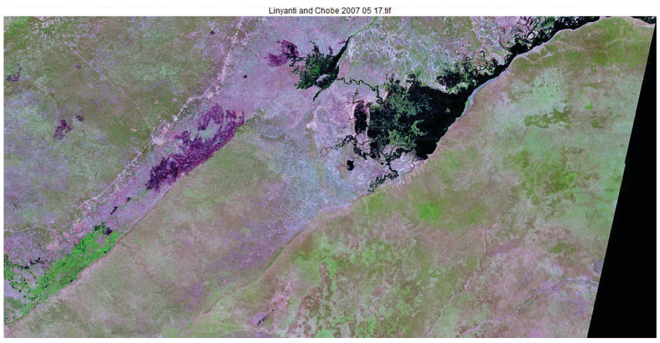
A dry phase of 26 years between 1984 and 2009. Liambezi was dry or had very little water in most of the 26 years of this for which images were available; 2004 was a striking exception. During the 26 years neither the Savuti Channel nor the Selinda Spillway reached the Savuti Marsh and Cuando River, respectively. The south-western corner and Zibadianja lagoon area of the Cuando had far less standing water than during the wetter earlier and later periods.

A wetter phase of 12 years from 2010 to 2021. Lake Liambezi carried water in all the 12 years. It was supplied with water by the Bukalo Channel and Chobe River in four of those 12 years. In the remaining eight years the Lake was recharged by rainwater while also holding water accumulated in previous years. The Savuti Channel flowed into the Savuti Marsh in six of the 12 years, while the Selinda Spillway joined the Cuando in nine of the 12 years.

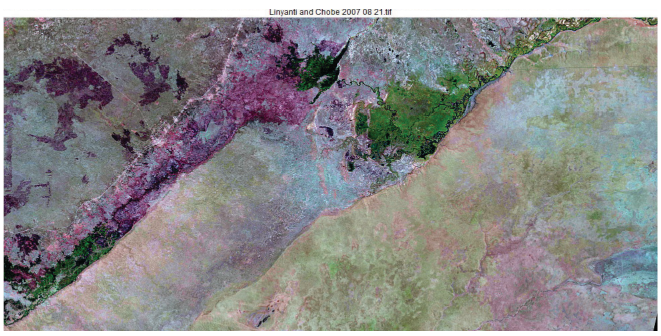
For Lake Liambezi to receive water from the Zambezi River, the level of the water (as measured on the flow gauge at Katima Mulilo) must be at about 7 metres, to allow it to get over a low ridge into the Bukalo Channel that is just east of the village of Bukalo. Water in the Chobe River pushes westwards (= 'backwards') to the Chobe floodplain but observations suggest that the water level must be over the 7 m threshold (at Katima) to allow Chobe water to enter Lake Liambezi. Water from the Chobe River pushed back into Lake Liambezi in only 11 of the 40 years for which images were available. During six of those years the Bukalo also flowed into the Lake.



14 March 2007: The Chobe Swamp contains water, but the Chobe River linking this to Lake Liambezi is dry.



17 May 2007. The Chobe River connects with Lake Liambezi. Both the Lake and Chobe Swamps are flooded.



21 August 2007. The flood recedes, with the lake water flowing eastwards down the Chobe back to the Zambezi.

Figure 15: Satellite images from March to August 2007. Note the upper Linyanti Swamps are dry (not green) throughout this period. Sequence of images from March to August 2007, showing the Chobe River pushing 'backwards' and filling Lake Liambezi.

Water from the Cuando River reaches Lake Liambezi occasionally, as in the 2009 image (Figure 14) via the Linyanti Swamps and Linyanti River. But in 37 of the 40 years in which images were available, the Linyanti River stopped flowing south-west of Liambezi, or its flow through the Linyanti Swamp was too small to be discerned.

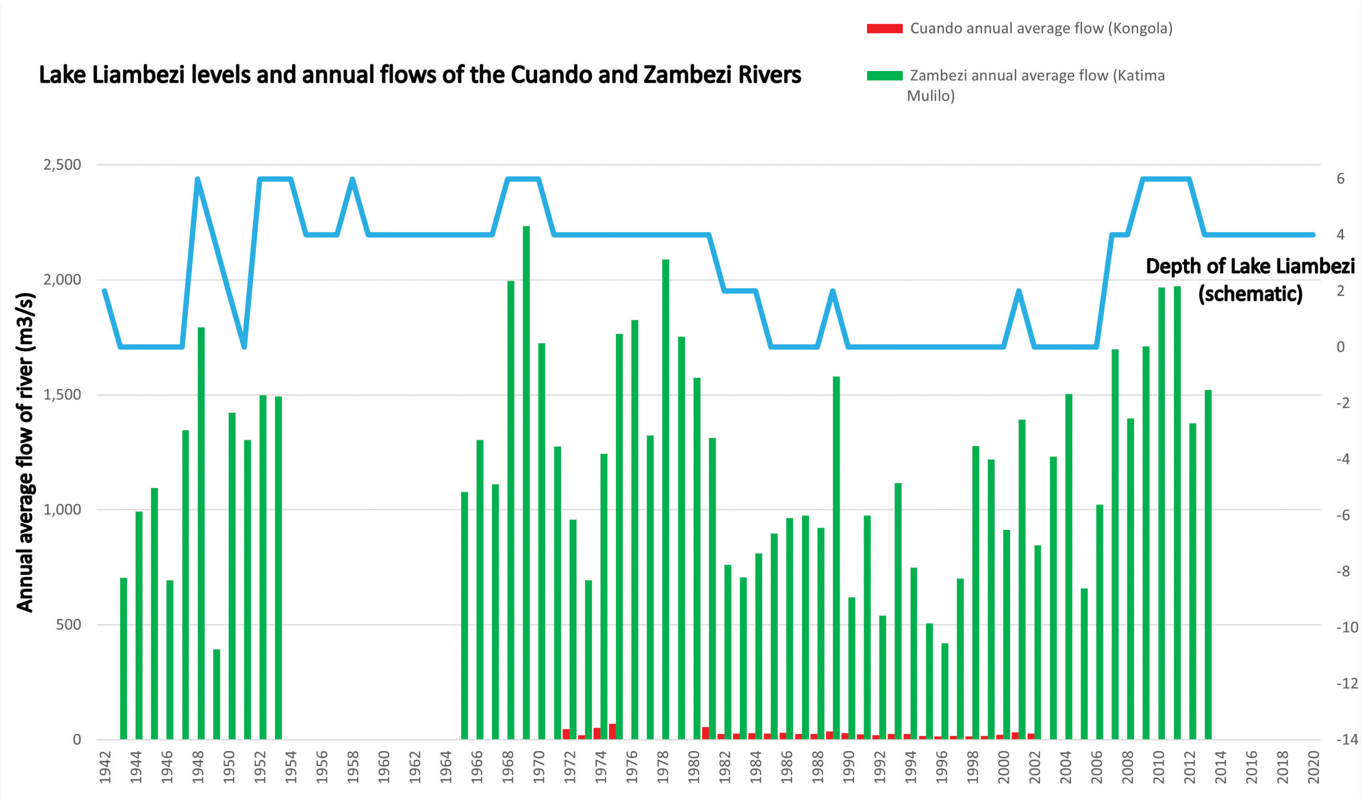


Figure 16: Schematic representation of the water level of Lake Liambezi from 1943 to 2020, plotted with the annual average flows of the Zambezi and Cuando Rivers.

Figure 17: Lake Liambezi in 2015. (Photos: John Pallett)

Water in the Linyanti can also originate from the Okavango via the Selinda Spillway: this joined the Cuando River 11 times out of the 40 years of available images, and got within a few kilometres of the Zibadianja lagoon in three years (Figure 18). During 18 of the 40 years flows along the Selinda (Magweqgana) Spillway did not come within 40 kilometres (traced along the Spillway) of the Cuando River's Zibadianja lagoon.

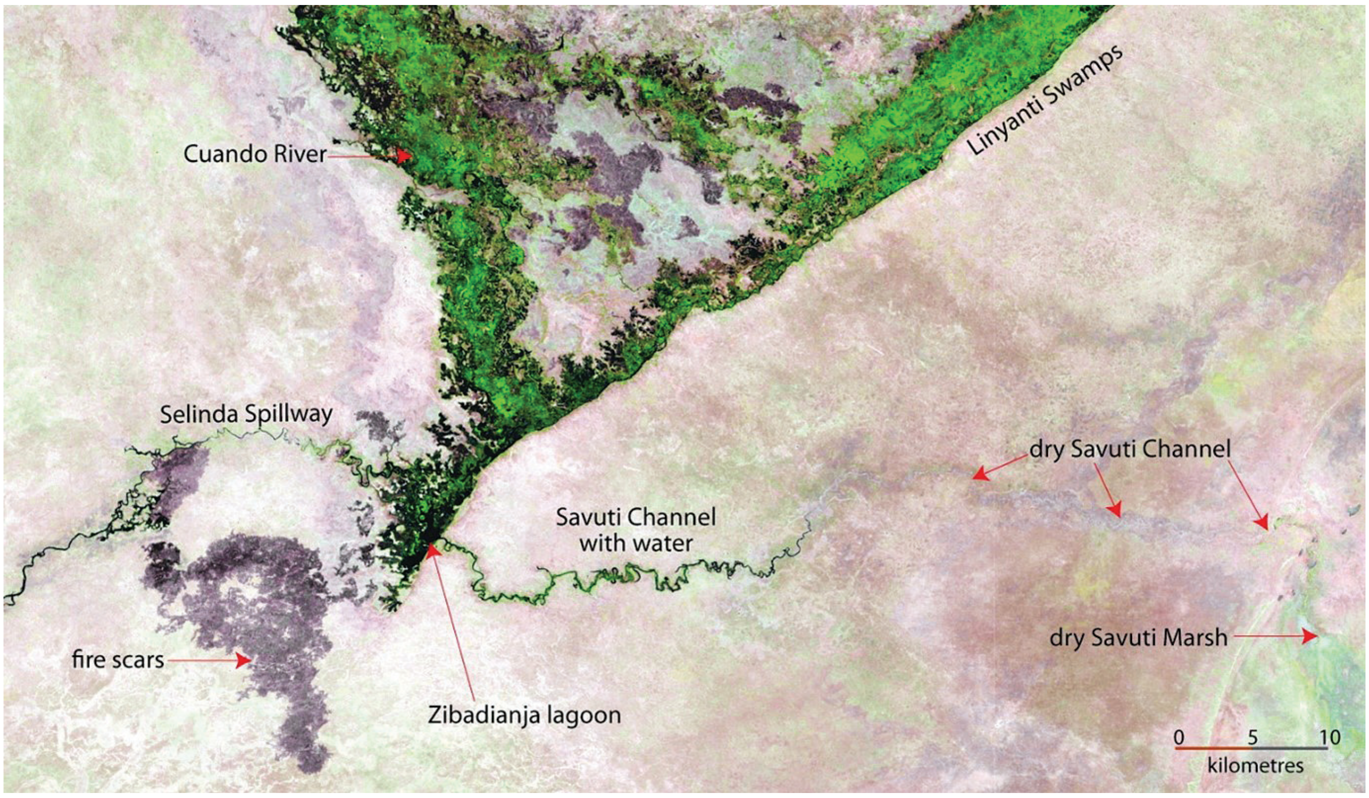


Figure 18: The south-western corner of the Cuando River where it turns north-eastwards into the Linyanti Swamps and becomes the Linyanti River. Water from the Okavango Delta is supplied by the Selinda Spillway, while Cuando water often supplies the Savuti Marsh.

The conclusion from the satellite imagery and earlier written records is that the Cuando River, via the Linyanti Swamps and Linyanti River, has rarely provided water to Lake Liambezi. The chances and volumes of water from the Cuando River then later being discharged into the Chobe and Zambezi Rivers are therefore small.

2.2 Recharge and discharge: Cuando River flow dynamics

From where does the Cuando get its water, and where does that water end up? The details tell us much about the functioning of the system and the interesting comparisons with its neighbours, the Okavango and Zambezi River Basins.

The deep, permeable sands that characterise the upper basin (see Section 3.4) soak up all rain that falls onto the ground within the catchment. The fact that there are any channels at all in this landscape indicates there must be subsurface features that obstruct the downward movement of water in places and send it sideways to seep into the tributaries further downslope. This is probably achieved by hardpan layers in the soil.

Flow of the Cuando River has been measured at Kongola since 1969/70, and for shorter periods of time at a few stations downstream of Kongola, on the Namibian and Botswana sides of the border[9]. The flow is relatively constant, revealing only significant peaks at times of very intensive rainfall, due to the slowing and delaying effect of the broad reedbeds upstream. Differences between the highest and lowest flows during the year are very modest: from an average of about 27 cubic metres per second in December to 39 cubic metres in July (Figure 19). The July peak flow at Kongola is about six months later than the peak rainfall month in the upper catchment, reflecting the extremely slow passage of the water.

The reason for this sluggish flow in the Cuando and its rather unvarying flow is its enormous floodplains, which are 5 to 15 kilometres wide for much of its length. From where it first widens in the north, approximately at the confluence of the Kembo and Cuando, to where it narrows sharply on Angola's southern border, the floodplain covers about 3,450 km^2 over a distance of just over 500 km. The main river channel is quite small, but the marshy floodplain on either side is covered in tall grasses, phragmites reeds and papyrus. Seepage into and through the floodplain causes huge evapotranspiration losses, and slows down the flow.

This is quite different from the Zambezi where volumes increase almost 12 times between low and high flow months: from 277 cubic metres per second in October up to 3,240 cubic metres in April (Figure 2). These figures also show that the Zambezi at Katima Mulilo carries about 34 times more water per year than the Cuando at Kongola.

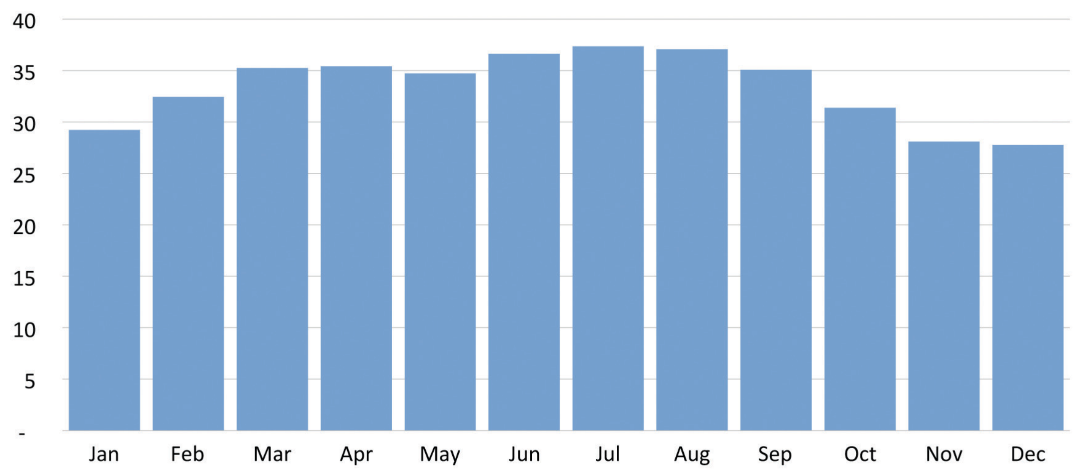


Figure 19: Average monthly flows (in m^3/s) of the Cuando measured at Kongola.

Annual total discharges of the Cuando River were measured consistently at Kongola between 1970 and 2020, providing a 50-year record that is shown in Figure 20.

9 i) DWA. 2005. Investigation of Groundwater Resources and Airborne-Geophysical Investigation of Selected Mineral Targets in Namibia Volume IV.GW.2.1. Groundwater Investigations in the Eastern Caprivi Region. Main Hydrogeological Report. Department of Water Affairs, Windhoek.
ii) Kurugundla CN, Morongwane BK, Bombo T. 2018. Kwando New Channel - Development and evolution of New Channel parallel to Kwando River in Botswana. Unpublished Report, Ministry Of Land Management, Water And Sanitation Services, Department Of Water Affairs, Botswana.

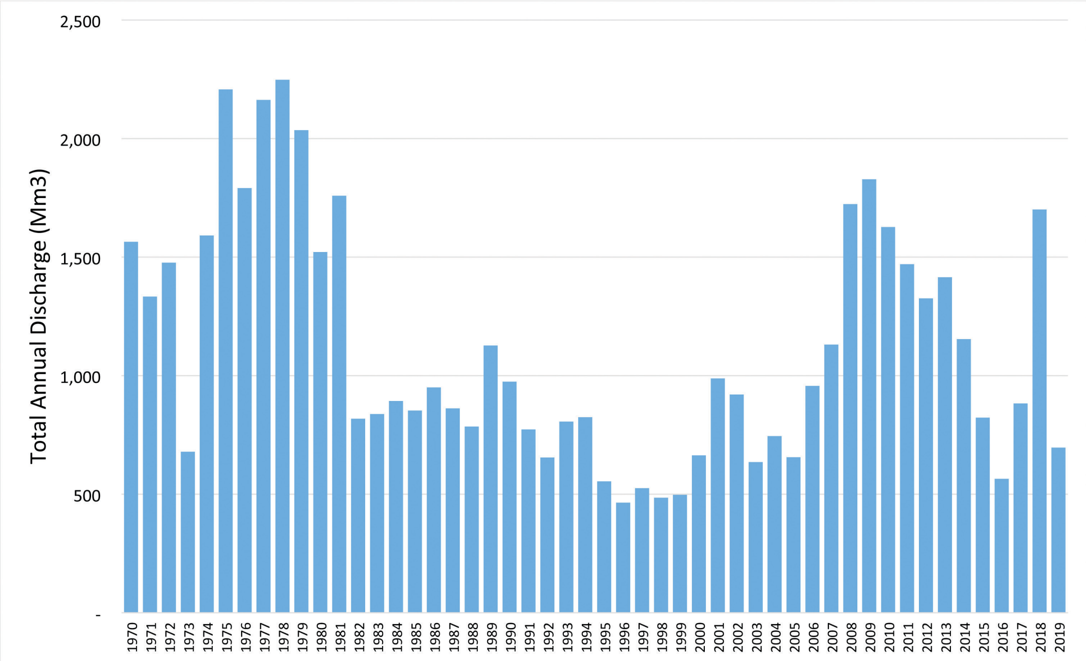


Figure 20: Discharge of the Cuando River measured at Kongola over 50 years to 2019.

A comparison between the Cuando and its immediate neighbour to the west, the Cuito River (a tributary of the Okavango), is revealing because both rivers arise from catchments of a similar size in an area of similar rainfall and substrate in the Angolan highlands. Important to note is the much lower volumes of water in the Cuando compared to the Cuito, as well as the Cuito's greater variability from year to year. Discharges along the Cuito vary regularly, each year's highest discharges following earlier rains, with reasonable correlations between rainfall and discharge volumes. By contrast, discharges on the Cuando seem to bear little relation to rainfall in its catchment. In 1989 and 2001, the Cuando's flow peaked towards the end of the year, suggesting that the water had taken almost a year to make its way from the upper catchment to Kongola. Peaks towards the end of summer, as happened in 1988 and 2000, probably reflect local rains adding to the river flow in the lower part of the Basin.

2.3 Groundwater

It is known from the upper Okavango Basin that groundwater plays an important role in the generation of river run-off in its headwaters[10]. The situation in the Cuando Basin is likely similar, based on a similar substrate and the recognised importance of the 'sponge' function of the soils. In the upper catchment, lateral seepage from groundwater into tributaries that feed the Cuando is the predominant form of recharge of the river's water. The great majority of rain falls on sands that soak up the rain, which must then percolate down to some depths (perhaps 30 – 100 metres below the surface) before at least some of the water reaches aquitards (hardpans) which force it laterally to seep out into tributaries further downslope. As a result of the slow downward percolation and lateral seepage of water, the Cuando's tributaries are recharged at a moderately even rate throughout the year. The upper catchment's deep

10 FAO. 2014. Cubango-Okavango River Basin Water Audit (CORBWA) Project – Synthesis Report. UN Food and Agriculture Organisation, Rome.

sands function like a sponge, absorbing and then gradually releasing water.

Interestingly, water temperature in the lower Kembo is colder than adjacent upstream and downstream sections, indicating possibly that cold groundwater is feeding into the Kembo channel in that area (Figure 21).

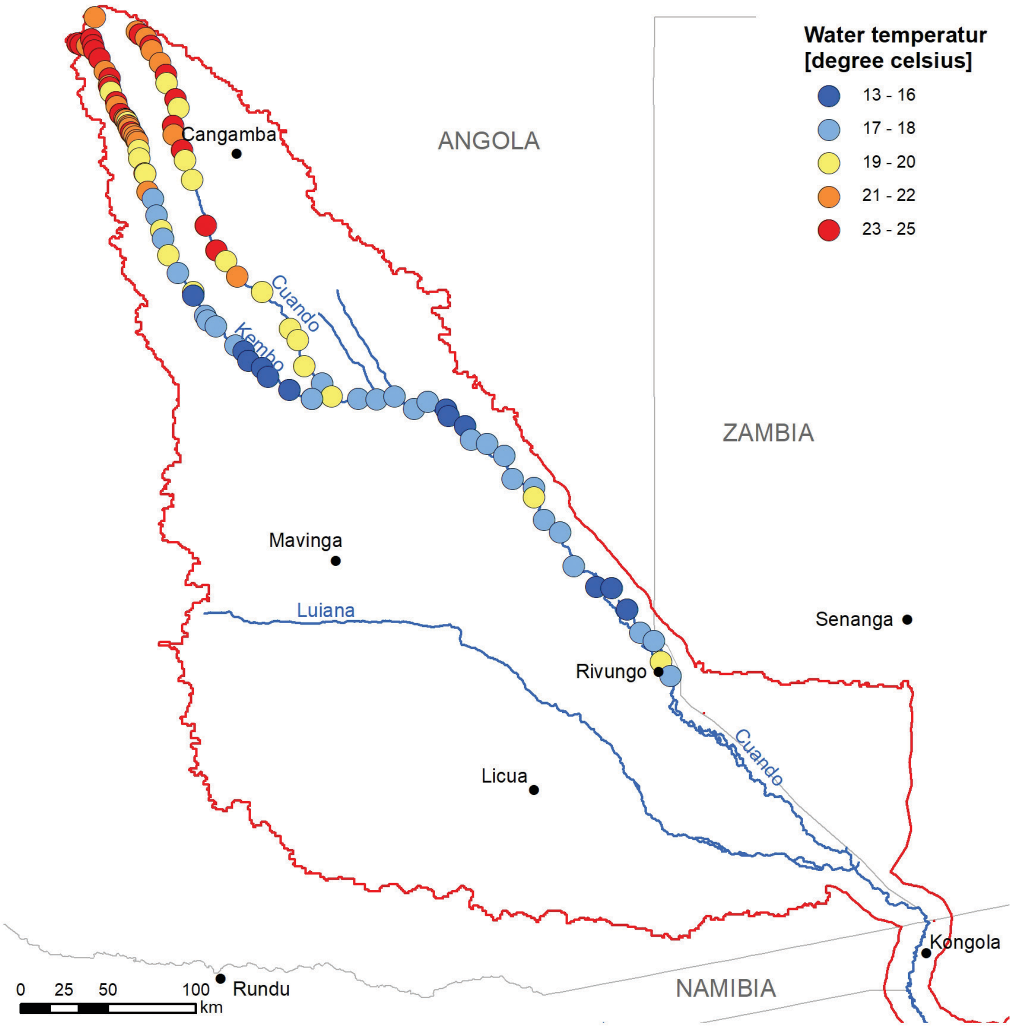


Figure 21: Water temperature recordings along the Kembo and Cuando Rivers during the 2018 NGOWP expedition.

But the groundwater situation changes as the topography flattens in the southern parts of the basin. Here, most groundwater infiltrates into the depths of the Kalahari sand sediments, contributing little or nothing to the Cuando. There is simply no significant slope to generate lateral recharge into the drainage lines. Thus the substrate in this part of the basin no longer acts as a slow-releasing sponge, keeping the river going. Instead, the river loses water by infiltration out of its channel, and the groundwater status in Zambezi Region in the vicinity of the Linyanti is patchy[11]. Recharge from the river is only effective up to a distance of two to five kilometres from the river course. Beyond that distance, the groundwater is recharged by local precipitation, and the quality varies and tends to deteriorate rapidly away from the rivers

11 DWA. 2005. Investigation of Groundwater Resources and Airborne-Geophysical Investigation of Selected Mineral Targets in Namibia Volume IV.GW.2.1. Groundwater Investigations in the Eastern Caprivi Region. Main Hydrogeological Report. Department of Water Affairs, Ministry of Agriculture, Water and Forestry, Windhoek.

and with increasing depth[12]. There are large areas where the groundwater is unpalatable and unfit for human consumption, mainly in the area immediately north of the Linyanti Swamps.

The above description refers to the relatively shallow groundwater that constitutes the Upper Kalahari Aquifer. Recent studies have revealed another, deeper and more significant aquifer north of the Linyanti Swamp in the Zambezi Region[13]. This Lower Kalahari Aquifer lies at depths between 130 and 250 metres, and is likely to have been formed more than 100,000 years ago, perhaps in an ancient (now subsurface) channel of the Zambezi River. This aquifer is recharged by local rainfall. The Cuando and Linyanti appear not to contribute water to this aquifer.

The International Water Management Institute has established a partnership with the KAZA TFCA Secretariat to investigate the status of the transboundary aquifers in KAZA[14], one of which is the Lower Kalahari Aquifer, also called the Nata-Karoo Aquifer[15]. No data or publications are yet available from this KAZA-GROW project, and its staff have been unable to identify any information to confirm the existence of the Nata-Karoo Aquifer[16].

These brief notes on the groundwater situation reflect the rather poor understanding of this aspect of the total hydrological cycle of the Cuando River. Unfortunately they cast little light on the issue of underground water connectivity between the Cuando and the Zambezi River systems. This aspect deserves further attention to clarify the extent of any connections between these rivers.

2.4 Water chemistry

2.4.1 Total dissolved solids

Total Dissolved Solids is a measure of the content of dissolved minerals, such as salt, in the water. Data collected in transects down the Kembo and the Cuando Rivers from the National Geographic Okavango Wilderness Project in 2018 (Figure 22 on the following page) show low levels of dissolved matter in the upper catchment and a gradual increase down the main stem of the river to the Zambian border. This reflects the very clean water derived from sandy soils that add very little in the way of minerals. It is almost as pure as distilled water in the far upper reaches!

2.4.2 Total dissolved oxygen

A useful measure of water quality is dissolved oxygen, since many aquatic animals depend on oxygen in the water. Oxygen that is chemically bound to hydrogen in the water molecule H2O is not available to animals; they need free oxygen which is dissolved in the water[17]. Dissolved oxygen (DO) was measured during the NGOWP expedition, as shown in Figure 23 on the following page.

12 Information drawn from i) Christelis G, Struckmeier W. 2001. Groundwater in Namibia: An explanation to the hydro-geological map. Ministry of Agriculture, Water and Forestry, Windhoek. ii) Mendelsohn J, Roberts C. 1997. A environmental profile and atlas of Caprivi.
13 Bäumle R, Himmelsbach T, & U Noell. 2019 Hydrogeology and geochemistry of a tectonically controlled, deep-seated and semi-fossil aquifer in the Zambezi Region (Namibia). Hydrogeology Journal (2019) 27:885–914
14 https://kaza-grow.iwmi.org/outputs/
15 UNESCO-IHP and UNEP (2016). Transboundary Aquifers and Groundwater Systems of Small Island Developing States: Status and Trends. UN Environmental Programme, Nairobi.
16 K. Villholth (personal communication)
17 From https://www.fondriest.com/environmental-measurements/parameters/water-quality/dissolved-oxygen/ A useful source for explanations of water quality parameters.

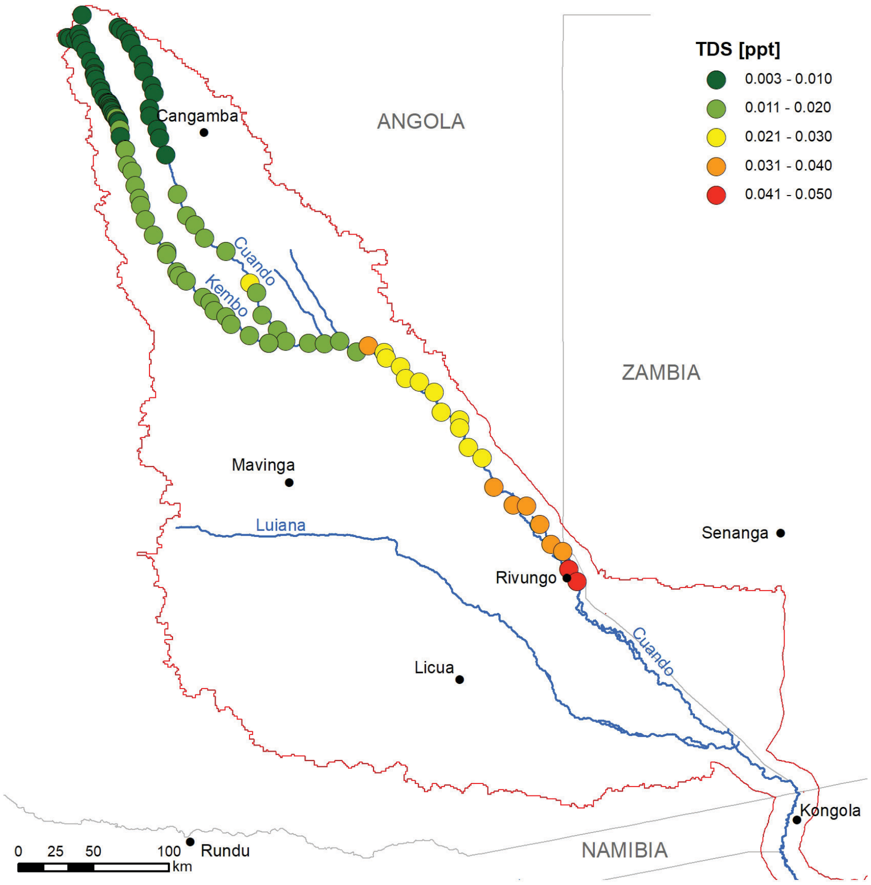


Figure 22: Total Dissolved Solids (measured in parts per thousand) in the Kembo and Cuando Rivers from the sources to Shangombo[18].

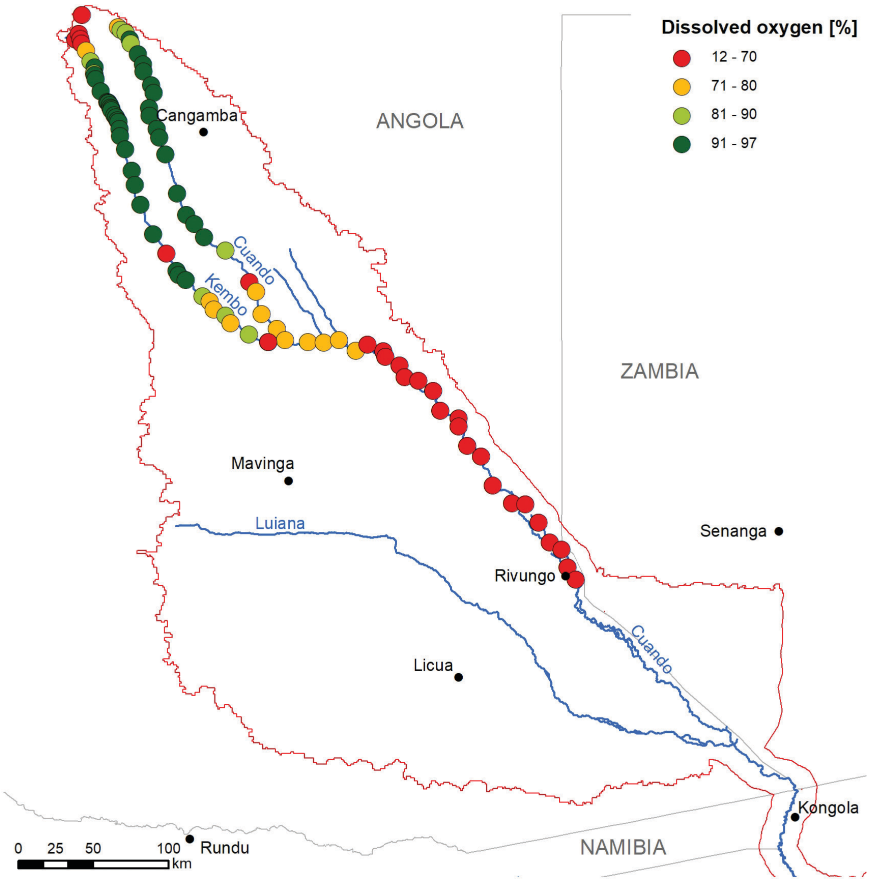


Figure 23: Dissolved oxygen in the waters of the Kembo and Cuando Rivers

18 From National Geographic Okavango Wilderness Project, 2020. Final Report: Scientific Exploration in Angola during 2018. Pp 70

2.4.3 Water pH

The water is acidic in the upper reaches, with pH levels around 5 (Figure 24), but approaches neutral quite quickly due to dilution by alkaline water from peat bogs and marshes.

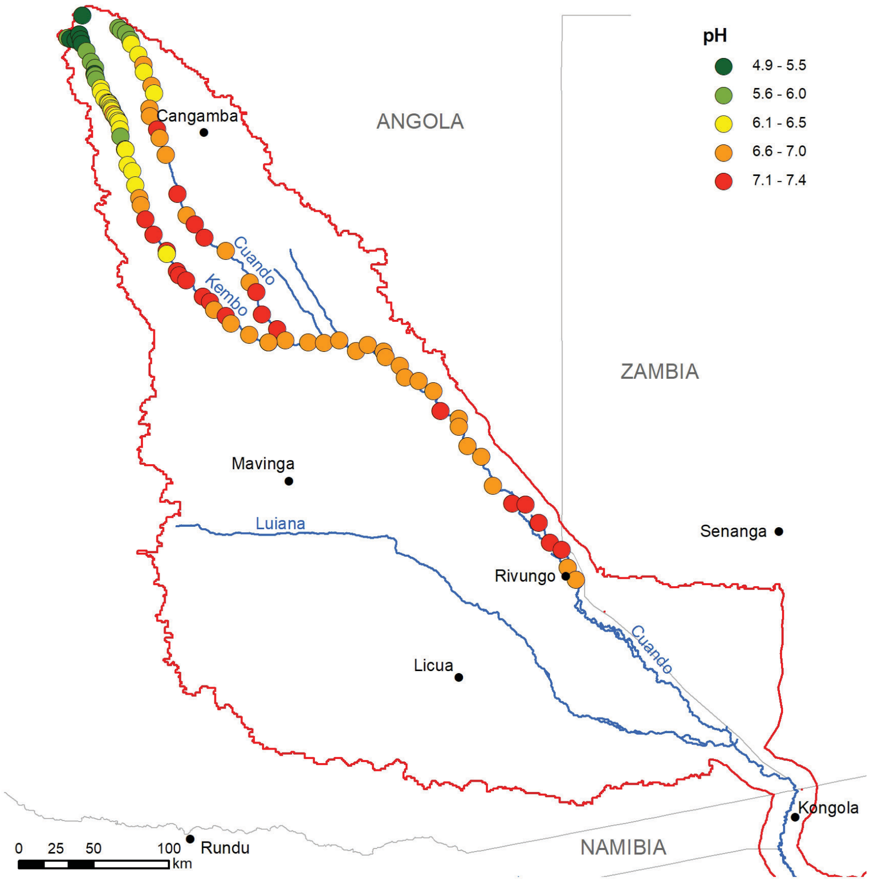


Figure 24: pH values in the Kembo and Cuando Rivers in the upper Cuando River Basin[19].

2.5 Implications of the hydrology of the Cuando River

2.5.1 Topographical definition of the Cuando River Basin

River basins are defined by their watersheds. These are the raised margins that divide drainages, those of one river system flowing off and down in one direction, those of a neighbouring river system flowing off the opposite side of the watershed. Defining these watersheds using digital terrain model data (DTM) is easy nowadays. The elevation data are processed with mapping software that defines the raised margins separating one basin or catchment from another. The Cuando River Basin is conventionally defined and mapped in this way. Figure 25 of the Okavango, Cuando and upper Zambezi Basins is based on topography. The boundaries between the basins are difficult to define in the flat area at the lower end of the Cuando, where it is impossible to identify the positions of ridges or margins. This definition also places the boundary of the Cuando Basin halfway along drainage lines between the Cuando and the Zambezi and the Okavango – a situation that conflicts with the definition of a watershed! This anomaly needs to be clarified with information on the flows in these drainage lines.

19 From National Geographic Okavango Wilderness Project, 2020. Final Report: Scientific Exploration in Angola During 2018. Pp 70

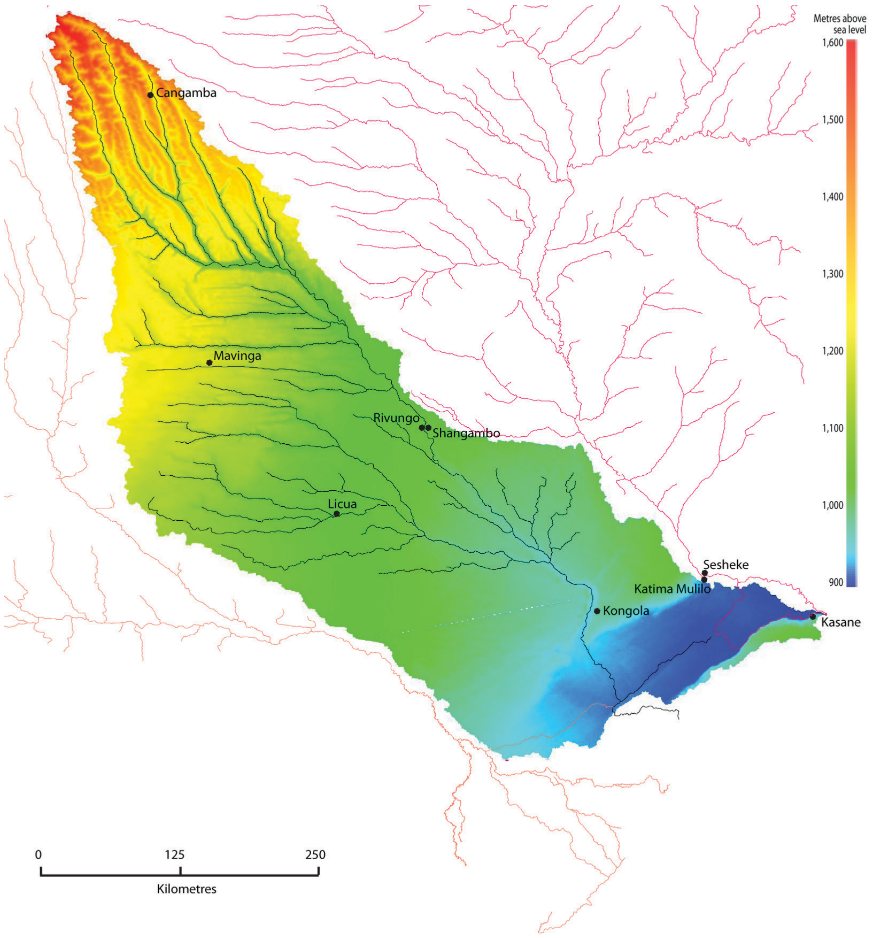


Figure 25: Elevations across the Cuando catchment.

Note that the Savuti Channel flows across the watershed, water of the Okavango Delta flows across the watershed via the Selinda Spillway, and the Chobe River and Bukalo Channel likewise flow from the Zambezi River across the watershed[20].

2.5.2 Definition of the Cuando River Basin by surface water hydrology

Until this project, no studies have documented the frequency and magnitudes of flow between the Okavango, Cuando and Zambezi Rivers. The investigations using satellite imagery from the past 50 years (described above) show that the surface links between these river basins are temporary, and only occur rarely.

This result is consistent with various observations made over the years, such as:

- Cronberg[21] et al. (1995): "Water of the Linyanti River waters is partly derived from the Kwando and partly from spilling from the Okavango Swamps, while the water of the Chobe downstream of Ngoma bridge mainly comes from the Zambezi River backflow."
- Department of Water Affairs[22] (Namibia) (2005): "Since 1981 the levels of Lake Liambezi started to drop significantly and the lake has been dry since 1985. The base flow of the Kwando River is not sufficient to support both Lake Liambezi and the Linyanti Swamp and River."

Therefore there is no justification for thinking of the Cuando as a tributary of the Zambezi River. For this to be the case, perennial flows of the Cuando would

20 Digital Terrain Model data from SRTM, ALOS and ASTER digital terrain model data; Cuando watershed boundaries from WWF-Zambia
21 Cronberg G, Gieske A, Martins E, Prince Nengu J, Stenstrom I-M 1995. Hydrobiological Studies of the Okavango Delta and Kwando/Linyanti/Chobe River, Botswana I - Surface Water Quality Analysis. Botswana Notes and Records, Vol. 27, 151-226.
22 DWA 2005. Investigation of groundwater resources and airborne-geophysical investigation of selected mineral targets in Namibia. Vol IV.GW.2.1 Groundwater investigations in the Eastern Caprivi Region - Main hydrogeological report. Dept of Water Affairs, Windhoek, and BGR Federal Institute for Geosciences and natural resources, Hannover.

have to flow through the Linyanti Swamps, Lake Liambezi, the Chobe Swamps and along the Chobe River, to ultimately reach the Zambezi. We can be certain this is not the case for all the time that Lake Liambezi is dry, which has been roughly one-third of the last 77 years. There is no evidence of regular surface flows from the Linyanti into the Chobe and Zambezi via Lake Liambezi in other years.

2.5.3 A functional definition of the Cuando River Basin

Defining the Cuando's Basin is challenged by:

1. The flat topography makes it hard, and sometimes impossible, to demarcate the Basin's borders.
2. The channels and rivers that link the Cuando to the Zambezi and Okavango River are temporary.
3. Much of the area defined topographically as the Cuando River Basin contributes little or no water to the Cuando River.

For the purpose of this report, the hydrologically active and important part of the river system are distinguished from that which is hydrologically dormant, insignificant or equivocal (Figure 26).

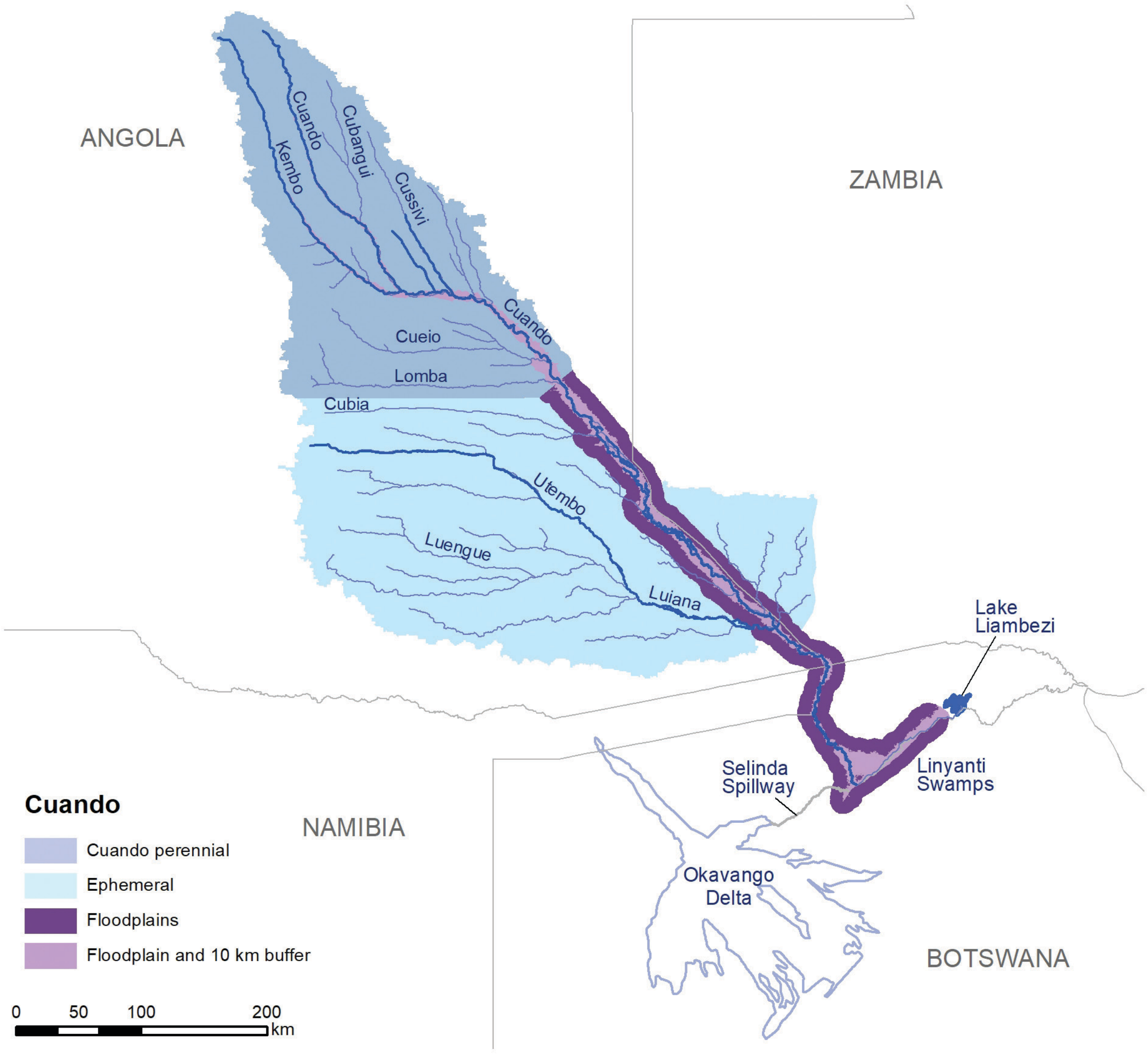


Figure 26: The hydrologically active part of the Cuando River Basin.

A final feature of the Cuando Basin needs to be emphasized: the position of the international boundary between Angola and Zambia. This boundary runs north-westwards from the Namibian border along the eastern ridge of the Cuando's floodplain valley.[23] Thus, all the Cuando's perennial flow and floodplain lies within Angola, a condition that counters widely held beliefs that the boundary follows the centre of the Cuando River or the western edge of the floodplain.

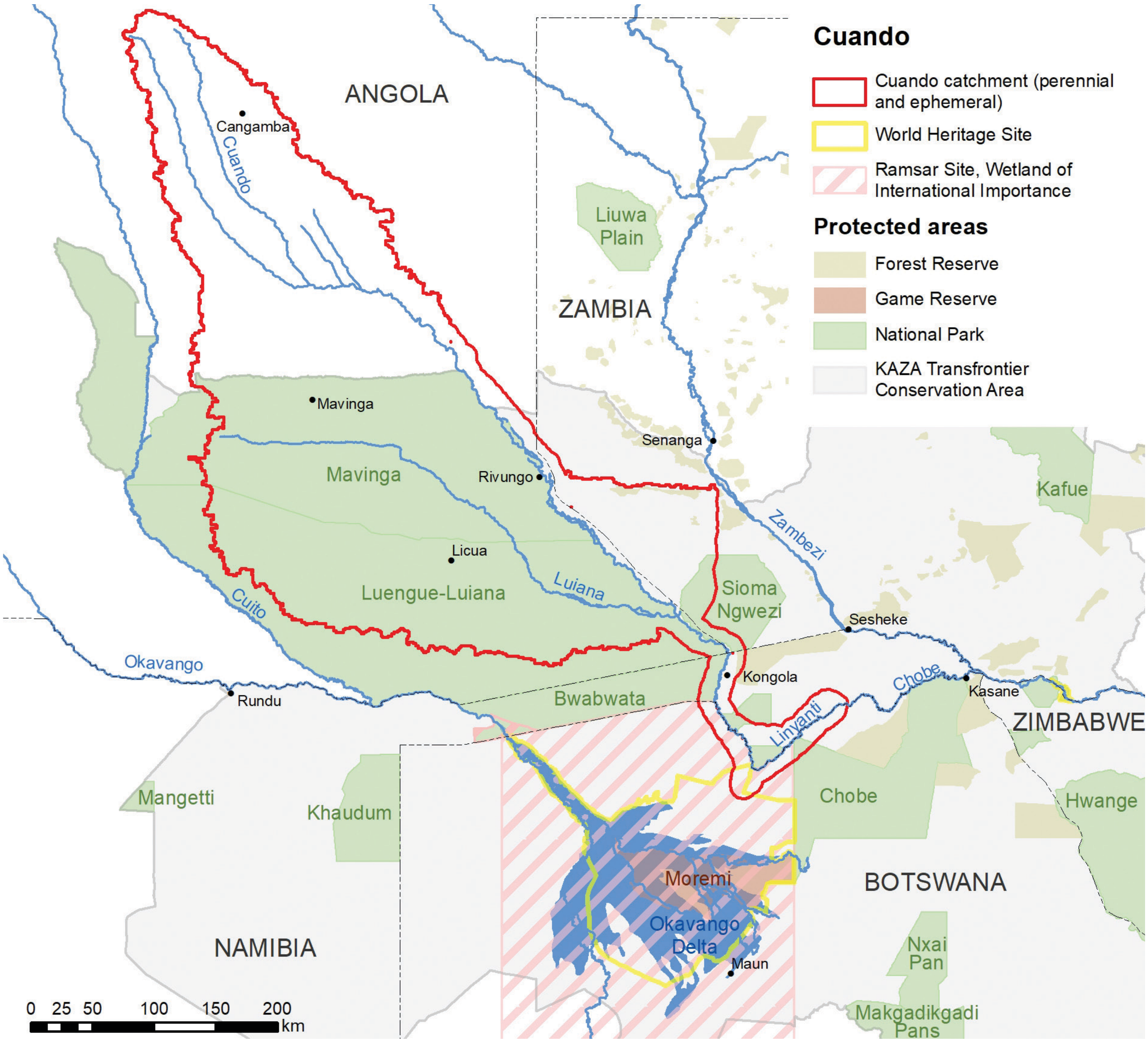


Figure 27: The Cuando River Basin as described in this State of the Basin Report, outlined in red.

23 Hangula, Lazarus: *The International Boundary of Namibia.* Windhoek 1993. Assumptions about the border gain credibility from the fact that some Zambian villages and one town (Shangombo) are strictly speaking located inside Angola. Note that the boundary shown in Google Earth runs along the eastern border of the floodplain. This is incorrect.

3. Bio-physical environment

3.1 Climate

Situated at the southern edge of the tropical zone, between 15 and 18 degrees south of the Equator, the Cuando River Basin experiences increasing seasonality from north to south. Also, the climate gets progressively drier southwards. Many tributaries rise in the wet Biè highlands in the north, but the climate gets drier and the river becomes a linear oasis running through dry surroundings in the central and southern parts. The combination of higher evaporation and lower rainfall at the distal end of the Cuando Basin results in the Linyanti frequently drying up before it nears Lake Liambezi.

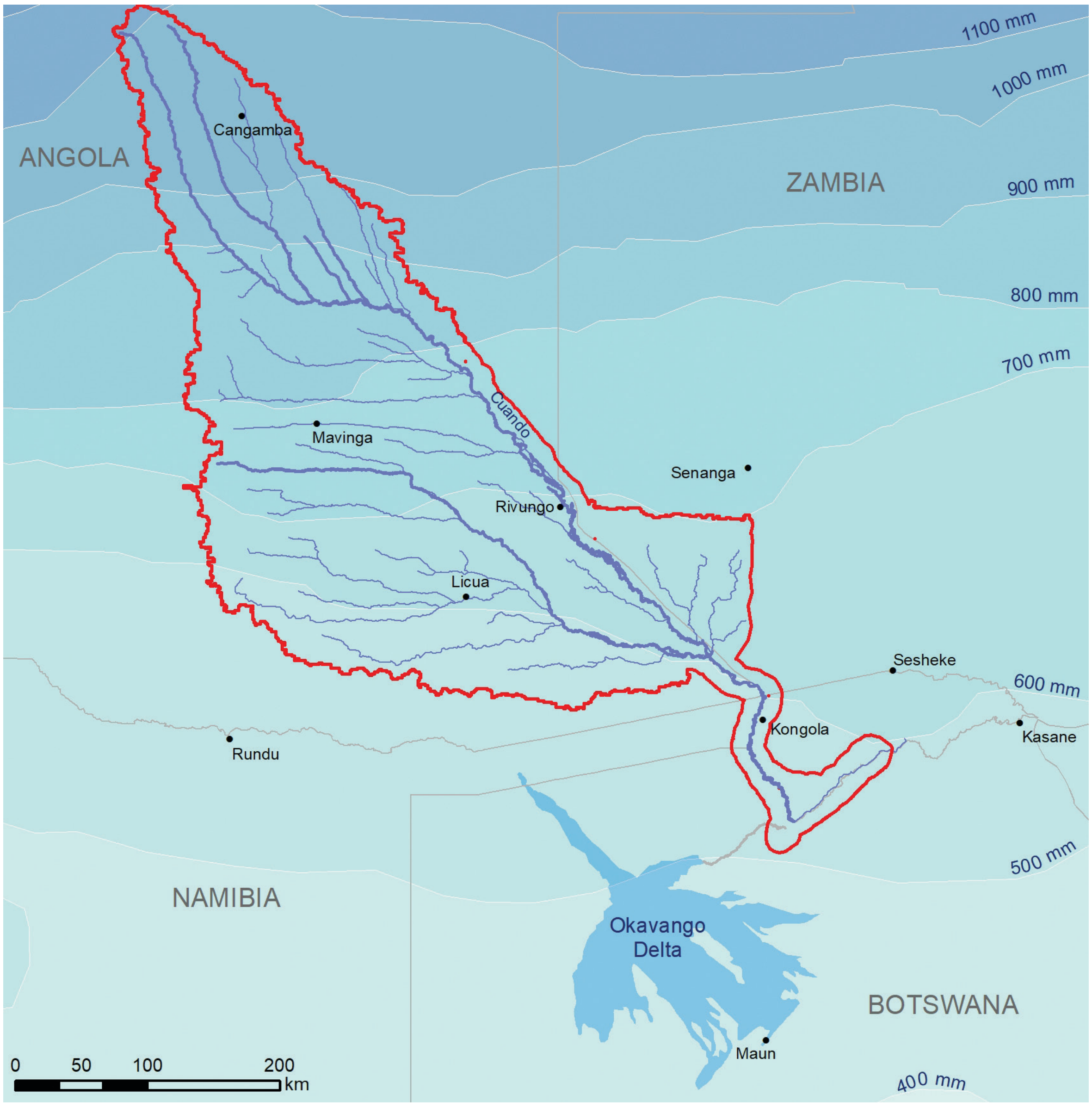


Figure 28: Isohyets showing the gradual decrease of average rainfall per year from north to south across the Cuando River Basin[24].

24 Source: Mendelsohn & el Obeid 2004. *Okavango River: Flow of a Lifeline*

3.1.1 Rainfall

The upper parts of the Cuando usually receive between 1,000 and 1,200 mm of rain per year, while the lower end receives between 600 and 800 mm (Figure 28). Almost all the rain falls between October and April, starting earlier in the north than the south (Figure 29). It mostly falls in afternoon thunderstorms which develop from rising and cooling air in the hot summer days.

Across the Basin, there are two main seasons: a warm wet summer from about October to April, and a cool dry winter in May to September. Summer day temperatures reach above 25°C and are usually humid and cloudy, cooling down slightly to above 15°C at night. Winter months are characterised by clear skies and moderate temperatures occasionally reaching below zero at nights, and up to about 25°C during the day.

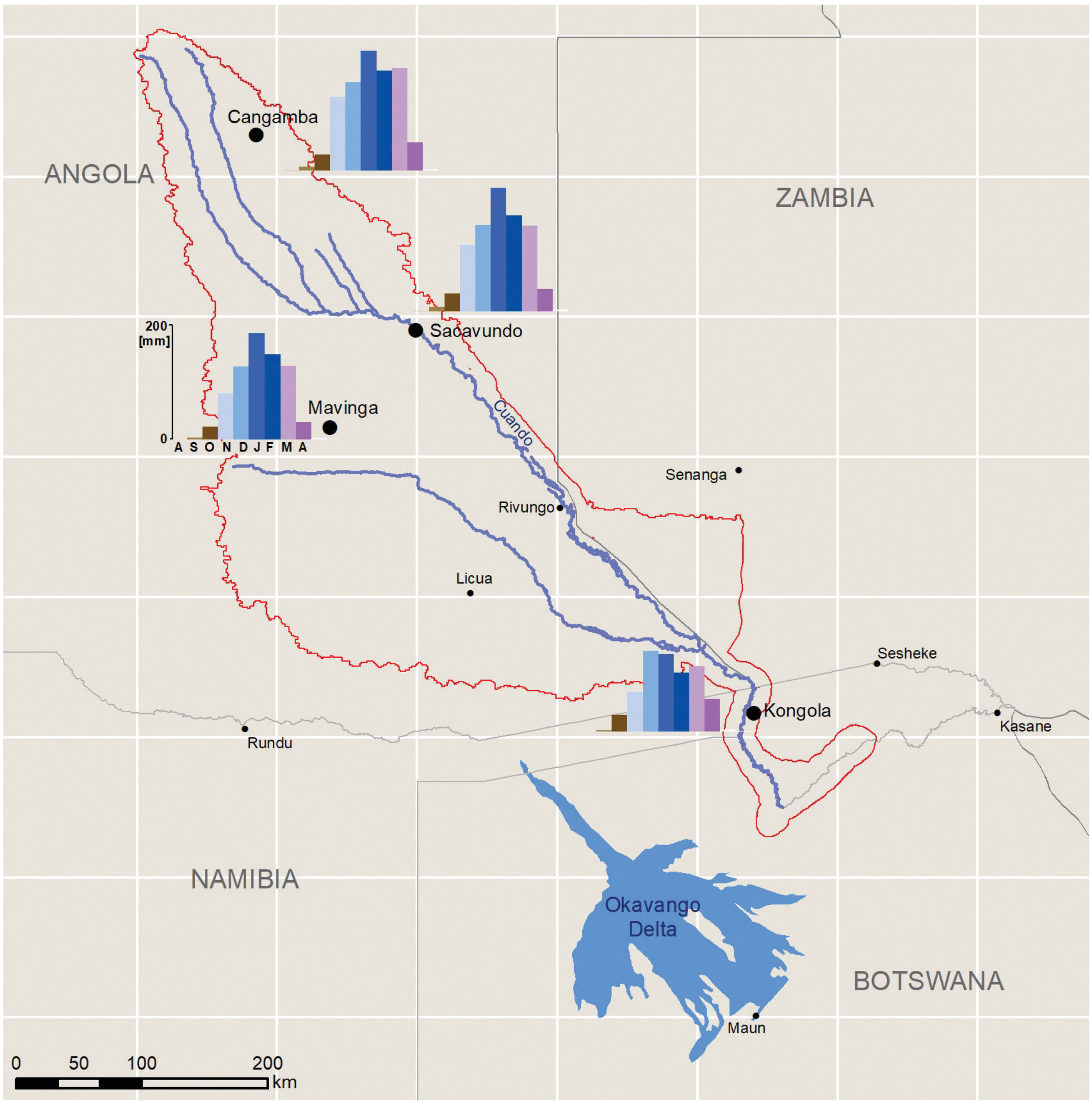


Figure 29: Monthly rainfall graphs for four centres in the Cuando Basin[25].

25 Adapted from (i) Mendelsohn & el Obeid 2004 *Okavango River: Flow of a Lifeline*. (ii) CHIRPS data.

3.1.2 Evaporation

Data from the Namibian weather station at Katima Mulilo indicate relatively constant potential evaporation of about 2,500 mm per annum, ranging between 150 mm/month in June and 300 mm per month in October. The higher figure in early summer reflects the warmer temperature and the scarcity of cloud cover at this time of year. Figure 30 shows that potential evaporation is always greater than rainfall. This probably explains why shallow groundwater is quite brackish, as the salts are left behind and gradually accumulate in the soil. Even during the year's wettest months (December, January and February), potential evaporation exceeds rainfall[26].

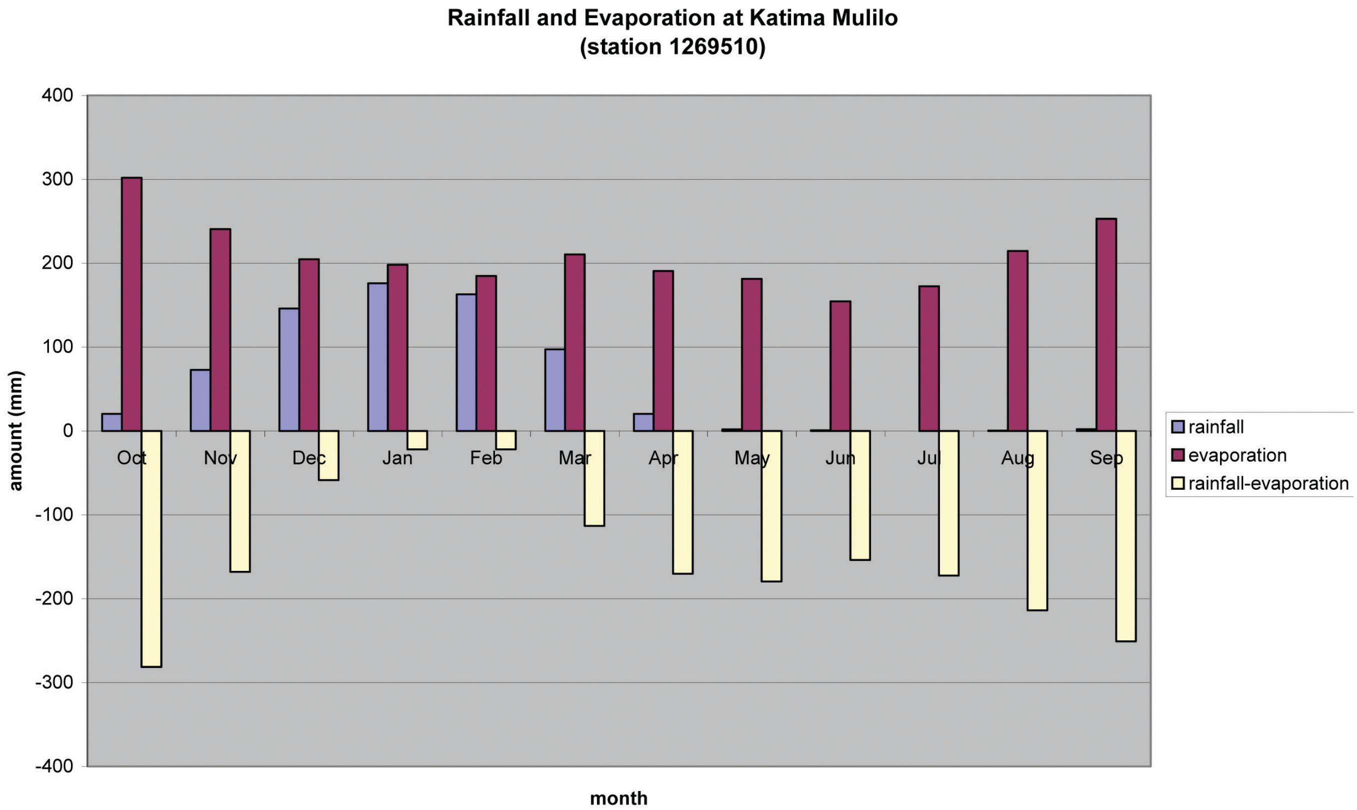


Figure 30: Monthly average rainfall and potential evaporation figures from the Katima Mulilo weather station[27].

Overall, the climate can be summarised in the Köppen classification, which is based mainly on rainfall and temperature[28]. Under this scheme, the far north-eastern parts of the Cuando River Basin are tropical, based on high average rainfall, a high number of days of rain per year (up to 140), and high temperatures almost year-round (both during the hottest and the coldest months). Most of the upper basin and the northern half of the middle basin are sub-tropical (Cwa), while all the southern half is classified as hot, semi-arid (Bsh) (Figure 31).

26 DWA 2005. Investigation of groundwater resources and airborne-geophysical investigation of selected mineral targets in Namibia. Vol IV.GW.2.1 Groundwater investigations in the Eastern Caprivi Region - Main hydrogeological report.
27 DWA 2005. As in Footnote 26 above.
28 While the Köppen classification system (https://en.climate-data.org/africa/angola-72/) helps to broadly classify the climate, it generalises to an extent that leads to inaccuracies. For instance the average evapotransiration in the Bsh class is 1,100 mm, but in reality the measured potential evaporation in this area is 2,500 mm.

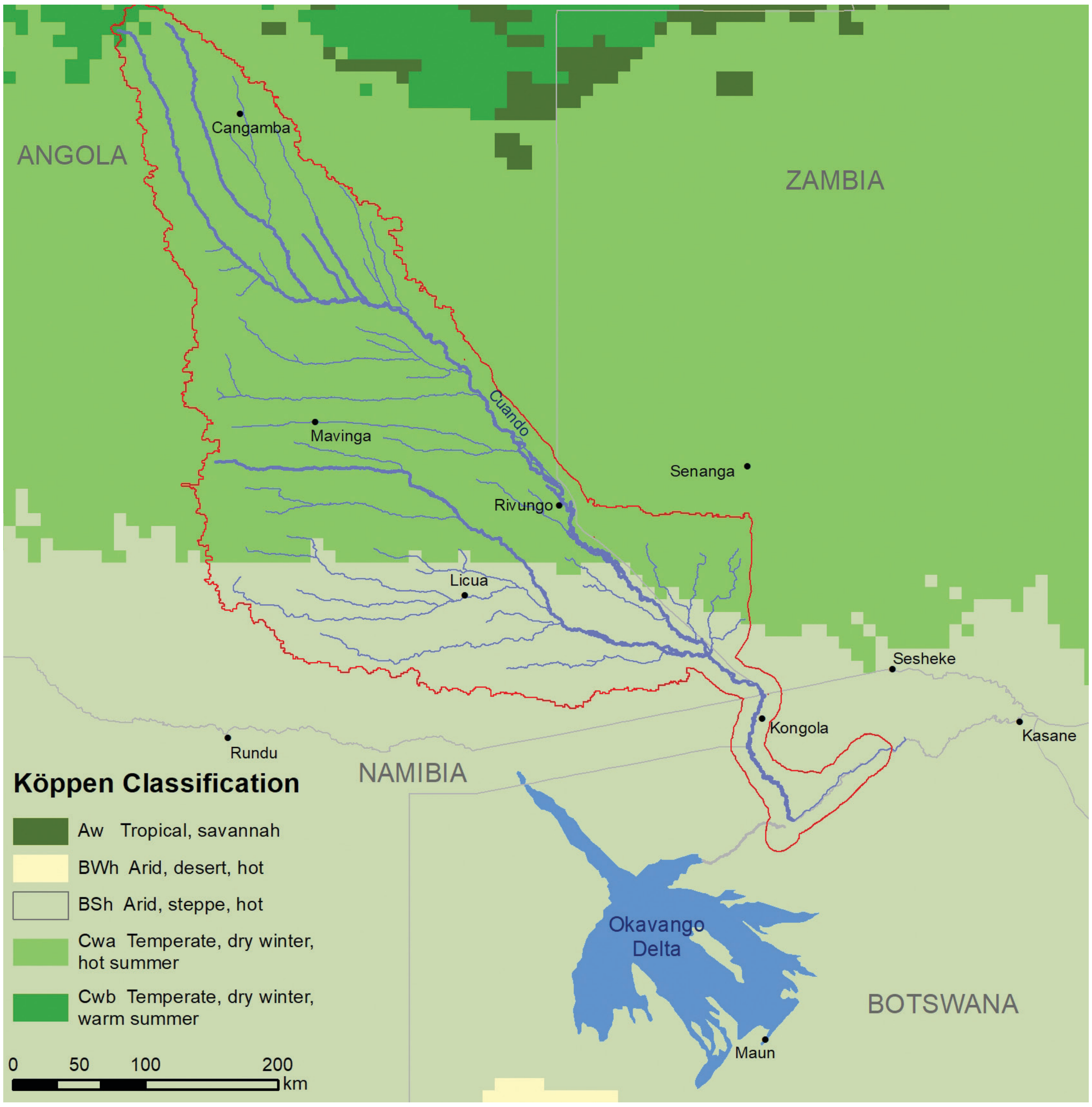


Figure 31: Climate categorisation of the Cuando River Basin according to the Köppen classification[29].

3.2 Geology

The geological factors that underlie the Cuando Basin are rather similar to those of the Okavango. Both rivers rise in the Bie Plateau in Angola and lie entirely in the sandy world of Kalahari sediments (see facing page), and both are strongly influenced by similar sets of structural faults in the basement rocks.

Kalahari

'Kalahari' means a much bigger area than just the Kalahari Desert that is mostly confined to Botswana. The Kalahari Basin refers to a great flat area in the centre of southern Africa which was created after the separation of the African continent from the Gondwana land mass. This area extends from

29 http://koeppen-geiger.vu-wien.ac.at/present.htm

the northern Cape through Namibia, Botswana, Angola and Zambia, to as far north as the area around the Congo River. A relatively dry climate allowed the basin to fill up with sands and water-borne deposits, creating the wide expanse of sandy substrate that we see today – reputedly the largest body of sand in the world. Dune patterns in this ancient Kalahari sand sea corroborate other geological evidence of a very much drier and colder climate in southern Africa at the time of the last Ice Age, about 18,000 years ago.

Figure 32: The geologically-defined Kalahari Basin

The basement rocks in the northern part of the basin comprise ancient sediments of the Damara Group, formed 700-550 million years ago and subsequently metamorphosed and covered by more recent sedimentary and basaltic rocks of the Karoo Group that are 300-180 million years old. More recently, during the Cretaceous (145-66 million years ago), stretching of the continental plate allowed pipes of magma to rise from deep in the Earth's mantle as kimberlites, which are the likely origin of diamonds that are sought by artisanal miners along the Longa, Cubia and Utembe rivers. Erosion of the Karoo basalts led to the formation of Calondo conglomerates that are visible in scattered Lower Cretaceous exposures along some the eastern tributaries[30] (Figure 33). These rocks are now almost entirely blanketed by Kalahari sand and water flowing over the surface earns very little in the way of nutrients from the quartz sand grains.

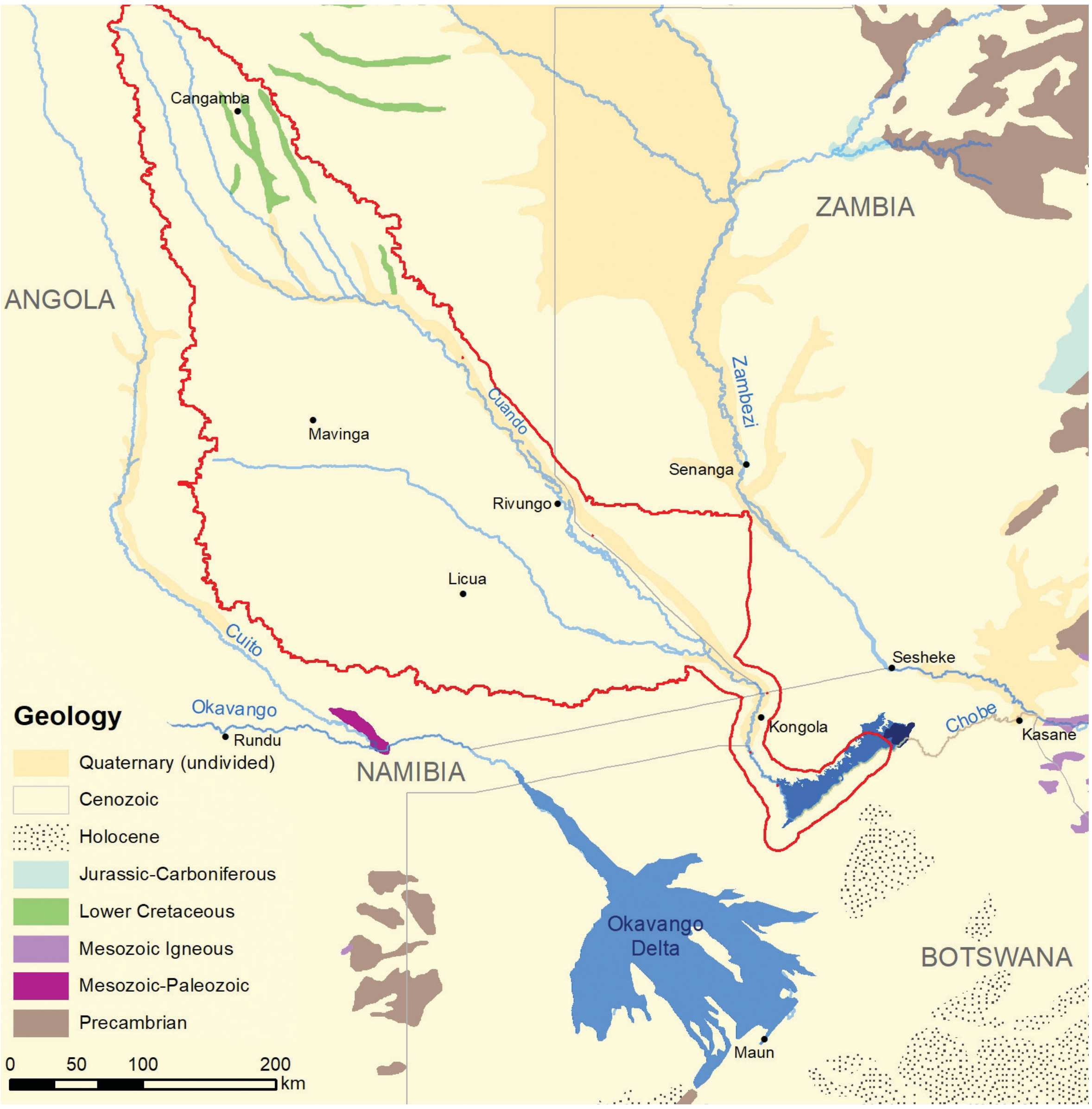


Figure 33: Geological features of the Cuando River Basin.

Although not very obvious when travelling in the area, the landscape in the far south-eastern corner of Angola and the long thin arm of Namibia previously known as the Caprivi Strip (now forming the Bwabwata National Park) is moulded into parallel dunes oriented ESE-WNW. The dunes manifest as gentle undulations in the landscape, and the vegetation they carry makes them not very obvious as dunes at all. It is thought that they were formed during the last Ice Age about 18,000 years ago, when rainfall was estimated to have been as low as 20% of the present value[31]. This is deduced from the fact that linear

30 Adapted from: i) Ponce de Leão, T (Laboratorio Nacional de Energia e Geologia, Angola) 2015. Geological Mapping of Angola. ii) Mendelsohn JM, vanderPost C, Ramberg L, Murray-Hudson M, Wolski P, Mosepele K. 2010. Okavango Delta: Rivers of Life. RAISON, Windhoek, Namibia.

31 Adapted from i) Lancaster N. 1981. Paleoenvironmental implications of fixed dune systems in Southern Africa. Palaeogeography, Palaeoclimatology, Palaeoecology 33(4): 327-346. ii) McCarthy T. 2009. *How on Earth? Answers to the puzzles of our planet.* Struik Nature, Cape Town.

dunes of this type only form if the rainfall is less than about 150 mm per annum, similar to the situation in the Namib Desert today. The pattern of dunes, lying on the western side of the Cuando, suggests that sand was carried down the Cuando River and then blown westwards by prevailing winds from the east. This fits in with the overall reconstruction of wind and dune patterns from this period of the geological past (see information on the Kalahari on page 37).

While the Kalahari sands completely hide the much deeper basement rocks, it is the structural features in the basement that dictate the route and pattern of the rivers on the surface. In the northern section, a set of parallel faults determines the south-eastwards orientation of the main tributaries, namely the Kembo, Cuando, Cubangui and Cussivi rivers. The larger of these faults extend 400 km south-eastwards, creating a long thin slice in the basement which the Cuando follows to the Namibian border.

Further south-east, another set of faults at roughly right-angles to the first halts the straight-line progression of the Cuando. The major Linyanti fault forces a kink in the flow and creates the mini-delta that is the Linyanti Swamps. The block on the south-eastern side of the fault is slightly higher, creating the clear NE-SW oriented boundary of the swamps (Figure 34).

The Linyanti continues in a north-east direction determined by the Linyanti fault, and the Chobe River is similarly structurally determined by the Chobe fault.

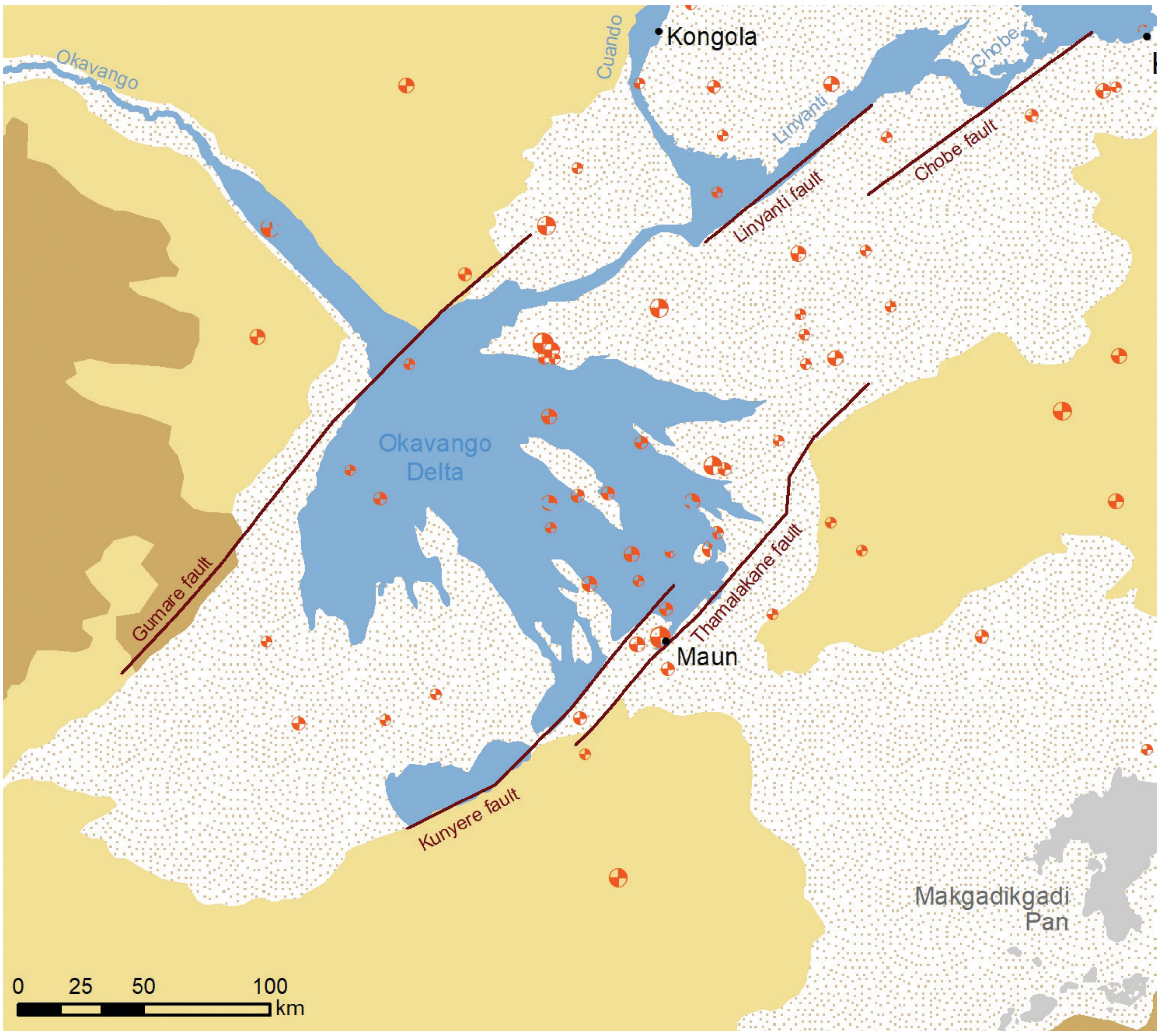


Figure 34: Structural geological features that dictate the shape and pattern of Cuando River flows[32].

32 Adapted From Mendelsohn et al. 2010 Okavango Delta: Floods of Life.

3.3 Topography

The far northern part of the Cuando Basin lies at an altitude of about 1,400 metres above sea level, in the Biè Plateau that forms part of the Angolan highlands. This is the hilliest part of the Basin and the only part of the Basin where there is significant relief at all. The clear difference in slopes in the upper parts of the Cuando Basin, compared to the middle and lower parts, is shown in Figure 36 below.

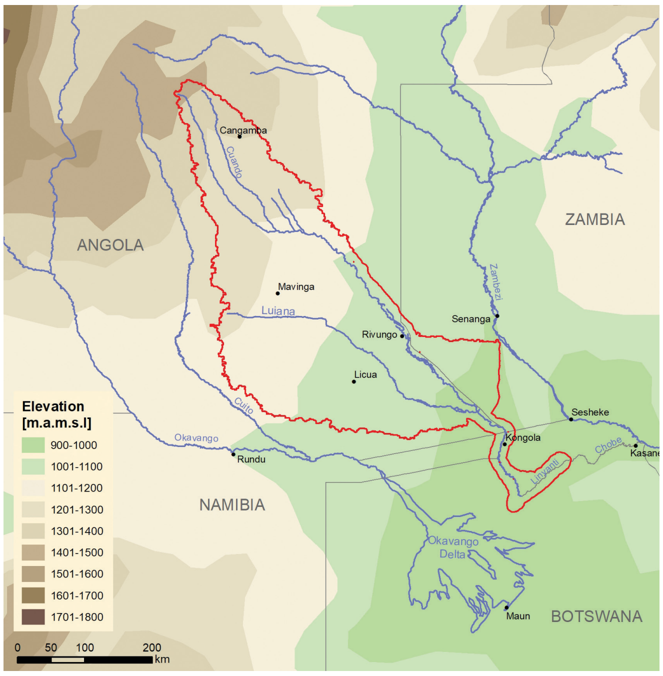


Figure 35: Altitudes across the Cuando River Basin.

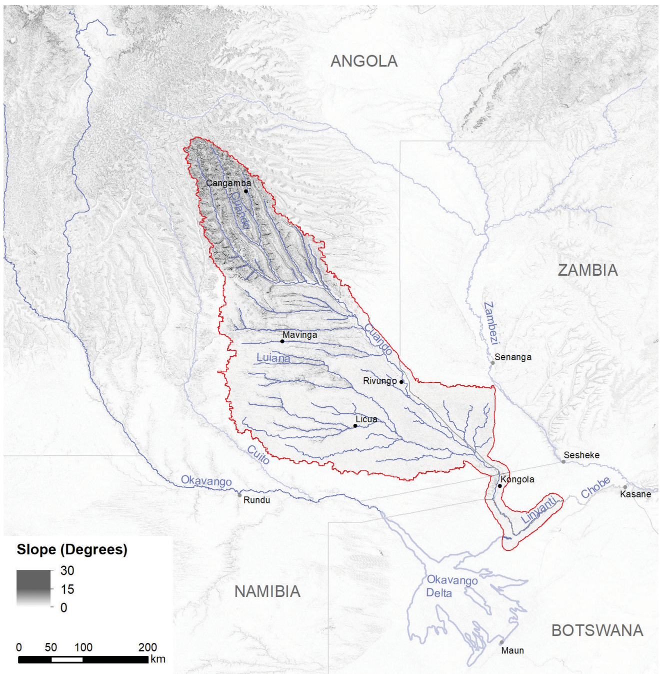


Figure 36: Slope measured in degrees across the Cuando River Basin[33].

The lowest part of the Basin is in the area of the Linyanti Swamps and Lake Liambezi, where the altitude is about 930 m above sea level. This sets the 'base level' for the river. Most rivers worldwide have their base level at the sea, and any erosion by the river water is driven by the power of water flowing downhill to reach sea level. However the Cuando and its western neighbours the Cuito and Cubango never reach the sea, and they cannot erode any lower than their lowest points in the incredibly flat landscapes of the Okavango – Linyanti – Chobe area. This explains why these rivers are so sluggish in their lower parts.

The gradient over the middle and lower parts of the Cuando River is shallow (Figure 37). From where the Lomba joins the main stem of the Cuando, the river drops only 70 m in its final 300 km, roughly equivalent to 23 cm per kilometre!

33 Derived from SRTM 90 metre digital elevation data from National Aeronautics and Space Administration (NASA; http://www2.jpl.nasa. gov/srtm). NASA's Shuttle Radar Topographic Mission (SRTM) has provided digital elevation data (DEMs) that is the source for this data, for over 80% of the Earth.

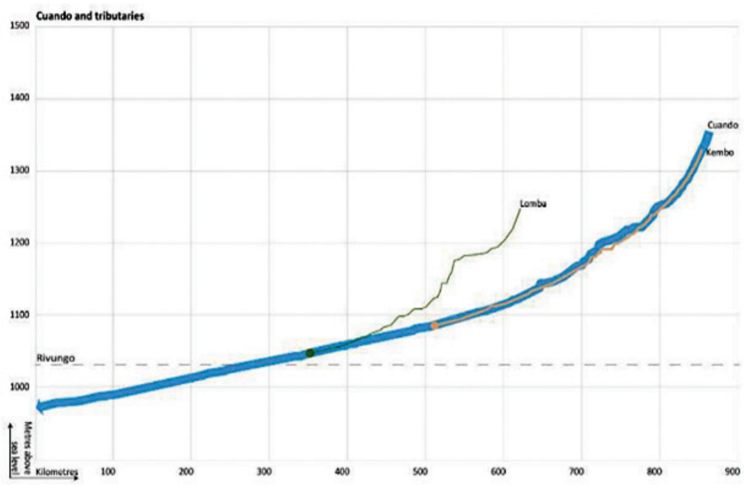


Figure 37: Gradient of the Cuando, Kembo and Lomba Rivers

3.4 Soils

Soils are a vitally important resource for all life on Earth, as they supply the conditions and nutrients that plants need, and plants are the source of all food for all animals and ourselves. Therefore it is useful and necessary to understand the soil characteristics of an area to inform land-use decisions. Local farmers have long demonstrated this understanding. For instance, crop fields in northern Namibia are concentrated on more clayey, richer soil patches, where productivity is superior; such attention to subtle differences in habitat needs to be applied in today's planning too.

3.4.1 Arenosols

Figure 38 (page 42) shows the distribution of soils across the Cuando River Basin[34]. It is obvious that the most widespread and extensive soil type in the basin is arenosol or wind-blown sand; this is not surprising as the river basin sits entirely within the geological Kalahari Basin, the largest continuous area of sand on Earth (see Figure 32). Sand is mostly composed of quartz grains; quartz itself is just silica (SiO_2), like glass, so the grains resist weathering and offer very little useful mineral nutrients for plant growth. These soils thus have very low fertility and also very low ability to retain water. Any organic matter in the soil is derived from the surface, where plant litter and animal waste decomposes in the uppermost horizon. Despite the relatively low fertility, there is a surprising amount of natural vegetation on these soils. Large trees such as teak and mangetti possess deep roots that extend to moist layers far below. Smaller trees and grasses rely on the short growing season during the rains and derive their nutrients from what litter accumulates and decomposes on the surface. Thus any removal of the vegetation cover (for cropping) depletes the soil of its main nutrient source and leads to rapid degradation of the soil quality.

34 Soil information drawn from i) ISRIC. ii) Jones A, Breuning-Madsen H, Brossard M, Dampha A, Deckers J, Dewitte O, Gallali T, Hallett S, Jones R, Kilasara M, Le Roux P, Micheli E, Montanarella L, Spaargaren O, Thiombiano L, Van Ranst E, Yemefack M , Zougmoré R (eds.). 2013. Soil Atlas of Africa. European Commission, Publications Office of the European Union, Luxembourg. 176 pp. iii) Mendelsohn J, Roberts C. 1997. An environmental profile and atlas of Caprivi. Ministry of Environment and Tourism, Windhoek. iv) Coetzee M. 2020. Notes on the 2020 soil map of Namibia. Prepared for the Ministry of Agriculture, Water and Land Reform, Namibia.

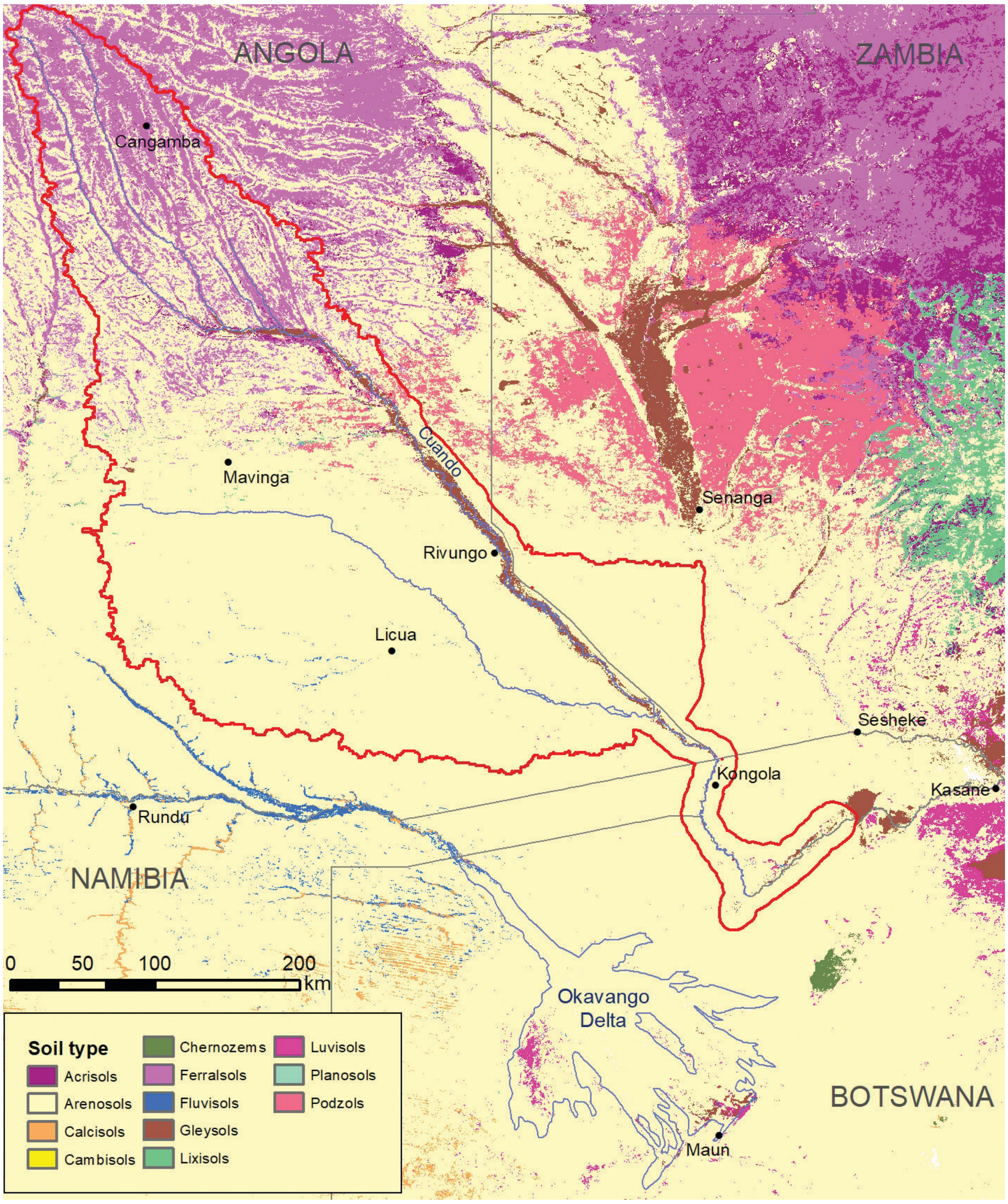


Figure 38: Major soil types of the Cuando River Basin[35].

The wind-blown origin of the arenosols is evident in the linear dunes in the far south-western corner of Angola and the adjacent areas of Namibia and Botswana. Fine-scale mapping of the soils reveals alternation of arenosols in the main body of the ancient dunes, with thin areas of calcisols in the interdune strips where reworking by the movement of water has contributed calcium to the soils, and there has been an accumulation of organic matter. Local farmers cultivate fields in the dune valleys to take advantage of the relatively good soils there.

35 http://eusoils.jrc.ec.europa.eu/library/maps/africa_atlas

3.4.2 Ferralsols

Similar to areas further to the north and east, the northern Cuando catchment is dominated by deeply weathered, acidic soil known as ferralsol. (The ferralsols in the upper catchment of the Cuando and adjacent rivers are extremely sandy and are often classified as arenosols.) The name ferralsol indicates the presence of iron (Fe) and aluminium (Al), which derive from the very weathered clay materials in the soil, dominated by the clay minerals kaolinite, haematite and goethite, but quartz is still the main primary mineral. The clays are derived from weathering of the basement rocks that they sit on, and the dominance of iron gives these soils an intense red, orange or yellow colour. Ferralsols are very poor in nutrients due to the iron and aluminium oxides being tightly bound together so these elements are not available for uptake by plants, and quartz being the main constituent. The soils have good porosity and permeability so water can infiltrate them easily, making them well-drained but also often desiccated. They are also prone to compaction and the surface can get sealed off, so they have limited use for cultivation. Their lack of nutrients is a serious limitation, and ferralsols are mostly used for shifting cultivation of maize, sorghum, millet and cassava. Yields are very low.

3.4.3 Fluvisols

Many of the broad marshes of the middle and lower Cuando have fluvisols, which are alluvial sediments of silt and clay that are deposited during periodic flooding. The marshes in Angola are broad – up to 15 km – and they get wider in the Linyanti Swamps and further downstream. They comprise coarse- to fine-textured materials that have been dumped in position during flooding events, usually with coarse material in the channel, and more finely-textured soil further from it. Over time they become stratified by chemical processes that take place when they are periodically wetted and dried out. These soils may appear to be ideal for crop production but they are derived from acidic parent material, and that acidity increases from being frequently saturated, so they are poorly suited for crops.

Peat deposits are classified as fluvisols, and they are a prominent feature of the marshes. These are derived from the reeds, sedges and other plants that grow and decompose in the water, forming masses of organic matter intermixed in varying proportions with clay and loam material deposited during flooding events. Decomposition rates are slow due to the shade cast by the vegetation itself and the waterlogged conditions during part of the year. Peats are important as they act like a sponge, becoming fully saturated then releasing the water slowly into river channels, keeping them steadily recharged. Much of the area around the Linyanti Swamps and Lake Liambezi have large deposits of peat as shown in the map of soil organic carbon in Zambezi Region, Namibia (Figure 39 on page 44).

3.4.4 Hardpans

Hardpans are cemented layers where precipitation of minerals in the soil has been concentrated, to form ferrocrete (iron-rich, also called laterite) or silcrete (cemented by silica), or calcrete which is more a feature of dry climates, from the precipitation of calcium carbonate. It is not certain what proportion of the soils in the Cuando Basin contain hardpans but they are probably widespread in the arenosols and ferralsols. This is deduced from the fact that the upper and middle Basin does have many surface channels, which must reflect the presence of some subsurface feature that forces water to the surface. Without any layer to do this, the rainwater would just percolate downwards.

Figure 39: Peat deposits in the Cuando River Basin[36].

36 Peat data from Center for International Forestry Research (CIFOR) - https://data.cifor.org/dataset.xhtml?persistentId=doi:10.17528/CIFOR/DATA.00058

3.4.5 Soil productivity

The main point from this description of the soils is that most of the Cuando River Basin has exceptionally poor soils in terms of their fertility and water holding capacity[37]. For example, yields of maize and millet average about 700 and 300 kilograms per hectare, which are among the lowest in Africa (https://datamarket.com).

However, the productivity of soil does increase from north to south, probably because soils in the drier south are less leached than by the higher rainfall in the north. Additionally, nutrients in alluvial soils were probably blown westwards out of the Cuando floodplains during very dry cycles, which would have left the Cuando drier over longer periods in the south than in the north. Evidence of these processes are abundant in southern Angola (Mendelsohn & Mendelsohn 2018).

A major consequence of these trends in soil quality is the increase in wildlife and fish (as indicated by counts of piscivorous birds) from north to south (described under Fauna).

3.5 Flora

Angola is botanically rich and floristically diverse but is the least intensively inventoried country in Southern Africa for plants[38]. Baseline botanical collections provide a better understanding of plant distribution within an area, and evidence for protecting areas of high plant diversity and conservation value, such as the headwaters of major river systems like the Cuando[39]. Currently there is very little georeferenced specimen data from the eastern half of Angola where much of the Cuando basin occurs, and the area therefore remains largely undocumented[40].

The Cuando basin area falls into three broad ecoregions[41]: Angolan Miombo woodland, Zambezian flooded grasslands and Zambezi Baikiaea woodland. These are further divided into five distinct vegetation types[42]: (i) Miombo woodland dominated by *Brachystegia* spp. and *Julbernardia paniculata*; (ii) grasslands, with some areas co-dominated with geoxylic suffrutices (see below); (iii) dry forest woodlands on deep Kalahari sands dominated my *Guibourtia coleosperma*, *Cryptosepalum exfoliatum* and *Marquesia macroura*; (iv) dry deciduous woodland dominated by *Baikiaea plurijuga*; and (v) floodplains dominated by *Cyperus papyrus* and *Phragmites mauritianus.* A more recent vegetation map of the Cuando River basin generated from satellite imagery*43* is shown in Figure 40 (page 46).

37 From (i) Asanzi et al. 2006; (ii)Ucuassapi & Dias 2006; (iii) Wallenfang *et al.* 2015
38 Huntley B, Matos E. 1994. Botanical diversity and its conservation in Angola. Strelitzia
39 Goyder DJ, Goncalves, FMP. 2019. The Flora of Angola: Collector, Richness and Endemism In: Huntley BJ, Russo V, Lages F, Ferrand N (eds) Biodiversity of Angola. Science & conservation: a modern synthesis. Springer Nature, Cham
40 Goyder DJ, Barker N, Bester SP, Frisby A, Janks M, Gonçalves FMP. 2018. The Cuito catchment of the Okavango system: a vascular plant checklist for the Angolan headwaters. PhytoKeys 113: 1–31. https://doi.org/10.3897/ phytokeys.113.30439
41 Burgess N, Hales JD, Underwood E *et al.* 2004. Terrestrial ecoregions of Africa and Madagascar – a conservation assessment. Island Press, Washington, DC
42 Barbosa LAG. 1970. Carta Fitogeográfica de Angola. Instituto de Investigação Científica de Angola, Luanda. (ii) Huntley B. 2019. Angola in Outline: Physiology, Climate and Patterns of Biodiversity In: Huntley BJ, Russo V, Lages F, Ferrand N (eds) Biodiversity of Angola. Science & conservation: a modern synthesis. Springer Nature, Cham
43 Wild Bird Trust South Africa. 2019. Okavango Catchments Vegetation, Land-cover, and Land-Use Classification, Derived From Sentinel-2 Satellite Imagery, circa 2017-18. Compiled by Geoterra Image (Pty) Ltd, South Africa.

Figure 40: Vegetation map of the Cuando River Basin[44].

Figure 41: Miombo woodland alongside the saturated Cuando floodplain. (Photo: NGOWP)

44 Wild Bird Trust South Africa. 2019. Same as Footnote 43.

3.5.1 Angolan Miombo woodlands

The vegetation map shows that the upper and central reaches of the Cuando basin are dominated by open and closed canopy Miombo woodland. Miombo refers to a broad-leafed, deciduous woodland that extends across large parts of Angola, Zambia, Mozambique and Tanzania. This type of woodland is dominated by genera of the Fabaceae plant family (legumes, beans) including *Brachystegia bakeriana*, *B. longifolia*, *Julbernardia paniculata* and *Cryptosepalum exfoliatum*, interspersed with several grass species. Generally, Miombo woodlands have open canopies, allowing herbs and grasses to grow beneath. However, closed canopy Miombo forests do occur in this area, where the grass layer is absent.

Figure 42a,b: Angolan Miombo woodland, commonly found in the upper and central reaches of the Cuando Basin. Bicuari National Park, South West Angola. (Photos: Frances Chase)

3.5.2 Grasslands

The grasslands are fire-adapted as they burn seasonally and have a vegetation rich in geoxylic suffrutices[45]. Geoxylic suffrutices are also called underground trees, referring to a large proportion of their woody organs being underground, with only seasonal above-ground shoots bearing leaves, flowers and fruit. Why geoxylic suffrutices have evolved is still debated; it is probably as a result of fire, but there is strong evidence that frost also plays a significant role.

The grasslands are considered to be of botanical interest, with the expectation that they may hold many rare, range-restricted and even undescribed species. Eighty percent of this habitat is said to occur within the eastern parts of Angola, extending to Zambia and DRC.

Figure 43: Cryptosepalum marviense, one of the many geoxyllic suffrutex plants forming the underground forests found in areas of grassland in the upper Cuando River Basin and more widely in eastern Angola. (Photo: John Mendelsohn)

45 (i) Goyder DJ, Barker N, Bester SP, Frisby A, Janks M, Gonçalves FMP. 2018. The Cuito catchment of the Okavango system: a vascular plant checklist for the Angolan headwaters. PhytoKeys 113: 1–31. (ii) Zigelski P, Gomes A, Finckh M. 2019. Suffrutex dominated ecosystems in Angola. In: Huntley BJ, Russo V, Lages F, Ferrand N (eds) Biodiversity of Angola. Science & conservation: a modern synthesis. Springer Nature, Cham. (iii) Maurin O, Davies TJ, Burrows JE, Daru BH, Yessoufou K, Muasya AM, van der Bank M, Bond WJ. 2014. Savanna fire and the origins of the 'underground forests' of Africa. The New Phytologist 204(1): 201–214. (iv) Finckh M, Revermann R, Aidar MPM. 2016. Climate refugees going underground – a response to Maurin *et al.* (2014). The New Phytologist 209(3): 904–909. https://doi.org/10.1111/ nph.13567

3.5.3 Baikiaea-Burkea woodlands

The central and lower reaches of the Cuando Basin are largely covered by open woodlands, commonly known as *Baikiaea-Burkea* woodland, occurring on deep Kalahari sands. This vegetation type is dominated by *Baikiaea plurijuga* and *Burkea africana* trees, and is associated with other well-known woody species including *Guibourtia coleosperma*, *Pterocarpus angolensis*, *Dialum englerianum* and groves of *Shinziophytum rautanenii*; these woodlands are interspersed with grasses up to 1.5 m tall including *Aristida stipitata* and *Triraphis schelcteri*. Floristically it is an important and varied area as it falls within the Zambezi Centre of endemism. *Baikiaea-Burkea* woodland is frequented by fires, due to significant amounts of grass and undergrowth. This gives rise to the rather 'bushy' nature of these woodlands, as fires kill the large standing trees by burning the trunk progressively more with each fire, till the trees collapse[46]. Bushy undergrowth springs up in their place.

3.5.4 Wetland plants

Botanically, the wetland and swamp areas along the Cuando River are not very diverse. Clump-forming plants from the Eriocaulaceae and Xyridaceae families are found here, as are canivourous plants including genera from plant families Lentibulariaceae and Droseraceae, while species of sedges and orchids have also been recorded from these seepage areas.

The Cuando River is unusual in that it contains abundant aquatic plants such as water lilies (Nymphaea species) (Figure 45). The Cuito River, by contrast, has narrower floodplains that are dominated by grasses and sedges, not reeds such as Phragmites and Papyrus.

Figure 44: Water lilies on the Cuando River. (Photo: Frances Chase)

Figure 45: Extensive, densely packed reedbeds flank the channels of the Cuando River. (Photo: Helge Denker)

This raises the intriguing question: in the apparent drought of nutrients in Cuando waters, where are these plants getting their food? While most of the channels flow over sands, there are exposures of conglomerates with clasts of basaltic rocks along the Cuando, Kembo, Cubangui and Cussivi tributaries (see Section 3.2). These 'Calondo' rocks are one possible source of minerals for the plants. Another is the likely presence of kimberlite rocks in areas along the Lomba, Cubia and Utembo tributaries, where small-scale miners seek alluvial diamonds.

46 Eastment C. 2020. How has Bwabwata National Park's woody vegetation changed in response to fire, rainfall and land use. M Sc thesis, University of Cape Town.

Figure 46: Cuando floodplain grasslands. (Photo: NGOWP)

A plant species list for the Cuando basin has been compiled (Appendix B), based on two botanical surveys[47] and records from the National Herbarium of Namibia (WIND). This species list covers areas of woodland, wetland and grasslands, and indicates the habitat where the species occur, if recorded.

3.5.4 Fire dynamics

Fire is an important driver of vegetation structure in savannas, maintaining grass communities and open woodland, and simultaneously recycling nutrients back into the ground. The effects of fire on savanna habitats vary according to:

i. the time of the year (with late dry-season fires being more intense and damaging to trees than 'cooler' fires about a month or two after the rainy season has ended),
ii. the frequency of fires (with annual fires cumulatively killing many large trees, while fires every 5-6 years or less frequent having less toll on large trees), and
iii. the intensity of the fire, which depends on the amount of combustible material available. This is influenced by the previous season's vegetation growth and both of the factors above.

Large areas of the Cuando Basin burn regularly, more so in the lower and middle parts of the Basin than in the north (Figure 47)[48]. Some fires burn on unchecked over weeks, covering tens of thousands of hectares. Such fires take a heavy toll on the trees, especially when intense fires burn annually over many successive years which eventually kills the trees so that they fall over and become fuel for future

47 The first survey was conducted as part of the South African Regional Environmental Program (SAREP) in 2013, by Frances Murray-Hudson (PSUB) and Timothy Harris (Royal Botanical Gardens, Kew) (Murray-Hudson F, Harris T. 2013 Botanical Report in: Trip Report: Aquatic biodiversity survey of the lower Cuito and Cuando river systems in Angola). The second survey was conducted as part of the Okavango Wilderness project in 2019 by Dr David Goyder (RBG Kew), Amandio Gomes (LUAI) and Dr Francisco Maiato Gonçalves (LUBA) from the region of Tempué and Ninde in northeast Angola.

48 i) Stellmes M, Frantz D, Finckh M, Revermann R, Röder A., Hill J. 2013. Fire frequency, fire seasonality and fire intensity within the Okavango region derived from MODIS fire products. Biodiversity and Ecology 5: 351–362. ii) Mendelsohn JM. 2019. Landscape Changes in Angola. In: Huntley BJ, Russo V, Lages F, Ferrand N (eds) Biodiversity of Angola. Science & Conservation: A Modern Synthesis. Springer Nature. iii) Beatty R. 2010. CBFiM in Namibia: the Caprivi Integrated Fire Management programme. Integrated Rural Development and Nature Conservation, Windhoek.

fires. Much of the savannas would probably have taller and denser tree cover if intense fires were less frequent. Fires in the upper parts of the Basin are largely confined to floodplain grasslands and open wooded grasslands adjacent to the water courses. There is relatively little combustible material in the miombo woodlands and so fires seldom penetrate these densely wooded habitats. However, at times fires fanned by strong winds rage through the woodland canopy, killing most trees.

Woodland and forest regeneration throughout the Basin is extremely slow because of the shortage of nutrients and water in the soil.

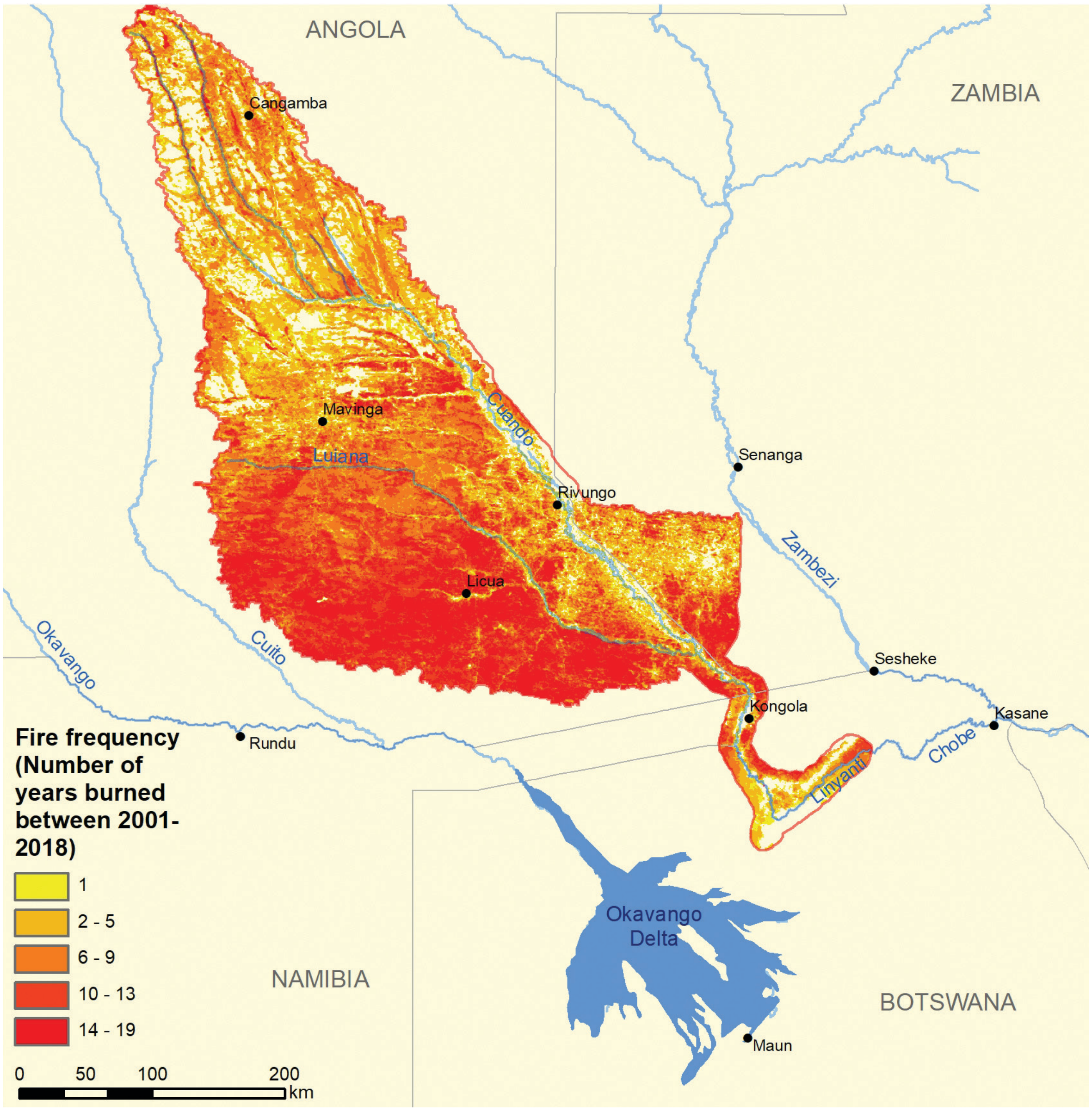


Figure 47: Fire frequency, depicted as the number of fires recorded in the 18-year period from 2001[49].

Few fires begin by natural causes. Such events require a combination of dry vegetation and a lightning strike without being followed by a downpour, which probably only happens infrequently at the end of the dry season as the summer thunderstorms start up. Undoubtedly, most fires are set by people, with a common cause being the preparation of land for crops by slash and burn. This practice generally

49 https://lpdaac.usgs.gov/tools/earthdata-search/

coincides with the late dry season, when weather conditions and fuel characteristics cause intense fires that easily get out of control. More than 50% of the southern Basin burns every year, and this pattern has not changed for at least the past 20 years[50].

Most burning happens in August and September when fires sweep across grassy and wooded areas of northern Botswana, Namibia's Zambezi and Kavango East Regions, and south-eastern Angola. These events have killed huge numbers – probably hundreds of thousands – of large trees such as *Burkea africana*, *Pterocarpus angolensis* and *Baikiaea plurijuga*, and in their place have sprung up dense shrublands dominated by *Baphia massaiensis*, *Terminalia sericea*, *Bauhinia petersiana* and other leafy shrubs[51].

Peat beds sometimes smoulder for months if they are ignited when dry, with the organic matter steadily burning unchecked until it is extinguished in the next flooding event.

Figure 48: During the dryer winter months, fires are common along the upper reaches of the Cuando and Kembo rivers. (Photo NGOWP)

50 i) National Remote Sensing Centre, 2002. A local operational tool for fire monitoring and management for the Kavango and Caprivi Regions. Report for Lux-Development, Directorate of Forestry, Ministry of Environment and Tourism, Namibia.; ii) Integrated Rural Development and Nature Conservation, 2006. Fire frequency and vegetation community structure in Caprivi. (Unpublished)

51 Eastment C. 2020. How has Bwabwata National Park's woody vegetation changed in response to fire, rainfall and land use. M Sc thesis, University of Cape Town.

3.6 Fauna

Rather little scientific work has been done on animals in south-eastern Angola, but the NGOWP expeditions, Panthera surveys and work done on behalf of the Kavango-Zambezi Transfrontier Conservation Area (KAZA) provide glimpses of what occurs in that part of the Cuando River Basin.

Animal densities are relatively low, largely as a result of the nutrient poor status of the habitat. Nevertheless, a considerable diversity of mammals, birds, reptiles, amphibians and fish has been documented in the wetlands and miombo woodland of the upper catchment of the Cuando.

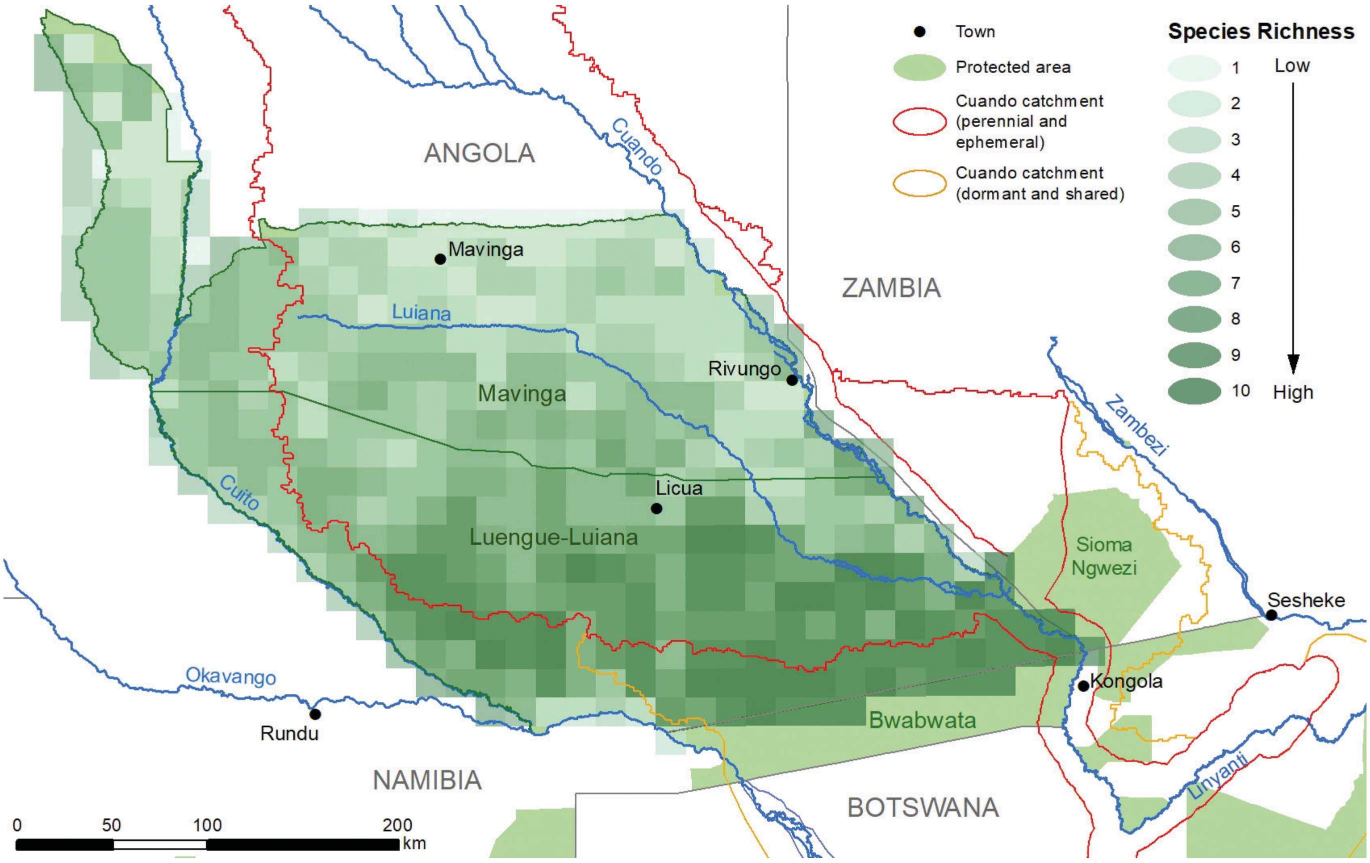


Figure 49: The number of 11 large carnivore and herbivore species predicted to occur across Mavinga and Luengue-Luiana National Parks[52].

3.6.1 Fish

The 2018 National Geographic expedition down the Cuando and Kembo Rivers focused (amongst other things) on the fish life in the waters, to compare the Cuando with the larger and better-known Cubango-Cuito Rivers[53]. Overnight fyke trap-nets were used at about 50 sites along the river transects.

A total of 37 species were recorded in the study: 30 on the upper Cuando, 13 on the Kembo and 15 on the main Cuando. The most widespread species was a small barbel, *Schilbe intermedius* (Figure 50). Similar to the situation in the Okavango, the species encountered in the headwaters gradually disappear as the

52 Funston P, Henschel P, Petracca L, Maclennan A, Whitesell C, Fabiano E & Castro I. 2017. The distribution and status of lions and other large carnivores in Luengue-Luiana and Mavinga National Parks, Angola. KAZA TFCA Secretariat (KAZA).

53 National Geographic Okavango Wilderness Project, 2020. Final Report: Scientific Exploration in Angola During 2018. Pp 70

river changes to a larger, slower flow in the downstream sections. The upper Cuando displayed the highest species diversity, including squeakers which are generalist omnivorous fish that are capable of living in a wide array of freshwater habitats.

Figure 50: Schibe intermedius *(Photo: NGOWP)*

Figure 51: Synodontis nigromaculatus *(Photo: NGOWP)*

3.6.3 Birds

The bird fauna of south-eastern Angola has received some attention but relatively little from recreational birders, who often provide much 'citizen science' information on interesting species and distribution records. Apart from the remoteness and difficulty of travelling in south-eastern Angola, this is an area of relatively uniform habitat with no species of birds that are known to be restricted to this area or habitat, and no species which can't more easily be found in accessible parts of Zambia and Namibia.

The main areas for birds that are endemic to Angola are found further west in the escarpment zone and in the far northern Namib, and further north of the Cuando in true forest habitat[54].

Sightings of Red-listed birds from the NGOWP trips raises hopes that at least some of these African iconic birds are still to be found in these remote parts of south-eastern Angola. Species that deserve mention are bateleur, white-headed vulture, wattled crane, and southern ground hornbill, all of which have suffered significant population declines over southern Africa over the past few decades[55].

Bird records from the NGOWP trips, which travelled along the rivers in mekoro, obviously focused mainly on water-associated species. These show an interesting trend of increasing frequency of fish-eating birds downstream to Shangombo. This is well exemplified by the maps for purple heron and reed cormorant (Figure 53 on page 54), both of which prey mainly on small to medium-sized fish and frogs[56].

Pied kingfishers are smaller birds than the two mentioned above, and prey on much smaller fish. These were recorded fairly evenly along the course of the rivers from source to Shangombo, possibly suggesting that their main food is more evenly distributed. These conclusions are, at this stage, unsubstantiated theories as there might be other important factors that affect the presence or absence of these birds, such as suitable habitat for nesting or the presence of competing or predatory species.

Wattled cranes, the largest and rarest crane in Africa, have a stronghold in the Okavango Swamps, and there is a small overflow from this population into the floodplains of the northern Okavango, Cuando and Chobe Rivers[57]. Individ-

54 Dean WRJ, Melo M, Mills MSL (2019) The avifauna of Angola: richness, endemism and rarity. In: Huntley BJ, Russo V, Lages F, Ferrand N (eds) Biodiversity of Angola. Science & conservation: a modern synthesis. Springer Nature, Cham
55 IUCN 2020. IUCN Red List of Threatened Species. Version 2020-2. https://www.iucnredlist.org
56 Hockey PAR, Dean WRJ, Ryan PG (eds). 2005. Roberts – Birds of Southern Africa, VIIth ed. Trustees of the John Voelcker Bird Book Fund, Cape Town.
57 Information drawn from i) Simmons RE, Brown CJ, Kemper J. 2015. Birds to watch in Namibia: red, rare and endemic species. Ministry of Environment and Tourism and Namibia Nature Foundation, Windhoek; ii) NGOWP report; (iii) Ward D. 2020. Crane sightings in Zambezi conservancies, 2014 to 2019. Namibia Crane News . (iv) Ward D. 2014. Crane sightings in East Caprivi communal conservancies 2009-2013. Namibia Crane News

uals were recorded at scattered localities along the Kembo and the upper and middle Cuando by the 2018 NGOWP expedition, and concentrations of 20 to 40 birds have been recorded in various wetlands of the Okavango, Cuando-Linyanti and the Zambezi-Chobe systems over the past 20 years. Wattled cranes occur and breed along many of the rivers in south-eastern Angola, as recorded by ground and aerial surveys[58]. Their numbers probably fluctuate depending on the status of ephemerally flooded pans and marshes across the wider area of north-eastern Namibia, north-western Botswana and south-eastern Angola. The total population is in decline, with degradation of wetlands cited as the main reason, so the relatively intact Cuando wetlands represent an important refuge for these birds.

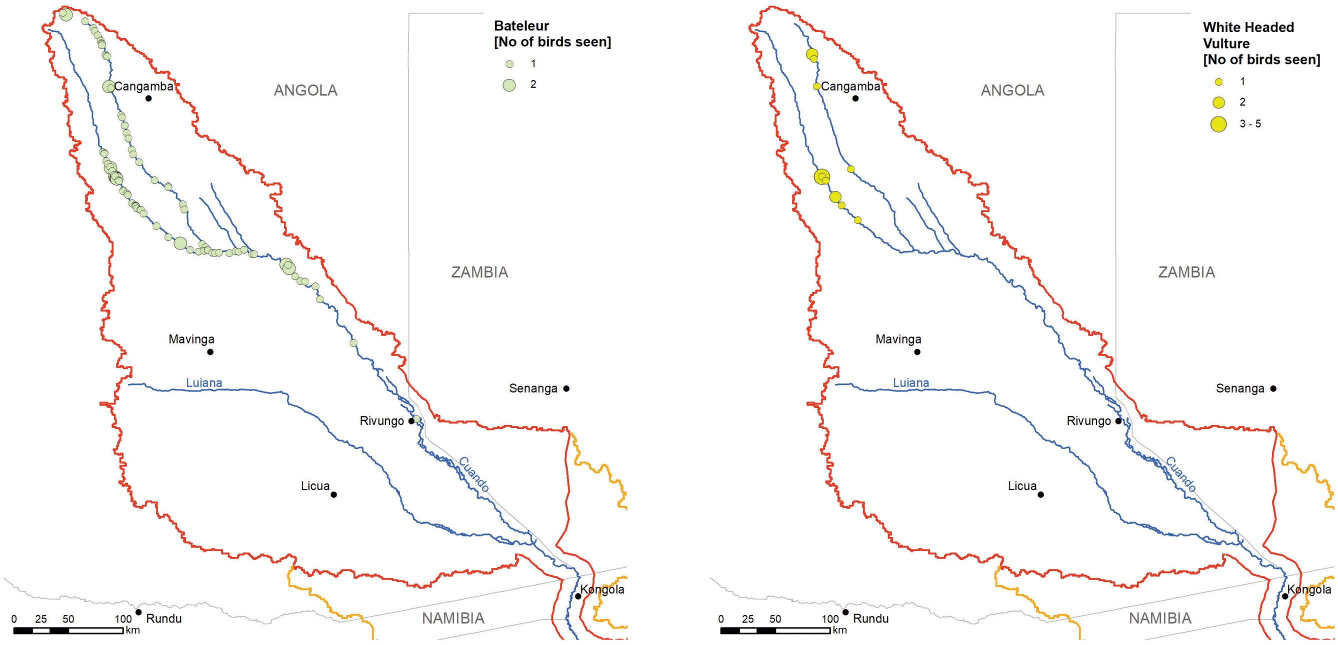


Figure 52: Observations of bateleur and white-headed vulture by the NGOWP trip down the Kembo and Cuando Rivers in 2018[59].

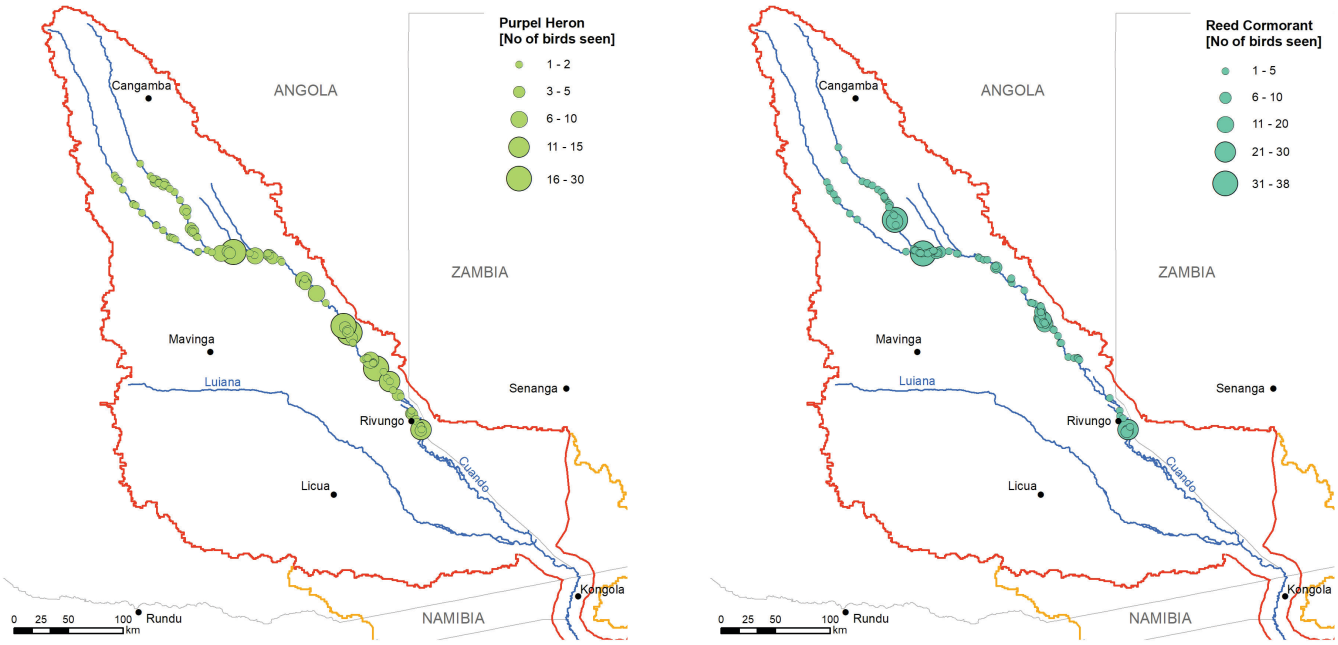


Figure 53: Records of two species of fish-eating birds from the National Geographic trip down the Kembo and Cuando Rivers.

58 Mendelsohn J 2020. Personal observations
59 From National Geographic Okavango Wilderness Project, 2020. Final Report: Scientific Exploration in Angola during 2018. Pp 70

Figure 54: (Left) Marabou stork colonies with up to 70 birds occur on small tree islands in the Cuando. (Right) Darter colonies and heronries were observed frequently along the Kembo and Cunado Rivers, indicating a healthy population of fish-eating birds. (Photos: NGOWP)

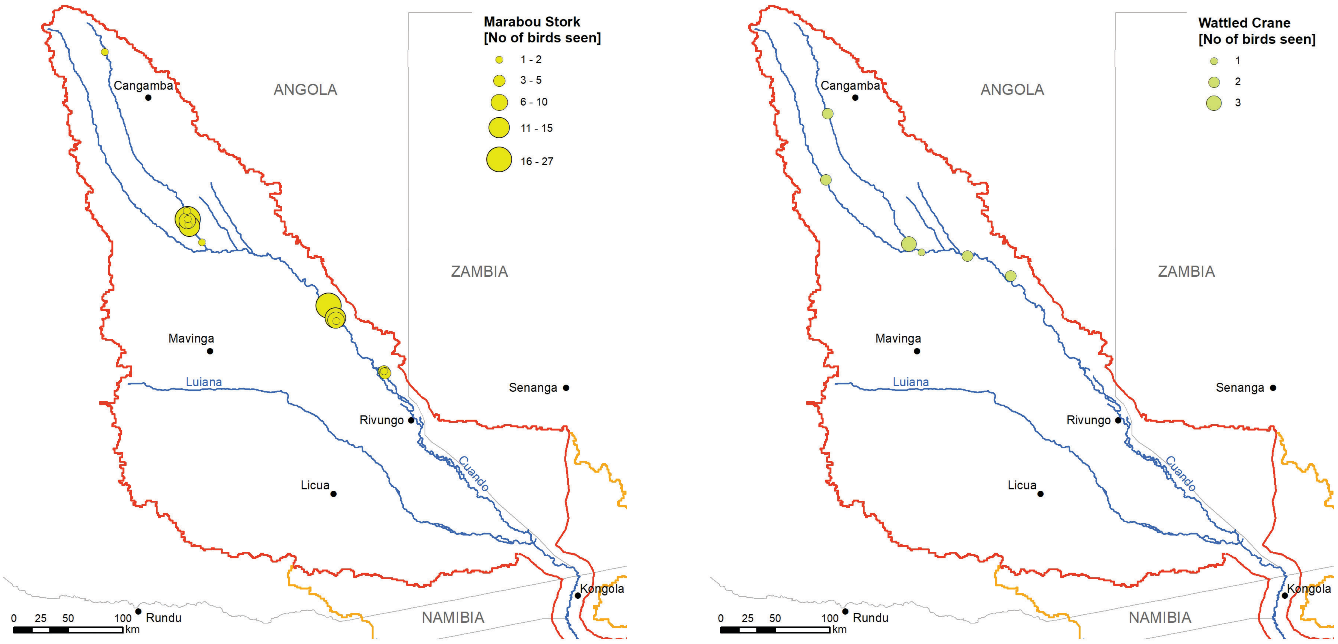


Figure 55: Records of marabou stork and wattled crane from the NGOWP expeditions, 2018.

Figure 56: (Left) Carmine bee-eater at a colony close to Kongola, Namibia. (Right) The African pygmy goose has a wide African distribution with a stronghold in quiet waters with emergent vegetation, often water lilies, in the Okavango-Cuando-upper Zambezi Rivers. (Photos: NGOWP)

3.6.4 Mammals

Angola is one of the least-known African countries in terms of its mammal fauna due to long periods of interruption in research, particularly during the civil war of 1975–2002[60]. This situation is changing as scientific interest in Angolan mammals grows, as shown by the NGOWP expedition and other conservation-related work. The far northern part of the basin has relatively few large mammals, and they are mainly vagrants to this area. This is borne out by the National Geographic expedition which recorded few and only scattered signs of large mammals such as elephant and hippo. But camera trap work in the area done by the NGOWP shows the presence of healthy populations of roan antelope, leopard, cheetah, duiker and other small mamamals and predators.

Large carnivores are relatively well established in the Luengue-Luiana National Park in far south-eastern Angola, as shown from the census of large animals in this and Mavinga National Park in 2015-16[61]. Spotted hyaena, leopard, African wild dog and cheetah occur here, while lion numbers are very low probably as a direct result of low populations of their preferred prey, namely medium-sized herbivores such as buffalo, wildebeest and zebra. Camera trapping also revealed a great diversity of typical savanna species of small carnivores such as serval, caracal and African wild cat, civet and genets (small-spotted and rusty-spotted), honey badger, striped polecat, jackals (predominantly side-striped, with low numbers of black-backed), and 6 species of mongooses. Spotted-necked otters were observed rather infrequently by the NGOWP expeditions along the Kembo and main stem of the Cuando River, but not African clawless otters which would also be expected in the rivers.

Elephant were recorded sporadically along the upper reaches of the Kembo and Cuando, although it is not clear whether these animals occur there permanently or if they move north-south seasonally. Signs of elephant such as dung and spoor were absent in most of the survey of Mavinga National Park in 2015-16, but were more common and widespread throughout most of the Luengue-Luiana NP, indicating that this is an important dispersal range for these animals in the KAZA Conservation Area. Luiana Partial Reserve was the military operations centre for UNITA (National Union for the Total Independence of Angola) during the civil war, and elephant numbers dropped severely because UNITA used elephant ivory to pay for arms and meat[62]. Elephant numbers have recovered since then but poaching of elephant is still considered to be serious, with another decline in the elephant population since 2005, and much of the poaching occurring along the Cuando River in south-eastern Angola and in Namibia[63]. The Great Elephant Count conducted in 2015 by aerial surveys estimated a total of 452 fresh elephant carcasses. Using this number in relation to the total number of elephants in the Luengue-Luina National Park, the carcass ratio gives an indication whether the population is increasing, stable or declining. For this park the ratio was 13%, indicating a very high level of mortality in the previous year, and that the population was in decline.

In the river waters themselves, hippo are rare upstream of the Cuando – Kembo confluence, and were only encountered once on the Kembo River during the NGOWP expeditions. This is possibly because of the small size of the channels. The expe-

60 Beja P, Vaz Pinto P, Veríssimo L, Bersacola E, Fabiano E, Palmeirim JM, Monadjem A, Monterroso P, Svensson MS, Taylor PJ. 2019. The Mammals of Angola. In: Huntley BJ, Russo V, Lages F, Ferrand N (eds) Biodiversity of Angola Science and Conservation A modern synthesis. Springer https://doi.org/10.1007/978-3-030-03083-4

61 Funston P, Henschel P, Petracca L, Maclennan A, Whitesell C, Fabiano E & Castro I. 2017. The distribution and status of lions and other large carnivores in Luengue-Luiana and Mavinga National Parks, Angola. KAZA TFCA Secretariat (KAZA).

62 Huntley BJ, Beja P, Vaz Pinto P et al (2019) Biodiversity conservation: history, protected areas and hotspots. In: Huntley BJ, Russo V, Lages F, Ferrand N (eds) Biodiversity of Angola. Science & conservation: a modern synthesis. Springer, Berlin

63 Chase MJ, Griffin CR. 2011. Elephants of south-east Angola in war and peace: their decline, re-colonisation and recent status. African Journal of Ecology 49: 353-361. Chase MJ, Schlossberg S. 2016. Dry-season fixed-wind aerial survey of elephants and other large mammals in southeast Angola – A Great Elephant Census Project. Elephants Without Borders, Kasane, Botswana.

dition had to be abandoned shortly downstream of Rivungo due to the presence of numerous hippos. These animals probably perform an important function of keeping channels open in the downstream sections, as they do in the Okavango Delta[64]. In addition, the relatively nutrient-poor waters of the rivers must surely benefit from the relatively large volumes of dung deposited in the water by hippos as well as elephants.

There are no census records of hippo numbers in the Linyanti-Liambezi system, just occasional observations. For instance, Lake Liambezi supported a large population of hippos in the early 1980s[65], and groups of up to 15 strong occupied parts of the Linyanti[66]. Altogether 21 of the Liambezi hippos were shot as they were exposed by the drying of Lake Liambezi up to 1985, while some of them moved into the Zambezi River. This scenario was repeated in 2016, during a period of drying in the Linyanti, when hippos were stranded in the diminishing channel and a number were allowed to be culled for own use by the Bamunu Conservancy[67]. Lastly, hippos have been recorded up to 90 km away from the main channel of the Cuando in the omirambas of the Bwabwata National Park during good rains[68].

Populations of large ungulates in south-eastern Angola vary, with some species (such as blue wildebeest, Cape buffalo and sable antelope) having been severely reduced during the civil war, and now in various stages of recovery in the face of continued offtake as bushmeat. Large mammal herbivores recorded for the Cuando River Basin are listed in Table 1[69].

The habitat over much of the Cuando Basin is not ideally suited for black rhino. There was purportedly a small population in southern Angola in the 1970s, but these animals were probably exterminated during the civil war[70]. The last mention of any black rhino in Namibia's Zambezi Region was of one shot near Kongola in the early 1970s[71]. There have been a few reported sightings in the Jamba-Bico area close to the Cuando in recent decades.

Figure 57: Mammals like red lechwe and lion are common in this area. (Photos: Charles J. Sharp & freepik.com)

64 McCarthy TS, Ellery WN, Bloem A. 1998b. Some observations on the geomorphological impact of hippopotamus (Hippopotamus amphibius L.) in the Okavango Delta, Botswana. African Journal of Ecology 36: 44-56.
65 Hines C. Caprivi Sugar EIA. Appendix B Terrestrial ecology.
66 Le Roux LJ. 1983. The Eastern Caprivi: An ecological summary with reference to larger mammals and their conservation. Unpublished report
67 Five stranded hippos to be culled. The Namibian 2016-08-04.
68 NNF. 2008. Hippopotamus: Background information and species management guidelines for Namibia's rare and valuable wildlife. Transboundary Mammal Project of the Ministry of Environment and Tourism, facilitated by Namibia Nature Foundation, Windhoek.
69 Information is drawn from i) Beja P, Vaz Pinto P, Veríssimo L, Bersacola E, Fabiano E, Palmeirim JM, Monadjem A, Monterroso P, Svensson MS, Taylor PJ. 2019. The Mammals of Angola. In: Huntley BJ, Russo V, Lages F, Ferrand N (eds) *Biodiversity of Angola Science and Conservation A modern synthesis.* Springer https://doi.org/10.1007/978-3-030-03083-4
70 Beja P, Vaz Pinto P, Veríssimo L, Bersacola E, Fabiano E, Palmeirim JM, Monadjem A, Monterroso P, Svensson MS, Taylor PJ. 2019. The Mammals of Angola. In: Huntley BJ, Russo V, Lages F, Ferrand N (eds) *Biodiversity of Angola Science and Conservation A modern synthesis.* Springer https://doi.org/10.1007/978-3-030-03083-4
71 Le Roux LJ. 1983. The Eastern Caprivi: An ecological summary with reference to larger mammals and their conservation. Unpublished report

Table 1: Large mammals recorded in the Cuando River Basin.

Species	Angola	Namibia – Zambezi Region
Common impala	Relatively small numbers in the Luengue-Luiana NP	Common, increasing
Tsessebe	Very rare in south-eastern Angola; However, the species was confirmed in the area through camera-trapping (Funston *et al* 2017)	Very low numbers
Red hartebeest	Possibly extinct in Angola	
Lichtenstein's hartebeest	Likely extinct in Angola	
Blue wildebeest	Formerly common throughout Angola but now in low numbers in the SE	Common, increasing
Cape buffalo	Previously common in SE Angola but populations were severely reduced during the civil war	Common, increasing
Common duiker	Common	Common
Roan antelope	Widespread and reasonably common in Angola	Reasonably common, increasing
Sable antelope	Reasonably common in Angola	Reasonably common, increasing
Oribi	Possibly in small numbers in SE Angola	
Steenbok	Present but uncommon SE Angola	Common
Sharpe's grysbok	Possibly in Namibia	
Southern reedbuck	Common	Reasonably common, increasing
Puku	Uncommon, possibly extinct in SE Angola	Not censused; possibly only a few indivuals in Nkasa Rupara NP.
Red lechwe	Present in SE Angola	Abundant pre-1990, now recovering but numbers only in the hundreds; increasing
Kudu	Present in SE Angola but in low numbers	Reasonably common, increasing
Bushbuck	Present in SE Angola but in low numbers	
Sitatunga	Present along the rivers	
Eland	Common in SE Angola	
Angolan giraffe	Small numbers in SE Angola	Small numbers
Hippopotamus	In small pockets in the larger rivers	
Bushpig	Common	Not censussed
Warthog	Common	Common
Plains zebra	In low numbers in SE Angola	Common

Wildlife populations have become well established in the Namibian part of the Cuando River Basin through the growth of community-based management of wildlife and the communal conservancy concept, combined with the formally protected areas in Zambezi Region that were proclaimed in 1990. Approximately one third of the land area of Zambezi Region now belongs to conservancies and State protected areas, and most of this is in fairly close proximity to the Cuando River, Linyanti Swamp and Lake Liambezi and the Chobe River. This has allowed wildlife numbers to increase, and increasing connectivity between areas under conservation management mean that animals can move more through the landscape, which has also helped numbers to grow. For instance, eland, wildebeest and giraffe were successfully reintroduced into conservancies and protected areas in the Mudumu North Complex in 2011, and have established a permanent presence there.

3.6.5 Wildlife Movements

The Namibian Ministry of Environment, Forestry and Tourism regularly conduct aerial surveys in the Zambezi Region, which supplement on-going wildlife monitoring efforts by communal conservancies on the ground. This information reveals the inter-connections between wildlife areas in the greater Okavango-Cuando-Zambezi area.

Elephants

While the recovery of the elephant population in northern Botswana is praised as a conservation success, it does pose several challenges. Riverine woodland habitat is being degraded from their high intensity browsing, and there is much human–elephant conflict especially around protected areas. But protected areas in neighbouring Angola and Zambia have low elephant densities, therefore dispersal of elephants from high density areas of northern Botswana is desired, to promote the growth of wildlife-based tourism in the overall KAZA area.

Satellite tracking of individual elephants (Figure 57 on page 60) has helped to show the extent of their movements, to pinpoint barriers and constrictions and to reveal preferred paths[72]. The Cuando is part of an important route – the Kwando Wildlife Dispersal Area – allowing elephants from Chobe to move across the conservancies and national parks along the river, into Angola and Zambia.

Various individuals coloured grey in the map (Figure 57) show the extent of movements between the four basin states of the Cuando, and the conspicuous barriers created by veterinary cordon fences north and west of the Okavango Delta. Green, pink and yellow tracks show the importance of the Cuando corridor linking Botswana and Angola, while the green path also reveals the Zambezi State Forest as a previously unrecognized route into Zambia.

Lion

Lions are especially valuable for tourism in the region. The Kwando Wildlife Dispersal Area (Figure 58 on page 60) is an important area for transboundary movement of many wildlife species including all of the larger carnivores, and is pivotal to the success of KAZA as a wildlife landscape and for the mobility of lions between Angola, Botswana and Zambia[73].

Lion numbers have recovered in the Mudumu landscape[74], creating new challenges with hotspots of conflict where human settlements coincide with lion dispersal corridors. The Kwando Carnivore Project has been helping to reduce these conflicts, which mostly occur where cattle are left to graze unattended close to or within protected areas. Construction of lion-proof enclosures for cattle at night, together with active herding of cattle by day and keeping cattle away from the national parks, all help to reduce the depredations of lions on livestock.

72 i) Stuart-Hill, 2012. ii) https://www.peaceparks.org/tfcas/kavango-zambezi/ iii) Cushman SA, Chase M, Griffin C. 2010. Mapping landscape resistance to identify corridors and barriers for elephant movement in southern Africa. In Cushman SA, Huettmann F (eds) Spatial Complexity, Informatics and Wildlife Conservation. Springer, pp 349-367.

73 Hanssen L, Kukuwe L, Sililo C. 2020. Human-Lion Conflict Mitigation in the Zambezi Region, Namibia. Kwando Carnivore Project report, June 2020.

74 Hanssen L, Kukuwe L, Sililo C. 2020. Human-Lion Conflict Mitigation in the Zambezi Region, Namibia. Kwando Carnivore Project report, June 2020.

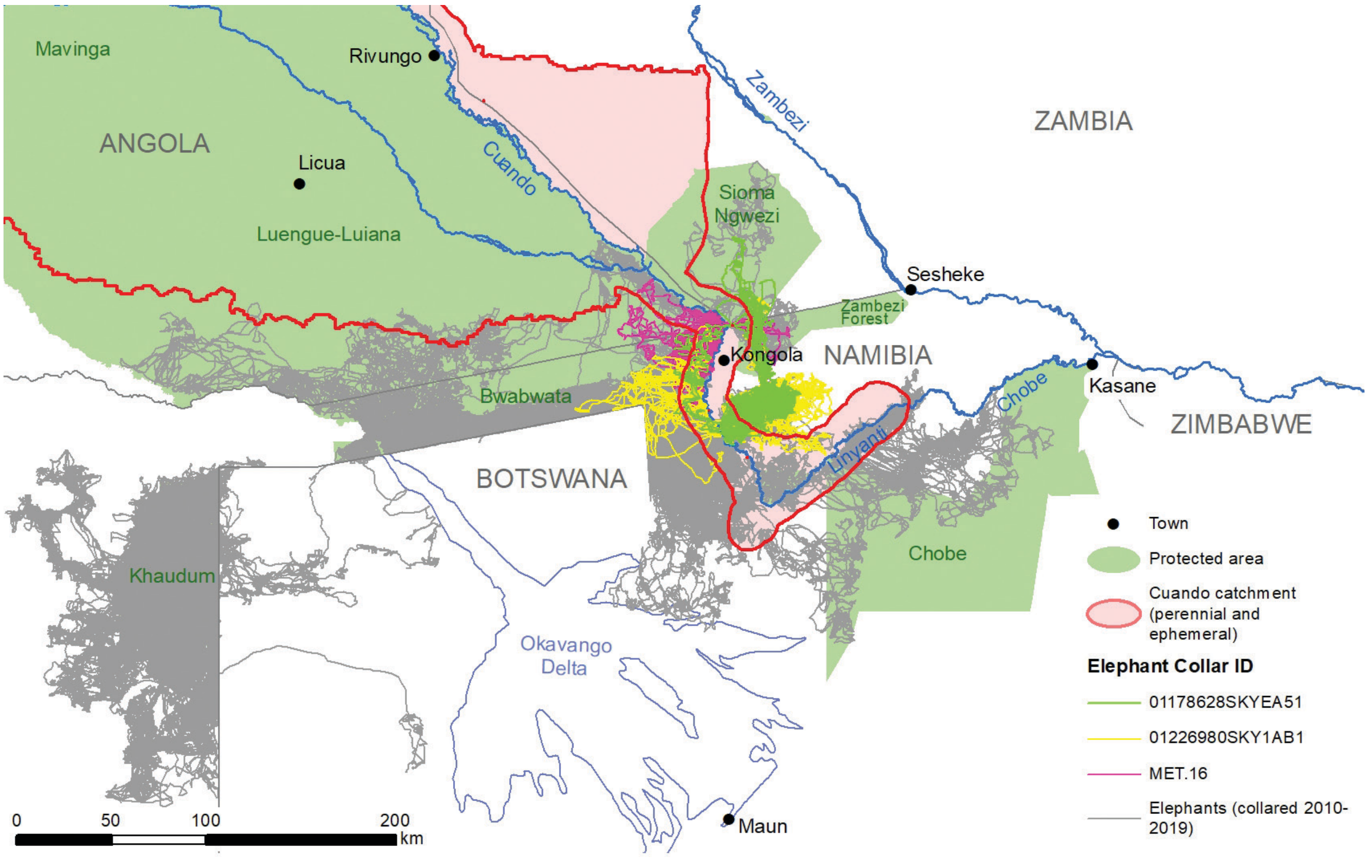


Figure 58: Elephant movement derived from collar data (2010-2019)[75].

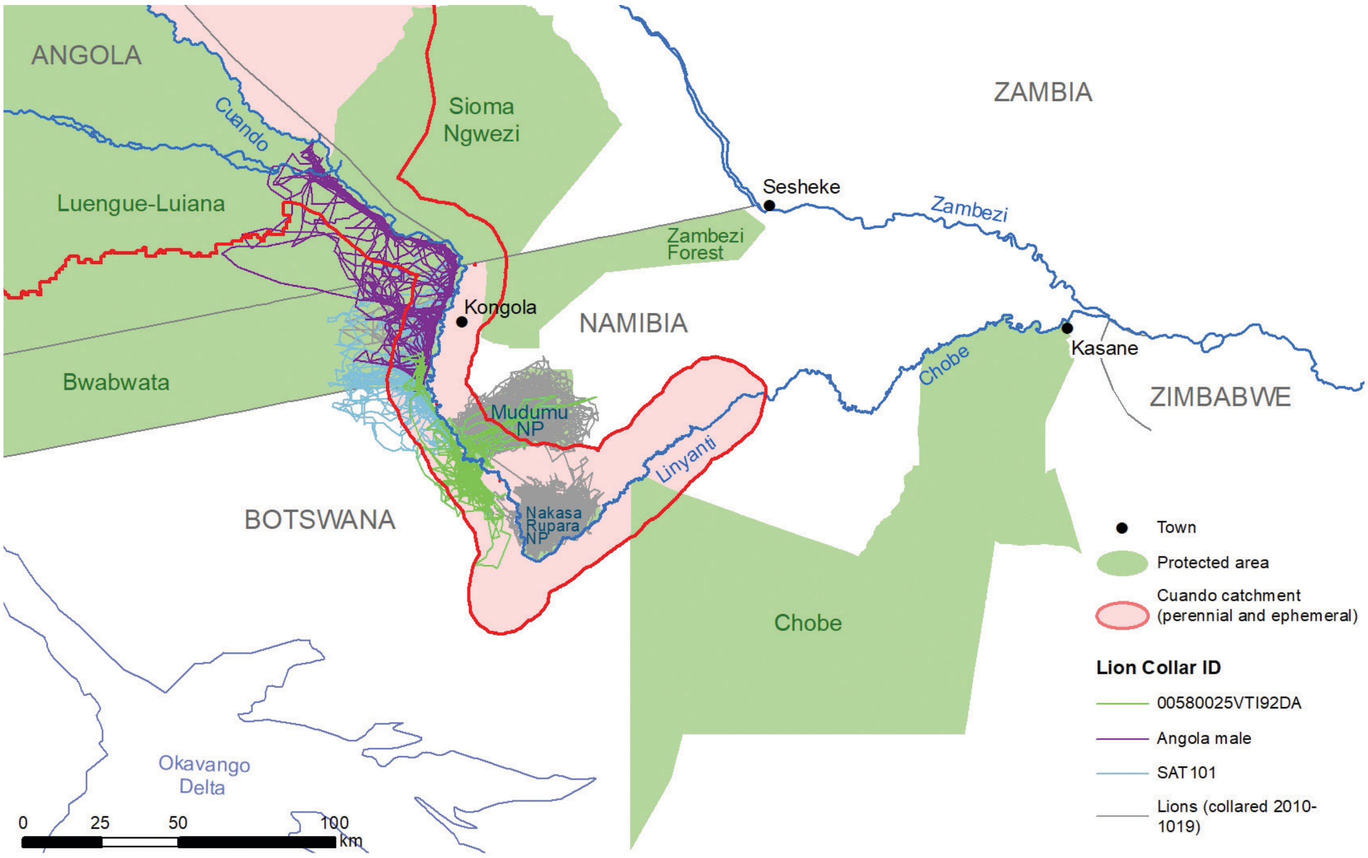


Figure 59: Lion movement derived from collar data (2010-2019). Note how these lions limit themselves to protected areas, thus avoiding regular contact with people and livestock. From MEFT 2020.

75 From Ministry of Environment, Forestry and Tourism data

4. Social environment

4.1 Administrative regions

The Cuando River Basin covers four countries: Angola, Zambia, Namibia, and Botswana. The areas covered by the various provinces and regions of these four countries are set out in Figure 59 and Table 2.

Figure 60: Administrative boundaries within and surrounding the Cuando River Basin

Table 2: Areas under the various administrative parts of the Cuando River Basin.

Country	Province / Region	Area in perennial / ephemeral parts of the Cuando River Basin (km²)		Sub-totals	
		Perennial and buffer	Ephemeral		
Angola	Moxico Province	25,604	492	26,096	102,520
	Cuando Cubango Province	24,739	51,685	76,424	
Zambia	Western Province	2,424	6,928	9,352	9,352
Namibia	Zambezi Region	4,373	0	4,373	4,373
Botswana	North-West Province	2,538	0	2,538	2,538
Sub-totals		59,678	59,105		
TOTAL					**118,783**

4.2 The people of the Cuando

Mapping of households and villages captured on Google Earth images allows a rough calculation of the population of the Cuando River Basin (Figure 61 and Table 3). There are just less than 40,000 households in the entire Cuando River Basin. Based on a rough estimate of 7 people per household, this amounts to about 274,330 people.

Figure 61: Settlements along the river in Angola are usually small and very remote. (Photo: John Mendelsohn)

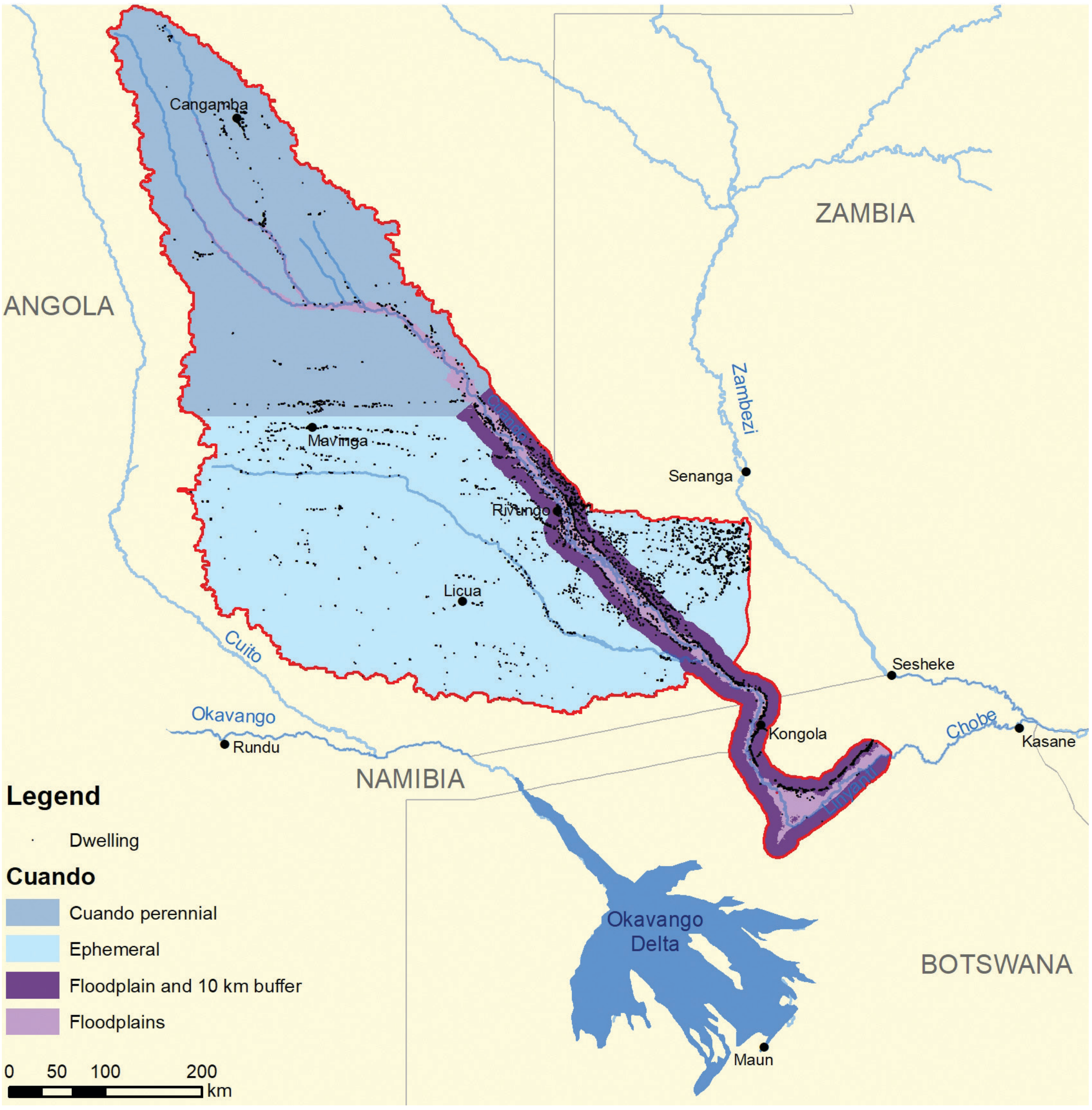


Figure 62: Distribution of households in the Cuando River Basin.

Figure 63: Number of households in each active zone of the Cuando Basin[76].

76 From mapping done for this project

Table 3: Number of households in each zone of the Cuando Basin.

Country	Zone	Number of households	Household sub-totals
Angola	Perennial	8,000	23,000
	Ephemeral	10,800	
	Floodplain	1,700	
	Floodplain 10 km zone	2,500	
Zambia	Ephemeral	3,300	7,100
	Floodplain	300	
	Floodplain 10 km zone	3,500	
Namibia	Floodplain	90	8,590
	Floodplain 10 km zone	8,500	
Botswana	Floodplain 10 km zone	500	500
Subtotals for each zone in all countries	Perennial	8,000	39,190
	Ephemeral	14,100	
	Floodplains	2,090	
	10 km floodplains zone	15,000	

The maps and table showing how the households are distributed shows a number of features:

- Few or no people live in large areas of the Basin. These areas have limited supplies of water and soil nutrients, and are remote from roads, services or commercial activity in towns and village.
- The perennial and ephemeral northern parts of the basin in Angola are very sparsely populated. Settlements are concentrated along the river channels, especially close to the main stem of the Cuando itself, and there is a very sparsely scattered number of isolated households throughout the rest of this area. The small towns of Cangamba, Mavinga, Rivungo and Licua have experienced various levels of development. They are significant as the only administrative and commercial centres serving large rural areas.
- The southernmost part of the basin, in Namibia and with only a small area in Botswana, is more densely sparsely populated, with a conspicuous ribbon of highly concentrated settlements along the main road that connects Kongola with Chinchimane and Katima Mulilo.
- People make their homes most often close to roads where there are opportunities for communication and trade.
- One of the special features of the Cuando is the large number of people who live in isolation on tiny islands deep in the floodplain (Figure 64). Mapping work done for this project indicates that over 900 families live on these islands. From observations made by the NGOWP expedition[77], the river is the main traffic route for movements around the area and is navigated using dug-out canoes, while people also follow small tracks and pedestrian paths away from the river. Fishing is done using funnel traps and nets. No livestock were encountered along the Kembo and Cuando Rivers until the Zambian border.

77 NGOWP 2020

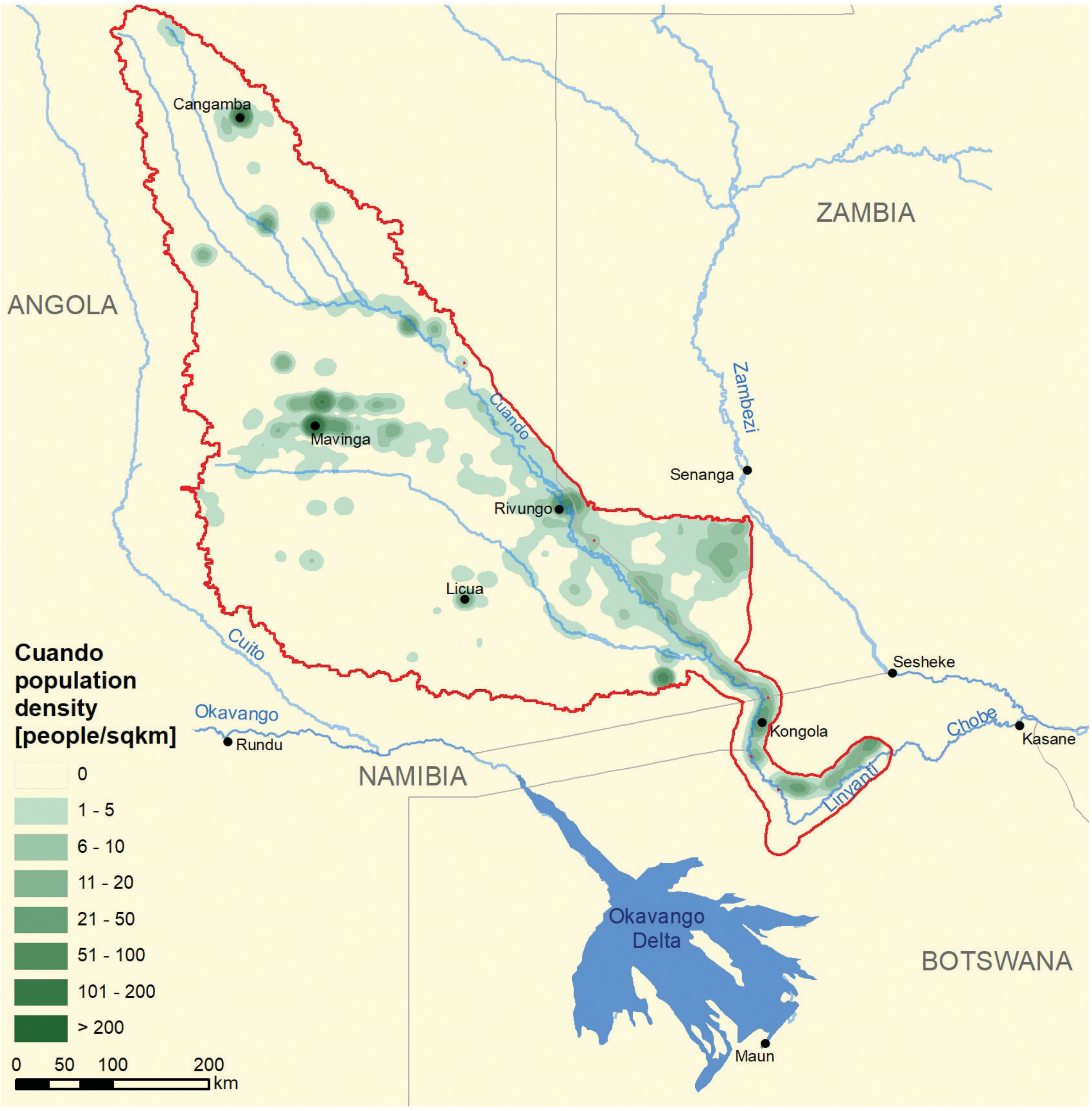


Figure 64: Population density in the active zone of the Cuando River Basin. This map is derived from the previous map of houses in the basin. Each mapped house was considered to have 7 people; these were then spread over a 'footprint' with a 5 km radius.

- There are also a number of isolated rural households throughout south-eastern Angola. They largely practice hunting, gathering and subsistence agriculture. Evidence of bushmeat harvesting is common in settlements and towns[78].

Note that the entire area between the Cuito and Cuando Rivers, south of roughly the latitude of Mavinga, make up the Mavinga National Park and the Luengue-Luiana National Park.

78 Funston P, Henschel P, Petracca L, Maclennan A, Whitesell C, Fabiano E & Castro I. 2017. *The distribution and status of lions and other large carnivores in Luengue-Luiana and Mavinga National Parks*, Angola. KAZA TFCA Secretariat (KAZA).

Figure 65: Many people live in remote homesteads in the Cuando floodplain, presumably fairly self-sufficient from the small circle of trees and crops around the homestead, supplemented by fish and bushmeat. (Photo: Helge Denker)

Figure 66: The town of Shangombo on the Zambian side of the border alongside the Cuando River. (Photo: John Mendelsohn)

Mapping of households and villages from satellite images taken between 2004 and 2018[79] show that the towns in south-eastern Angola were mostly growing fast, at rates over 10% per year. Large towns were growing faster than small ones, but it is not known how much the remote towns such as Licua and Mavinga were growing. While much of the growth could be ascribed to the large numbers of people returning to these areas once the civil war ended in 2002, the growth of towns also reflects the general movement of people away from rural areas in search of services and cash income in towns.

The situation is similar in Namibia, where 28% of Zambezi Region people lived in urban areas in 2001, while in 2011 that had grown to 31%[80]. Similarly, in Zambia the town of Shangombo had a growth rate of 2.9%, the highest in the Lower West Zambezi Game Management Area[81], and higher than the average rural growth rate of 2.1% for the whole country[82].

As populations grow, so the demand for crop fields, grazing areas and other natural resources grows. The livestock stocking rate of Zambezi conservancies is generally higher than recommended rates, and the high density often drives herders into areas allocated for wildlife areas.

79 Mendelsohn J, Martins A. 2018. River catchments and development prospects in south-eastern Angola. RAISON.
80 NSA. 2012. Namibia 2011: Population and housing census Main report. National Statistics Agency, Windhoek.
81 DNPW. 2015. General Management Plan for the Lower West Zambezi Game Management Area 2015-2025. Unpublished report of the Department of National Parks and Wildlife, Lusaka. CSO. 2012. Zambia 2010 census of population and housing. National analytical report. Central Statistics Office, Lusaka.
82 CSO. 2012. Zambia 2010 census of population and housing. National analytical report. Central Statistics Office, Lusaka.

4.3 Land uses

4.3.1 Crops

There is relatively little crop cultivation and few people in the upper Cuando Basin because soils are so poor. Nevertheless areas of woodland are cleared for dryland cropping[83], but the fields are typically used only for a few years before being abandoned, requiring new fields to be cleared.

The crops that are grown vary depending on what does best with the available rainfall, on the available soil. Thus manioc is the main crop in the upper parts of the Basin, supplemented with maize and often inter-cropped with melons and beans. Sweet potatoes are cultivated along the margins of water courses. In southern Angola people grow maize, bananas and sweet potatoes close to the river and on islands within the expanses of marshes.

Crops that can be stored for long periods are almost always kept for domestic consumption. The only areas where some vegetables and occasional cereals are sold are around the towns (Cangamba, Mavinga etc.) because those are the only markets in the Angolan catchment. It is likely that there is also a busy market in Shangombo in Zambia, which is probably supplied largely by Angolan traders and local small holders. Smallholders in Namibia often sell maize and vegetables to markets in Katima Mulilo.

As one moves south and rainfall decreases, maize and millet become more prevalent. There is some diversity in cultivation: the staples are maize, millet and sorghum, and these are complemented with pumpkins, groundnuts and beans[84].

4.3.2 Harvesting and trade of natural products

Harvests of natural products are almost entirely intended for sale, and for many residents in the Basin these sales are their only sources of cash income. Harvests are thus of high value and depend on local supplies, durability, access to markets and demands in those markets. This is the case in Angola where there are no social grants.

People harvest what is available from the surroundings: resources such as fish, honey in miombo woodlands, and bush meat. These products can be dried and/or transported to markets relatively rapidly.

Other products that involve some processing and marketing are traditional liquor, manioc and melons. All of these products involve a low level of use of natural resources, with a strong reliance on the provisions and regulatory services provided by a relatively intact natural environment.

83 Information drawn from Raison. 2019. River catchments and development prospects in south-eastern Angola.
84 DoF. 2014. Forest management plan, Lubuta community. Unpublished report, Directorate of Forestry, Ministry of Agriculture, Water and Forestry, Windhoek.

4.3.3 Fishing

Fish populations are not very high in the Angolan Cuando because of the low nutrient levels in the river waters. Nevertheless fish are present and of course are utilised by the relatively small numbers of people living close to the waters.

Lake Liambezi at the distal end of the river system is much more productive and when it carries water it supports a high diversity and abundance of aquatic flora and fauna. The fishing industry was valued at N$34 million per year in 2011[85] and provided employment, livelihood support and cash income for households adjacent to the lake and further afield. Fish are an important source of protein in the region for all households.

4.3.4 Livestock

There are very few livestock in the northern part of the Cuando Basin: some poultry and a few goats, and virtually no cattle. Cattle and goat numbers increase slightly as one moves southwards in Angola, but everywhere the numbers are small due to disease and the effects of the civil war, when armies commandeered all livestock for rations.

Livestock numbers are much higher in Namibia and Zambia, where they play an important role in livelihoods and the economy. There were close to one million cattle in Zambia's Western Province in 2016[86].

4.3.5 Forestry

Wood is an important resource for both local and commercial users in the region. Local users mainly collect (dead) firewood for cooking, and harvest standing trees for construction purposes[87].

The woodlands in Namibia and south-eastern Angola are dotted with trees that have recently become a focus for commercial logging; the hardwood trees rosewood (*Guibourtia coleosperma*), Zambezi teak (*Baikaiea plurijuga*) and Angolan teak (also called kiaat or mukwa *Pterocarpus angolensis*), are the main targets. Large specimens of these slow-growing trees are mostly over 100 years old[88], so concerns have been raised on this rapid over-exploitation and the connections to international logging cartels that have been active in Zambia and DRC, and the fact that only a tiny fraction of the value of the wood is achieved in Namibia and Angola. But, in the wider perspective, far greater

85 Tweddle D, Weyl O, Hay C, Peel R, Shapumba N. 2011. Lake Liambezi, Namibia: fishing community assumes management responsibility. WWW Project.
86 CSO. 2018. Zambia in figures 2018. Central Statistics Office, Lusaka.
87 De Cauwer V, Knox N, Kobue-Lekalake R, Lepetu JP, Matenanga O, Naidoo S, Nott A, Parduhn D, Sichone P, Tshwenyane S, Yeboah E & Revermann R. 2018. Woodland resources and management in southern Africa. In: *Climate change and adaptive land management in southern Africa – assessments, changes, challenges, and solutions* (ed. by Revermann R, Krewenka KM, Schmiedel U, Olwoch JM, Helmschrot J & Jürgens N), pp. 296-308, *Biodiversity & Ecology*, 6, Klaus Hess Publishers, Göttingen & Windhoek. doi:10.7809/b-e.00337
88 i) DoF 2009. Inventory report Sachona ii) Mendelsohn J, el Obeid S. Woodland and forestry in Namibia. iii) FAO 2018

numbers of these trees are lost to uncontrolled fires, which generate few prevention measures and no public reaction. Similarly, land clearing for cropping is given full public approval but is equally destructive of the natural vegetation. A community forest report from Zambezi Region estimated that teak woodland in 2014 made up only about 10% of the total area categorised as Kalahari woodland; the remaining 90% was teak shrubland, which is the result of frequent fires. Changes in tree cover are mapped in Figure 66.

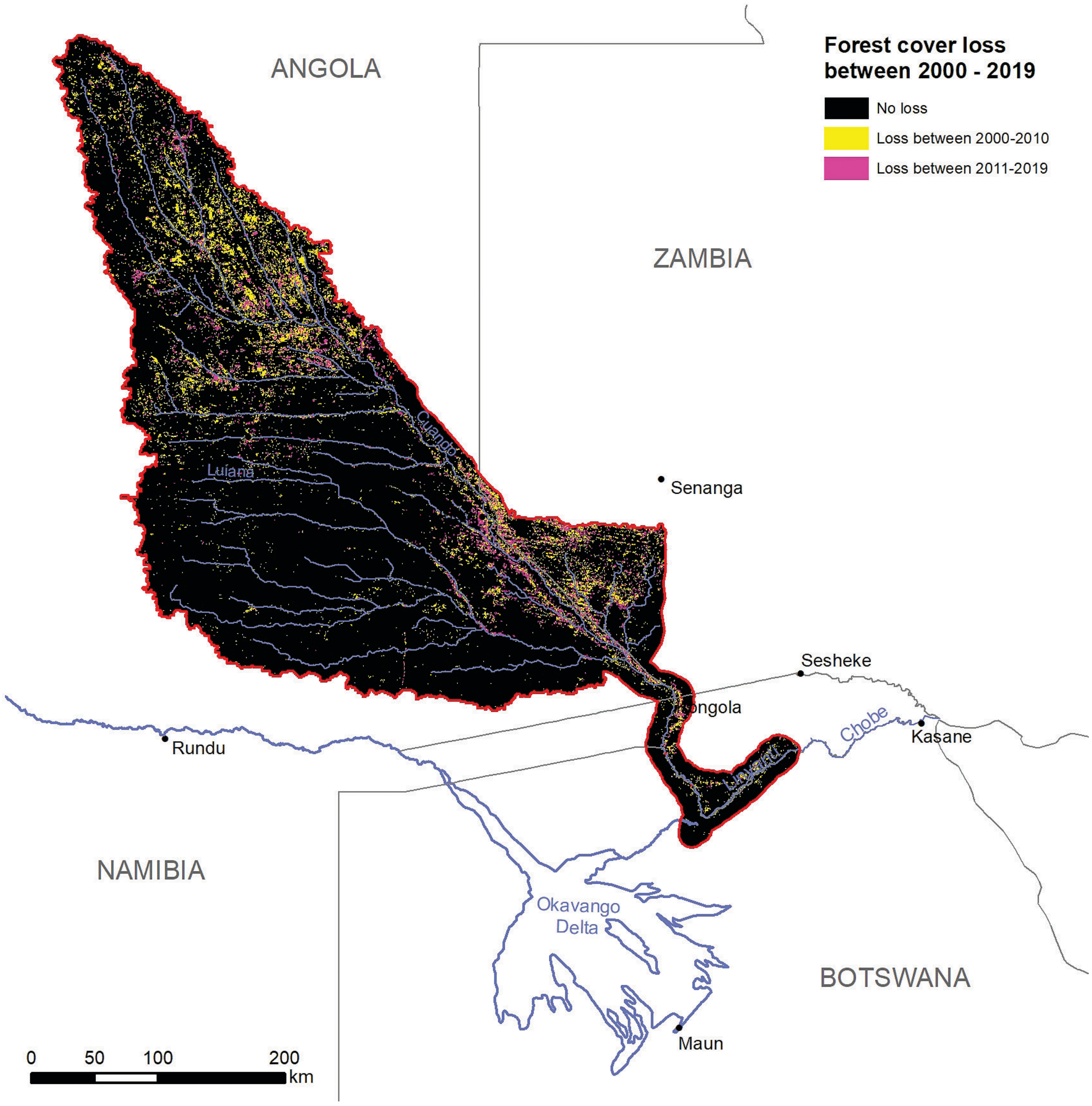


Figure 67: Loss of tree cover from 2000 to 2019 across the Cuando River Basin[89].

An average of 200 ha of forest cover has been lost per year since 2001 in the northern Namibian conservancies, with most of this being from 12 conservancies in the Kavango and Zambezi Regions[90]. A total of 556 ha of forest have been lost from the core wildlife zones of conservancies, and 2,209 ha from multiple use zones over this period.

89 Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. "High-Resolution Global Maps of 21st-Century Forest Cover Change." Science 342 (15 November): 850–53. Data available on-line from: http://earthenginepartners.appspot.com/science-2013-global-forest.

90 Coldrey K, Turpie J. 2019. Climate Change Vulnerability and Adaptation Assessment for Namibia's Communal Conservancies - Final report. Prepared for WWF-Namibia by Anchor Environmental Consultants, Cape Town.

4.3.6 Mining

The thick covering of Kalahari sand throughout the Cuando Basin makes detection and recovery of minerals very difficult, and there is no conventional mining in the Basin. But alluvial diamonds are not influenced by this factor, and these are sought by small numbers of artisanal miners in river channels in the upper and middle parts of the basin[91]. Apart from the observations of scattered diamond mining activities, there is no information on the extent of these operations, the volumes that are processed, or the degree to which local residents participate and benefit.

4.3.7 Conservation

Much of the Cuando Basin is managed for conservation in one form or another. Indeed, there can be few large river basins anywhere in the world that experience such protection and management.

The central Angolan portion of the Cuando Basin is occupied by the Mavinga and the Luengue-Luiana National Parks, which fill the south-eastern corner of the country. The extent of these reserves – now 84,400 km^2 – was significantly increased when they were designated in 2011, from their original much smaller areas when they were 'Partial Reserves'. These two reserves now constitute one of the largest contiguous national park complexes in any one country in Africa.

The Cuando River Basin includes part of the Sioma Ngwezi National Park in Zambia, which itself is surrounded by the Lower West Zambezi Game Management Area[92]. This park is largely undeveloped but is expected to grow its tourism facilities through the KAZA initiative. The park is not fenced and allows free movement of animals from the bordering parks of Botswana and Namibia, following the corridor along the Cuando River.

Areas under conservation management in Namibia that are contiguous with the Cuando River include three National Parks: Bwabwata, Mudumu and Nkasa Rupara[93], as well as a number of conservancies[94]: Kwandu, Mayuni, Mashi, Balyerwa, Dzoti, Bamunu and Salambala. The Kwandu, Sachona, Zilitene, Sikanjabuka and Bukalo Community Forests also lie within the limits of the perennial zone of the Cuando Basin. Lastly, the Zambezi State Forest also supports a surprising diversity of wildlife and in numbers not previously recognised[95]. These areas combine to create a conservation landscape that is large enough to allow migratory species such as elephants to use the landscape optimally based on their seasonal needs. The conservation landscape includes areas identified as key wildlife corridors, backed up with measures to assist conservancies keep the corridors open for wildlife.

On the Botswana side, the Cuando River is contiguous with the Okavango Delta Wildlife Management Area which includes the identified area of the Okavango Swamps Ramsar Site (i.e. a Wetland of International Importance) and the Okavango Swamps World Heritage Site. Further downstream, where the Cuando is called the Linyanti River, it has a short distance of river frontage in the Chobe National Park.

The 'landscape conservation' concept has been taken to the next level with the establishment of the trans-

91 Funston *et al* 2017; Mendelsohn and Martins 2018.
92 https://www.kavangozambezi.org/en/sioma-ngwezi-national-park
93 (Mamili National Park has subsequently been renamed Nkasa-Rupara was first proclaimed as the Mamili National Park. It was renamed in reference to the two dominant islands Nkasa and Rupara in this part of the Linyanti Swamp. Mamili referred to the seven chiefs of that name who, from 1864, ruled over the Mafwe people living in this part of Zambezi Region.
94 MEFT/NACSO. 2021. The state of community conservation in Namibia (Annual Report 2019). Ministry of Environment, Forestry and Tourism, Windhoek, and the Namibian Association of CBNRM Support Organisations, Windhoek.
95 MLR. 2015. Integrated Regional Land Use Plan for the Zambezi Region. Ministry of Land Reform, Windhoek.

frontier conservation area known as KAZA, the Kavango-Zambezi TFCA. Encompassing 520,000 km², this is the largest trans-frontier conservation area in the world, formed through the signing of the KAZA Treaty on August 18, 2011, by the five signatory countries - Angola, Botswana, Namibia, Zambia, and Zimbabwe – in recognition of the remarkable biodiversity assets contained within the landscape. The KAZA TFCA embraces three river basins, some of Africa's least developed wild spaces, a mosaic of more than 20 national parks, the world's largest Ramsar Site (the Okavango Delta), and a wealth of wildlife. A key objective of KAZA is to join fragmented wildlife habitats into an interconnected mosaic of protected areas and transboundary wildlife corridors, which facilitates movement of animals across international boundaries.

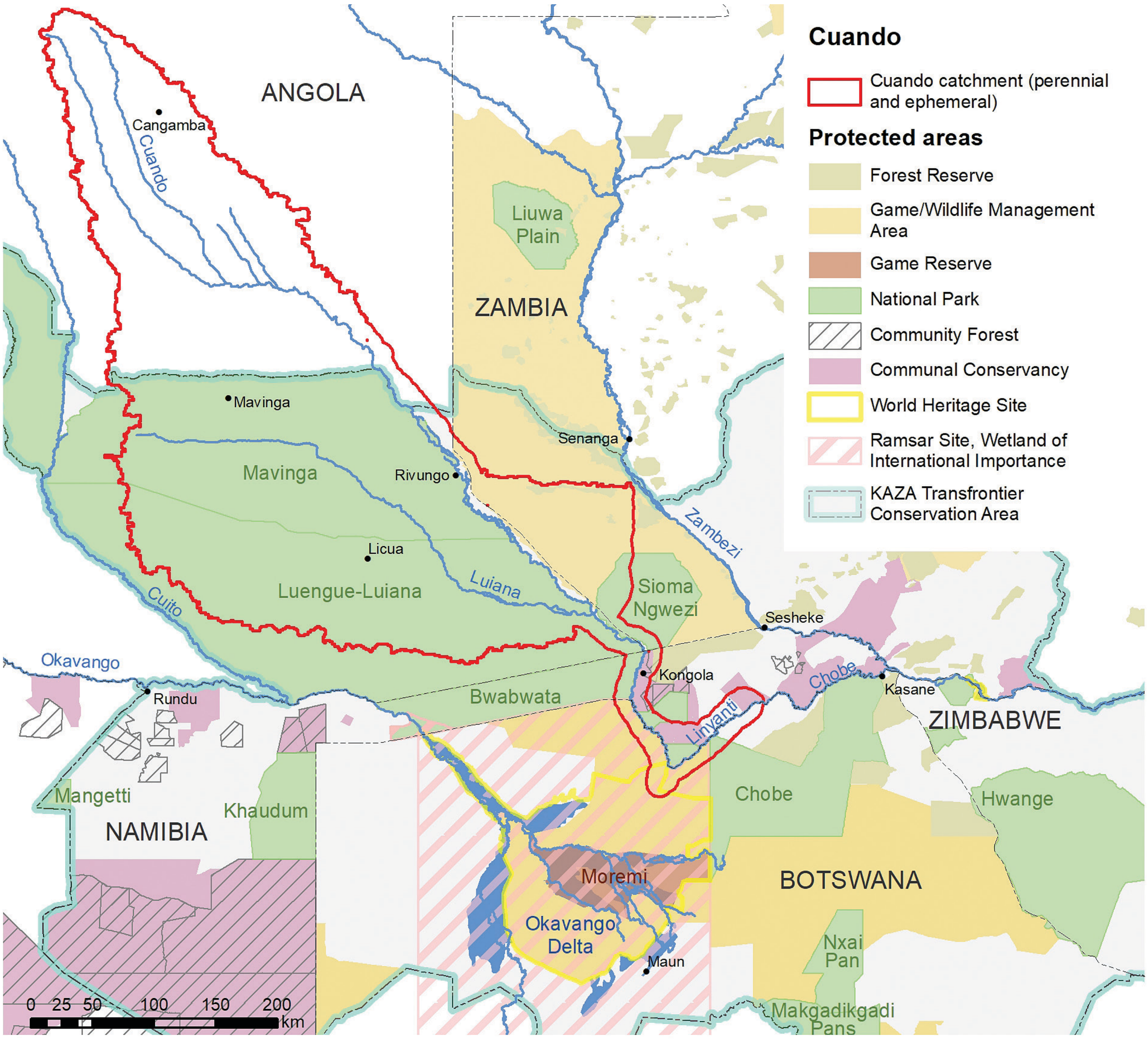


Figure 68: Conservation areas in and surrounding the Cuando River Basin.

Land use plans and careful zonation plans within the conservancies can help to minimize the conflicts between settlements and wildlife. For instance, the Mashi Conservancy has established specific zones where hunting is permitted, where corridors can allow wildlife movements, where tourism activities and collection of veld foods can occur, and where livestock grazing and watering can proceed. Location of water points is particularly important; certain water points are dedicated entirely to wildlife and they are purposely situated away from settlements, to minimize the potential for conflict. Conservancy game guards are trained in maintenance of water facilities so that these systems are kept functional, to further avoid problems that would arise in situations where wild animals wandered into settled areas due to lack of water at the dedicated points.

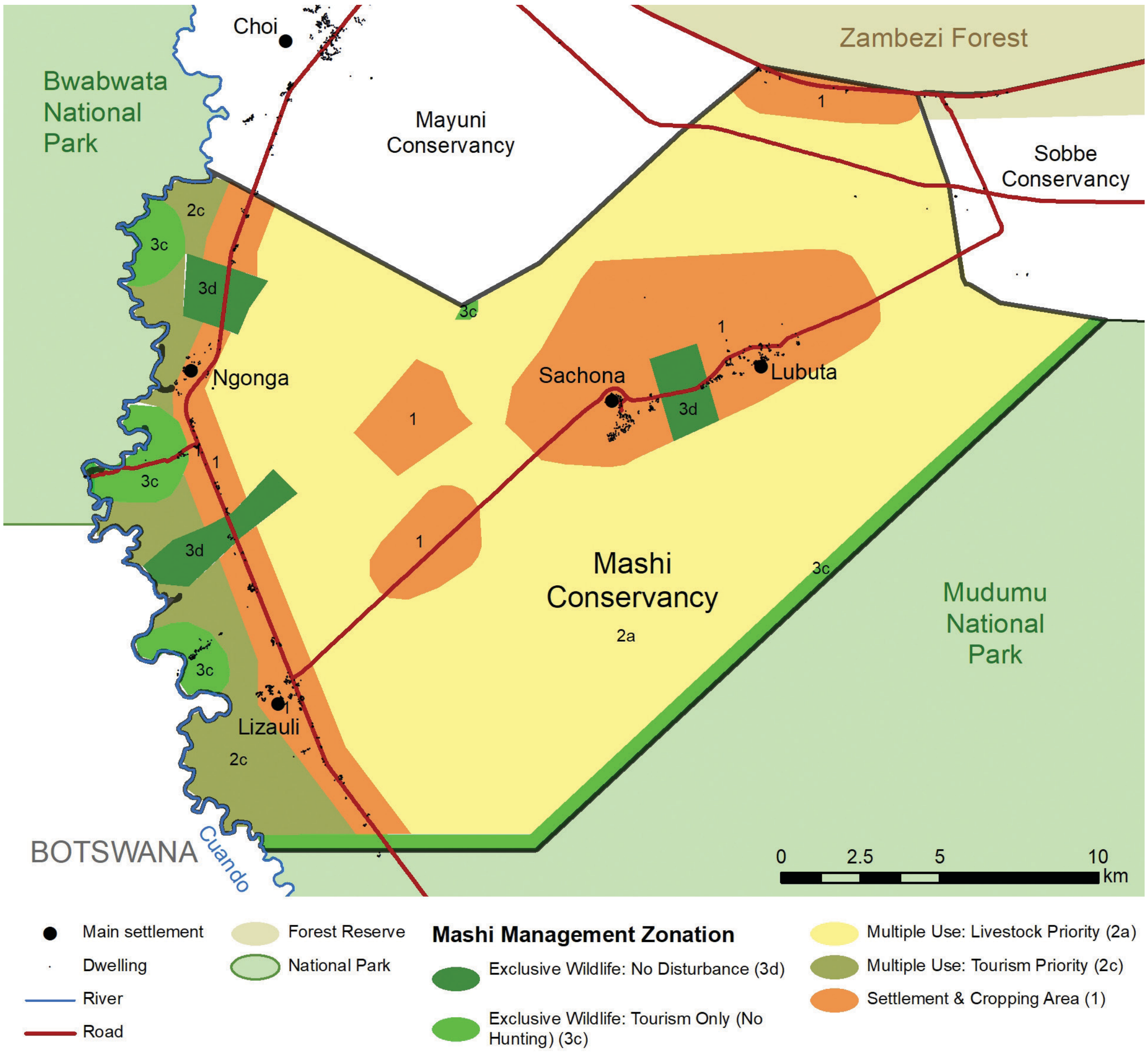


Figure 69: Zonation plan of the Mashi Conservancy alongside the Cuando River[96].

Further to the conservancies concept, 'landscape level' conservation is being promoted in Namibia. This aims for collaborative management between the conservancies, community forests and protected areas, all of whom have the main objective to use the wildlife and natural resources as an economic driver in the overall area[97].

96 Mashi Conservancy. 2013. Wildlife Management and Utilization Plan for Mashi Conservancy. Unpublished report.
97 No footnote in Word doc

The Mudumu-Mamili Landscape Conservation Area is an example. This is a cluster of communal area conservancies, community forests and state-run protected areas in Zambezi Region that cooperate in the management of wildlife, forests and other natural resources. The Complex brings together park officials, other government departments such as Forestry, local communities, traditional leaders and non-governmental organisations. Joint management activities include an early burning regime that is applied in conservancies and parks around the same time of the year, joint game counts between conservancy game guards and MET rangers, and joint anti-poaching patrols between the game guards and rangers. In the Kwandu, Mayuni and Mashi conservancies, wildlife corridors have been established to enable wildlife in the hinterland to have access to water at the Cuando River. People have agreed to move away from the floodplains so these can be left as secure habitats for wildlife. Resource harvesting is allowed in the corridors, but no cropping or human settlement. Conservation agriculture practices are applied so that the need for shifting agriculture is reduced, and conservancies are beginning to adopt holistic range management techniques. These co-management activities have enabled the Ministry of Environment, Forestry and Tourism to re-introduce game into the conservancies in the complex.

4.3.8 Urban expansion

The expanding population and the preference for people to settle along roads is leading to wildlife corridors across the main roads being blocked. Town and regional planning recommendations in Zambezi Region to cluster settlements have not been effective, even though they would reduce the high costs of providing water and services to the dispersed settlements along the roads.

5. Past developments and future prospects

5.1 Subsistence agriculture

Crop production in the Cuando Basin is not easy, and for this reason south-eastern Angola has always been thinly populated. The poor soils support natural woodlands but when these are cleared for crops they are deprived of their main source of nutrients – leaf litter – and quickly become exhausted. Normally such fields are only cultivated for a few years; they are then abandoned and a new patch is cleared. Thus the clearing of new fields is a continuous process, leaving more and more of the region denuded of woodland and forest. Surpluses are usually stored to survive possible future shortages, rather than being sold, and also because transport and marketing opportunities are mostly absent. Social grants are available to people in Namibia, but not in Angola.

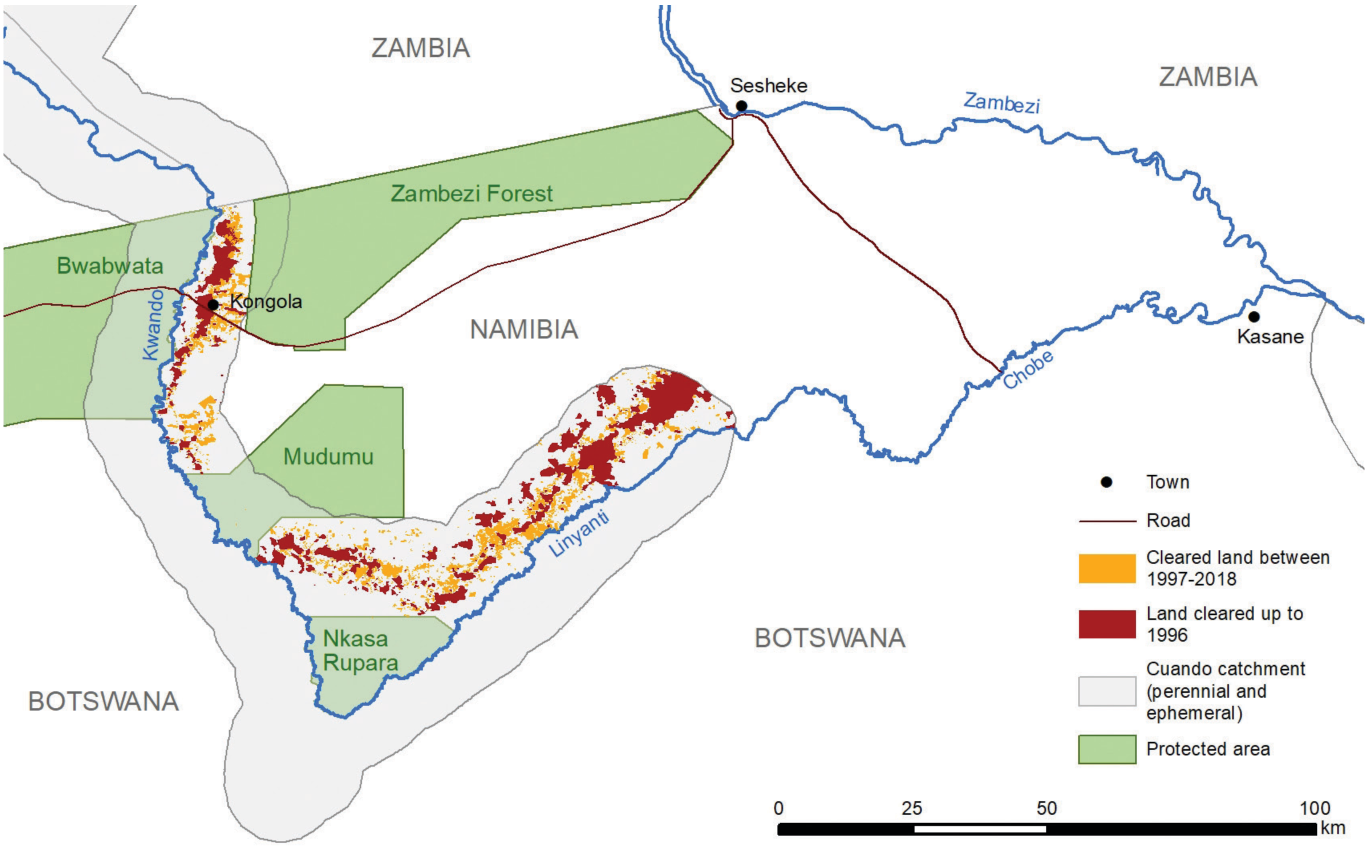


Figure 70: Land clearing in the Namibian part of the Cuando River Basin.

5.2 Commercial agriculture projects

5.2.1 Caprivi Sugar and Lake Liambezi fisheries

During those times when Lake Liambezi is dry, people traditionally use the grassland for livestock grazing, and the fertile clay-loam soil for crops. The agricultural potential was the focus of the Caprivi Sugar Project[98], started in 1991, with plans to use Zambezi River water to irrigate a 10,000 ha area on the north and north-western edge of Lake Liambezi[99]. Water was to be transported to the site via a canal running from Katima Mulilo or the Kalimbeza area. A sugar factory and refinery was included in the proposal. Construction even commenced, with the introduction of a low wall 4 km long and 1.5 m high, to protect the plantation area from flooding. While this might have kept water out for a short period, it was obviously going to be ineffective against the rise of the overall water level, and construction was abandoned.

The project was subsequently expanded when Namibia's fisheries ministry proposed a plan to recharge Lake Liambezi to help the artisanal fishery. This would be done by excavating the Bukalo Channel to a depth that would allow more frequent access of water from the Zambezi River down the channel. This project was combined with the agricultural one to establish if they would complement or conflict with each other, depending on the extent and depth of the floodwaters. To resolve this, a detailed topographic study was included to model the alterations to the Bukalo Channel that would achieve the intended flooding, and to determine the likelihood that such flooding would drown the intended fields on the north-western side.

The Environmental Assessment of this project, and the subsequent broader Strategic Environmental Assessment, included close examination of the engineering and economic feasibility (MAWRD 2002). These studies concluded that a sugar mill would only be marginally viable, and that the potential was considerably less than originally envisaged. The low viability of sugar prompted the assessment to advise that a mixed crop regime should be developed, to reduce the dependence on a single crop and market, and to suit the cultural profile of the area. The scheme was subsequently abandoned.

5.3 Cuando water uses and demand

The first and most important point about the Cuando is it is probably one of the most pristine of all rivers on Earth today. Much of the upper and central parts of the basin are inaccessible to vehicles due to the extensive floodplains and lack of roads or bridges. The NGOWP expeditions down the Kembo and Cuando Rivers encountered far fewer people and recorded negligible human impacts and human-based threats in comparison to their trips down the Okavango, which itself is a relatively unspoiled river. There are only six significant towns on the Cuando River: Cangamba and Rivungo in Angola, Shangombo on the Zambian side opposite Rivungo, and Kongola, Linyanti and Chinchimane in Namibia.

Availability of water is very often the main constraint to settlement and development. Settlements close to the main rivers rely on river water, and the almost

98 (i) Ministry of Agriculture, Water and Rural Development. 1998. Final Feasibility Study, Caprivi Sugar Sector Project, Namibia. Compiled by FC Schaffer & Associates, IncUnpublished report, Ministry of Agriculture, Water and Land Reform, Windhoek. (ii) Ministry of Agriculture, Water and Rural Development. 2002. Environmental Assessment Study for the Caprivi Sugar Sector Project, Namibia. Compiled by AfriDev Associates (Pty) Ltd, South Africa, and SIAPAC Namibia.
99 MAWRD 1998, 2003

non-existent provision of piped water in the towns in Angola means that most residents use the rivers for their domestic consumption and use, including laundry, washing and sanitation. The significance of this impact is not clear, but there must be some pollution downstream of the towns of Cangamba, Mavinga, Rivungo and Shangombo.

Further away from the rivers, people in rural areas depend heavily on groundwater resources. However, as noted in Section 2.3, groundwater in the Cuando part of Zambezi Region is frequently brackish and inadequate in quantity. The varying water quality and unreliable yields have resulted in some of these borehole schemes being replaced with piped water supplies drawn from the Zambezi River. Surface pipelines are visible along the roads connecting Katima Mulilo with Kongola and Ngoma.

The poor groundwater status prompted a search for stronger-yielding aquifers in Zambezi Region, using electromagnetic surveys carried out by helicopter and ground surveys in 2004-05[100]. Indeed, it is now known that there is a second aquifer lying deeper than 100 m in the southern and western parts of the region, which is separated from the brackish shallower water by a thick clayey layer. This aquifer has a much higher potential for exploitation and provides good quality freshwater, making it an additional source for rural and semi-urban water supply in this part of the Cuando Basin.

Groundwater exploration has been generally poor across the entire Cuando Basin.

5.4 Climate change predictions for the Cuando Basin

Nowhere in the world are predictions of the future climate very accurate, and southern Africa is no different[101]. This does not detract from the fact that the climate is definitely changing, and that it is caused by human activities[102]. Climate change predictions have been made for the KAZA Trans-frontier Conservation Area[103]. Total annual precipitation is projected to decline by 4.6% by 2050, relative to historical (1960 – 1990) precipitation, averaged over the whole TFCA. The prediction is worse for the north-western parts of the total area, with Angola and parts of Zambia and Namibia expected to get substantially drier. The average annual temperature over the whole of KAZA is expected to increase by 3°C, and again the western parts of the area (Angola and parts of Zambia and Namibia) are expected to warm more than the other parts of the TFCA.

Climate change impacts on vegetation

Some predictions have been made on what the future climate will do to the vegetation of south-eastern Angola and the KAZA TFCA. Some thickening of

100 DWA. 2005. Investigation of Groundwater Resources and Airborne-Geophysical Investigation of Selected Mineral Targets in Namibia Volume IV.GW.2.1. Groundwater Investigations in the Eastern Caprivi Region. Main Hydrogeological Report. Department of Water Affairs, Ministry of Agriculture, Water and Forestry, Windhoek.

101 Hughes DA, Kingston DG, Todd MC. 2011. Uncertainty in water resources availability in the Okavango River basin as a result of climate change. Hydrology and Earth Systems Sciences 15: 931–941. www.hydrol-earth-syst-sci.net/15/931/2011/ doi:10.5194/hess-15-931-2011

102 IPCC, 2014: *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

103 Sourced from Coldrey K, Turpie J. 2020. Climate Change Vulnerability and Adaptation Assessment for Protected Areas of the Kavango–Zambezi (KAZA) Landscape. Prepared for WWF Madagascar by Anchor Environmental Consultants, Cape Town. The figures are based on data from WorldClim Version2 and CMIP5. Baseline climate data for the study area was derived from Worldclim historical data, which provides average monthly climate data for mean and minimum temperature and for precipitation for the period 1960–1990 at a spatial resolution of about 1 km^2. Seven global climate models sourced from the Coupled Model Inter-comparison Project (CMIP5), and considered to be the best simulation of the climate in Africa (Conservation International, 2018), were used to project the climate for the period 2040-2060, under the representative concentration pathway (RCP) 8.5 scenario, at the same spatial resolution as the baseline data.

wooded areas can be expected as a result of increased CO_2 fertilisation and a change in the fire regime. Increasing temperatures will cause higher evapotranspiration rates, and coupled with lower rainfall and increasing frequency of droughts, is expected to lead to an increase in tree mortality, which might also increase fire frequency. All of these factors are likely to accelerate woodland degradation, which will probably manifest as bush thickening.

Climate change impacts on wildlife

Future changes in the distribution of various animal species are difficult to predict – some may even say impossible. This is because of the many factors that will affect each species over and above the shift in the climate envelope, which itself has great uncertainty. Additional factors such as habitat changes, barriers to range changes, changes in hydrology, and the inherent potential that each species possesses to cope with the changes, will all play a role in determining how species distributions may change in future. Nevertheless, species distribution models compiled by Conservation International serve as a 'first approximation' of species distributions fifty years from now, based purely on the climate niche models developed under three different climate scenarios. This has been done under a WWF Namibia project that assessed vulnerability of conservancies to climate change in Namibia and the KAZA TFCA.

For the KAZA TFCA the area of highest expected species richness currently is in the southern reaches of the area, specifically the Namibian, Botswanan and Zimbabwean sections. This is based on the distributions of 44 amphibian, 17 reptile, 307 bird and 140 mammal species. By the year 2070, these species' ranges and the diversity of species are predicted to decline across the whole area and for all the groups considered.

Climate change impacts on livelihoods

The Okavango system has enjoyed more study than the Cuando, including this statement in 2006[104]: "the combined effects of human abstraction and climate change, manifested in increased temperatures, decreased rainfall and reduction in river flows, may result in significant drying of the Okavango Delta." Recognizing the similar status of the two basins, this conclusion can perhaps also be applied to the lower Cuando.

The prospect of stronger and more frequent droughts that are predicted for southern Africa will impact on water resources, agricultural productivity and the potential for fires[105]. These are likely to exacerbate the practices of shifting cultivation and the already high frequency of bush fires. In Namibia's Zambezi Region, flood events are frequent and they impact on agricultural practices[106]. During periods of adverse weather, households are likely to rely more heavily on natural resources and may resort to illegal methods of attaining these resources.

104 Murray-Hudson M, Wolski P, Ringrose S. 2006. Scenarios of the impact of local and upstream changes in climate and water use on hydro-ecology in the Okavango Delta, Botswana. Journal of Hydrology 331: 73-84. https://doi.org/10.1016/j.jhydrol.2006.04.041

105 Carvalho SCP, Santos FD, Pulquério M (2017) Climate change scenarios for Angola: an analysis of precipitation and temperature projections using four RCMs. Int J Climatol 37:3398–3412.

106 (i) Mushabati, LF. 2014. Flood risk perceptions and coping strategies of residents in the Kabbe Constituency of the Zambezi Region (Namibia) (Doctoral dissertation). (ii) Tamayo, C. Hernández, F. Muñiz, A. Gil, A. 2011. Flood risk management plan for the Namibian Ministry of Regional and Local Government, Housing and Rural Development. iii) Barnes *et al* 2012.

5.5 Conservation as a priority land use

What is the fate of the Cuando River and the remote parts of the Basin in south-eastern Angola? Conservation as an economically profitable land use must be considered. The KAZA TFCA is already in place, and could be extended to include the massive Bulozi Plain which may be the largest ephemeral wetland system in Africa[107].

The establishment and expansion of KAZA does not mean that the entire area will or should become a giant game reserve for wildlife, or that local people should be considered as intruders in a wilderness where animals take first place. Rather, KAZA and the associated institutions which recognize conservation as the underlying land use, recognize the importance of wildlife as a profitable basis for the economy. Wherever possible, means are sought to reduce conflict between people and wildlife, and to enable people to make a living from wildlife and natural resources.

KAZA draws on a few important factors that are relevant to the economic situation of Angola, Namibia, Botswana and Zambia.

Firstly, an economy based on the wetlands and wildlife is a major economic opportunity for the various community conservation areas and National Parks. This is described as an opportunity, but in reality it is the only option available. Short of engineering the landscape in a way that would cause huge ecological and social disruption, it would be impossible to eradicate the wildlife and build an entire economy based on only livestock and crops. This justifies the argument that it is more sensible and indeed more profitable to find ways to tolerate and actually encourage wildlife in the places where they can do least harm to people as well as generating new economic benefits.

Revenue that is delivered to the local economy from wildlife mainly comes from trophy hunting and tourism[108]. In 2018, conservancies in the Zambezi Region generated over N$15 million in revenue from hunting (comprising 66% of their total income), whilst close to N$6 million was earned from joint venture tourism . Conservancies facilitated the creation of 758 jobs in the region during the same year. Income and job creation figures have steadily increased every year since gazetting of the first conservancy in the late 1990s. While trophy and 'shoot and sell' hunting generate high revenues, the 'own use' quota is also important, allowing the hunting of animals for meat which is often the only means of obtaining meat protein.

Conservancies are piloting others ways to diversify the natural economy. For instance, Payment for Ecosystem Services (PES) is being successfully tested as a means to generate revenue streams from wildlife. Under this principle, conservancies earn a levy that is paid by visitors for sightings of iconic species such as elephants and lions.

Secondly, a wildlife-based economy will be better able to buffer local people from the risks of climate change[109]. It is likely that traditional agricultural methods are going to become less productive in future as temperatures increase and floods and droughts become more extreme. Wildlife is more resistant to climate change, and will ultimately provide a useful complement to local livelihoods made more vulnerable in the future climate that is predicted.

A key recommendation from the vulnerability and adaptation assessment for Namibia's communal conservancies[110] is that the habitat provided by Na-

107 Beilfuss R. 2018. https://www.savingcranes.org, info@savingcranes.org
108 MET/NACSO. 2020. The state of community conservation in Namibia (Annual Report 2018). MET/NACSO, Windhoek.
109 Coldrey K, Turpie J. 2019. Climate change vulnerability and adaptation assessment for Namibia's communal conservancies - Final report. Prepared for WWF Namibia by Anchor Environmental Consultants, Cape Town.
110 Coldrey K, Turpie J. 2019. Climate change vulnerability and adaptation assessment for Namibia's communal conservancies - Final report. Prepared for WWF Namibia by Anchor Environmental Consultants, Cape Town.

mibia's northern perennial river systems should be secured as it is a critical resource for wildlife in the neighbouring conservancies.

Thirdly, a wildlife-based economy requires an intact natural environment, and this provides other services that are used and appreciated by local people. For instance, the wide floodplain and marshes of the middle and lower parts of the Cuando River contribute an invaluable service of purifying the water in the river itself. A parallel situation is observed in the upper part of the Cubango catchment, where the Okavango water gets quite murky from soil erosion and ash from bush fires. Further downstream the river is clear again, which is probably achieved by the dense phragmites reed beds lining the river channel.

There is also a case for preserving the wilderness value of the Cuando. Much of the Cuando is not broken, so why start to break it? Fewer and fewer wilderness areas remain in the world, and here is an opportunity to keep one wilderness. Few people live in the Basin, so few people would be disadvantaged.

Fire management

One important benefit of community-based management through the involvement of conservancies and community forests, is the opportunity to implement controlled burning with the cooperation of local residents. Ideally this should be done early in the dry season when weather conditions and fuel characteristics allow low-intensity fires that are controllable, with less likelihood of spreading into extensive wildfires. Additionally, maintenance of firebreaks, clearing around homesteads and important resources, and a reduced frequency of fires, all can help to reduce the negative consequences of uncontrolled wildfires[111].

5.6 Environmental degradation

As noted above, the Cuando is one of the most pristine river systems on Earth, and there is relatively little degradation of its resources. Having said that, some negative impacts of human activities are noticeable, and provide early warning signs of deterioration of the overall condition of the river and basin.

5.6.1 River pollution

The northern and central parts of the basin are sparsely populated, but concentrations of people are found in a few towns, notably Cangamba, Mavinga and Rivungo. A lack of systems for collecting domestic waste and sewage is evident in many Angolan coastal towns, and in most towns in Moxico Province the rivers are used for washing by local villagers; these features also characterise the towns in south-eastern Angola, and water pollution is evident downstream of the major towns[112]. Fortunately the floodplains have a cleansing effect and the quality of the water is restored downstream.

The villages of Kongola and Chinchimane and other small settlements in Zambezi Region in Namibia are situated away from the immediate vicinity of the Cuando floodplain, and households have access to communal taps for their domestic water needs, so there is less direct use of the river water by local people.

111 Beatty R. 2010. CBFiM in Namibia: the Caprivi Integrated Fire Management programme. Integrated Rural Development and Nature Conservation, Windhoek.

112 Information drawn from: i) Development Workshop 2016 Water resource management under changing climate in Angola's coastal settlements. Project Number: 107025–001. Final technical report to the International Development Research Centre (IDRC), Canada. ii) CETAC. 2017. *Estudo das Nascentes do Planalto Central*. Centro de Estudos Tropicais e Alterações Climáticas, Huambo. iii) Mendelsohn J, Martins A. 2018. River catchments and development prospects in south-eastern Angola. RAISON.

5.6.2 Fire

The high frequency of bush fires in south-eastern Angola and north-eastern Namibia has been noted above. This is responsible for much of the change from open woodland to bushy scrub in these areas. Fires are mostly caused by people, either to clear land for cultivation or to promote fresh growth of pastures, and these activities usually occur towards the end of the dry season, when fires are hotter and more damaging to trees than early dry season fires[113]. Large trees are killed when such fires occur in successive years, and they are replaced by low scrubby bush.

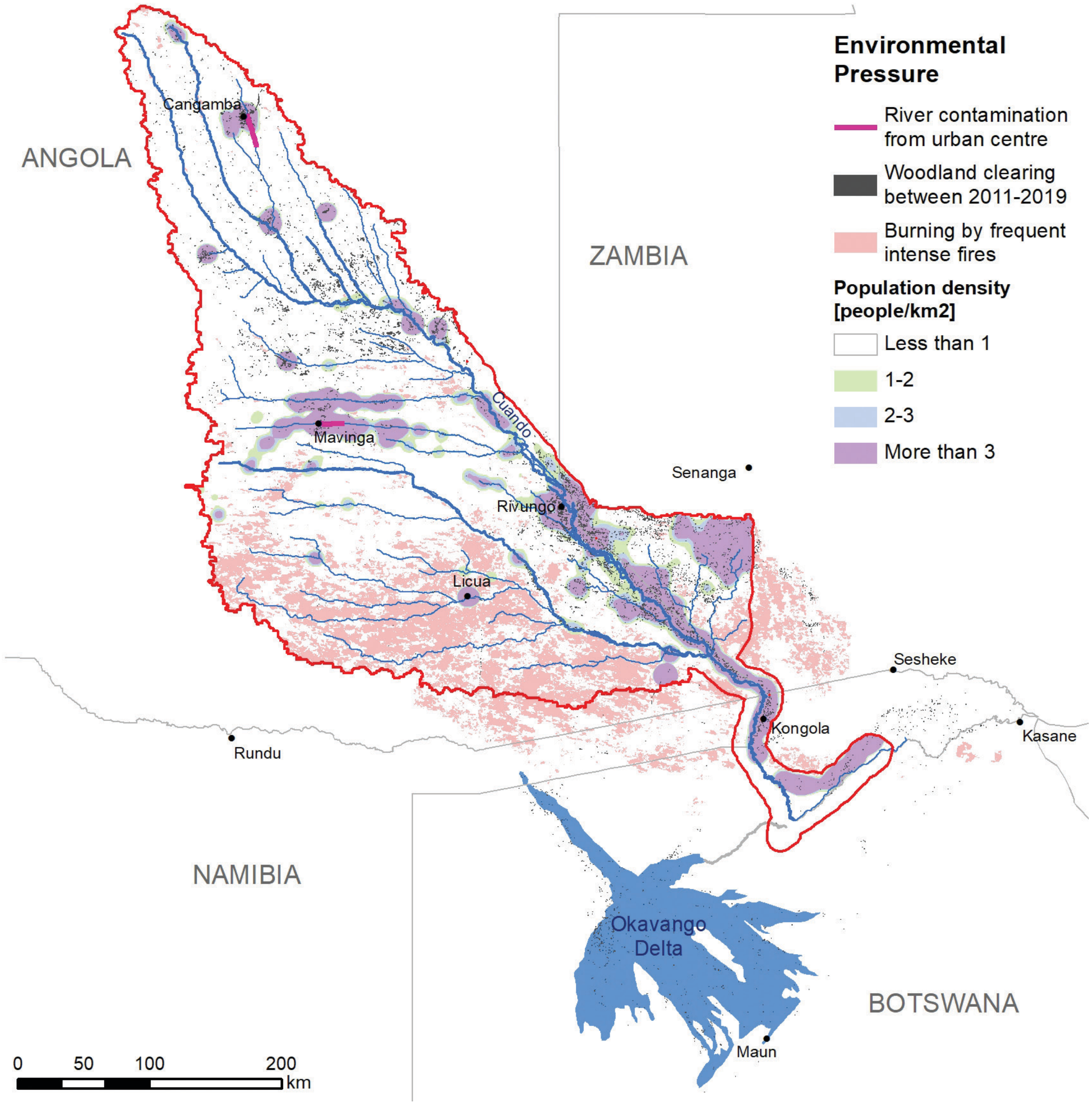


Figure 71: Environmental pressures in the Cuando River Basin.

113 Mendelsohn JM. 2019. Landscape changes in Angola. In: Huntley BJ, Russo V, Lages F, Ferrand N (eds) Biodiversity of Angola. Science & conservation: a modern synthesis. Springer Nature, Cham

6. Conclusions

The following are some of the important points about the Cuando River Basin.

- The Cuando River and its courses are normally self-contained or confined to several perennial sources, notably the Cuando, Kembo, Cubangui, Cueio, Cussivi and Lomba, and to its terminus in the Linyanti Swamps.
- Sporadically, the Cuando receives flows of water from ephemeral water courses such as the Cubia and Luiana and from the Okavango Delta via the Selinda Spillway.
- The Cuando sometimes overspills via the Savuti Channel into the Savuti Marshes of the Mababe Depression which is rarely connected to the Okavango Delta via the Khwai River.
- Water of the Linyanti rarely flows into Lake Liambezi. This ephemeral lake of water is usually fed by floodwaters of the Zambezi River pushing up the Chobe River or via the Bukalo Channel from overspill near Katima Mulilo.
- The river and its tributaries carry exceptionally clean water with few nutrients and very low biomass of aquatic animals.
- The river is valuable as a linear oasis, especially in compensating for the absence of nutrients and water elsewhere.
- The upper parts of the basin experience higher rainfall and more leaching of the soil than areas further south; the lower rainfall and higher rate of evaporation in the south result in more soil nutrients.
- Low nutrient and water-holding capacity lead to naturally low biomass of terrestrial fauna, few people, little land degradation, and near-pristine habitats.
- The frequency and intensity of fires, especially in the teak savannas, leads to significant losses of large trees and thickening of scrubby growth in its place.
- There are very low levels of environmental degradation, especially in Angola where relatively few areas of woodland and forest have been cleared, the river is not used for irrigation to any substantial extent anywhere, and there are probably very few contaminants in the water.

From food security to income security

It is clear that rural societies are moving from subsistence livelihoods based on food in depauperate areas to cash-based livelihoods in places where incomes are available. People everywhere seek ways to improve their lives. This is done through making incomes and living in places where there are opportunities to earn money. This drive is especially acute in areas that have poor environmental productivity and thus little to sell. This is the situation in many parts of the Cuando Basin, and this is why urban centres are growing so rapidly, often doubling in size every 10 or so years[114].

Urban migration and transitions from food to income economies are to be encouraged so that people may access a better quality of life, especially in areas with little potential. Such shifts are the logical, and most efficient way to decrease poverty, create decent livelihoods, and potentially minimise environmental degradation. Encouraging urban migration can also stem the prevailing expansive processes of deforestation, bush-meat hunting, over-fishing, soil nutrient loss and expansion of areas damaged by bush fires, for example.

Soil qualities are the fundamental cornerstones governing almost all aspects of the Cuando's life,

114 Despite arguments to the contrary, large agricultural schemes create relatively few jobs for local people. The driving focus of these schemes is operational mechanization which requires expertise of a kind that is unlikely to be found in many parts of the Basin.

hydrology, economy and potentials. Notably, the great majority of soils place severe limits on plant and animal production and are very poorly suited to agriculture. Most rural areas are so unproductive that they can do little more than sustain poverty and ongoing deforestation if they continue being used for subsistence purposes.

Drawing on these points, development and practice in the Cuando Basin might best be led by goals:

- That promote wellbeing from incomes that enable residents to be both food and cash secure.
- That discourage the perpetuation of livelihoods that remain mired in poverty while degrading the environment for short-term subsistence.
- That recognise the principles of ecosystem service provisioning with respect to water flows in opposing gradients, with greater provisioning upstream and greater utilisation downstream. This should be balanced by a return flow of value to increase upstream incentives.
- That recognise as wilderness the large areas not suited to human occupation.

Concentrating development around urban centres and other areas of economic activity

The development of urban centres should be encouraged and facilitated in ways that attract rural people to benefit from improved commercial and social services. The siting and development of these centres should be guided by the following considerations:

- Having close access to major trade routes, by rail or road.
- Being close to areas that can support reasonable yields and production, especially for the production of crops that would be sold directly and rapidly to residents in these centres. The immediate returns from such sales provide incentives that allow farmers to adopt high-input – high-output production strategies. Unimpeded market access will therefore be as valuable as the production potential of the soil.
- Being able to provide key services, such a health care, education, telecommunication, administration, banking and other commercial facilities.
- Ensuring that both the formal and informal economy functions efficiently. The latter is especially important in providing incomes to poorer, uneducated people who would not find formal employment or be able to create formal enterprises.
- The provision of secure, tradable tenure to provide residents with property they can develop to provide investments and economic benefits in the short and long term.
- The need to protect important local environmental resources, especially those that might add further value to the centres.

Appendix A

Organisations with an established presence and activities in the Cuando River Basin.

Name	Main focus of activities	Country	
Elephants Without Borders	Elephant conservation and moveme nts	Angola, Zambia, Namibia, Botswana and others	
The HALO Trust MGM	De-mining	Angola	
Instituto Nacional de Biodiversidade e Áreas de Conservação (INBAC)		Angola	
Associação de Conserva-ção do Ambiente e Desen-volvimento Integrado Rural Angola (ACADIR)		Angola	
IRDNC		Namibia	
KAZA		Angola, Botswana, Namibia, Zambia and others	
Kwando Carnivore Project		Namibia	
Namibia Nature Foundation	Fisheries, agriculture	Namibia	
National Geographic	Okavango – Zambezi Water Tower Project	Angola	
Panthera			
Peace Parks Foundation		Zambia	
Southern African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL	Open Data and Informa-tion on Climate Change and Adapted Land Management in Southern Africa	SADC countries	
WWF Namibia WWF Zambia		Namibia Zambia	

The Halo Trust
https://www.halotrust.org/where-we-work/africa/angola/
In 2021, the Halo Trust will begin a project in partnership with the Angolan government to clear landmines in the Okavango headwaters—a World Heritage Site, which forms part of the five-country Kavango-Zambezi Trans Frontier Conservation Area (KAZA). Here, landmines make it almost impossible to conserve and protect the habitat and wildlife poaching is rife. Clearing the mines will lay the foundations for conservation-led development, allowing wildlife and local people to thrive.

ISCED
In October 2012, CIBIO (Research Centre in Biodiversity and Genetic Resources) at the University of Porto, Portugal, and ISCED-Huíla (Lubango) established a collaborative research, capacity building and advanced training project – the ISCED/CIBIO TwinLab initiative

Kwando Carnivore Project
https://www.facebook.com/KwandoCarnivoreProject/
The Kwando Carnivore Project is based in the Zambezi Region of Namibia. The overall aim of the KCP is the conservation of large carnivores through applied research and human wildlife conflict mitigation.

Panthera
https://www.panthera.org/
Panthera is devoted exclusively to the conservation of the world's 40 wild cat species and their ecosystems. The mission of Panthera is to ensure a future for wild cats and the vast landscapes on which they depend.

Appendix B

Plant list for the Cuando River Basin

Plant Family	Genus species	Habitat (if recorded)
Acanthaceae	*Asystasia gangetica* subsp. *micrantha*	
	Barleria mackenii	
	Blepharis serrulata	
	Blepharis tenuiramea	
	Crabbea nana	
	Dicliptera betonicoides	
	Duosperma crenatum	Grassland
	Justicia anselliana	
	Justicia betonica	
	Justicia bracteata	
	Justicia divaricata	
	Justicia monechmoides	
	Lepidagathis macrochila	Woodland
	Monechma debile	
	Thunbergia aurea	
	Thunbergia gossweileri	Woodland
Aizoaceae	*Zaleya pentandra*	
Alismataceae	*Limnophyton angolense*	Wetland
	Limnophyton obtusifolium	
Amaranthaceae	*Achyranthes sp.*	
	Aerva leucra	
	Hermbstaedtia scabra	
	Mechowia grandiflora	Grassland
Amaryllidaceae	*Crinum sp.*	
	Nerine laticoma	
	Tulbergia leucantha	
	Scadoxus multiflorus subsp. *multiflorus*	
Anacardiaceae	*Lannea edulis*	
	Lannea gossweileri subsp. *gossweileri*	
	Lannea schweinfurthii var. stuhlmannii	
	Lannea schweinfurthii var. tomentosa	
	Ozoroa longipes	
	Ozoroa stenophylla	Grassland
	Rhus tenuinervis var. meikleana	
	Rhus quartiana	
Anisophylleaceae	*Anisophyllea fruticulosa*	Grassland
Anthericaceae	*Chlorophytum galpinii var. matabelense*	
	Chlorophytum stoltzii	
Annonaceae	*Annona stenophylla* subsp. *nana*	Grassland
	Friesodielsia obovata	
Apiaceae	*Afrocarum imbricatum*	Wetland
	Centella asiatica	
	Hydrocotyle verticillata	

Plant Family	Genus species	Habitat (if recorded)
Apocynaceae	*Ceropegia lugardiae*	
	Ceropegia nilotica	
	Chamaeclitandra henriquesiana	Grassland
	Cynanchum gerrardii	
	Diplorhynchus condylocarpon	Woodland; Grassland
	Gomphocarpus fruticosus	Wetland
	Landolphia lanceolata	Grassland
	Orthanthera jasminiflora	
	Raphionacme globosa	Grassland
	Raphionacme linearis	Wetland
	Raphionacme velutina	
	Strophanthus welwitschii	Woodland
	Tacazzea apiculata	Wetland
	Xysmalobium holubii	Wetland
Arecaceae	*Phoenix reclinata*	
Asparagaceae	*Asparagus buchananii*	
	Asparagus cooperi	
	Asparagus laricinus	
	Asparagus nelsii	
	Dracaena mannii	Woodland
Asphodelaceae	*Bulbine capitata*	
Asteraceae	*Ageratum conyzoides*	
	Biden biternata	
	Bidens pilosa	
	Crassocephalum crepidioides	
	Dicoma anomala	
	Dicoma plantaginifolia	Grassland
	Distephanus divaricatus	
	Emilia baumii	Grassland
	Felicia welwitschii	
	Geigeria burkei var. zeyheri	
	Gnaphalium filagopsis	
	Grangea anthemoides	
	Gymnanthemum amygdalinum	
	Helichrysum nudifolium	
	Laggera decurrens	
	Linzia glabra	
	Melanthera marlothiana	
	Nicolasia stenoptera subsp. *stenoptera*	
	Nidorella resedifolia subsp. *frutescens*	
	Parapolydora fastigiata	
	Passacardoa baumii	Grassland
	Pechuel-loeschea leubnitziae	
	Pleiotaxis ambigua	Grassland
	Pseudognaphalium luteoalbum	Grassland
	Senecio strictifolius	Wetland
	Sphaeranthus flexuosus	
	Vernonia bullulata	Grassland
	Vernonia longipedunculata var. manikensis	Woodland
	Vernonia ornata	Wetland

Plant Family	Genus species	Habitat (if recorded)
Asteraceae	*Vernonia perrottetii*	
	Vernonia potamophila	
Bignoniaceae	*Markhamia obtusifolia*	
	Markhamia zanzibarica	
Boraginaceae	*Heliotropium baclei*	
	Heliotropium ovalifolium	Woodland
Burmanniaceae	*Burmannia madagascariensis*	Wetland
Burseraceae	*Commiphora africana*	
	Commiphora angolensis	
Campanulaceae	*Wahlenbergia banksiana*	Grassland
	Wahlenbergia napiformis	
	Wahlenbergia undulata	Grassland
Capparaceae	*Boscia albitrunca*	
	Capparis tomentosa	
Caryophyllaceae	*Dianthus zeyheri*	
	Pollichia campestris	
	Polycarpaea corymbosa	
Celastraceae	*Cassine aethiopica*	
	Gymnosporia senegalensis	
	Gymnosporia senegalensis – suffrutescent form	Wetland
	Mystroxylon aethiopicum	
	Salacia luebbertii	
Chrysobalanaceae	*Parinari capensis*	Grassland
	Parinari curatellifolia	Woodland
Colchicaceae	*Camptorrhiza strumosa*	
	Gloriosa sessiliflora	Wetland
	Gloriosa superba	
Combretaceae	*Combretum celastroides*	
	Combretum collinum subsp. *gazense*	
	Combretum elaeagnoides	
	Combretum hereroense	
	Combretum imberbe	
	Combretum psidioides subsp. *Dinteri*	
	Terminalia brachystemma	Woodland
	Terminalia prunioides	
	Terminalia sericea	Woodland
Commelinaceae	*Commelina africana*	
	Commelina benghalensis	
	Commelina diffusa	
	Commelina subulata	
	Commelina zambesica	
	Floscopa flavida	
Connaraceae	*Rourea orientalis*	
Convolvulaceae	*Evolvulus alsinoides*	
	Ipomoea dichroa	
	Ipomoea welwitschii	Grassland
	Jacquemontia tamniflora	

Plant Family	Genus species	Habitat (if recorded)
Convolvulaceae	*Merremia pinnata*	
	Seddera suffruticosa	
	Xenostegia tridentata	
Crassulaceae	*Kalanchoe lanceolata*	
Cucurbitaceae	*Acanthosicyos naudinianus*	
	Citrullus lanatus	
	Kedrostis foetidissima	
	Momordica balsamina	
	Trochomeria macrocarpa subsp. *macrocarpa*	
	Trochomeria polymorpha	Grassland
	Trochomeria subglabrata	Grassland
	Zehneria marlothii	
Cyperaceae	*Bulbostylis burchellii*	
	Bulbostylis hispidula subsp. *pyriformis*	
	Bulbostylis sphaerocarpa	
	Cladium mariscus subsp. *jamaicense*	
	Cyperus articulatus	Wetland
	Cyperus deciduus	Wetland
	Cyperus denudatus	Wetland
	Cyperus dives	
	Cyperus esculentus	
	Cyperus haspan	Wetland
	Cyperus imbricatus	
	Genus species	
	Cyperus margaritaceus	Grassland
	Cyperus mwinilungensis	Wetland
	Cyperus papyrus	Wetland
	Cyperus pectinatus	
	Cyperus proteus	Wetland
	Cyperus rotundus	
	Cyperus schinzii	
	Cyperus sphaerospermus	Wetland
	Cyperus squarrosus	
	Cyperus tenax	
	Eleocharis brainii	
	Eleocharis cubangensis	
	Eleocharis dulcis	
	Eleocharis geniculata	Wetland
	Eleocharis limosa	Wetland
	Eleocharis variegata	Wetland
	Fimbristylis complanata	Wetland
	Fimbristylis dichotoma	
	Fuirena ciliaris	
	Fuirena obcordata	Wetland
	Fuirena pubescens	
	Fuirena umbellata	Wetland
	Kyllinga alba	
	Pycreus unioloides	Wetland
	Rhynchospora corymbosa var. corymbosa	Wetland
	Rhynchospora holoschoenoides	Wetland
	Schoenoplectiella erecta	

Plant Family	Genus species	Habitat (if recorded)
Cyperaceae	*Schoenoplectus corymbosus*	Wetland
	Scleria erythrorrhiza	Wetland
	Scleria veseyfitzgeraldii	Wetland
Dioscoreaceae	*Dioscorea asteriscus*	
Dipterocarpaceae	*Monotes africanus*	Woodland
	Monotes dasyanthus	Woodland
Droseraceae	*Drosera flexicaulis*	Wetland
	Drosera indica	
Ebenaceae	*Diospyros batocana*	Woodland
	Diospyros chamaethamnus	
	Diospyros lycioides	
	Euclea crispa	Woodland
	Euclea divinorum	
Equisetaceae	*Equisetaceae ramosissimum*	
Eriocaulaceae	*Eriocaulon lanatum*	Wetland
	Eriocaulon teucszii	Wetland
	Eriocaulon welwitschii	
	Mesanthemum glabrum	Wetland
	Syngonanthus wahlbergii	Wetland
Eriospermaceae	*Eriospermum bakerianum*	Grassland
Euphorbiaceae	*Acalypha villicaulis*	
	Clutia benguellensis	Grassland
	Croton gratissimus var. gratissimus	
	Croton gratissimus var. subgratissimus	
	Croton megalobotrys	
	Erythrococca menyharthii	
	Euphorbia benthamii	
	Euphorbia matabelensis	
	Euphorbia monteiroi	
	Euphorbia neopolycnemoides	
	Euphorbia transvaalensis	
	Maprounea africana	Woodland; grassland
	Phyllanthus reticulatus	
	Pseudolachnostylis maprouneifolia	
	Tragia okanyua	
	Uapaca nitida	Grassland
Fabaceae	*Abrus precatorius* subsp. *africanus*	
	Acacia erioloba	
	Acacia erubescens	
	Acacia galpinii	
	Acacia hebeclada subsp. *hebeclada*	
	Acacia luederitzii	
	Acacia nigrescens	
	Aeschynomene indica	
	Albizia versicolor	
	Alusicarpus zeyheri	
	Amblygonocarpus andongensis	
	Baikiaea plurijuga	Woodland
	Baphia massaiensis subsp. *obovata*	Woodland

Plant Family	Genus species	Habitat (if recorded)
Fabaceae	*Merremia pinnata*	
	Seddera suffruticosa	
	Xenostegia tridentata	
Flacourtiaceae	*Oncoba spinosa*	
Gentianaceae	*Enicostema axillare*	
	Exacum oldenlandiodes	
	Exochaenium teucszii	Wetland
	Faroa minutiflora	
	Faroa salutaris	Wetland
	Neurotheca loeselioides	Wetland
	Sebaea baumiana	Wetland
Gisekiaceae	*Gisekia africana*	
Haloragaceae	*Laurembergia repens* subsp. *Brachypoda*	
	Myriophyllum spicatum	
Hyacinthaceae	*Albuca sp.*	
	Dipcadi glaucum	
	Drimia altissima	
Hydrocharitaceae	*Lagarosiphon muscoides*	
	Ottelia muricata	
	Ottelia ulvifolia	
Hypericaceae	*Psorospermum baumii*	Woodland
Iridaceae	*Gladiolus dalenii*	
	Lapeirousia schimperi	
Ixonanthaceae	*Ochthocosmos lemaireanus*	Grassland
Lamiaceae	*Acrotome angustifolia*	Woodland
	Clerodendrum buchneri	Grassland
	Coleus buchananii	
	Hoslundia opposita	
	Kalaharia uncinata	
	Plectranthus betonicifolius	
	Plectranthus mirabilis	
	Pycnostachys stuhlmannii	
	Rotheca myricoides	
	Vitex angolensis	
	Vitex madiensis subsp. *milanjiensis*	Grassland
Lauraceae	*Cassytha pondoensis var. pondoensis*	Grassland
Lentibulariaceae	*Utricularia firmula*	Wetland
	Utricularia inflexa	
Lycopodiaceae	*Lycopodiella affinis*	Wetland
Lythraceae	*Ammannia sp.*	Wetland
	Nesaea cordata	
	Nesaea crassicaulis	
	Nesaea rigidula	
Malvaceae	*Grewia flavescens*	
	Grewia schinzii	
	Grewia retinervis	

Plant Family	Genus species	Habitat (if recorded)
Malvaceae	*Hermannia eenii*	
	Hibiscus calyphyllus	
	Hibiscus cannabinus	
	Melhania forbesii	
	Pavonia clathrata	
	Pavonia senegalensis	
	Sida ovata	
	Triumfetta dekindtiana	
	Triumfetta sonderi	
Marsileaceae	*Marsilea nubica*	
Melastomataceae	*Antherotoma debilis*	Wetland
	Antherotoma gracilis	Grassland; Wetland
Meliaceae	*Trichilia emetica*	
	Turraea zambesica	
Menispermaceae	*Cissampelos mucronata*	Wetland
	Cocculus hirsutus	
	Tinospora caffra	
Menyanthaceae	*Nymphoides indica subsp. occidentalis*	Wetland
	Nymphoides rautanenii	Wetland
Molluginaceae	*Glinus lotoides*	
	Limeum fenestratum	
Moraceae	*Ficus fischeri*	
	Ficus pygmaea	Wetland
	Ficus sycomorus subsp. *gnaphalocarpa*	
	Ficus verruculosa	Wetland
Myricaceae	*Morella serrata*	
Myrtaceae	*Eugenia malangensis*	Grassland
	Syzygium cordatum var. cordatum	Wetland
	Syzygium guineense subsp. *guineense*	Woodland
	Syzygium guineense subsp. *huillense*	Wetland
	Syzygium owariense	Woodland
Najadaceae	*Najas horrida*	
Nymphaeaceae	*Nymphaea nouchali var. caerulea*	Wetland
	Nymphaea petersiana	
	Nymphaea sulphurea	Wetland
Ochnaceae	*Ochna cinnabarina*	
	Ochna pulchra	Woodland
	Ochna pygmaea	Grassland
	Sauvagesia africana	Wetland
Olacaceae	*Ximenia caffra*	Woodland
Oleaceae	*Jasminum streptopus*	Grassland
Onagraceae	*Ludwigia adscendens*	Wetland
	Ludwigia octovalvis	Wetland
Orchidaceae	*Disa caffra*	Wetland
	Disa hircicornis	Wetland
	Disa welwitschii	Wetland

Plant Family	Genus species	Habitat (if recorded)
Orchidaceae	*Eulophia calantha*	Wetland
	Eulophia cucullata	Woodland
	Eulophia malangana	Wetland
	Eulophia penduliflora	Wetland
	Eulophia speciosa	Wetland
	Eulophia walleri	
	Habenaria zambesina	Wetland
	Orthochilus trilamellatus	Wetland
	Platycoryne buchananiana	Wetland
	Platycoryne micrantha	Wetland
	Satyrium buchananii	Wetland
	Satyrium riparium	Wetland
	Satyrium trinerve	Wetland
Orobanchaceae	*Alectra orobanchoides*	
	Alectra rigida	
	Alectra vogelii	Wetland
	Buchnera henriquesii	
	Buchnera hispida	
	Cycnium tubulosum	Wetland
	Gerardiina angolensis	Wetland
	Melasma calycinum	Wetland
	Micrargeriella aphylla	Wetland
	Striga angolensis	Wetland
	Striga bilabiat	Wetland
Osmundaceae	*Osmunda regalis*	Wetland
Parkeriaceae	*Ceratopteris thalictroides*	
Pedaliaceae	*Limnophila ceratophylloides*	Wetland
	Limnophila fluviatilis	
Plumbaginaceae	*Plumbago zeylanica*	Woodland
Poaceae	*Acroceras macrum*	
	Andropogon eucomus	Grassland
	Andropogon eucomus Nees	
	Aristida barbicollis	
	Aristida congesta	
	Aristida meridionalis	Woodland
	Aristida vestita	
	Bothriochloa bladhii	
	Bothriochloa insculpta	
	Brachiaria nigropedata	
	Brachiaria nigropedata	
	Cymbopogon caesius	
	Cymbopogon schoenanthus subsp. schoenanthus	
	Cynodon dactylon	
	Dactyloctenium aegyptium	
	Dactyloctenium giganteum	
	Digitaria ciliaris	
	Digitaria milanjiana	
	Digitaria seriata	Woodland
	Elionurus muticus	

Plant Family	Genus species	Habitat (if recorded)
Poaceae	*Elionurus tripsacoides*	
	Enteropogon macrostachyus	
	Entolasia imbricata	
	Eragrostis echinochloidea	Woodland
	Eragrostis gummiflua	
	Eragrostis inamoena	
	Eragrostis lappula	
	Eragrostis lehmanniana	
	Eragrostis nindensis	
	Eragrostis obtusa	
	Eragrostis pallens	Woodland
	Eragrostis rigidior	
	Eragrostis superba	
	Eustachys paspaloides susbp. *paspaloides*	
	Heteropogon contortus	Woodland
	Hyparrhenia anthistirioides	
	Hyparrhenia hirta	
	Hyperthelia dissoluta	Woodland
	Imperata arundinacea	
	Leersia hexandra	
	Melinis repens subsp. *repens*	Grassland
	Melinis repens subsp. *grandiflora*	
	Monocymbium ceresiiforme	Grassland
	Mosdenia leptostachys	
	Oryza longistaminata	
	Panicum fluviicola	Wetland
	Panicum maximum	Woodland
	Panicum maximum	
	Panicum repens	
	Panicum subalbidum	
	Paspalum scrobiculatum	
	Pennisetum glaucocladum	Wetland
	Perotis patens	
	Phragmites australis	Wetland
	Phragmites mauritianus	Wetland
	Rhytachne rottboellioides	Grassland; Wetland
	Sacciolepis typhura	Wetland
	Schmidtia pappophoroides	
	Schmidtia pappophoroides	
	Setaria sphacelata var. sericea	Wetland
	Setaria sphacelata var. sphacelata	
	Setaria verticillata	
	Sorghastrum nudipes	Grassland; Wetland
	Sporobolus congoensis	Wetland
	Stipagrostis hirtigluma	
	Stipagrostis uniplumis	Woodland
	Themeda triandra	
	Trachypogon spicatus	
	Tricholaena monachne	
	Triraphis schinzii	

Plant Family	Genus species	Habitat (if recorded)
Poaceae	*Urochloa brachyura*	Woodland
	Vossia cuspidata	
Polygalaceae	*Polygala africana*	
	Polygala albida	Woodland
	Polygala fragilis	Grassland
	Polygala gomesiana	Wetland
	Polygala kalaxariensis	
	Polygala krumanina	
	Polygala robusta	Grassland
	Polygala spicata	Wetland
	Securidaca longepetiolata	
Polygonaceae	*Oxygonum dregeanum*	
	Oxygonum delagoensis	
	Persicaria decipiens	
	Persicaria limbata	
	Persicaria madagascariensis	
Pontederiaceae	*Eichhornia natans*	
Potamogetonaceae	*Potamogeton schweinfurthii*	
	Potamogeton thunbergii	
Proteaceae	*Faurea delevoyi*	Woodland
	Faurea saligna	Wetland
	Protea baumii subsp. *baumii*	Wetland
	Protea gaguedi	
Ranunculaceae	*Clematis villosa* subsp. *stanleyi*	Grassland
Rhamnaceae	*Helinus integrifolius*	
	Ziziphus mucronata subsp. *mucronata*	
Rosaceae	*Cliffortia nitidula*	Wetland
Rubiaceae	*Agathisanthemum bojeri*	
	Ancylanthos rubiginosus	
	Empogona kirkii subsp. *kirkii*	
	Fadogia graminea	Grassland
	Gardenia brachythamnus	
	Gardenia volkensii	
	Leptactina prostrata	Grassland
	Oldenlandia capensis var. capensis	
	Otiophora elatior	Wetland
	Pentodon pentandrus	Wetland
	Pygmaeothamnus zeyheri	Grassland
	Spermacoce senensis	
	Vangueria cyanescens	
	Vangueriopsis lanciflora	
Salviniaceae	*Azolla pinnata*	
	Salvinia molesta	
Santalaceae	*Thesium atrum*	Grassland
	Thesium subaphyllum	Grassland

Plant Family	Genus species	Habitat (if recorded)
Sapindaceae	*Cardiospermum corindum* *Cardiospermum halicacabum*	
Scrophulariaceae	*Bacopa floribunda* *Limnophila indica*	Wetland
Sinopteridaceae	*Pellaea calomelanos*	
Solanaceae	*Datura metel* *Solanum delagoense* *Solanum nigrum*	
Strychnaceae	*Strychnos potatorum* *Strychnos pungens*	
Tecophilaeaceae	*Walleria mackenziei*	Grassland
Thelypteridaceae	*Cyclosorus interruptus*	
Thymelaeaceae	*Gnidia kraussiana var. kraussiana*	Grassland
Trapaceae	*Trapa natans*	
Turneraceae	*Tricliceras lobatum* *Tricliceras longepedunculatum* *Tricliceras schinzii*	Grassland
Typhaceae	*Typha capensis*	Wetland
Verbenaceae	*Lantana angolensis* *Lantana camara* *Lantana rugosa* *Phyla nodiflora*	Ruderal
Vitaceae	*Cyphostemma congestum* *Cyphostemma kaessneri*	Woodland
Xyridaceae	*Xyris anceps var. minima* *Xyris capillaris* *Xyris friesii*	Wetland Wetland
Zygophyllaceae	*Tribulus terrestris*	

Notes