River catchments and development prospects in south-eastern Angola

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This document bring together two reports. The first was commissioned by WWF and TNC through Pegasys to provide an overview and understanding of resources, processes and challenges in the catchments of the Cubango, Cuito, Cuando and Zambezi Rivers in Angola. Chapters 1 to 9 comprise the first component. Chapters 10, 11 and 12 make up the second report, which provides an overview of agriculture in Angola, a review of large-scale developments in the Cubango catchment, and recommendations for developments.

2018

Contents

1. Introduction

The information and processes described in this section focus on the catchments of the Cubango, Cuito, Cuando and Zambezi rivers within south-eastern Angola. Their upper catchments and the Western Zambezi broadly form an area called the Okavango-Zambezi Water Tower. This is a highland consisting largely of sand which delivers most of the water carried south by the four rivers. Little, if any water is added in the lower catchments of the Cubango, Cuito and Cuando. All three rivers later flow south into Namibia and Botswana, and no further.

The Zambezi is somewhat different, its upper catchment consisting of the Western Zambezi in Angola; and the elongate Bulozi Floodplain, that straddles the border of Angola and Zambia; and then the eastern Zambezi within Zambia. Water flowing into the Barotse Floodplains thus comes from three rather different, and perhaps complementary drainage systems

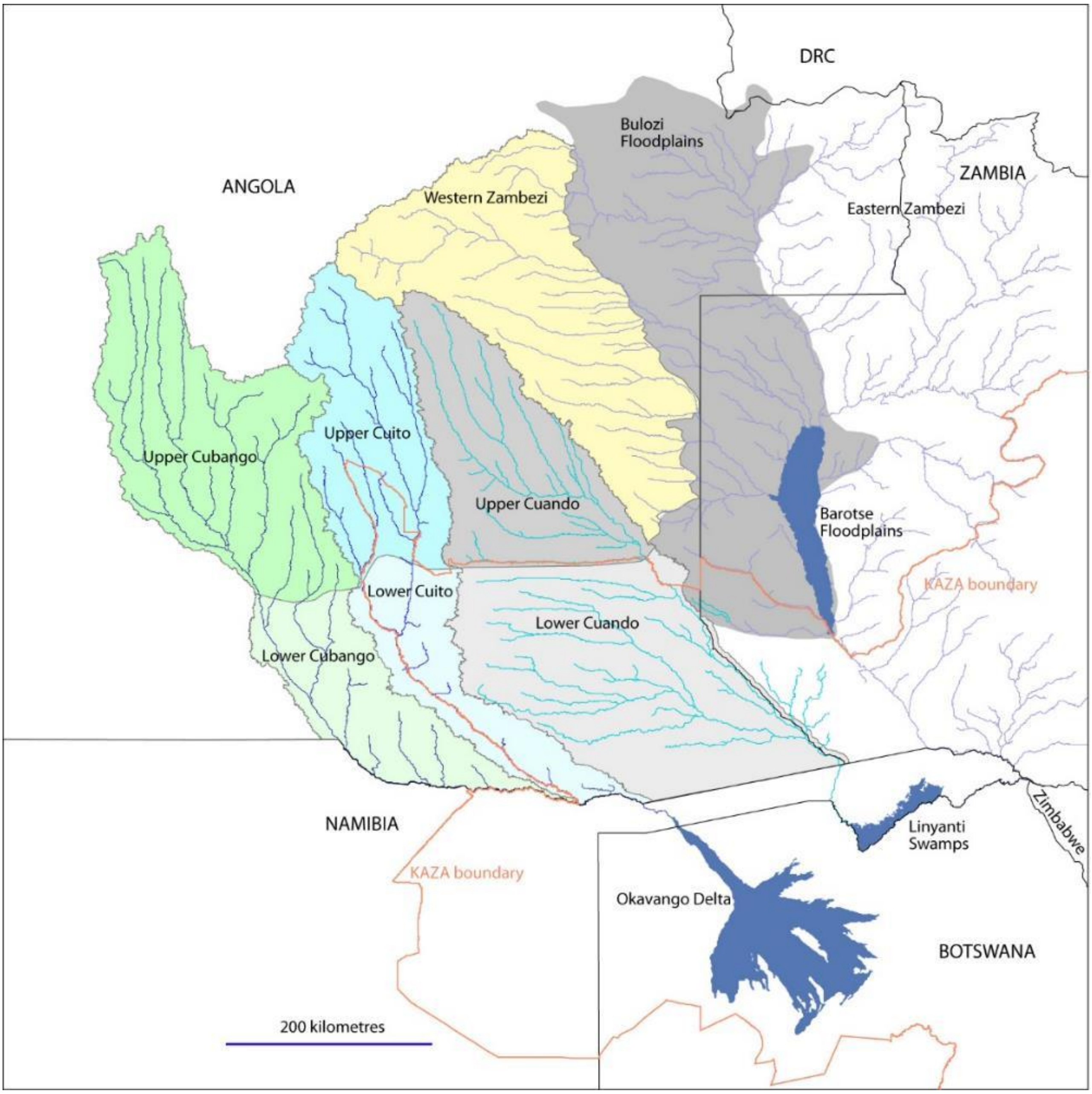


Figure 1. The catchments of the Cubango, Cuito, Cuando and Zambezi rivers within south-eastern Angola, and the floodplains, swamps and deltas into which the rivers later flow.

This report has two major purposes. First, is to inform managers and others concerned with KAZA about the origins of the four rivers that flow as linear oases through the trans-frontier conservation area. This was the need expressed by WWF (World Wildlife Fund) and TNC (The Nature Conservancy), and the document presented here forms part of the report commissioned for these two organisations. The second purpose comes from a need identified and expressed separately by TNC, which was to assemble information on the Upper Cubango, particularly regarding its functioning and current, proposed and possible developments. These developments may influence episodic flows in the Cubango River which are now critical for the productive functioning of the Okavango Delta.

2. Geology, topography and climate

The geology and geomorphology of south-eastern Angola is rather simple, at least in its overall proportions. In the far north-west much of the landscape rises to between 1,600 and 1,850 metres above sea level. This highland ridge forms part of Angola central plateau, known as the *Planalto*. The area is underlain with a mix of extremely old granites and meta-sediments, all formed on some ancient surface at least 2 billion years ago. One of the units – the Jamba Sequence of meta-sediments – has iron deposits that have been mined over hundreds of years by local people, and then more recently at Jamba and Chamutete. None of the iron resources lie within south-east Angola’s catchments, however.

The Eburnean granites and Jamba meta-sediments are exposed in many places, while shallow Acrisols and Ferralsols overlay the rocks elsewhere in the north-west. Run-off in the upper Cubango catchment after rain can be rapid and erosive as a result of the exposed rock surfaces and shallow soils. That run-off contributes much to the floodwaters that periodically inundate floodplains along the Cubango/Okavango River and in the Okavango Delta. Surges of production and reproduction by plants and animals are generated when these pulses of water mix with nutrients lying dormant in the floodplains (see page 27).

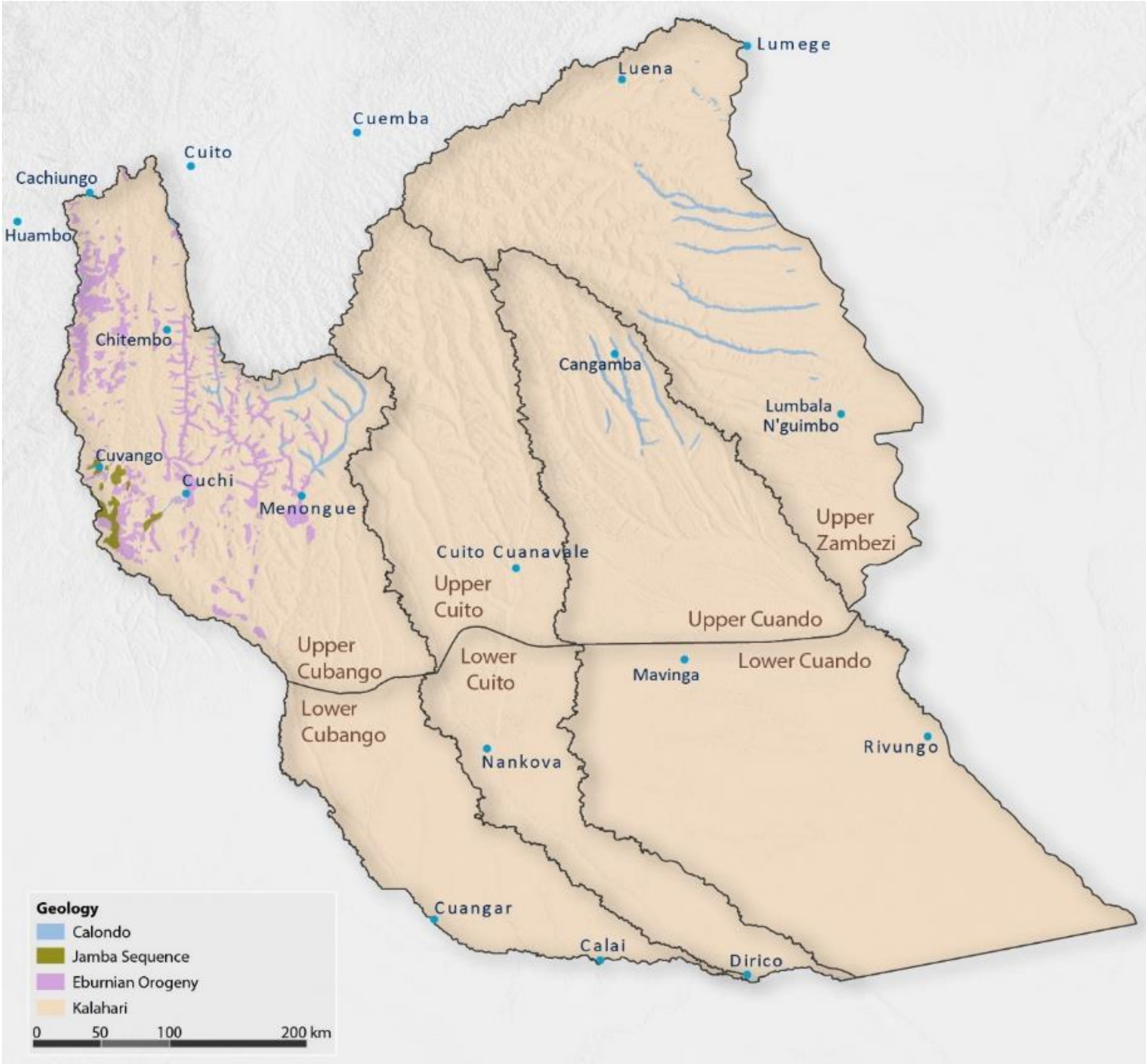
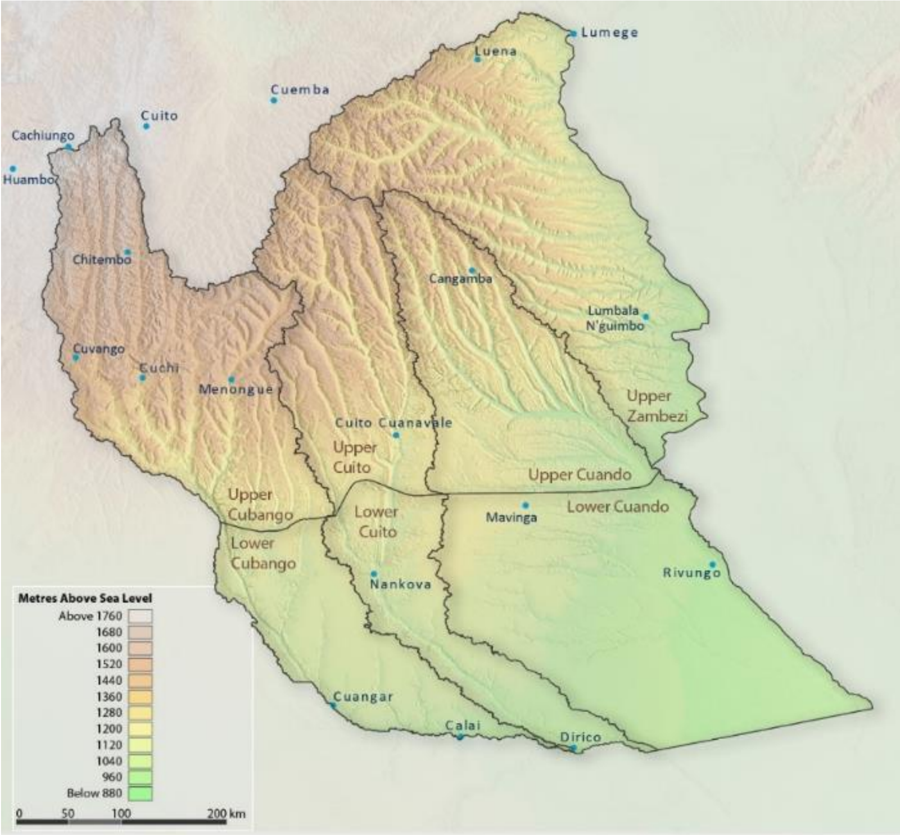


Figure 2. The geology of south-eastern Angola (adapted from de Carvalho (1981), McCourt et al. *(2013) and Mendelsohn & Mendelsohn (2018).*

The ancient granites and meta-sediments are most exposed in the west, and gradually less so to the east where they are covered by deeper Kalahari sediments. Thus from about Menongue eastwards it is extremely rare to find any rocks. Exceptions are narrow exposures of Calonda (also called Kwango) conglomerates formed largely of basalts during the Cretaceous (145 to 66 million years ago). It is doubtless from these Calonda conglomerates that alluvial diamonds have been washed to be found in small numbers by artisanal miners along the Longa, Cubia and Utembe rivers in the Cuando River catchment. From those same basalt conglomerates may have come most of the nutrients that support dense, tall growth of plants in the Cuando River floodplain.



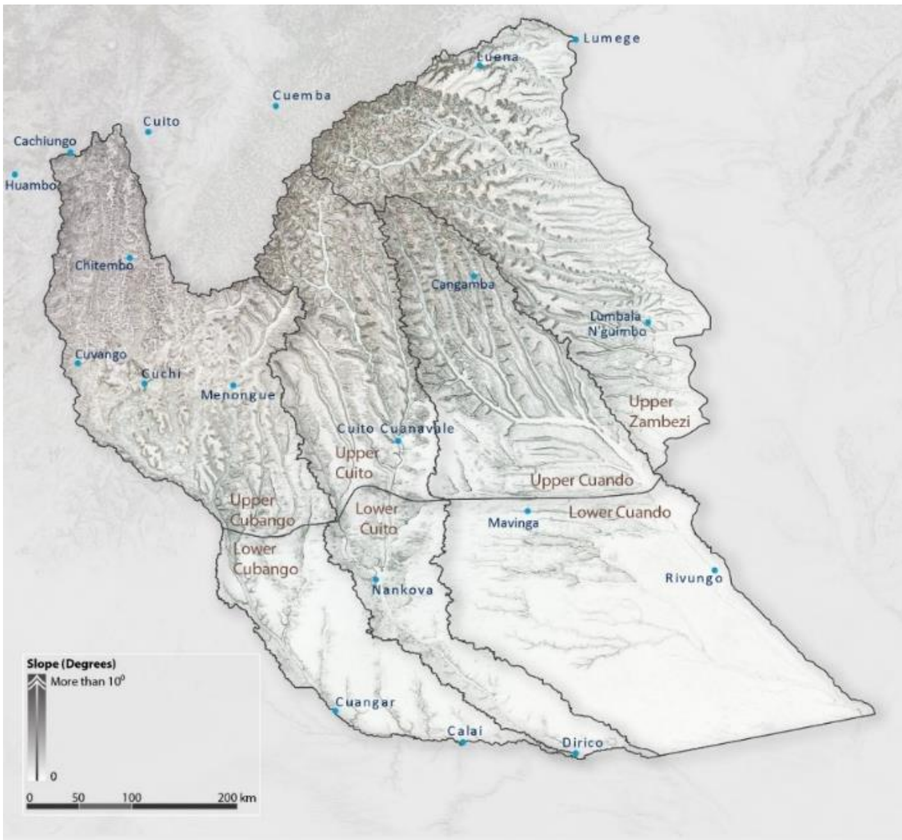


Figure 3. Elevations in metres above sea level (top) and slopes measured in degrees (bottom). Derived from SRTM 90 metre digital elevation data from National Aeronautics and Space Administration (NASA; http://www2.jpl.nasa. gov/srtm).

Topographically, south-eastern Angola drops gradually from the highest elevations in the north to the lowest areas along the Namibian border, which are about 1,000 metres above sea level. The northern areas are also the hilliest, particularly in the headwaters of the Cuito, Cuando and Lungue-Bungo of the western Zambezi.

It is likely that the upper catchments of Angola's major rivers were lifted up at some stage, so that they now form a gigantic dome (R. Swart personal communication). The other half of dome lies to the north from where two main rivers and their tributaries flow: the Casai of the Congo Basin and the Cuanza which ends in the Atlantic just south of Luanda. What is now being called the Okavango-Zambezi Water Tower thus really consists of the upper catchments of six major rivers; anticlockwise: the Cubango, Cuito, Cuando, western Zambezi, Casai and Cuanza. The first four flow south, and the last two north.

The base level – which sets the slope and speed of flow – of the Cuanza is thus at sea level, while all the rivers of the south-east have base levels between about 950 and 1,100 metres above sea level. Flows of the Cuanza River are therefore much more aggressive than all the south-eastern rivers, and this is why there is a great amphitheatre where the Cuanza has and will continue to erode southwards between the upper catchments of the Cubango and Cuito.

The lower catchments of the Cubango, Cuito, and Cuando are extremely flat and sandy, which means that most rainwater is absorbed on the sandy surface before seeping away to unknown depths. Tributaries in the lower catchment of the Cubango and Cuito are thus completely dry most of the time, while the larger rivers that flow into the Cuando are either dry or carry very modest flows.

Climate

South-eastern Angola typically has two seasons: a dry, cool winter between May and September, and a warmer, wetter summer from October to April. The winter is dominated by anti-cyclonic conditions that then extend over much of southern Africa. The skies are normally cloudless. Mornings are cold (< 10^{o} Celsius), often very cold and with occasional frost in the uppermost catchments, while the days and early evening are warm with temperatures between 15 and 25^{o}C. It is during the dry winter months that most bush fires sweep across the area. The cloudless skies are then so smoky that solar radiation is dimmed, especially during August and September when most fires burn.

During the summer months, night time temperatures are normally above 15^{o}C and above 25 ^{o}C during the day. The majority of rain falls from afternoon thunderstorms which develop from rising and cooling air earlier in the day. Almost all rain is received between October and April, but the rains start earlier in the north than the south. This is because most rain is derived from moist air that moves progressively south from the tropics. For the same reason, the northern areas get more rain but also have a short drier period in January and February when the moist Intertropical Convergence Zone (ITCZ) is south of Angola.

The driest areas in south-east Angola are along the southern border with Namibia where annual rainfalls normally range between 500 and 600 millimetres. The upper catchments of the Cuito, Cuando and western Zambezi usually receive between 1,000 and 1,200 mm per year, while the more elevated upper Cubango catchment gets between 1,200 and 1,400 mm.

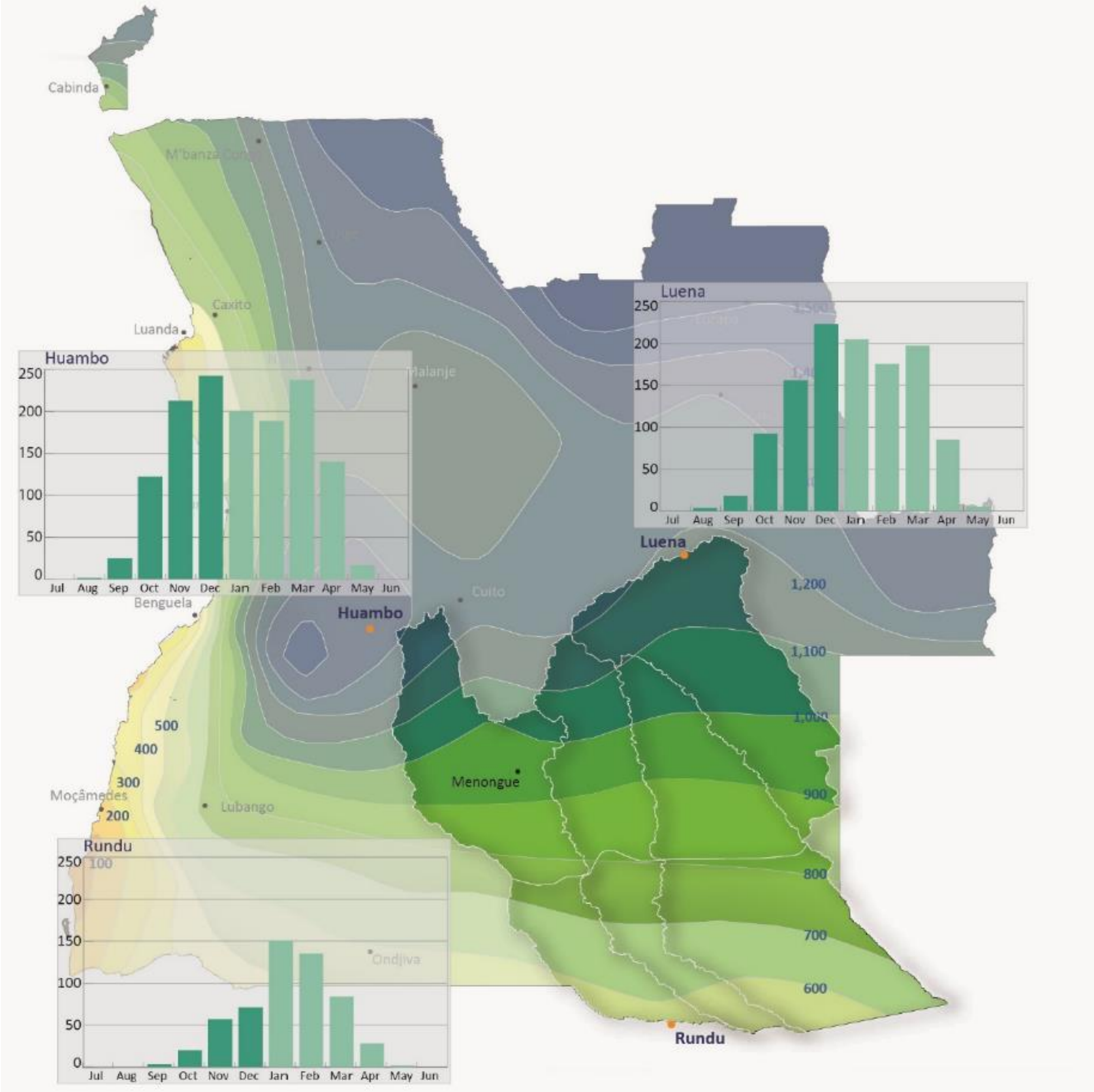
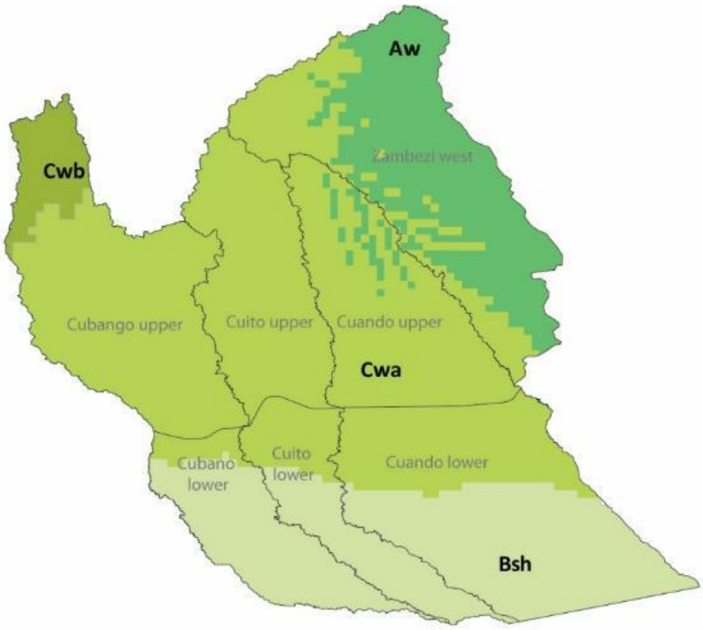


Figure 4. Average annual rainfall in south-eastern and the rest of Angola, and average monthly rainfall at Huambo, Luena and Rundu. (Source: Worldclim data (www.worldclim.org); Huambo: from records collected at Chianga, Luena: historical records collected by Development Workshop, Luanda; Rundu: from Ministry of Agriculture, Water and Forestry, Windhoek).

Winds that have prevailed from the east and north over a very long time have also played a major role in shaping local topography and the distribution of soils, roads and people in interesting ways. For example, immediately to west of many pans are lunette dunes formed from pan sediments scoured out by wind and deposited on the lee sides of the pans. Similarly, longitudinal dunes west of the Cuando River were formed from soil washed out of the river when it was dry.

Soils immediately west of rivers are often a mix of aeolian sand and fine grained clays blown out of the river floodplains. The soils are thus more fertile and loamy than those east of the rivers. As a result, local residents preferentially have their fields west of the rivers, and roads have normally been built west of the rivers. All these patterns are easy to see in satellite images, such as those in Google Earth.

Several climate parameters are provided for the four Köppen climate zones in south-eastern Angola (Figure 5). The classification is based largely on rainfall and temperature characteristics. The Aw zone in the north-east and covering much of the western Zambezi catchment is tropical in nature, the Cwb and Cwa zones are temperate, and Bsh in the south is dry.



	Cwb	Cwa	Bsh	Aw
Average annual rainfall (mm)	1,400	1,050	550	1,300
Number of rainy days	101 to 140	101 to 140	21 to 60	101 to 140
Average annual temperature (ºC)	19	20	22	21
Maximum average temperature (ºC)	26	29	31	28
Minimum average temperature (ºC)	12	12	13	13
Average maximum temperature in hottest month (ºC)	28	33	35	31
Average minimum temperature in coldest month (ºC)	8	4	3	9
Sunlight (number of hours/year)	2,600	2,800	2,800	2,400
Evapotranspiration (Thornthwaite) (mm)	900	1,000	1,100	1,000

Figure 5. Catchments in south-eastern Angola fall into four Köppen classes, as shown in the map together with a selection of climate parameters in the table.

3. Soils in Angola's south-eastern river catchments

Arguably, soils have a greater influence on the history, structure, economy, vegetation, and drainage than any other single feature of south-eastern Angola's geography. It is because of soils that river water is so clean and flows so slowly, that the topography is so gentle, and the region so sparsely populated, for example. What is more, the future of the region and its people rests most profitably in domains that recognise the limits set by soil conditions, as well as the assets that certain soils provide.

Two large soil units predominate in the catchments: Arenosols and Ferralsols, and they extend over large areas elsewhere in Angola. Gleysols and Fluvisols are two other significant soil units in south-eastern Angola. Both are localised in small patches along rivers and in small upland valleys and are under-represented at the mapping scale used for the ISRIC data in Figure 6.

The distribution and variety of soils described here is derived from detailed, high resolution mapping from a great volume of data sources by ISRIC (see www.isric.com). However, it should be noted that many of the soil classifications are reached on the basis of probability. This means that given the information available, the soils shown in any one area are most likely to be of the type shown. Moreover, even if the soil type indicated is correct, there can be much variation in its properties from one patch or area to another, which may render the soil more or less suited to different purposes.

Soils are of little interest to most people, who generally assume that soils look and are the same, and vary little in their suitability for agriculture or their effects on vegetation, the distribution of people or topography, for example. These assumptions are naïve and dangerous because decisions made about land uses are then often wrong. For these reasons – and to ensure that appropriate information and understanding is available – that the pages ahead present substantial detail about the types of soils and their properties in south-eastern Angola.

Major points

At the outset, it is important to draw attention to several key and critical features about the region's soils. The first is that soils in most areas are exceptionally poor, particularly in terms of their fertility and water holding capacity (Asanzi *et al*. 2006; Ucuassapi & Dias 2006; Wallenfang *et al*. 2015. For example, yield of maize and millet average about 700 and 300 kilograms per hectare, which are among the lowest in Africa (https://datamarket.com). Second, farming that aims to produce significant fields from poor soils requires substantial expenses to fix soil deficiencies. The more the structure of a soil must be altered or its fertility improved, the greater the cost and the lower the potential gain. Equivalent farming on better soils is thus cheaper and more profitable. Third, managing such challenging soils requires considerable expertise and experience. Fourth and paradoxically, soils in areas with the highest rainfall are generally less fertile than the same soils in drier areas of south-eastern Angola. This is because most nutrients are either leached by rain or absorbed and bound-up in luxuriant vegetation growing in high rainfall areas.

Fifth, there is relatively little erosion in south-eastern Angola, particularly over the vast, flatter areas of sandy Arenosols and Ferralsols. Sixth, as result of prevailing winds from the east, soils on the western sides of rivers are generally more fertile than those to the east. Easterly winds carry fine clays and silts from the rivers and their floodplains when they are dry, and then deposit the fine sediments in the west where they mix with sand to form more loamy soils.

Seventh, there are small patches of better soils in places. These offer opportunities for productive, profitable agriculture in certain areas, but elsewhere their potential is limited. They may be suited to only certain crops for which there is poor demand, and they may be so distant that transport costs for inputs and harvests are prohibitive, for example.

Eighth, there are substantial beds of peats in the low-lying centres of many river valleys, especially those that meander across broad, sandy landscapes. The significance and value of the peat remains unknown.

Finally, the broad ridge – or water tower – of sandy, permeable Arenosols and Ferralsols that form much of the northern catchment area function as a sponge, slowly releasing water in places to provide steady flows into the major rivers; but also perhaps storing vast volumes in very deep aquifers. Those aquifers may be found to important water resources, as is the newly discovered aquifer in the Cuvelai

(https://www.bgr.bund.de/EN/Themen/Wasser/Projekte/laufend/TZ/Namibia/ceb_fb_en.html).

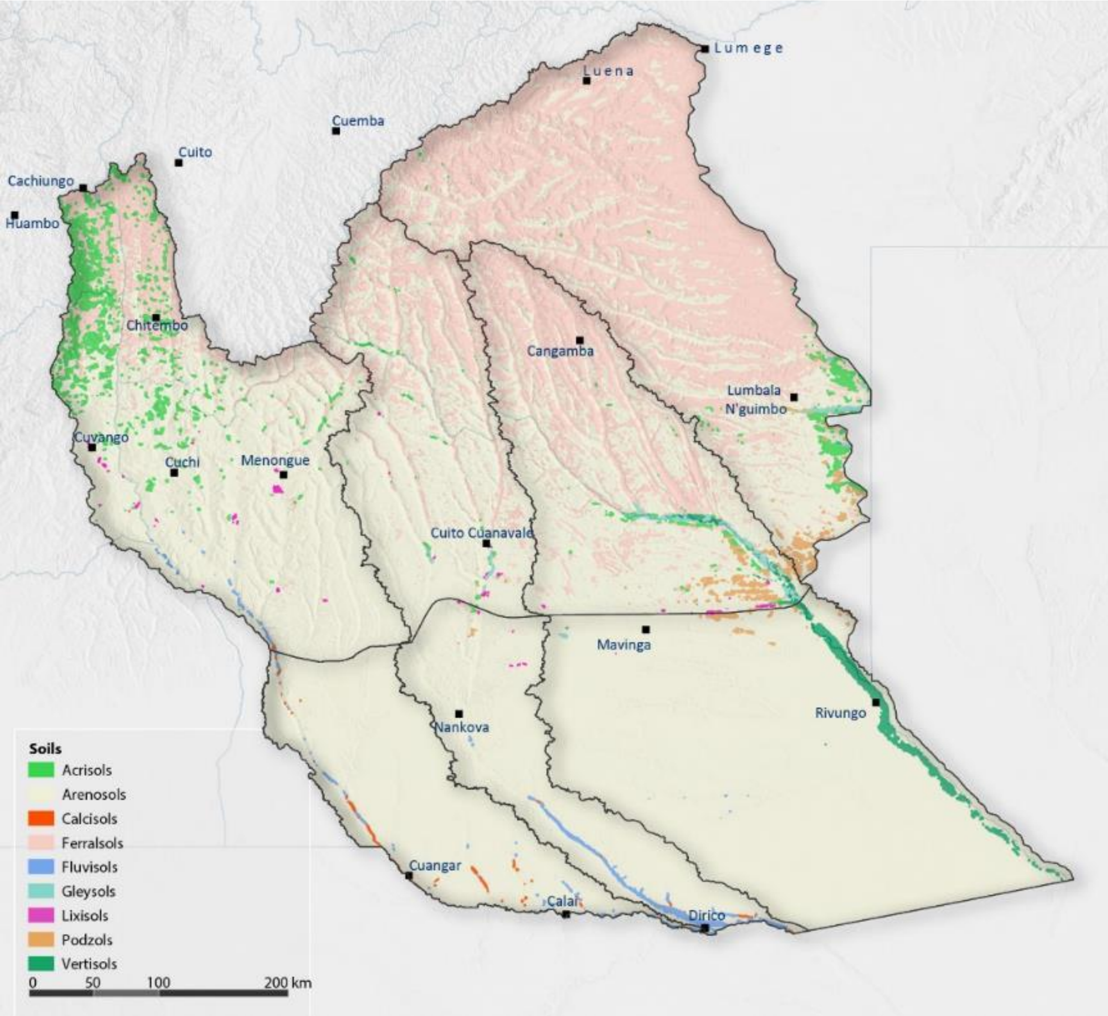


Figure 6: The distribution of soils in the catchments of south-eastern Angola. Source: International Soil Reference and Information Centre (ISRIC) https://soilgrids.org

Table 1: Percentages of the catchments covered by different soil types

Type	Percentage area
Ferralsols	24.3%
Arenosols	72.9%
Acrisols	1.4%
Lixisols	0.0%
Gleysols	0.2%
Podzols	0.3%
Vertisols	0.4%
Fluvisols	0.3%
Calcisols	0.1%

Source: International Soil Reference and Information Centre (ISRIC) https://soilgrids.org

Arenosols

These soils cover most of the central and southern areas of the region; and they also cover much of the Kalahari Basin which is the largest continuous area of sand on Earth.

Arenosols are wind-blown or aeolian sediments that are largely devoid of nutrients. The Available Water (storage) Capacity (AWC) of these soils is also very low, sometimes as low as 3% by weight because the pores between sand grains are relatively large. The ability of Arenosols to store and make water available to crops is therefore usually very low, and water from recent rainfall is lost rapidly. For example, after heavy rains a water content of 22% can be reduced to 11% in just 48 hours. Infiltration rates in sandy soils vary between 2.5 and 25 cm/hour and may be 250 times faster than in clay soils (less than 0.1 cm/hr).

Quartz and feldspars are the principal minerals found in Arenosols, together with smaller fractions of micas and ferromagnesian minerals. The nature of the clay fraction in Arenosols depends on weathering conditions and parent rock, but for this region it is mainly composed of kaolin, in which the capacity to expand and to store water is also limited.

The Arenosols in south-eastern Angola are deeply leached and decalcified soils with a low capacity to store base minerals. The soils are also acidic (Wang et al. 2007). Their A-horizons are shallow and/or contain little or poorly decomposed organic matter. The natural vegetation survives on re-cycling nutrients, and roots are almost exclusively in the O-horizon and in a shallow A-horizon.

Arenosols in the region are best left under their natural vegetation, particularly so in the deeply weathered Albic (white) Arenosols. As nutrient minerals are all concentrated in the humus and top 20 cm of the soil, removal of the vegetation inevitably results in infertile badlands that have little ecological or economic value. While forested or wooded, the land can still produce some timber and other plant resources. The permanent cultivation of annual crops requires management and inputs that are usually not economically justifiable. Root and tuber crops are easy to grow, notably cassava and sweet potato (in the north of the region), which tolerate low nutrient levels. Groundnuts can be cultivated on the better soils. However, high yields can't be expected due the combination of low fertility, low water storage capacity and cold conditions in the winter months (particularly for cassava). Cattle ranching has potential, but requires investment to modify and manage grasslands, particularly in the eastern areas of the region, as well as the preservation of some woody plants for shade and browse.

Ferralsols

This soil type is dominant in the upper catchments. Ferralsols are associated with old, stable geomorphological surfaces and areas where recent processes that lead to soil formation are absent. These are soils with very weathered material, rich in kaolinite and sesquioxides (iron and aluminium), deep, easy to work with, but very poor in nutrients. They are easily identified by their intense red, orange or yellow colour that characterize the deep, uniform soil horizons. Ferralsols are normally very deep (usually several meters thick) with diffuse horizon boundaries. Quartz is usually the main primary mineral.

Most Ferralsols are clayey (a consequence of advanced weathering), and the presence of micro-aggregates (various particles composed of mineral, organic and biotic materials bound together during soil formation) reduces moisture availability to most crops. The clay assemblage is dominated by kaolinite, hematite and goethite.

Stable micro-aggregates explain the excellent porosity, good permeability and infiltration rates of Ferralsols. In soils with high (positively charged) iron oxide and (negatively charged) kaolinite contents, the soil structure is stable, due to the bonding of opposite elements. However, surface sealing and compaction limit the use of these soils for cultivation.

Their good permeability and stable microstructure make Ferralsols less susceptible to erosion than most other tropical soils. Moist Ferralsols are friable and easy to work, even after a short period of drying conditions. They are well drained but also often desiccated because of their low water storage capacity.

However, the chemical fertility of Ferralsols is poor. Dissolved minerals are absent and cation retention is weak. Under natural vegetation, some nutrient elements taken up by the roots are eventually returned in falling leaves and other plant debris to the surface soil. But the bulk of all nutrients are taken up and held in the living trees and other plant. Almost all plant nutrients available in the soil (and living plant roots) are concentrated in the upper 10 to 50 cm soil layer. The root zone is rapidly depleted of plant nutrients if the process of nutrient cycling is interrupted, for example by low input sedentary subsistence farming.

Phosphorus retention is limited in Ferralsols, which are also normally low in nitrogen, potassium, secondary nutrients (calcium, magnesium, sulphur) and many micro-nutrients. Even silica deficiency is possible if silica-demanding crops (such as rice or permanent pastures) are grown. However, manganese, aluminium and zinc, which are soluble at low pH, may reach toxic levels.

Thus, while Ferralsols have good physical properties their low natural fertility, and lack of nutrients are serious limitations. Ferralsols are used mostly for shifting cultivation of maize, sorghum, millet and cassava in the region. Yields are very low.

Liming (application of $CaCO3$), the application of phosphate rock and a full complement of fertilisers are required for sustainable crop production, but the costs of fertilizers and their application strongly limit the economic viability of agriculture. Liming is used to raise the pH-value of the surface soil, to combat aluminium toxicity and to raise the cation exchange capacity (CEC).

Maintaining soil fertility by manuring, mulching and adequate fallow periods and prevention of surface soil erosion are also important management requirements. However, nutrients will be completely depleted if fallow periods are too short. The good physical properties of Ferralsols and the often gentle topography of the catchments create misleading expectations that encourage intensive land uses that are not viable because production is low and shifting cultivation requires that woodlands be progressively degraded.

Calcisols

Calcisols have substantial accumulations of lime (calcium carbonates). They originate mostly from alluvial, colluvial and aeolian deposits of sediments, and are often predominantly covered in xerophytic shrubs, and trees and ephemeral grasses. Patches of Calcisols occur along perennial and ephemeral rivers in the lower Cubango catchment (Figure 6), where they probably formed from alluvial sediments first deposited as Fluvisols.

Cross-sections through landscapes with Calcisols normally show a gradual transition from shallow soils with rather diffuse signs of lime to deeper soils richer in carbonates. The translocation of calcium carbonate from the surface horizon to an accumulation layer at some depth is the most prominent soil forming process in Calcisols, and it is common to find the surface horizon wholly or partly de-calcified. The way in which lime is redistributed varies greatly, but commonly includes deposits usually called calcrete.

Many Calcisols are old soils with their development having been slowed by recurrent periods of drought during which other important soil forming processes, such as chemical weathering, accumulation of organic matter and the translocation of clay, came to a virtual standstill.

In Calcisols the organic matter content of the surface soil is sometimes low, as a consequence of the rapid decomposition of plant debris. Most of these soils have a medium or fine texture and good water-holding properties. Surface crusts may hinder the infiltration of rain and irrigation water, particularly where the surface soils are silty, and surface run-off over the bare soil often results in gully erosion.

Calcisols contain only 1 or 2 percent organic matter but are rich in plant nutrients. The pH is near-neutral in the surface soil, but slightly higher at a depth of 80 to 100 cm where the carbonate content may be 25 percent or more. Calcisols can be highly productive for a wide variety of crops if irrigated, drained (to prevent the build-up of salts) and fertilised. Many vegetable crops can successfully be grown on irrigated Calcisols fertilised with nitrogen, phosphorus and micro-elements, such as iron and zinc.

Fluvisols

Fluvisols form from alluvial sediments of silt and clay deposited by the periodic flooding of floodplains along rivers, and in deltas and alluvial fans and lakes. These water bodies thus receive fresh deposits of sediments during floods. In the Angolan catchments of the Cubango, Cuito, Cuando and Zambezi Fluvisols are more widely distributed than suggested by their portrayal in Figure 6, and probably lie in many of the broad floodplains that characterise the Cuando, Cuito and many stretches of the Cubango and the major Zambezi tributaries.

Fluvisols in upstream river lengths are normally confined to narrow strips of land adjacent to the actual riverbed. In the middle and lower stretches of the river, the floodplain is wider, often with levees. Fluvisols close to the river are coarser, while finely textured soils are found further from the main channel.

Permanent or seasonal saturation with water preserves the stratified nature of the original deposits. The characteristics of Fluvisols depend largely on their wetness and on when the sediments were deposited. Over time, the sediments change (or mature), becoming stratified by chemical processes associated by drying (oxidizing) and wetting (reducing).

Fluvisols generally have neutral or near-neutral pH values, which do not impair the availability of nutrients. The good natural fertility of most Fluvisols means they are well-suited to annual crops or orchards, although flood control, drainage and/or irrigation are normally required to manage the soils. For several weeks a year these soils should be dry when microbial activity and the mineralization of organic matter can occur. Dryland crops can be grown on Fluvisols, but normally with some form of artificial water control.

Although the wide floodplains of Fluvisols along many of the rivers in south-eastern Angola appear ideal for rice and other crop production, these soils are generally very acidic and thus poorly suited to crop production. This is due to the acid nature of the parent material that produced the alluvial sediments as well as the effects of being saturated in water which leads to acidification.

Acrisols

Acrisols are relatively abundant in the north-west, particularly in the uppermost catchment of the Cubango and its associate rivers (Figure 6). These soils generally form on old land surfaces with hilly or undulating topography, and in regions with a wet tropical climate – all three conditions hold in that north-western area, as described elsewhere in this report for geology, topography and rainfall. Light forest is the natural vegetation on Acrisols.

Acrisols are characterized by a dominance of clays, a general deficiency of base or cation minerals, as well as most other minerals that have been leached away. Exceptions are iron and aluminium. The clay fraction consists almost entirely of kaolinite and some gibbsite.

Acrisols beneath protective forest cover have porous surface soils, but the valuable surface horizon degrades and forms a hard surface crust if the vegetation is removed. The crust limits the penetration of water during heavy rain, resulting in serious surface erosion. It is probably for this reason that erosion gullies are more abundant amongst Acrisols than anywhere else in the region (see Figure 7).

Acrisols have poor chemical properties. Levels of plant nutrients are low and aluminium toxicity limits crop growth. Microbial activity is low, and the natural regeneration of surface soils degraded by farming is very slow.

The preservation of the surface soil and its important organic matter is a necessity for farming on Acrisols. Mechanical clearing of natural forest to remove roots and deep tilling brings toxic levels of aluminium in the subsoil to the surface which kills seedlings.

Carefully managed cropping systems and thorough fertilization is required if fields are to be used year after year. These requirements cannot be met by peasant farmers and so the widely-used ‘slash and burn’ agriculture is the only alternative form of crop farming. Some regeneration of Acrisols is possible if fields are used for short periods (one to three years only) and then left fallow for long periods of up to 10 years. No regeneration will take place if the interval between cropping years is shorter, and erosion of the surface soils and their nutrients will destroy the weak productive structure of these soils.

Some un-demanding, acidity-tolerant cash crops such as pineapple or cassava can be grown with moderate success. Rain-fed and irrigated crops can only be produced after the expensive application of large quantities of lime and various fertilisers. Organic matter can be maintained if annual crops are rotated with improved pasture.

Lixisols

Lixisols are strongly weathered soils in which clay has been washed down from the surface layers to an accumulation horizon at some depth. They originate from unconsolidated, strongly weathered and strongly leached, finely textured materials.

These soils occur in areas with a warm climate and a pronounced dry season, and are very similar to Acrisols. In the Cubango, Cuito, Cuando and Zambezi catchments, Lixisols occur in small isolated patches spread across a broad zone in the middle reaches of these rivers (see Figure 6).

Lixisols have low levels of available nutrients and low nutrient reserves. However, their chemical properties are generally better than those of Ferralsols and Acrisols because of their higher pH and the absence of severe aluminium toxicity. Most Lixisols drain easily, and their capacity to hold moisture is also slightly better than those of Ferralsols or Acrisols with the same contents of clay and organic matter. Nonetheless, the low absolute level of plant nutrients and low cation retention by Lixisols makes recurrent inputs of fertilizers and lime a precondition for arable farming

Savannah or open woodland vegetation normally characterises Lixisols, and these areas are widely used for low volume grazing. Preservation of the surface soil with its organic matter is of utmost importance. Degraded surface soils have low stability and are prone to erosion if exposed to the direct impact of raindrops. Tillage of wet soil or the use of heavy machinery will compact the soil and damage the structure of its E horizon. Chemically and physically deteriorated Lixisols regenerate very slowly.

Perennial crops are to be preferred over annual crops. Unlike Acrisols, the cultivation of tuber crops (cassava, sweet potato) or groundnut increases the danger of soil deterioration and erosion. Rotation of annual crops with improved pasture has been recommended to maintain the organic matter content of Lixisols.

Gleysols

Figure 6 shows Gleysols covering tiny areas of the Cubango sub-catchments and those of the Cuito, Cuando and Zambezi rivers. However, these soils are much more abundant and widely distributed than the mapped data indicate. This is because Gleysols are restricted to tiny patches, most of which are too small to be detected at 250 metre mapping resolution of the ISRIC data. Gleysols are extremely important for local residents who grow a variety vegetables on these dark, moist soils.

These soils are found in two landscapes. The first is in the upper Cubango catchment where Gleysols fill the bottoms of shallow valleys. The soils are formed by the colluvial movement of minerals (and water) down the adjacent hill slopes. The second is along the margins of floodplains throughout south-eastern Angola. Here, the Gleysols are confined to narrow strips between the regularly inundated floodplains and adjacent grasslands and woodlands growing on drier sandy soils. It is often hard to distinguish different zones of Gleysols and Fluvisols in these areas.

Gleysols are usually wet, their moisture content varying seasonally, being extremely wet during the summer rain seasons and drier during the winter months. Farmers use drainage ditches and channels to manage soil moisture. Strong reduction and oxidation (redox) chemical processes and a gleyic layer or horizon characterise these soils. Iron is removed from this layer by oxidation, leaving the gleyic layer soil devoid of the brown and red colouration derived from iron. The uppermost A horizon layer is rich in organic matter and may be up to 50 centimetres thick. This upper layer is also relatively fertile and well-suited to horticulture. Cereals generally do not grow well in Gleysols.

Podzols

Figure 6 shows rather large areas of Podzols around the middle reaches of the Cuando River. These soils typically have sub-surface impermeable laterite soils formed by the vertical migration of iron and aluminium oxides. Podzols are generally acidic and low in fertility. Nothing appears to be known about the use of these soils in south-eastern Angola

Vertisols

Figure 6 shows much of the mid and lower Cuando River valley filled with Vertisols, which seems surprising given the predominance of wind- and waterborne sediments throughout this and other areas of the Kalahari Basin. Moreover, since most of the Cuando valley in this area is flooded for much of the time (see page 30), it seems more probable that these are Fluvisols.

However, the relative abundance of phragmites, papyrus and other large aquatic plants in the Cuando valley suggests the soils must have been formed from sediments with considerable nutrient contents, unlike other soils in the region. That lends support to the idea that these are indeed Vertisols, and they may be the products of basalts along the Kembo and upper Cuando where there are outcrops of metasedimentary Calando (or Cuango) Group Rocks that have basaltic origins.

Hardpans

Hardpans are extremely important in retaining rainwater near the surface, and forcing water out of the soils and into the hundreds of thousands of tributaries that eventually fill the major rivers. There would probably be few drainage lines in the absence of hardpans since about 97% of the region is covered in soils that are highly permeable (Arenosols, Ferralsols and Acrisols).

Acrisols and Ferralsols often have accumulations ferrocrete (laterite) or silcrete which function as hardpans, from anywhere between immediately beneath the surface up to tens of metres deep. Layers of calcrete may form in the drier southern areas of the region, and Podzols often have impermeable laterite layers below the surface.

Soil fertility and water holding capacity

Most soils in the region are relatively infertile and can hold limited amounts of water. In order of severity, Arenosols, Ferralsols, Acrisols and Lixisols are most deficient in these respects. Cumulatively, these soils make up 97% of the Cubango Sub-catchment and 98% of the entire south-eastern region covered by the catchments shown in Figure 6. These soils will only produce moderate or better yields if they are fertilised regularly with a spectrum of nutrients, and if abundant lime (calcium carbonate) is applied to lower their acidity.

In order of increasing fertility and moisture availability, the following soils are most suited to crop production: Podzols, Calcisols, Fluvisols, Vertisols and Gleysols. There are approximations, however, and much local variation for crop potential is to be found from area to area. Fluvisols in the region are normally too acidic for arable agriculture.

Erosion

Ferralsols, Acrisols, Lixisols and Calcisols are the most erodible soils in the region. However, severe erosion normally only occurs when the surface layers of these soils are damaged when plant cover is removed, they are tilled, surface crusts develop, and organic material is removed from their surface layers.

Only in the north-west and around major towns is erosion evident in the form of gullies large enough to be seen and mapped from high resolution satellite images (Figure 7). The concentration of gullies in the northwest is likely due to a combination of factors: reasonably steep slopes, erodible Acrisols with relatively limited rain permeability, high human density and consequential plant cover loss, and high rainfall.

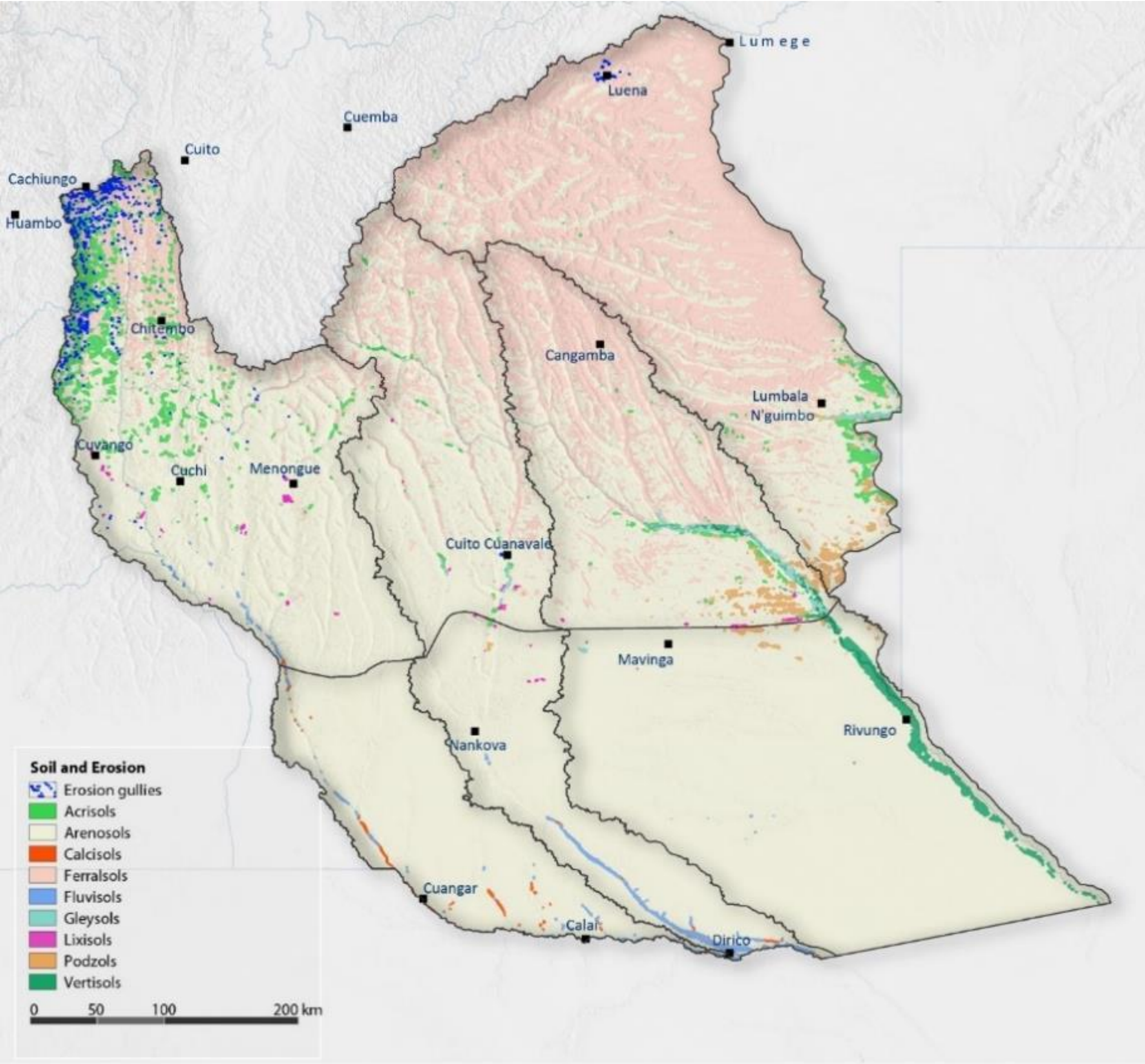


Figure 7. The distribution of large erosion gullies seen and mapped from high resolution (0.5 metre pixels) satellite images. Source: mapping by RAISON.

Figure 8: Around Luena soil erosion has been severe on steep slopes originally formed by slumping (see page 32). These images show the expansion of erosion in one such slump between 2003 and 2018. Note the growing density of houses around the slump. The photographs span an area of 1.6 kilometres from west to east. Source: images from Google Earth.

Peat

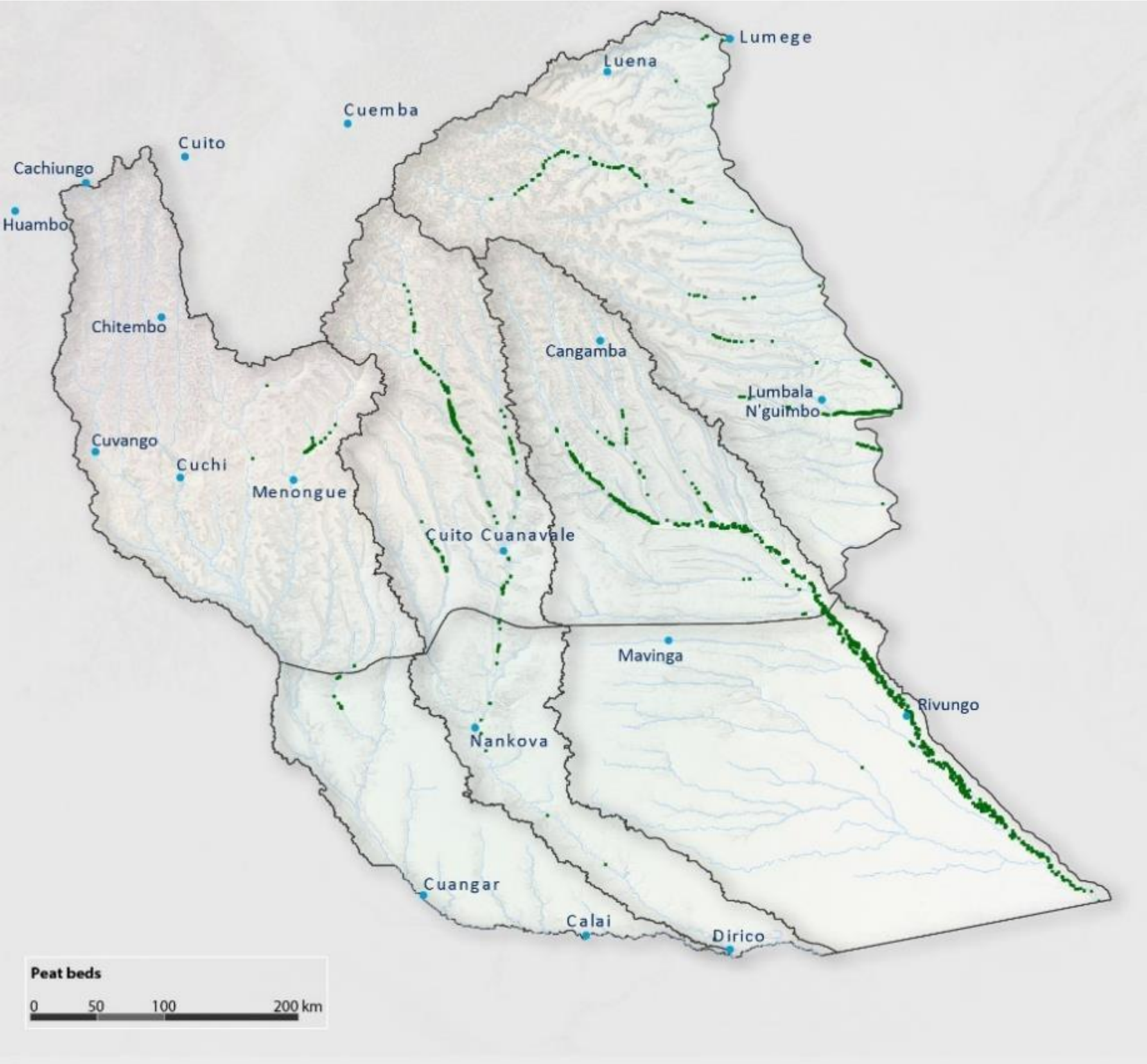


Figure 9: The distribution of peat in south-eastern Angola. Source: Peat data from Center for International Forestry Research (CIFOR) - https://data.cifor.org/dataset.xhtml?persistentId=doi:10.17528/CIFOR/DATA.00058

Beds of peat present along many of the rivers and their tributaries, especially where their valleys are shallow and flow rates are slow. The peat is most concentrated in the lowest sections of the valleys where the ground is permanently wet. The map in Figure 9 shows the distribution of larger peat beds, but there many more smaller beds along smaller drainage lines. In satellite images (such as those available through Bing and Google), peat beds are usually the very dark areas close to river lines, whereas adjacent paler zones are dry grasslands and underground forests.

Little is known about peat in the region, such as its age, the depths and organic carbon content. If verified, peat beds underlying the broad Cuando river valleys could have significant value as carbon sinks.

Sand

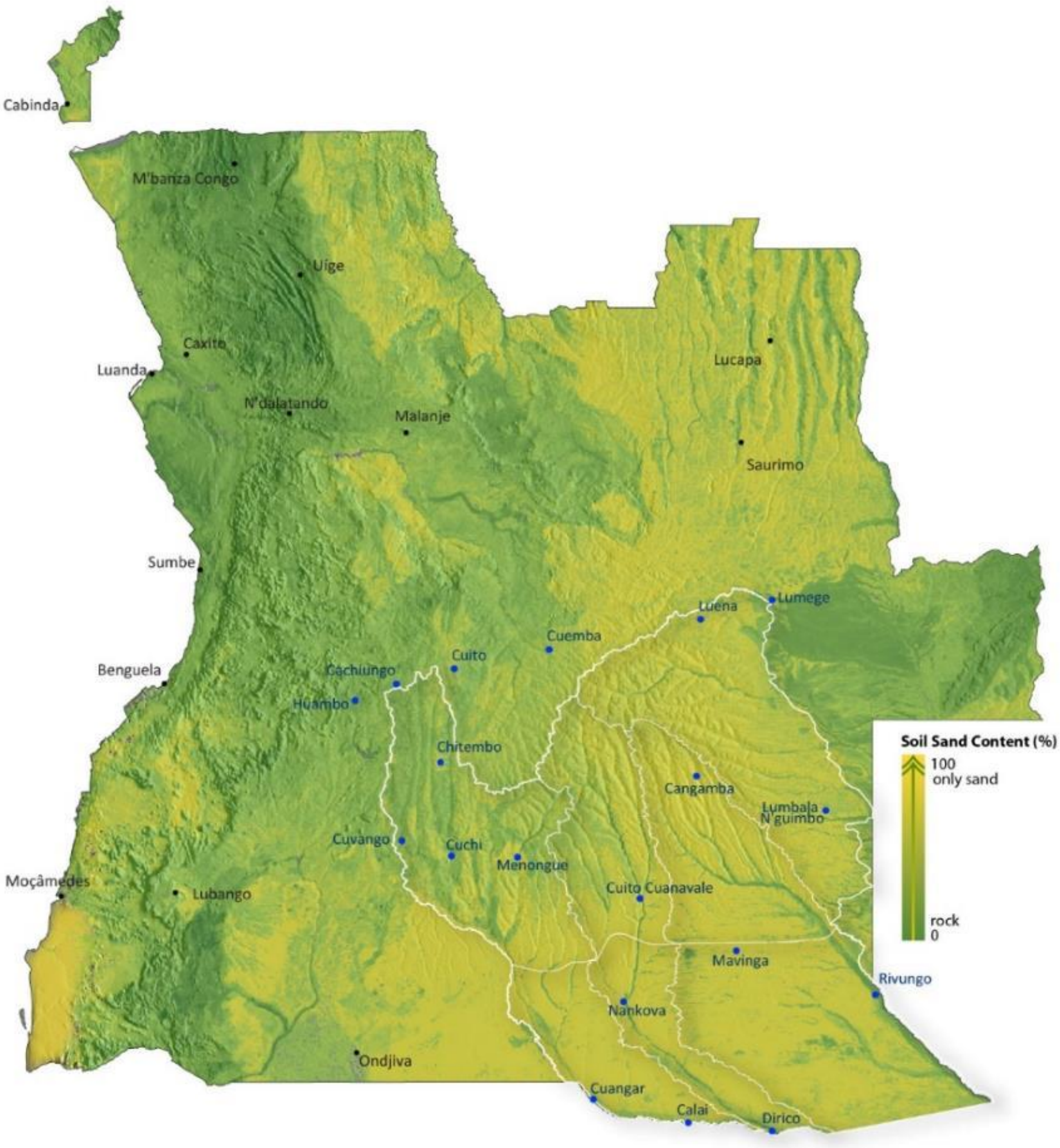


Figure 10: The distribution of sand in Angola. Source: https://soilgrids.org

Sand is the coarse textured mineral fraction of soil, its main minerals being quartz and feldspar. Soils with a high content of sand are often dry, nutrient deficient and fast draining systems. They have low Cation Exchange Capacity (CEC), which means that sands have a very low capacity to store nutrients. Large pore spaces in sandy soil result in easy drainage and low capacity to retain water. For this same reason, sandy soils have little or no ability to transport water from deeper layers through capillary transport. Tillage serves little or no purpose because moisture in the seedbed is easily lost. The only way to improve the capacity of sand to store nutrients and water is to add organic material.

Much of the eastern half of Angola has soils with a high sand content (>60% of soil composition). All these areas support few people because yields are low, and crops limited to hardy cereals such as millet and sorghum in the south and manioc in the north. Farming is typically of a subsistence nature, and crop produce is not for sale because production is low, demand is low as a result of the small population, and the need to store surpluses to avert future shortages is high. Sands are characterised by low input – low put farming systems.

Organic carbon

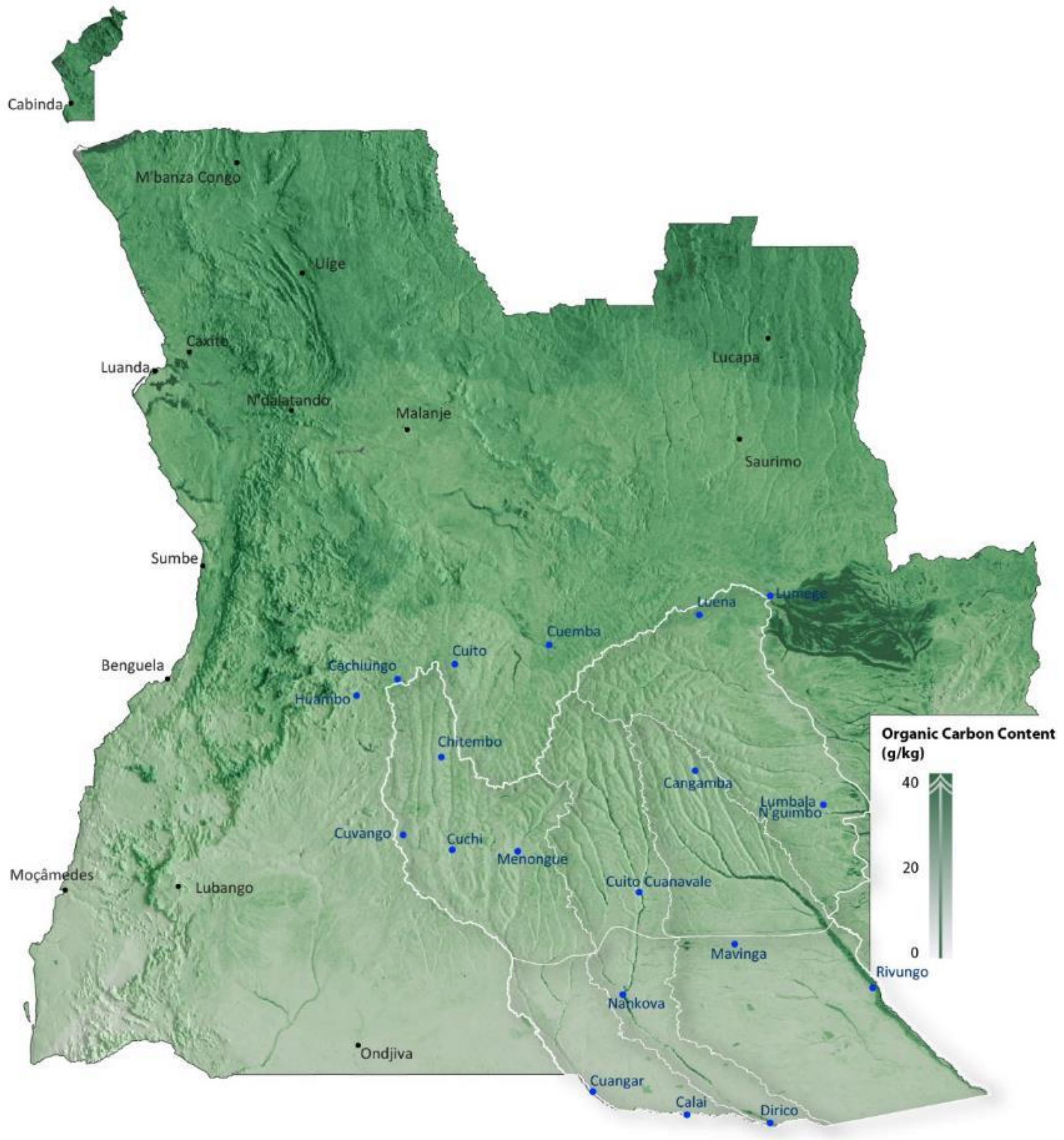


Figure 11: The distribution of Soil Organic Carbon in Angola. Source: https://soilgrids.org

Organic Carbon is the main source of energy for soil microorganisms, and is one of the most important constituents in supporting plant growth as a source of energy, making available nutrients through mineralization, providing aggregate stability, and holding nutrients and water.

A direct effect of low Soil Organic Carbon is reduced microbial biomass, and microbial activity to mineralise nutrients. In non-calcareous soils (which include the majority of Angolan soils), aggregate stability, infiltration, drainage, and airflow are also reduced. Scarce Soil Organic Carbon results in less diversity in soil biota which can disturb the soil environment, and cause increases in pests and disease, for example.

Soil Organic Carbon is usually very low throughout Angola, and almost absent in the south-eastern catchments. However, significant organic carbon levels may be present in Fluvisols deposited by flooding in river valleys.

Nitrogen

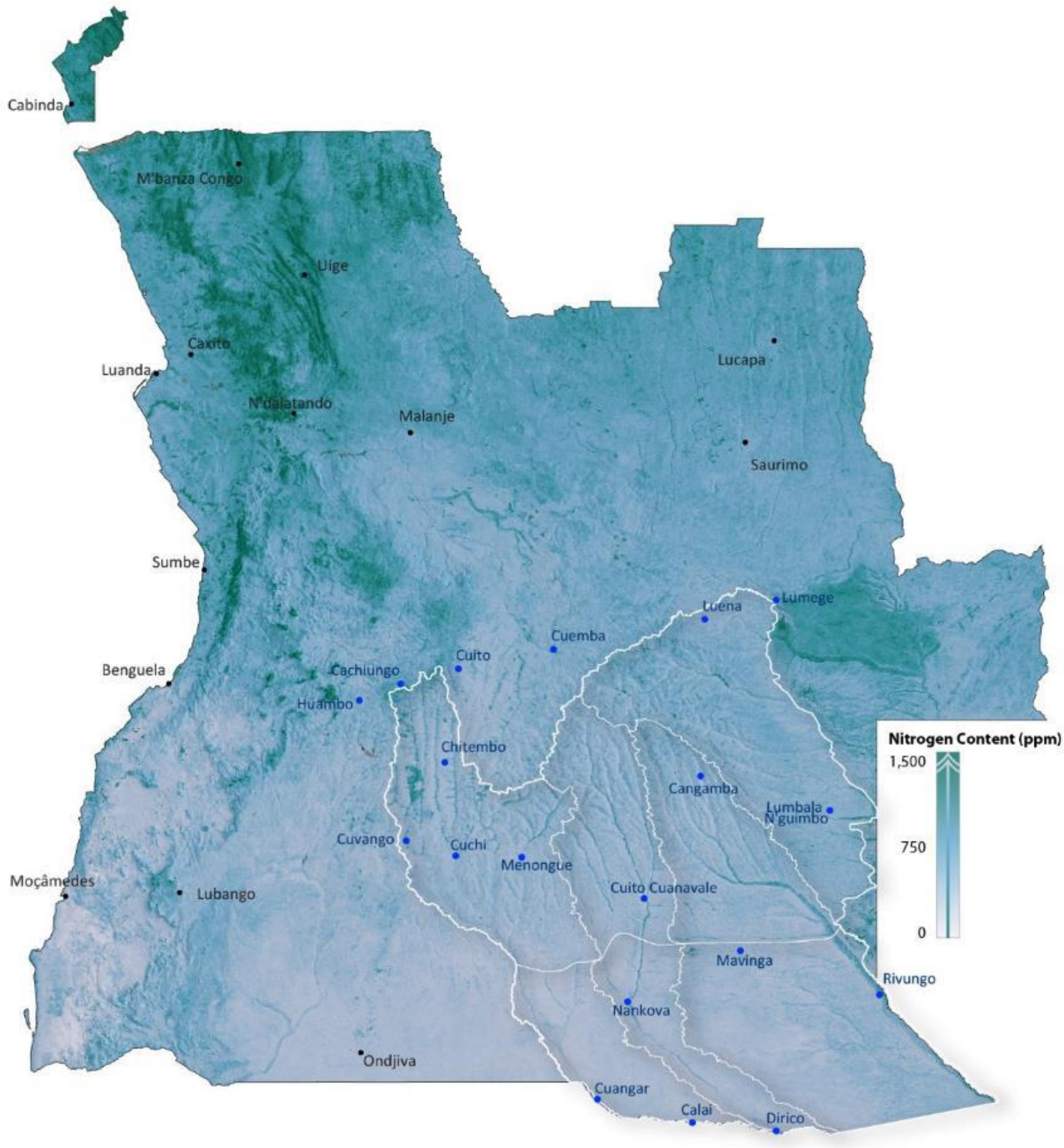


Figure 12: The distribution of soil nitrogen in Angola. Source: https://soilgrids.org

Microbes mineralise and thus transform organic nitrogen into inorganic forms (such as nitrate and ammonia) which can be used by plants. Mineralisation happens during the rainy, warm growing season, thus providing plants with a steady supply of nitrogen.

Nitrogen is present as positively charged ammonium ions (NH_4^+) or negatively charged nitrate (NO_3^-). Ammonium ions are not mobile and are intermediaries in the conversion of organic Nitrogen into nitrates, which are highly mobile in the soil. Nitrates can therefore move readily towards plant roots, but they can also be leached out of reach of plant roots. Sandy Arenosols are the most prone to nitrate loss through leaching.

The organic nitrogen content of soils is low throughout most of Angola. Nitrogen is usually associated with organic matter in the topsoil, and organic nitrogen is soon depleted once forest is removed and fires become frequent.

Cation exchange capacity

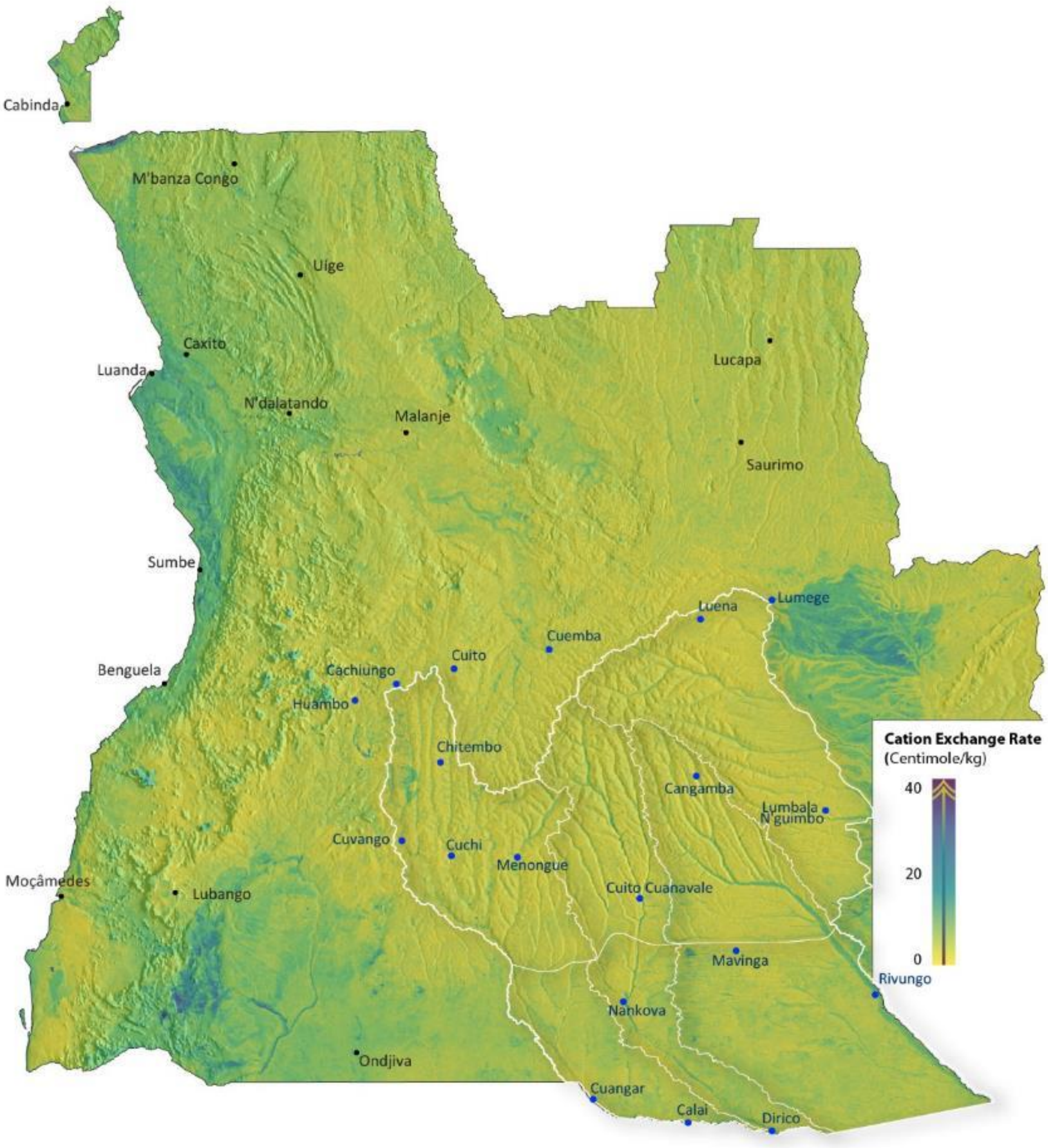


Figure 13: Cation exchange capacity (CEC) in Angola. Source: https://soilgrids.org

Cation exchange capacity (CEC) is the total capacity of a soil to hold exchangeable cations which influences the soil's ability to hold onto essential nutrients. It is an inherent soil characteristic and difficult to alter significantly. Soils with a higher clay fraction and organic matter content tend to have higher CEC, which also buffers against soil acidification. Sandy soils (with almost no clay) rely heavily on the high CEC of organic matter for the retention of nutrients in the topsoil.

The clay mineral and organic matter components of soil have negatively charged sites on their surfaces which adsorb and hold positively charged ions (cations) by electrostatic force. This electrical charge is critical for the supply of nutrients to plants because many nutrients exist as cations (e.g. magnesium, potassium and calcium). In general terms, soils with large quantities of negatively charged particles are more fertile because they retain more cations. The main ions associated with CEC in soils are the exchangeable cations calcium (Ca2+), magnesium (Mg2+), sodium (Na+) and potassium (K+), which are generally referred to as the base cations. In most cases, summing the analysed base cations gives an adequate measure of CEC.

Soils dominated by clays with variable surface charges are typically strongly weathered, such as Ferralsols. Their fertility declines with decreasing pH which can be induced by clearing and agricultural practices. The lower the CEC of a soil, the faster the soil pH will decrease with time.

Soils with a low CEC are more likely to develop deficiencies in potassium (K+), magnesium (Mg2+) and other cations while high CEC soils are less susceptible to the leaching of these cations. In Angola CEC is usually low, due to the dominance of acidic Ferralsols and Arenosols. It is in the young soils in river valleys that higher values of CEC can be found.

4. Rivers and surface hydrology

The catchments of all the rivers that flow through KAZA are to the north, in Angola and Zambia, where they span some 1,200 kilometres from East to West, and lie between about 11.5 and 17.5 degrees South.

Figure 14: The catchments of rivers flowing through KAZA

For purposes of this study, the catchments were divided into a number of zones. In Angola, from west to east: the upper and lower catchments of the Cubango, Cuito and Cuando Rivers, and the western Zambezi catchment. These are the zones covered by RAISON's assessment of biophysical and socio-economic conditions, while Pegasys provided equivalent information for the Zambezi River's Bulozi and Zambian catchment zones. Little information is as yet available for the Bulozi Floodplain (Mendelsohn & Weber 2015, Zigelski *et al*. 2018).

The upper and lower catchments of the Cubango, Cuito and Cuando, respectively separate areas that are steeper and more elevated (see page 8) with surface flows that are more permanent, from those in the lower areas that are much flatter, with more ephemeral tributaries. Most flows of water into KAZA therefore come from the upper catchments, while supplementary flows from the lower catchments only follow extremely wet periods.

The complementary roles and functioning of these rivers and catchments are considerable. For example, the western Zambezi in Angola produces a steady flow of water, while river discharges from the Bulozi and Zambian zone are more episodic and variable. How these complementary flows support downstream wetlands – such as the Barotse Floodplains – remains to be understood. The complementary roles of water supplied to the Okavango Delta by the Cubango and Cuito Rivers are described below.

Cubango

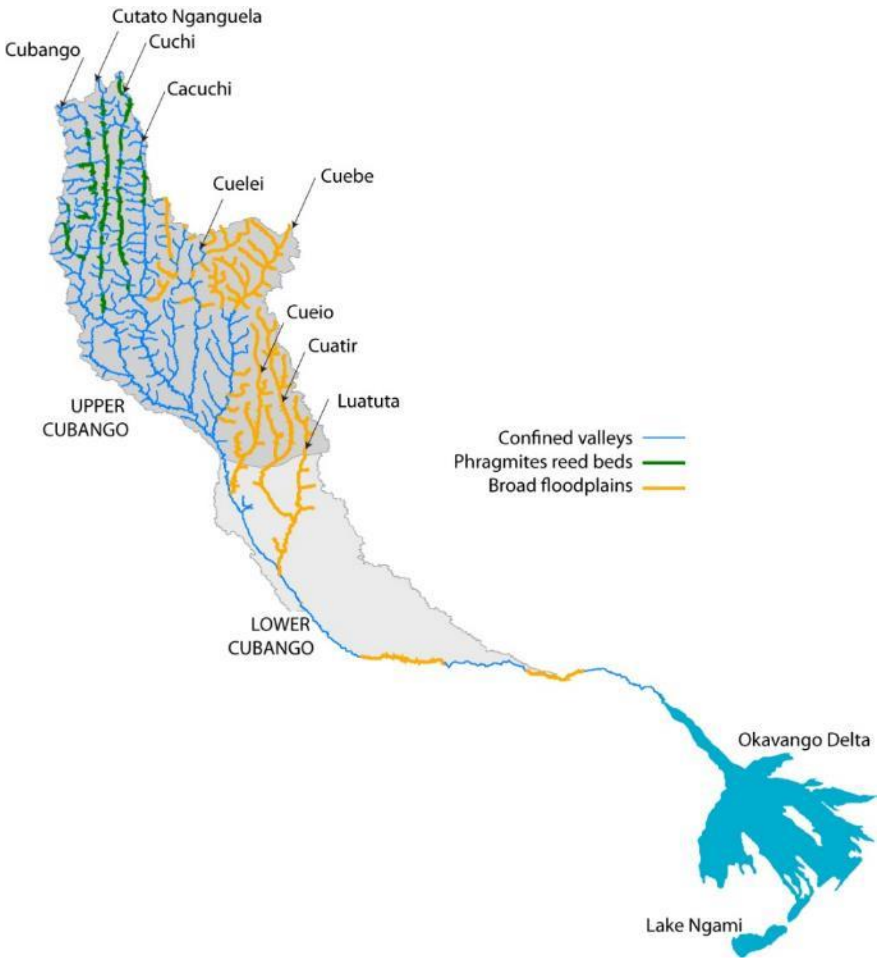


Figure 15: Rivers and sub-catchments of the Cubango

The Cubango is divided into two quite separate groups of rivers. The first group is to the west and farthest north. From here, the Cubango, Cutato Nganguela, Cuchi and Cacuchi rivers flow southwards, parallel to each other. They originate off the highest elevations at about 1,700 metres above sea level, from areas underlain by extremely old meta-sediments and igneous rocks that formed at least 2 billion years ago. The rock formations have since been weathered into gently rolling hills. Most soils are derived either from these rocks – and are thus old, weathered and leached – or are sandy sediments deposited there by wind.

Rural populations in the headwaters of this first group of rivers are denser than anywhere else in south-eastern Angola (see page 53). This is for several reasons: the area's soils are somewhat more fertile (with more Acrisols and Gleysols than the Arenosols and Ferralsols that predominate elsewhere); services and commercial activities associated with the nearby and long-established trade and communication routes are present, as are large towns (Huambo, Cuito, Cachiungo, and Chinguar); and the rainfall is higher and the climate cooler in these highlands. Possibly, the area also has a lower disease burden.

All four rivers have comparatively steep gradients, their flows accelerate in places where the rivers tumble down rapids or small waterfalls. The Cubango's flow is most even, generally following a fairly straight course. In a few places, however, the river meanders through sizeable beds of phragmites reeds. Similar meanders and reed beds are much more extensive and characteristic of the Cutato Nganguela and Cuchi rivers, and to a lesser extent the Cacuchi. Observations from aerial and ground surveys of these rivers in July 2018 suggested that the reeds may 'clean' the water, since both rivers appear much murkier in their upper than their lower reaches. The reed beds may thus trap and filter out materials in the water, including suspended solids, minerals and pollutants.

Elsewhere, these four rivers flow along fairly shallow, but confined valleys, often with stretches of riparian forest alongside. This separates them from most of the second group of rivers, which are to the east: the Cuelei, Cuebe, Cueio, Cuatir and Luatuta. These largely drain sandy substrates, and their courses are often flanked by broad floodplains, of grasslands and some beds of peat close to the actual river lines. Water flows are generally slower and vary less during the year than those of the first group to the west and north. The chemistry of the eastern rivers probably differs as well, in all likelihood being more acidic but also cleaner with lower TDS (total dissolved solids) and conductivity levels than in the Cubango and its associated rivers.

The two groups of rivers probably also provide complementary supplies of water: fast, episodic and probably with more minerals from the west; but cleaner, slower and more stable from the sandier eastern areas.

Flows from the upper Cubango also complement those from the Cuito in a way that has particular value for the Okavango Delta in Botswana. The Delta broadly consists of three wetland environments: permanent swamps, and seasonal and occasional floodplains. The permanent swamps provide stable habitats for plants and animals, which live there from year to year with little new production. The steady flows of the Cuito River do much to maintain these permanent waters and their life, especially in the dry season when the Cubango's levels are low (see page 33).

It is following good rains in its upper catchment that the Cubango contributes vital pulses of floodwaters to the Delta, in particular to its seasonal and occasional floodplains. They remain dry and dormant until the arrival of floodwaters that then trigger great flourishes of production. Plants germinate and grow, the dormant eggs of all kinds of tiny aquatic animals hatch, frogs emerge from the ground beneath, fish swim in to spawn, birds fly in to feed and nest, and all sorts of mammals move in to feast, fatten and breed. Indeed, it is during these periodic floods that much of the Delta's rich biodiversity is produced (Mendelsohn *et al*. 2010). Little of that would happen in the absence of floodwaters coming from the western upper Cubango catchment.

Albeit on a more localised and less familiar scale, the same kind of episodic production occurs in seasonal and ephemeral floodplains along the Cubango/Okavango River. Unfortunately, the existence or importance of these flooding processes have not been recognised in major development and strategic plans, as well as studies of environmental flows in the Okavango Basin. Several references are provided at the end of this report for those interested in understanding more about the importance of periodic flooding and floodwaters (see Cronberg *et al*. 1996, Hogber *et al*. 2002, Krah *et al*. 2006, Lindholm *et al*. 2007, and McCarthy *et al*. 2002).

Cuito

Figure 16 The upper and lower catchments of the Cuito and its major tributaries.

The Cuito's catchment lies immediately east of the Cubango catchment. However a large block of land between the northernmost sections of these two catchments has been captured by the Cuanza River which flows first to the north and then on to the coast, south of Luanda, where it has a base level at its mouth. As a result it has more erosive power, and that has progressively captured parts of both the upper Cubango and Cuito catchments.

The Cuito and Cuanavale have their sources far to the north, at elevations around 1,400 masl. The two rivers flow southwards, in parallel, up to their confluence at the famous town of Cuito Cuanavale, which lies at 1,250 masl. From there, the Cuito continues south for 140 kilometres to the town of Nankova where it is joined by the Longa, bringing with it flows from the Luassinga and Cuiriri Rivers which joined the Longa upstream. After Nankova, no regular or substantial tributaries flow into the Cuito. Close to Dirico on the Namibian border, the Cubango converges with the Cuito River.

The entire Cuito catchment is underlain by sandy, highly permeable and infertile soils. With the exception of small waterfalls – far to the north along the Cuito and Cuanavale, and then again immediately north of the Namibian border – all its component rivers meander across flat, grassy floodplains. These are often underlain by peat close to the drainage courses. Swathes of grassland that extend away from the rivers become increasingly shrubby and woody (mainly with so-called underground trees or geoxylic suffrutices) as elevations rise. These grasslands are located mainly in the upper catchment, and are probably maintained largely by frequent fires, and – in places – by hardpans which cause the upper soil layers to be saturated during wet periods.

Six major source lakes have been identified in the uppermost catchment areas: the Cuito, Cuanavale, Limpulo, Mbambi, Cunde and Calua lakes.

Cuando

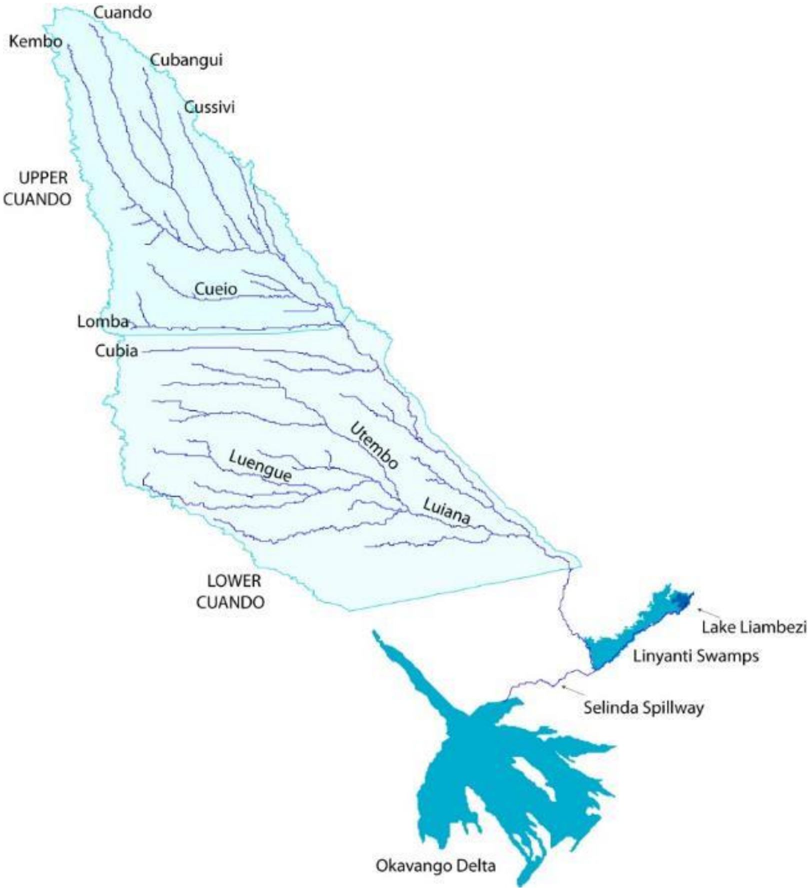


Figure 17: Rivers and sub-catchments of the Cuando

The Cuando is the most natural, undisturbed and enigmatic river in southern Africa, perhaps in all of Africa. Its lowermost reaches in Namibia, its inland delta (Nkasa Ruparo), and its terminal swamp (Linyanti) shared with Botswana, are known to tourists and many other people. Yet the entire Cuando catchment in Angola is remote and familiar only to its residents. All of the catchment upstream of the Namibian border lies within Angola. This is because the Zambian border runs along eastern edge of the Cuando. The river and its entire floodplain thus lie in Angola, even though numerous Zambians have settled in villages along the eastern margins of the floodplain and even on islands deep within the floodplain. There are only three significant towns on the Cuando River: Cangamba and Rivungo in Angola, and Shangombo on the Zambian side opposite Rivungo. Lake Saliakembo is the only major source lake currently known in the upper Cuando.

Perhaps the most unusual aspect of the Cuando is its structure and hydrological functioning. Average flow rates at Kongola (the only place along the entire river where water flows are measured) are 33.9 cubic metres/second, which is equivalent to just over one billion cubic metres per year. No flows of any significance enter the Cuando below Kongola, thus all the water in the Cuando, as represented by these figures – comes from Angola.

Of all the rivers in Angola, the Cuando has the most extensive abundance of macrophytes, which must be supported by substantial nutrient supplies. But from where could these nutrients have come, given that soils throughout the Cuando's catchment are so infertile (see page 13)? The most likely explanation is that the minerals were derived from basaltic rocks upstream along the Cuando, Kembo, Cubangui and Cussivi Rivers where there are outcrops of Calondo rocks (see page 7). In addition, other rich sources of nutrients may lie west of the main Cuando, for example in areas along the Cueio and Lomba Rivers. This possibility is suggested by the presence of alluvial diamonds along those rivers, which might be derived from local kimberlites.

Zambezi

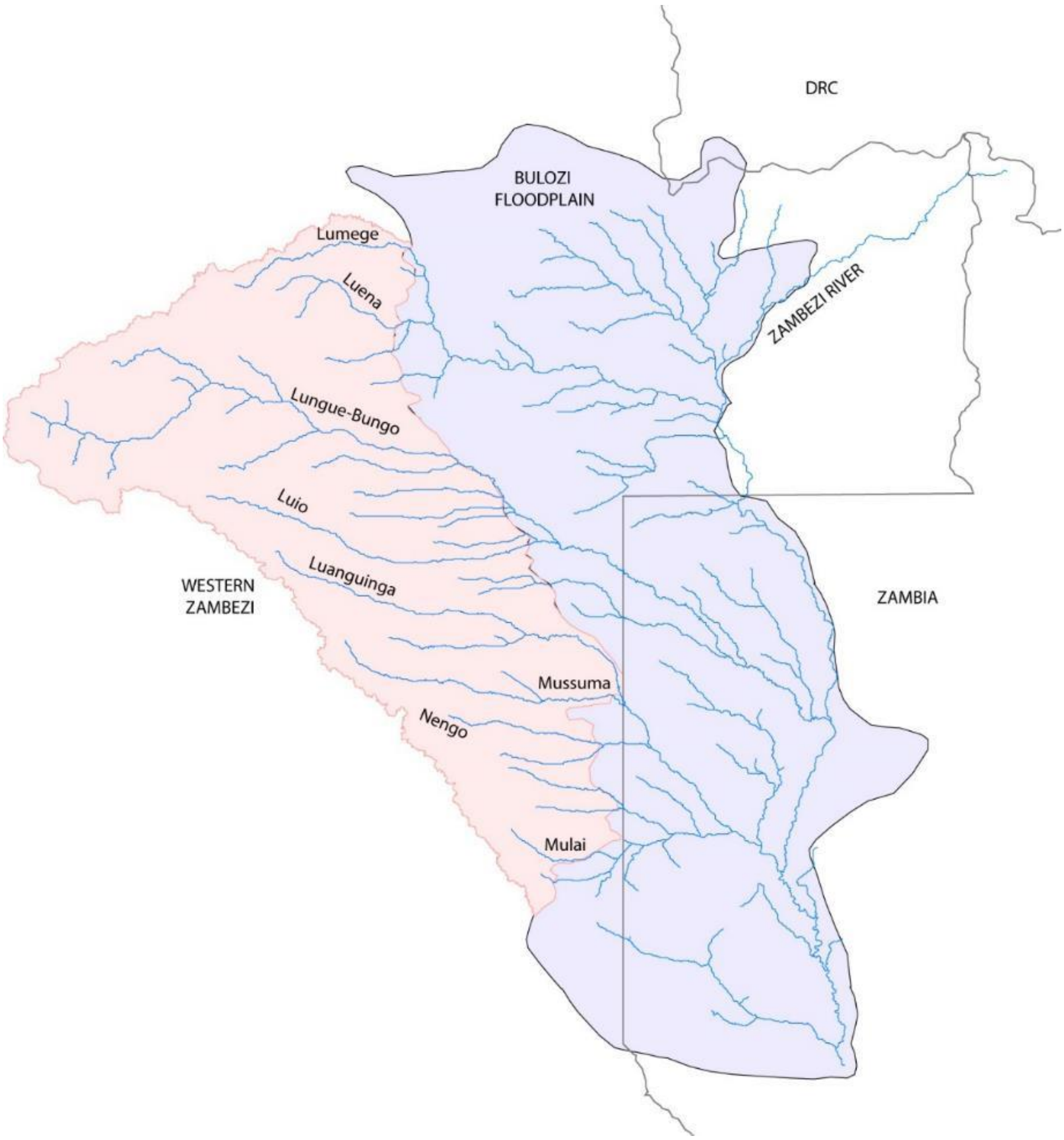


Figure 18: Rivers and sub-catchments of the Zambezi west catchment

Although the Zambezi river system is normally and popularly associated with Zambia, its western catchment in Angola is substantial, and probably has, at least, dual significance for the downstream functioning of this great river. First, the sandy highlands of the western Zambezi operate as a giant sponge that stores and gradually releases steady flows into the major rivers, such as the Luena, Lungue-Bungo and Luanguinga that later feed the Zambezi. It is important to assess these volumes to understand their total annual contribution to the upper Zambezi, as well as the proportions of the upper Zambezi's discharge they make up at different times of the year. These flows may be significant, especially during the dry season when water from Angola may do much to support perennial wetlands along the Zambezi, such as the Barotse Floodplains.

A second feature concerns the role of the western rivers in contributing to the seasonal inundation of the Bulozi Floodplains, when they become a massive and probably important breeding ground for the upper Zambezi's fish populations. The western rivers may also maintain year-round water levels in *refugia* for adult fish within this flat nutrient-rich expanse. Three source lakes have been identified in the Zambezi west catchment: Lakes Tchanssengwe, Dala and Sapua.

Recharge and discharge

Comparatively little is known about mechanisms of recharge and discharge in the catchments. Water levels and flows have only been measured at Rundu (for the Cubango), at Andara and Mohembo (for the Okavango as it enters its Delta) and at Kongola (for the Cuando) in recent times. Because no tributaries join the Cubango downstream of Rundu or after its confluence with the Cuito, the Cuito's discharges can be estimated by subtracting measures at Andara/Mohembo from those at Rundu. To our knowledge, no flow measurements are available for the Zambezi's tributaries in Angola.

It is fair to assume that rivers in the upper Cubango are recharged rapidly by rainfall because rock surfaces are exposed in places, and many of the soils are shallow and less permeable than in other areas. These surges of water are also apparent from the large seasonal changes in discharge from this river. The same assumption cannot be made elsewhere, or in the other rivers, however. The deep, permeable soils throughout the rest of the catchments (mainly Arenosols and Ferralsols) mean that all rain sinks into the ground, only to emerge later as seepage into tributaries. How much later is unknown, as are variations in duration between rain and recharge.

Likewise, we can only speculate about the mechanisms that produce seepage into tributaries. The image in Figure 19 below shows the bottom and centre of a large amphitheatre-like valley where loose sands have slumped when and where water seeped out at the base of a slope. Erosion in this particular slump has been accelerated recently by the removal of plant cover by residents in Luena, but its shape, size and probably functioning are equivalent to hundreds of similar extensive gullies that occur in the more elevated and incised areas of the sandy upper catchments of the Cuito, Cuando and Zambezi. Most slumps are completely vegetated, but examples of large recent gullies are to be seen at Lake Tchanssengwe (18.64 East, 12.42 South), at 19.32 East, 11.80 South, and at 18.99 East, 12.22 South. These recent slumps are likewise devoid of vegetation, but in these cases as a result of natural slumping, erosion or landslides.

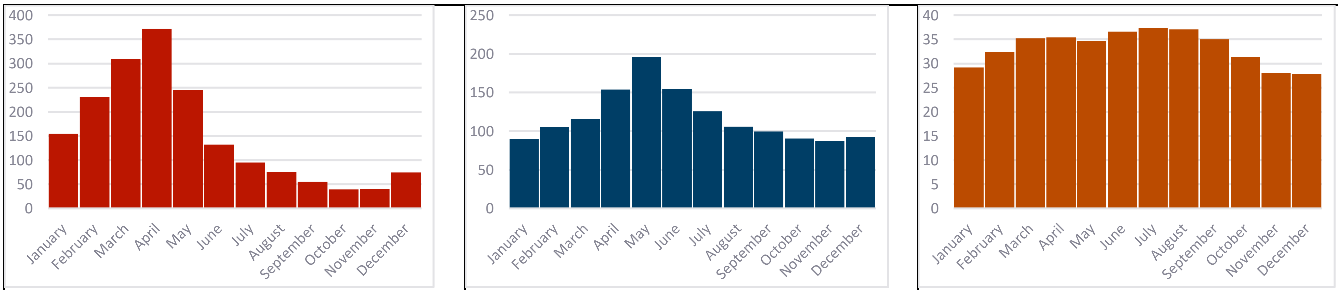
Figure 19. Slump and erosion gully at Luena (19.93 East, 11.78 South). The image was taken in May 2018, showing upper levels of ground water saturation in 2018, 2013 and 2003. The top of the saturated zone is about 60 metres below the surrounding plateau.

What the slumps seem to reveal is seepage of water at a particular level, probably where a hardpan limits groundwater from permeating deeper. Water is thus forced to move laterally and out of the ground, if and where there is a slope. Presumably, the hardpan at the base of the gully is stable, and so the dark zones in Figure 19 indicate areas of wet or saturated soil. The upper limits of saturation vary from year to year, as seen in images taken in 2003, 2013 and 2018. Between those years, the thickness of the saturated zone varied by about 6 to 10 metres.

There are major differences in the volumes and timing of discharge between the Cubango, Cuito and Cuando. For example, the Cuito supplies about 45% of all the water flowing into the Okavango Delta, with the remaining 55% coming from the Cubango. However, these proportions vary during year. Thus, the Cubango supplies about double the Cuito’s volume water between January and June, whereas the reverse holds when Cubango flows are lowest from July to December when the Cuito’s discharge is about double that of the Cubango.

The total annual discharge of 1.068 billion cubic metres by the Cuando is almost 4 times lower than that of the Cuito. This is surprising because their catchments are similar in size and lie side-by-side, sharing much the same upper topography, soils, rainfall and geomorphology. However, in the lower catchment areas their structures differ greatly: the Cuito meanders across grassy floodplains that are seldom wider than one or two kilometres, while the Cuando’s meandering path is across a floodplain generally 10 or more kilometres wide. Moreover, the Cuando’s floodplain supports vast areas of phragmites reeds, papyrus and tall grasses. Evaporation and transpiration from the Cuando are therefore probably greater than from the Cuito, and this is perhaps the best speculative explanation for the two rivers discharging different volumes by the time they reach the southern border of Angola.

The Cuando’s flows are also slower than those of the Cuito, and very much slower than the Cubango’s. Peak flows along the Cubango and Cuito reach the southern border of Angola in April and May, respectively; whereas the highest flows on the Cuando at Kongola are measured in July and August (
Figure 20). On average, these annual trends hold true for the Cubango and Cuito in most years, but not for the Cuando. The Cuando’s discharges vary considerably from year to year, as shown over 22 years when the Cuando’s flows were measured consistently (Figure 21). In some years, discharges peaked at the end of the year, suggesting that rainwater that fell in the upper catchment during the previous summer may have taken much of the year to reach Kongola. In other years, flows peaked towards the end of summer, perhaps as a result of local rains adding to river flows in the Kongola area.



Cubango	Cuito	Cuando

Figure 20: Average discharges in cubic metres per second along the Cubango (at Rundu), the Cuito (at Dirico) and Cuando (at Kongola). Note how Cubango flows vary much more than those of the Cuito, which – in turn – are much more variable than flows along the Cuando. Note the different scales of the y-axes. Data kindly supplied by the Hydrology Division, Ministry of Agriculture, Water & Forestry, Namibia.

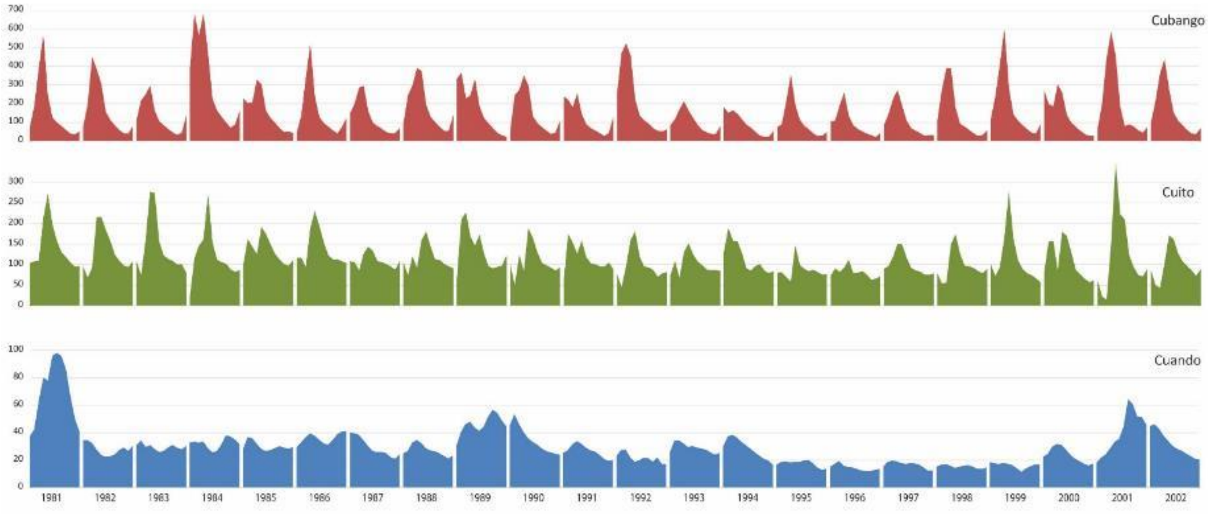


Figure 21: Discharges in cubic metres per second along the Cubango (at Rundu), the Cuito (at Dirico) and Cuando (at Kongola) between 1981 and 2002. Note the different scales of the y-axes. Each year runs from January to December. Data kindly supplied by the Hydrology Division, Ministry of Agriculture, Water & Forestry, Namibia.

Although the main Cubango, Cuito and Cuando rivers have many tributaries in their lower catchments, none of these water courses deliver much, or any water. While rainfall is somewhat lower than in the upper catchments, the water courses are dry mainly because of their soils and topography. Since all three lower catchments are extremely flat and sandy (see pages 8 and 22), most rain must seep away and disappear into deep aquifers, leaving little water to flow on the surface. Hydrological models need to be adjusted to account for the virtual absence of recharge in these lower catchments.

Mixing water

For much of the time the Cubango/Cuito, Cuando and Zambezi are discrete bodies of water, but they connect with each other when water levels are high. For instance, the Selinda Channel links the Okavango Delta and the Cuando's Linyanti Swamps. Water in the Zambezi spreads across the Eastern Floodplains and can flow along the Chobe River and Bukalo Channel into Lake Liambezi and then into Linyanti Swamps. The flows can be reversed so that Okavango, Cuito and Cuando water makes its way into the Zambezi. Flood water in the Cuando and Okavango Delta can flow into the Mababe Depression, or water from the Okavango and Cuito may fill Lake Ngami or reach Lake Xau and the Makgadikgadi Pans down the Boteti Channel.

Figure 22: The complex of interconnected wetlands formed from flows down the Okavango, Cuito, Cuando and Zambezi Rivers in north-eastern Namibia and northern Botswana. The Cuando is sometimes described as a tributary of the Zambezi, but Cuando water only rarely flows far enough through the Linyanti Swamps, Lake Liambezi, the Chobe Swamps and River, ultimately to reach the Zambezi. Equally, Okavango water may reach the Linyanti through the Selinda Spillway or, conversely, Cuando water may flow west along the Spillway into the Okavango Delta. High water conditions which permit these connections have been recorded sporadically in recent years, such as in the early and late 1960s and again between 2008 and 2012. But river flows have also been very low. For example, Lake Liambezi and Lake Ngami were dry between the early 1980s and 2004.

Water chemistry

Expeditions of the National Geographic-Okavango Wilderness Project collected water quality measurements at daily stops during May to June 2017 on the Cubango River, and May to July 2018 on the Cuando River. In addition, measurements were taken in May 2018 in lakes at the sources of the Cuito and Cuanavale Rivers.

Total dissolved solids (TDS), salinity and conductivity are similar parameters of water quality, largely measuring the dissolved salt or ion content of water. Unsurprisingly, the three measures varied in similar ways along the Cuando. The lowest levels were close to the sources of the Cuando and Kembo, while the highest values were downstream in the lower catchment area of the Cuando and close to Zambia. Similar trends were observed along the Cubango, but with two exceptions. First, levels of salts and dissolved solids between the uppermost and middle reaches of the river rose more rapidly than along the Cuando. Second, levels also declined somewhat in the middle reaches south of Cuvango town, perhaps as a result of the diluting effects of water added by the Cacuchi, Cuelei, Cuebe and Cuatir Rivers. All these rivers largely drain sandy substrates (similar to those of the Cuando (and Cuito) and their waters are thus also likely to carry fewer salts and dissolved solids.

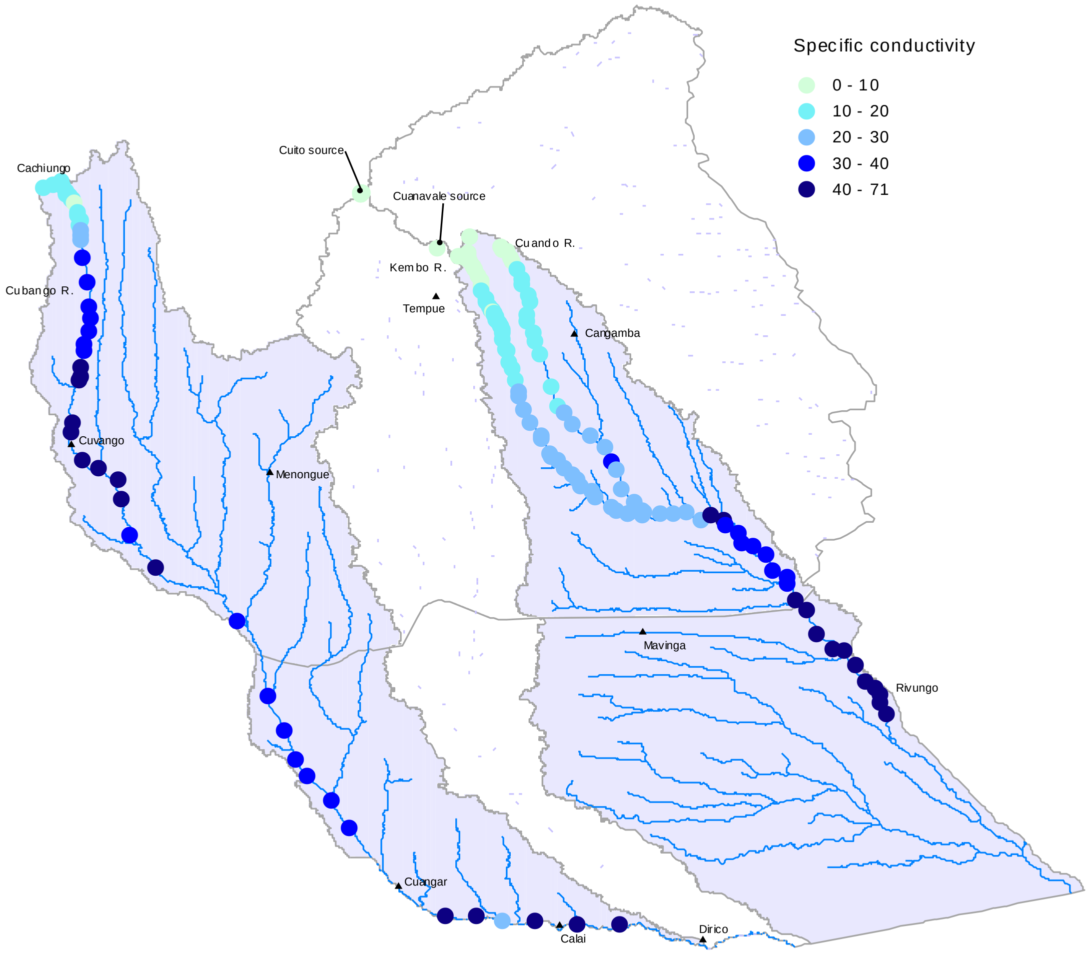


Figure 23. Measures of water conductivity (shown here as Specific Conductivity) along the Cubango varied between 8 and 44 µS/cm, and along the Cuando between 4 and 70 µS/cm. Distilled water typically has conductivity levels of less than 3 µS/cm, whereas tap water generally exceeds 50 µS/cm. Data kindly supplied by National Geographic-Okavango Wilderness Project

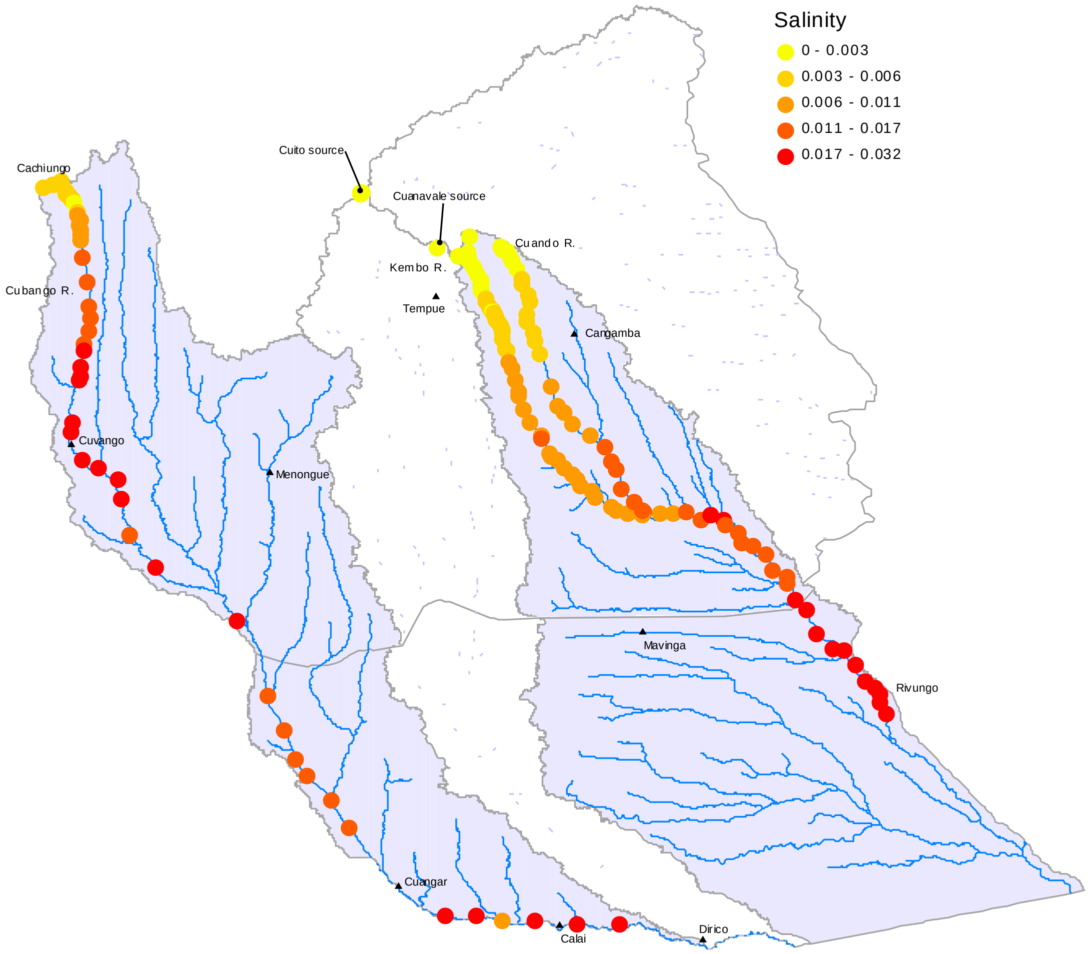


Figure 24. Salinity is measured in PSUs, short for Practical Salinity Units, which are approximately equivalent to parts per thousand. The lowest levels were about 0.002 and the highest about 15 times higher at 0.03. Even these higher salinity values are low compared to those in many freshwaters, and are about 1,500 times lower than in sea water. Data kindly supplied by National Geographic-Okavango Wilderness Project

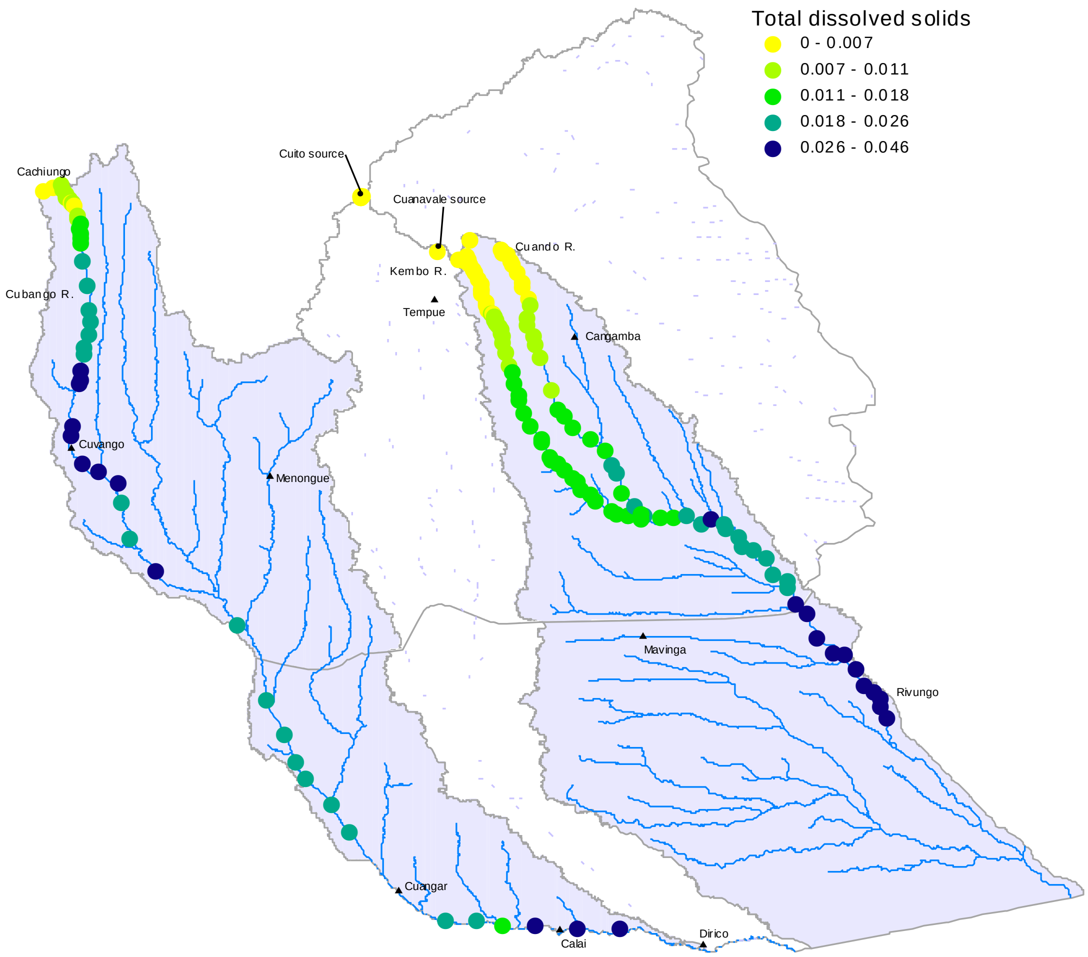


Figure 25. Total dissolved solids (TDS) is a measure of all the ion particles smaller than 0.0002 cm in the water. Unlike salinity and conductivity, TDS levels include dissolved organic matter – such as hydrocarbons and urea. These derivatives of organic processes may be associated with waste water or pollution, but are also products of plant decomposition in reed beds and peat etc. TDS values are expressed in ppt (parts per thousand) which are equivalent to milligrams/1000 per litre of water. The lowest TDS values (0.005 ppt) measured in the Cubango were at its source near Chicala Cholohanga, and the highest (0.029 ppt), above the river's confluence with the Cuito. Equivalent values ranged between 0.003 ppt in the source lakes and at the sources of the Kembo and Cuando to 0.046 south of Rivungo on the Cuando. All these values are typical of those found in very fresh or almost distilled water (https://www.fondriest.com/environmental-measurements/parameters/water-quality/conductivity-salinity-tds/#cond9). Data kindly supplied by National Geographic-Okavango Wilderness Project

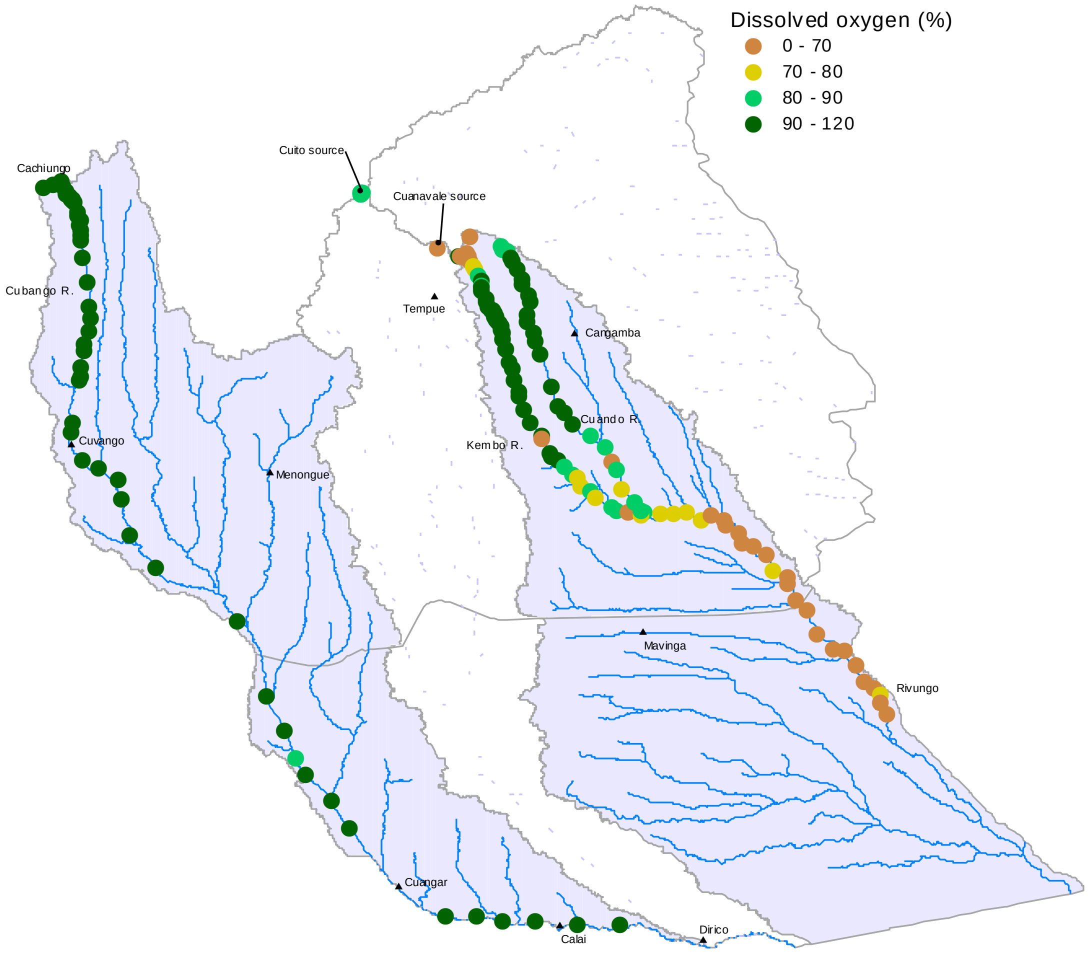


Figure 26. Measurements of dissolved oxygen reflect the volume of free oxygen dissolved in the water. This is oxygen as a molecule, and not oxygen chemically bound to other elements, such as the oxygen tied to hydrogen in water molecules. This map depicts values of dissolved oxygen measured as a percentage of possible saturation concentrations. While oxygen saturation levels varied little along the Cubango, generally exceeding 90%, there were major fluctuations along the Cuando and Kembo. Low saturation levels were measured close to the sources, but down the river, percentages rose rapidly to above 90% before progressively dropping again to less than 70% along parts of the river dominated by broad floodplains of phragmites reeds. Why oxygen levels should rise and fall so much along the Cuando's rivers is not clear. Data kindly supplied by National Geographic-Okavango Wilderness Project

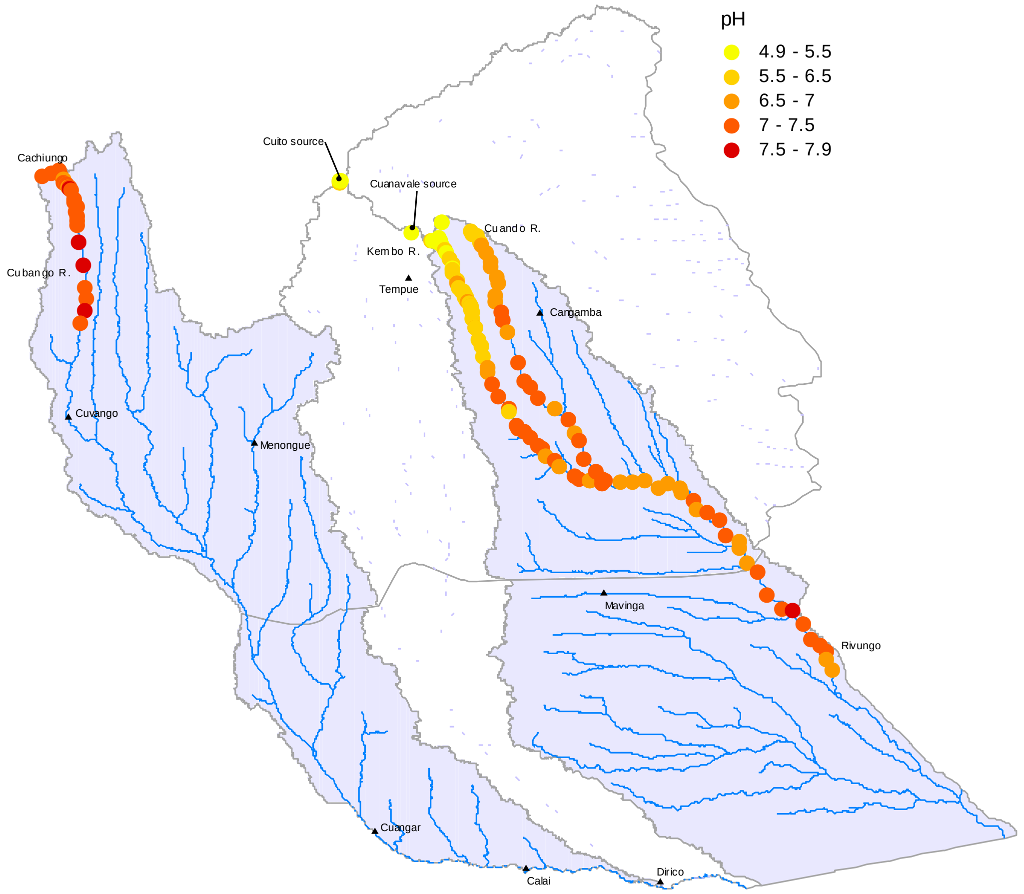


Figure 27. pH levels were close to neutral in the uppermost stretches of the Cubango (the sensor for pH then ceased to function for the remainder of that expedition). Water in the upper reaches of the Cuando and Kembo and in the Cuito and Cuanavale source lakes was extremely acidic, with pH readings often below 5.5. Thereafter, pH levels rose gradually to reach more neutral figures of between 6.5 and 7.5. Data kindly supplied by National Geographic-Okavango Wilderness Project

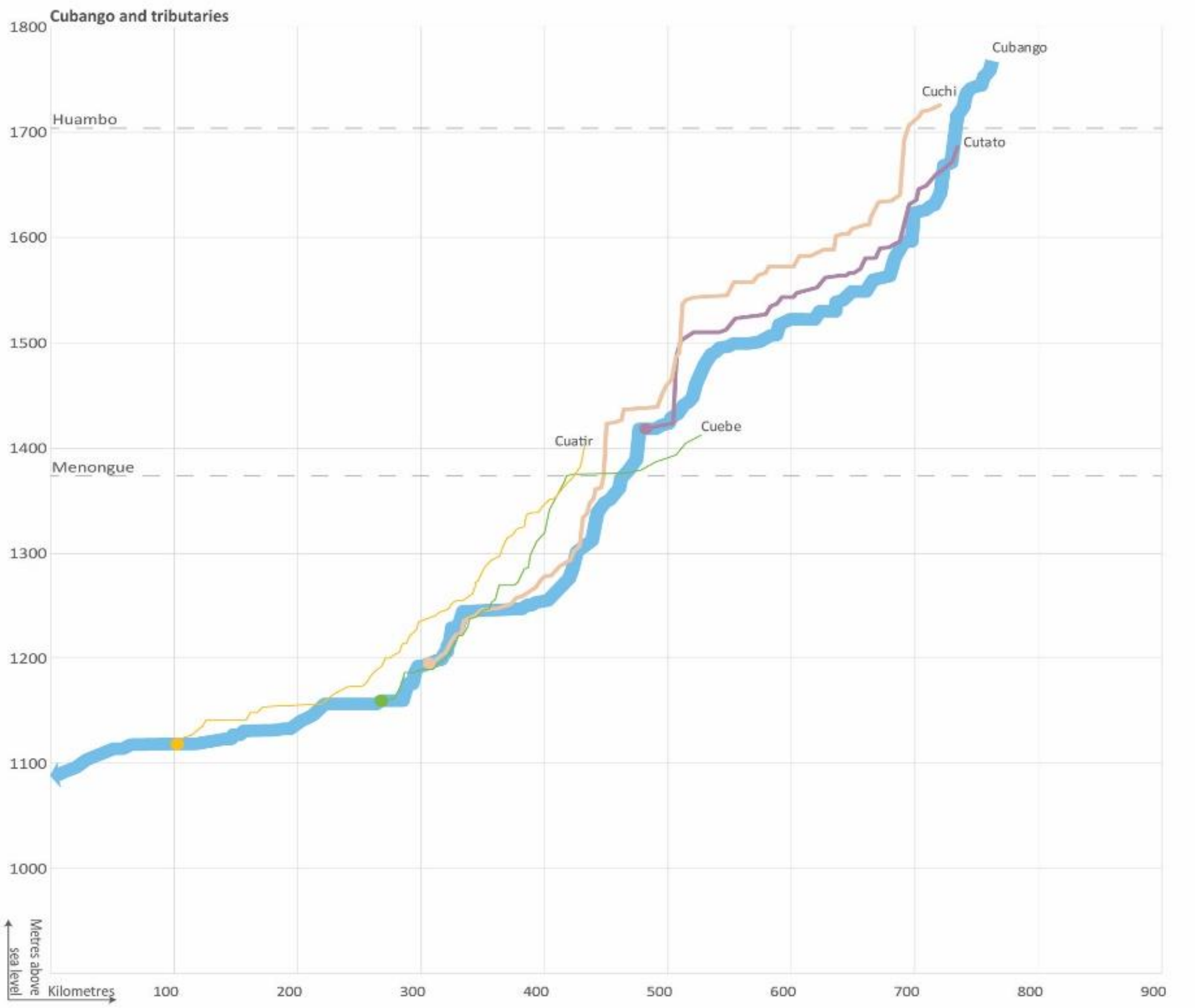
Soils in the headwaters of the Cuando (and doubtless the Cuito, Zambezi and even the Cuebe, Cuelei and Cuatir) are acidic in having low base cation contents, which is true in most parts south-eastern Angola (see page 22).

Gradients

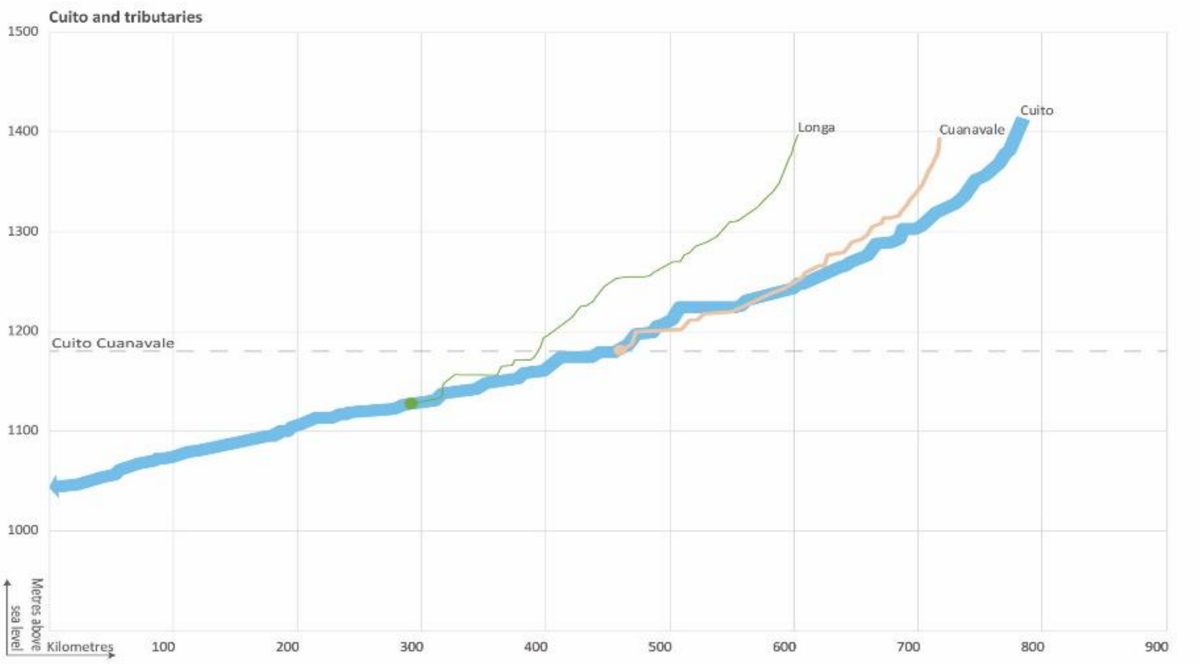
The profiles of the Cuito and Cuando rivers are similar. They, and their respective upstream sister rivers – the Cuanavale and Kembo – flow in parallel, from comparable elevations and with similar gradients until their confluences. While several other tributaries coming off similar elevations join the Cuando, only the Longa River later joins the Cuito. Interestingly, the Longa (and its major feeders – the Luassinga and Cuiriri) and the Cuito and Cuanavale all originate from similar elevations. And it is at these elevations that the Cuatir and Cuebe begin their courses before joining the Cubango. All these rivers come from, and mostly flow across very sandy substrates.

Within approximately 300 kilometres of their sources, the Cuito and Cuando drop about 210 and 250 metres respectively. By contrast, the Cubango and its associated parallel rivers (the Cuchi and Cutato Nganguela) drop about 400 metres over their *first* 300 kilometres.

These three rivers then flatten out, adopting more gradual flows and lower gradients. Thus, in their *last* 300 kilometres before reaching the southern border of Angola, the Cubango falls about 100 metres, the Cuito 90 metres and the Cuando only 70 metres. In other words, water in the Cuando falls only 23 centimetres per kilometre, or 0.23 millimetres per metre!



Cubango and tributaries
Cubango
Cuchi
Huambo
Cutato
Cuebe
Cuatir
Menongue
Metres above sea level
Kilometres
1800
1700
1600
1500
1400
1300
1200
1100
1000
100
200
300
400
500
600
700
800
900



Cuito and tributaries
Cuito
Longa
Cuanavale
Cuito Cuanavale
Metres above sea level
Kilometres
1500
1400
1300
1200
1100
1000
100
200
300
400
500
600
700
800
900

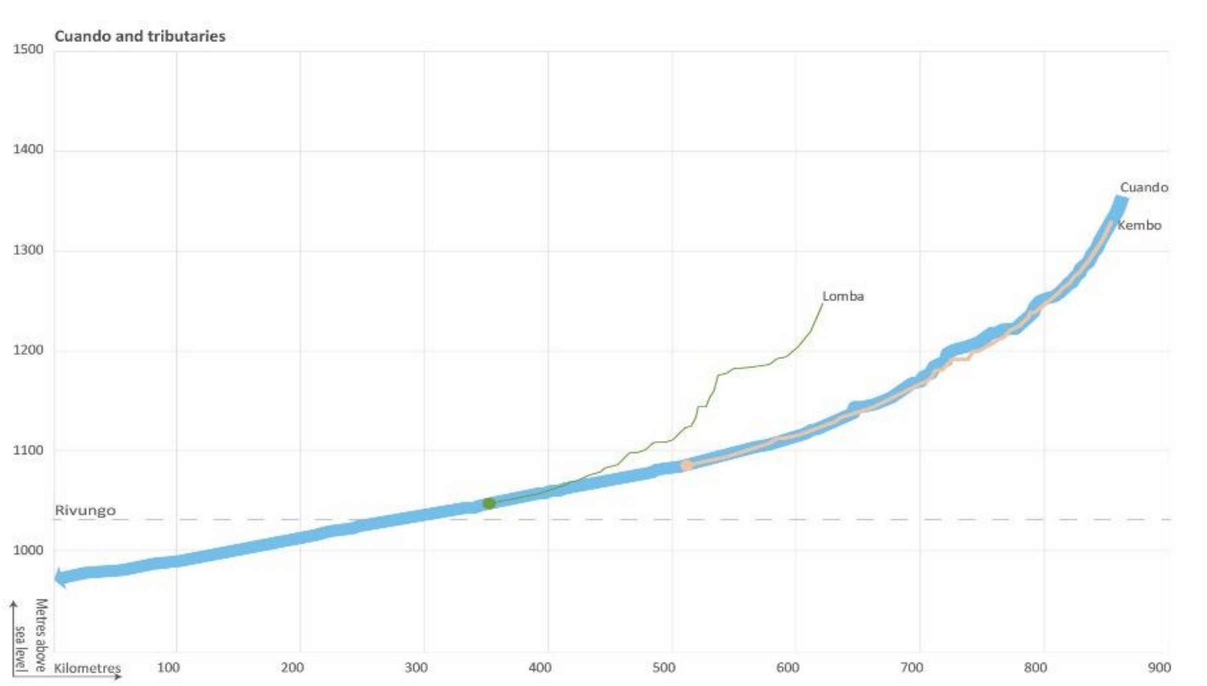


Figure 28: Elevational profiles of rivers of the Cubango, Cuito and Cuando systems running from their sources on the right to the southern border of Angola. The x-axis is the distance from the border to the sources, while the y-axis is elevation metres above sea level.

5. Biological resources

The division of the catchments into upper and lower zones was designed to focus on differences in their hydrological functioning. The upper catchments, together with the Zambezi west area, are on higher ground, with more topographical relief and higher rainfall than the flatter, drier and lower catchment areas to the south. Most river flow is expected from the northern, upper catchments, while in the south, the rivers function more as linear oases.

As may be expected, these zones correspond with quite different vegetation types and cover. The upper catchments are dominated by miombo woodland and forest, while open deciduous savannah characterises the lower catchments. Large, hot, dry season fires burn much of the lower catchments every year, while fires in the upper zones are smaller, less frequent and intense, and normally do not penetrate the dense miombo.

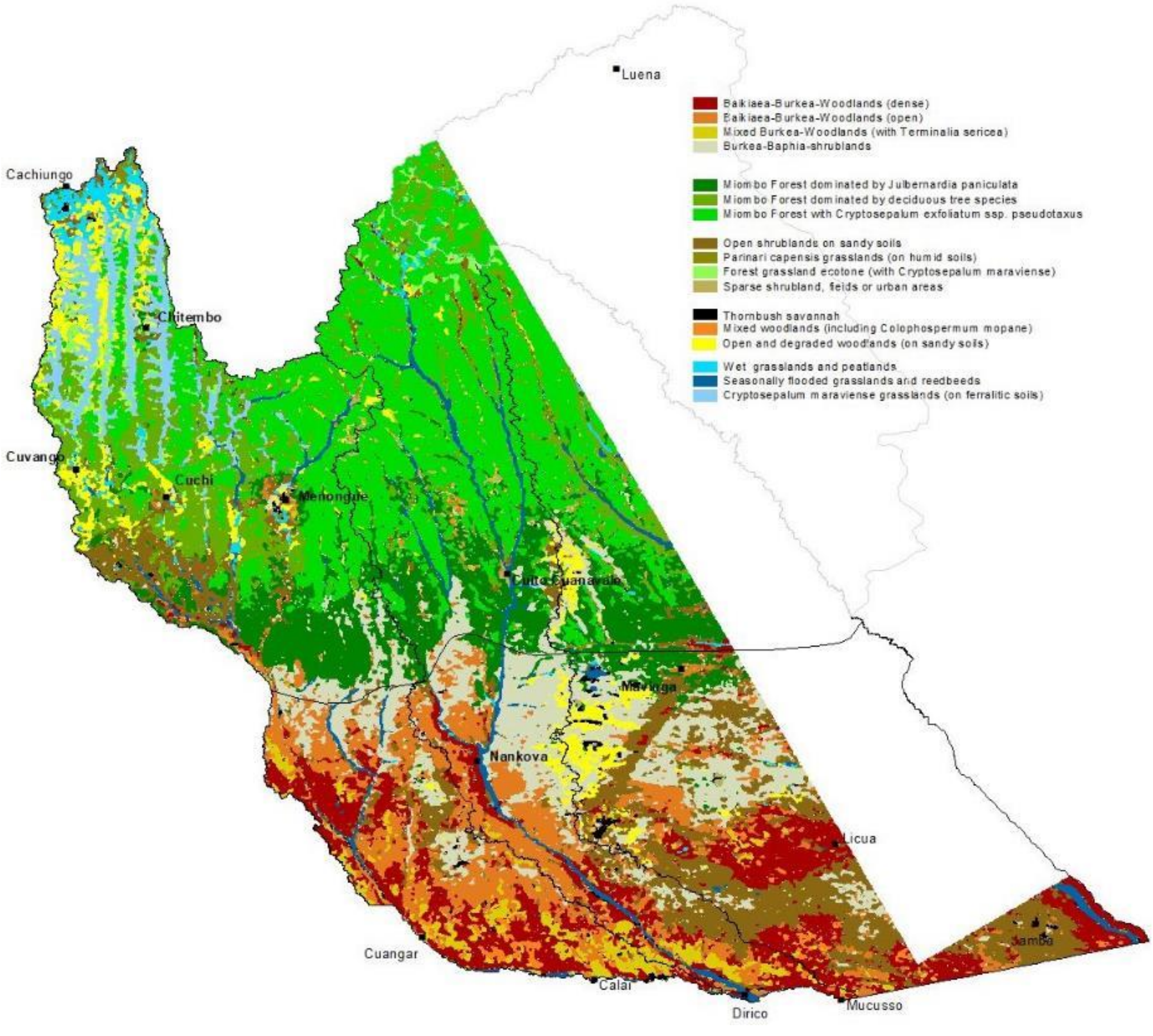


Figure 29. Vegetation types in the catchments of the Cubango and Cuito Rivers (adapted from Stellmes et al. 2013a and Revermann et al. *2018).*

Vegetation types

Broadly speaking, vegetation in the Angolan catchments can be separated into areas dominated by grasslands and trees. The grasslands are typically in areas that are saturated – at least sporadically – by flood waters or rainwater trapped on hardpans just below the surface. Grasslands in the densely populated north-western part of the Cubango catchment have probably evolved as a result of several reasons: from being saturated by rain or flood waters; as a result of emergent woody plants being killed by fire or frost; or from clearing for crops.

Trees in this area are indeed confined to those with underground growth forms, known as *geoxylic suffrutices*. Locally, these grassland-covered underground forests are called *ongote*. Some large areas of *ongote*, dominated by the colourful suffrutex *Cryptosepalum maraviense*, cover the sides of valleys in the upper Cubango.

Woodlands are divided between those known as miombo in the northern half of the area and the southern mix of savannahs and shrublands. A variety of *Brachystegia* species, *Julbernadia paniculat*a and *Cryptosepalum exfoliatus* characterise miombo, while the southern savannahs are dominated by *Baikiaea plurijuga, Burkea africana, Erythrophleum africanum, Terminalia sericea* and *Baphia massaiensis*. The savannahs are sometimes called Kalahari Woodlands or Burkea-Baikiaea woodlands.

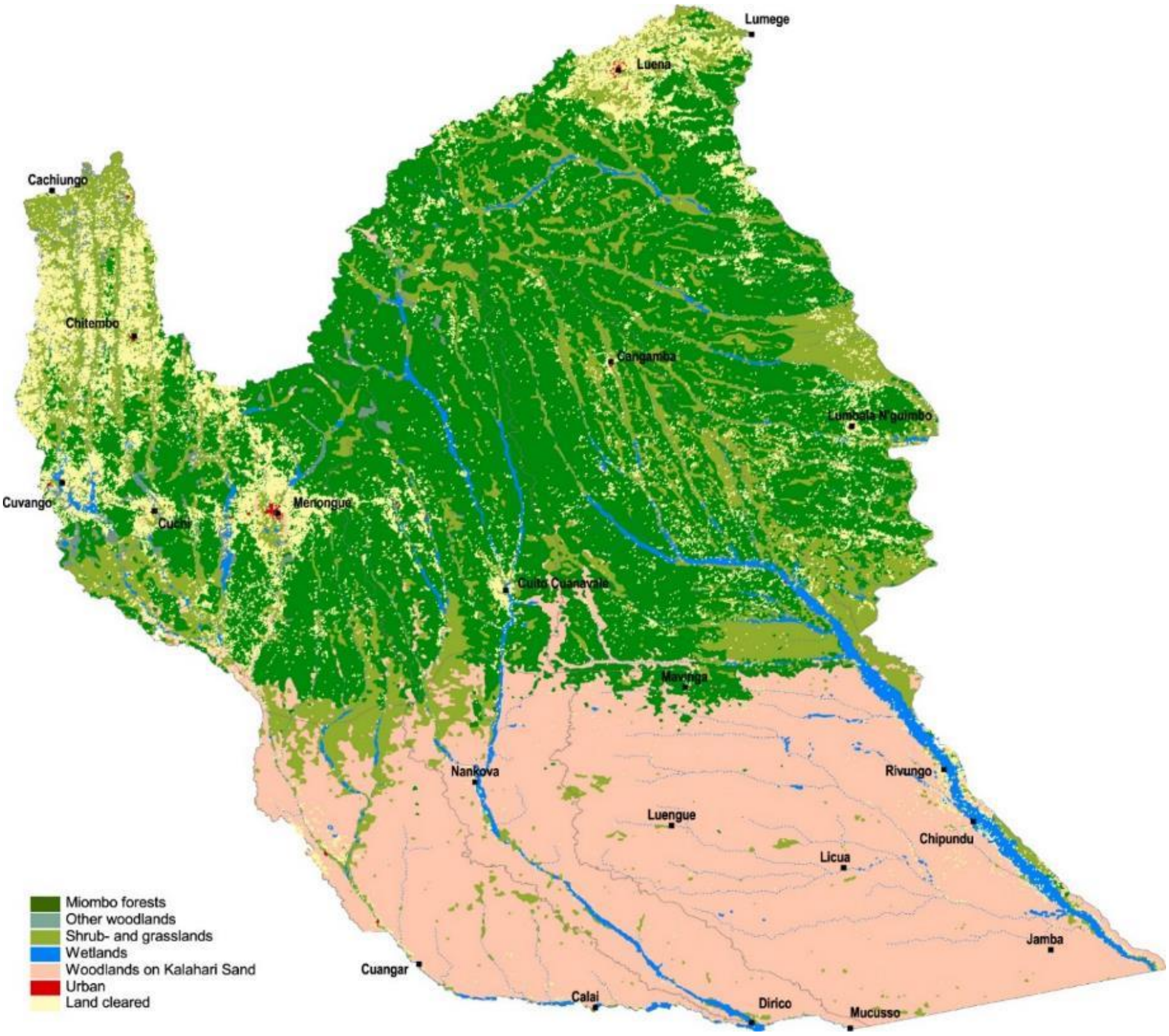


Figure 30. Vegetation structure in the catchments (adapted from Stellmes (2013a) and data from https://earthenginepartners.appspot.com/science-2013-global-forest/download_v1.2.html (Hansen et al. *(2013)).*

The southern savannahs are extremely variable and patchy (Figure 29), for reasons that are seldom evident. However, local variation in soil properties probably causes much of the patchiness, especially where different hardpans determine the degree and frequency of upper soil layers being saturated after heavy or prolonged rains. Fire also plays a major role in favouring or impeding the growth of certain species and growth forms. For example, many of the savannahs would probably have taller and denser tree cover if intense fires were less frequent (see page 49).

Major rivers of the Zambezi broaden towards the east, opening into deltas as they reach into the Bulozi Floodplain (Figure 30). Miombo woodlands grow on the deep sands elevated above the grassy, wet floodplains. Figure 30 also shows how much natural vegetation cover has been cleared for short bouts of farming.

Figure 31 demonstrates that plant production is highest in the upper catchments, particularly in miombo woodland or forest in the Zambezi west area.[1] By contrast, plant production is relatively low in the river valleys and floodplains, in the grass and shrublands of the northern upper Cubango, in areas cleared for crops, and in large patches in the lower catchments.

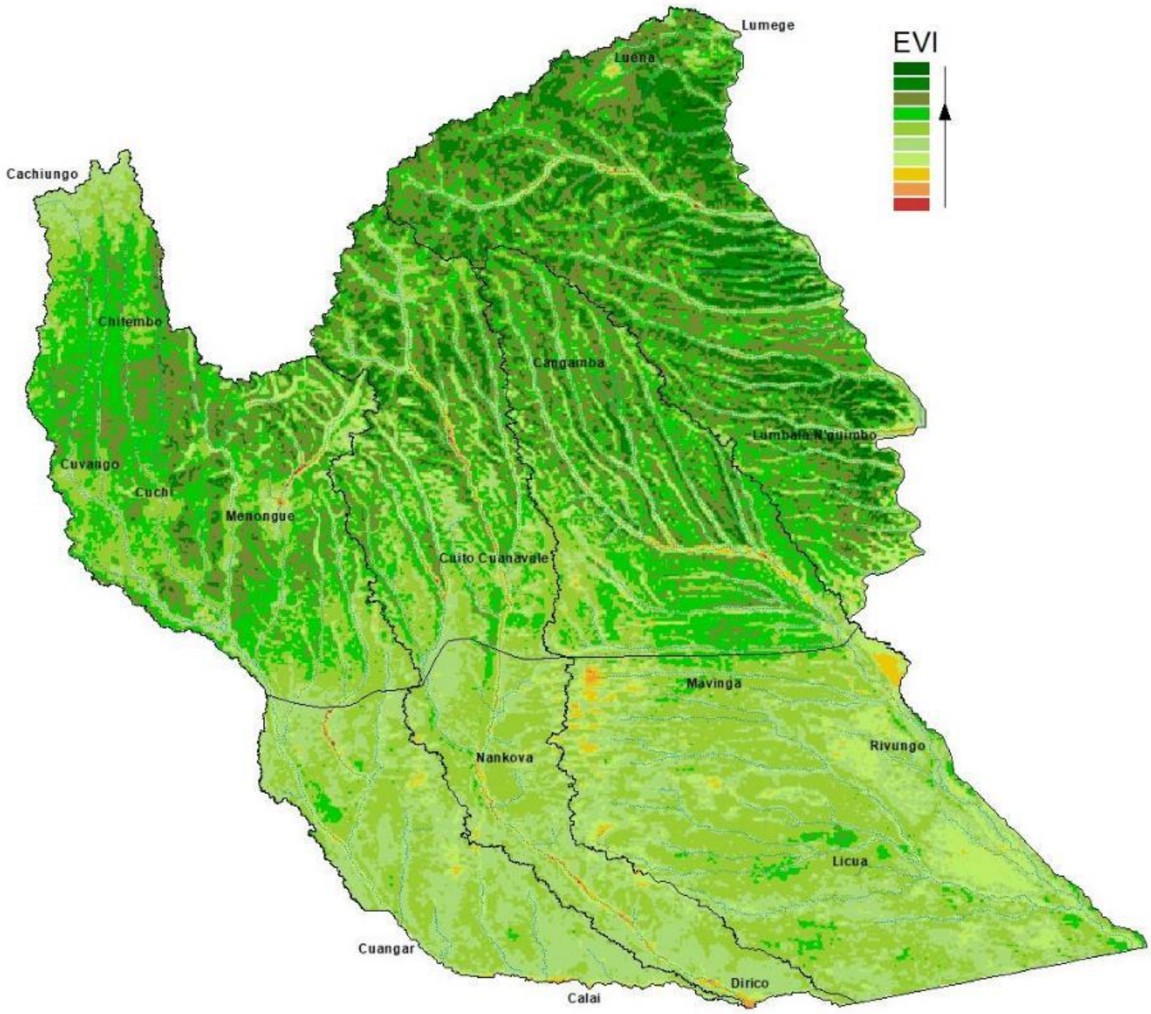


Figure 31. Average Enhanced Vegetation Index (EVI) between 2000 and 2012. EVI is a measure of the average amount of green cover or plant canopy cover. (From Africa Soil Information Service (AfSIS; http://www.africasoils.net/data/datasets?page=1. Resolution is 250 m).

1 It is often hard to decide if these are forests or woodlands. Many areas are obviously densely forested while others are open, more savannah-like. Separating and mapping the two is technically not viable at the scales used here. And the terms have to be used with care, since their meanings are loaded; forest suggesting habitats of greater value, complexity and diversity than woodlands, for example.

Forest or woodland loss

Large areas of woodland or forest are cleared each year to plant dryland crops, mainly manioc, maize or millet. The fields are typically used for a few years (seldom more than 5) before being abandoned. They are seldom used again. For example, only 3% of abandoned fields in south-eastern Angola were used again during the ensuing 20 years (Schneibel *et al.* 2016). The same study, which covered a large block that includes Chitembo, Cuchi and Menongue, found that 5.6% of all forested land was cleared between 1989 and 2013.

The distribution and extent of clearing between 2001 and 2017 is shown in Figure 32 for all the catchment areas, and in more detail for the north-west and north-eastern areas in Figures 5 and 6, respectively. Most clearing occurred in the upper catchments, while clearing in the southern areas was concentrated mainly along the Cubango and Cuando rivers. Some areas shown as cleared in remote areas where few people live were due to intense fires destroying the tree cover.

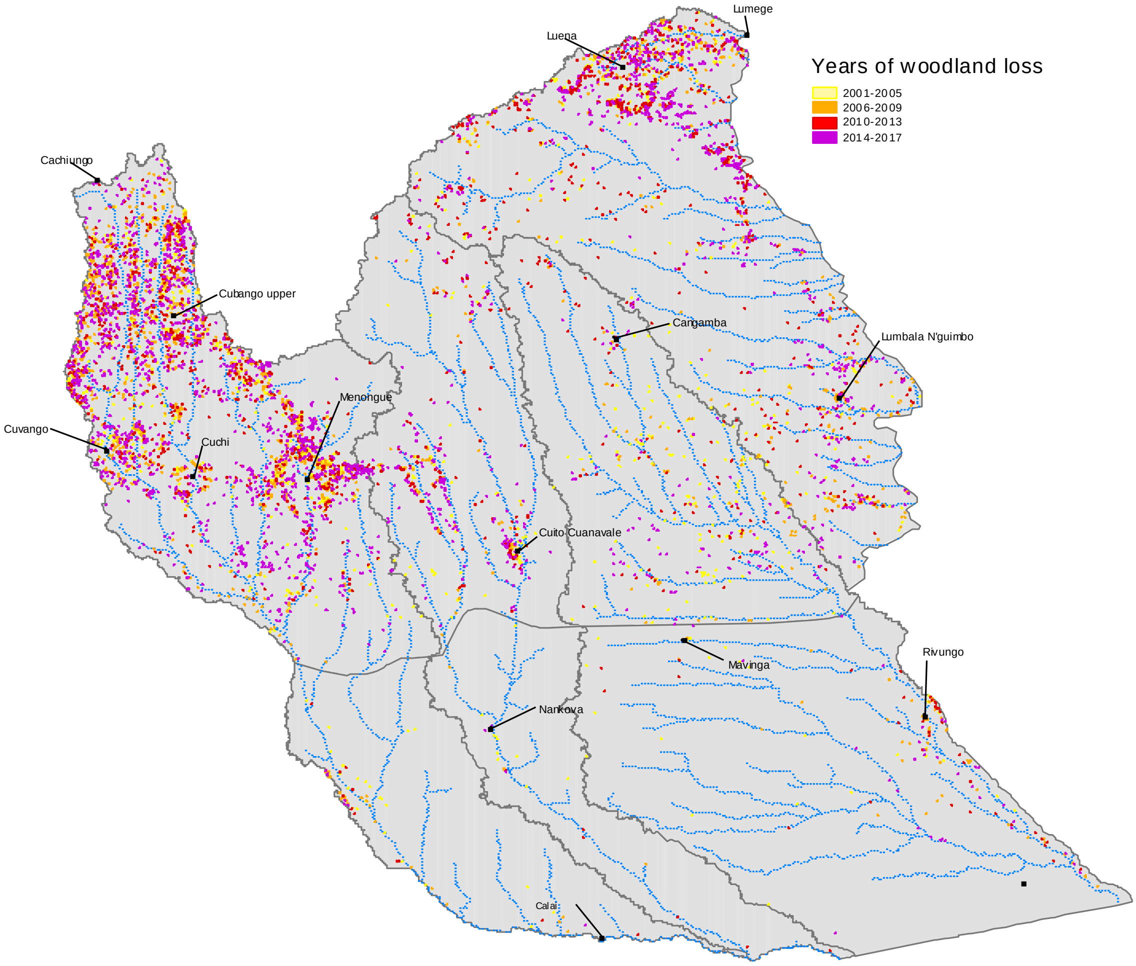


Figure 32. Areas which were wooded or forested in 2000 and from which all tree cover was lost between 2001 and 2017 (from http://earthenginepartners.appspot.com/science-2013-global-forest).

Figure 33 and Figure 34 shows that much of the clearing occurs along major roads where people choose to settle to benefit from the access to roadside markets and transport. This is particularly evident along the main roads connecting Luena and Lumbala Nguimbo, and the road running north and south of Chitembo. Another striking impact on settlement and clearing is that of the road between Cuvango and Cachiungo. This runs along the watershed between the Cubango and Cutato Nganguela, and this is where many villages have been established. By contrast, there is no parallel road – and few people – on the parallel watershed between the Cutato Nganguela and Cuchi rivers.

Another pattern visible in Figure 33 and Figure 34 is the concentration of clearing in concentric rings around major urban centres, such as Luena, Cuchi, Chitembo and Menongue. The concentric rings are oldest in the centre, since it is in these areas closest to the towns that fields were cleared first. As the towns and their peri-urban populations grew, so the clearing for farms moved progressively outward onto virgin soil. Images in Schneibel *et al.* 2016 show the concentric expansion of clearings more clearly – indeed spectacularly – than does Figure 33.

Commercial logging for high quality timber has escalated during the past 5 or 6 years. Most of the timber is from Angolan rosewood *Guibourtia coleosperma* and Angolan teak *Pterocarpus angolensis,* harvested in the lower catchments. The logging has elicited considerable protest and commentary, and tens of thousands of large trees must have certainly been harvested. However, it is hard to assess the environmental consequences of the logging. Certainly the selective removal of trees of a particular type and size seems less damaging than the wholesale removal of all plants for fields or the killing of trees and other plants by bush fires. Curiously, few if any concerns are ever raised about fires and land clearing in south-eastern Angola.

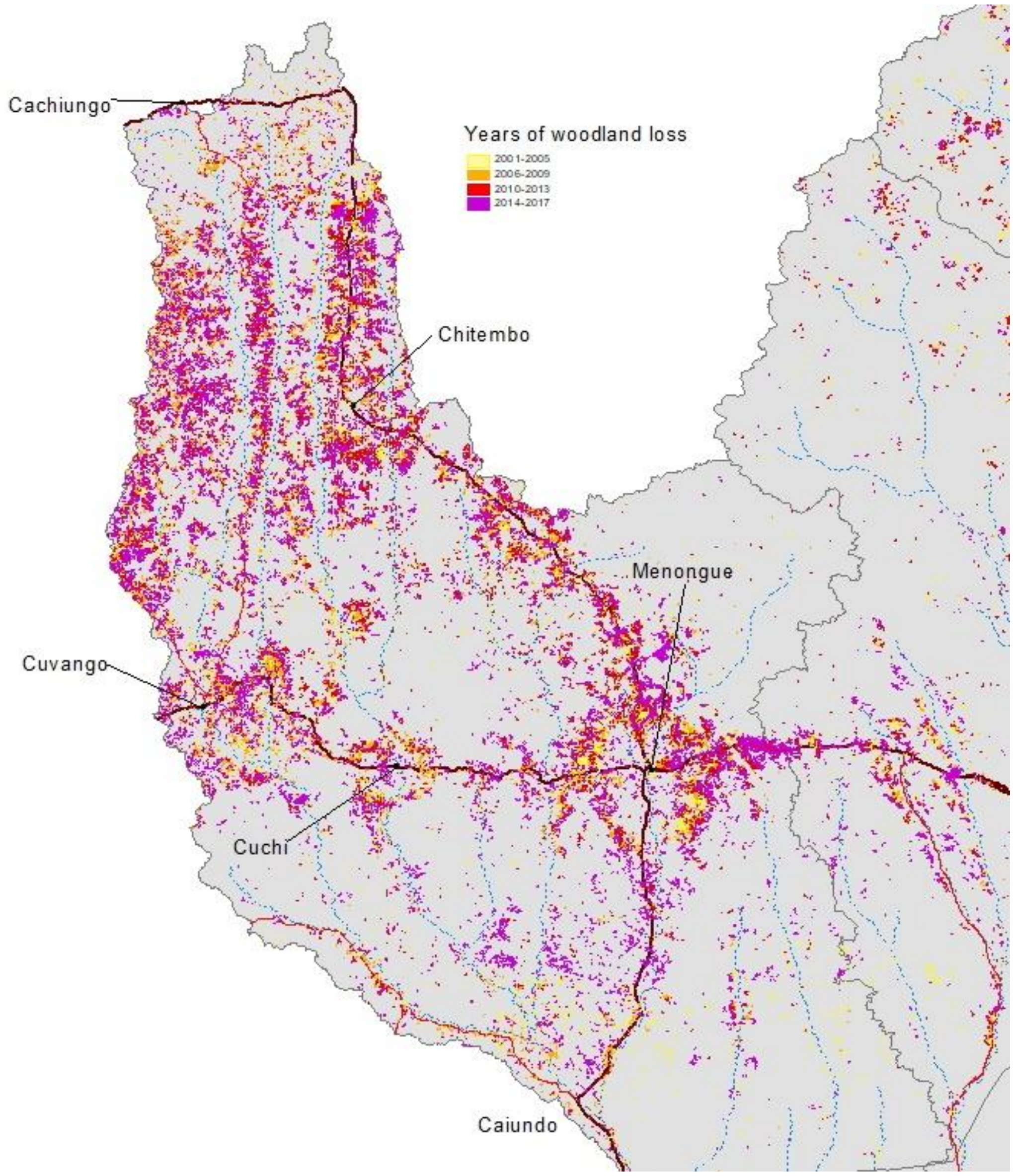


Figure 33. Areas in the north-west which were wooded or forested in 2000 and from which all tree cover was lost between 2001 and 2017 (from http://earthenginepartners.appspot.com/science-2013-global-forest).

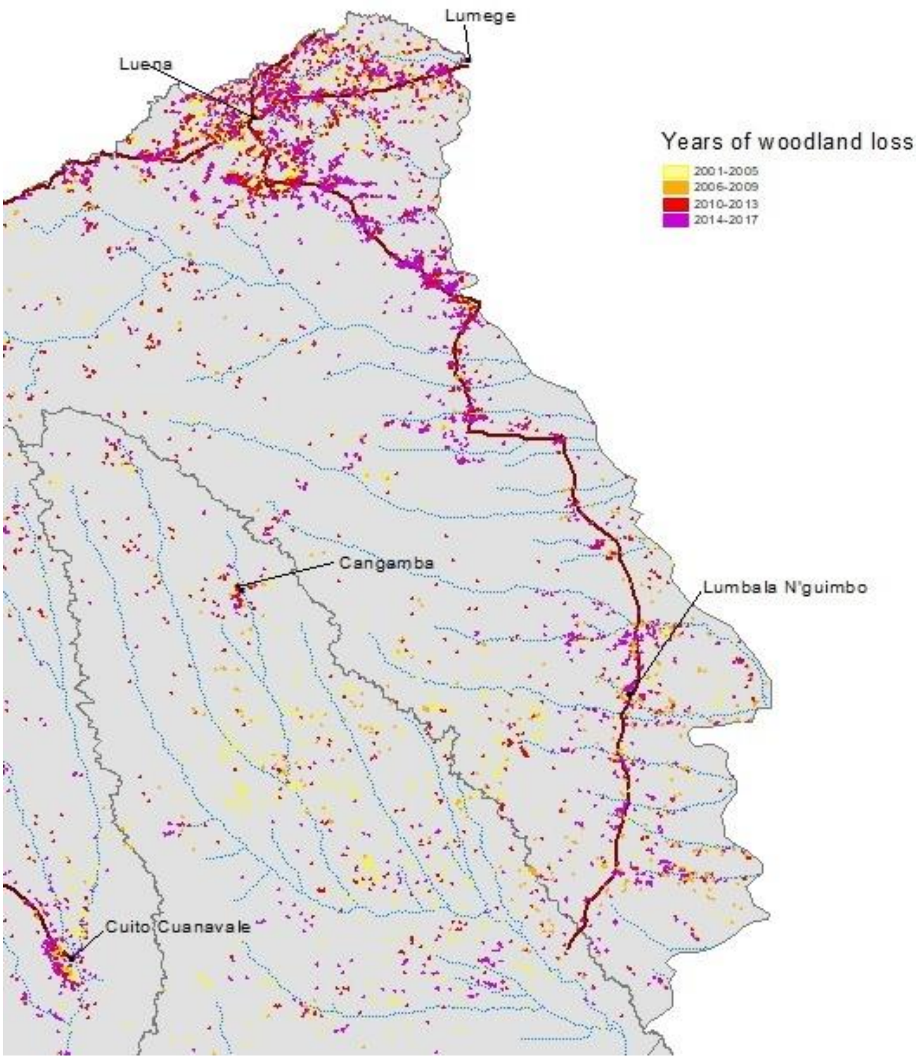


Figure 34. Areas in the north-east which were wooded or forested in 2000 and from which all tree cover was lost between 2001 and 2017 (from http://earthenginepartners.appspot.com/science-2013-global-forest).

Fire frequency and intensity

The majority of burning is in August and September. Fires in the southern, lower catchments are much larger, and more frequent and intense than those in the miombo woodlands of the upper catchment (Stellmes et al 2013a; Mendelsohn 2019). Fires are usually set by people, and only rarely in October are fires ignited by lightning.

Most fires sweep from east to west across the southern landscape. They are largely fuelled by dry grass and shrubs, leaf litter and dead wood. Much of the dead wood is from trees that burned and were killed previously. Their demise is progressive over several years, each fire burning off more and more of their trunks until they finally die and fall over (Mendelsohn & el Obeid 2005).

In the northern upper catchments, fires are normally confined to the grassy river valleys and to patches of open shrub and tree savannah. Occasionally, strong winds fan fires to such an extent that they rage through the miombo canopy, often killing the trees in the process. Peat beds sometimes burn (Stellmes *et al*. 2013a), and smoulder over long periods (pers. obs.). Comparing the upper catchments, fires are more frequent in the Cuando than in areas around the other rivers (Figure 35).

Fires are also frequent in the far northern areas of the Cubango catchment, particularly in the uppermost parts of the Cubango and Cuchi rivers and downstream along these and the parallel Cutato Nganguela and Cacuchi rivers. Observations suggest that considerable quantities of ash are washed into the rivers, but the impacts of ash on increased turbidity and other features of water quality are not known.

Along the same rivers in the upper Cubango are large reed beds, predominantly of phragmites, through which the rivers meander. It is likely that the reeds filter out suspended and dissolved solids, but this filtering and cleaning is probably impeded when the reeds burn, which they do in many, if not most years.

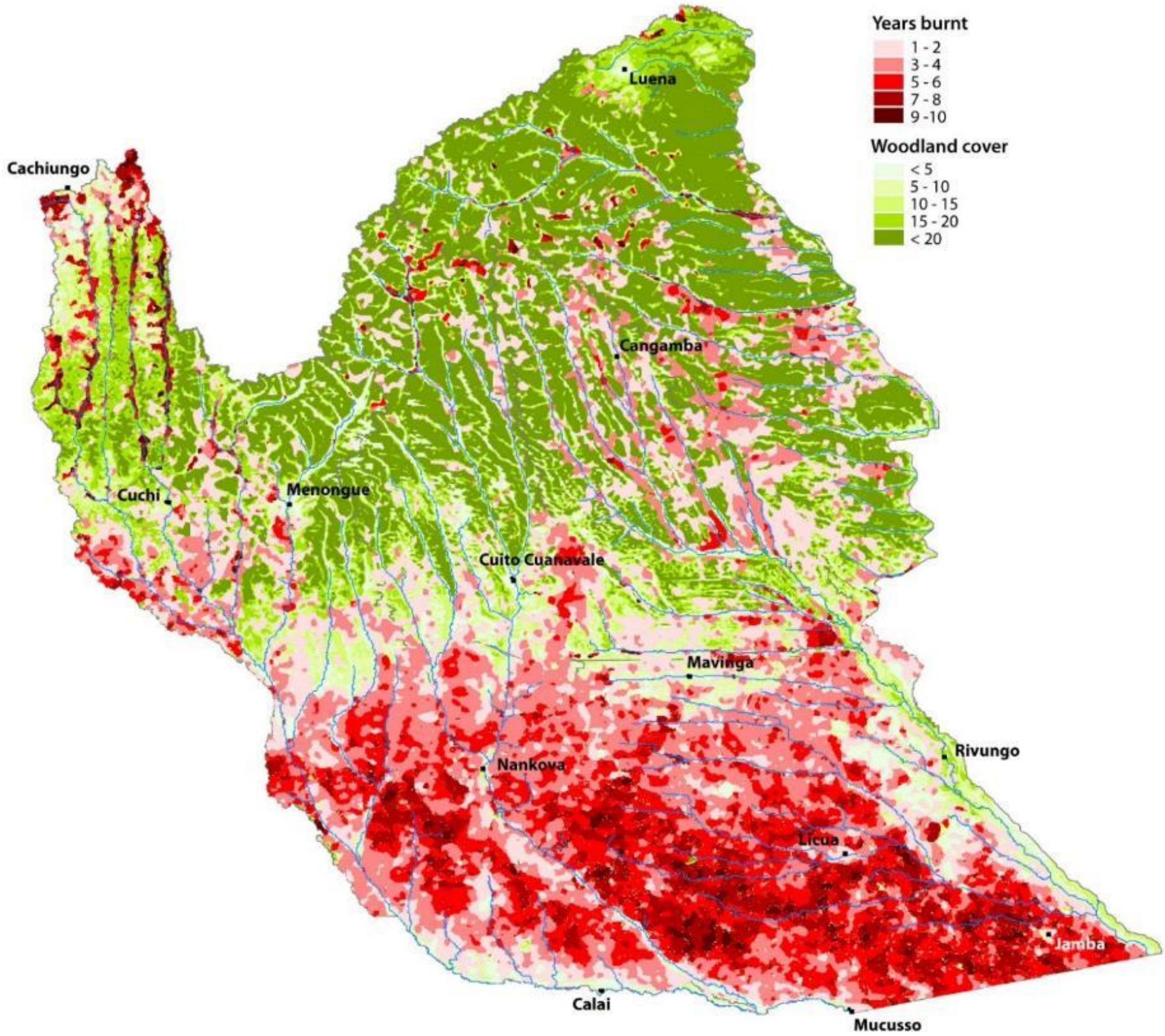


Figure 35. The number of years in which burns occurred from 2000 to 2010 (i.e. 11 years). From Archibald et al. (2010). Original data in 500 metre pixels, and data available at http://wamis.meraka.org.za/products/firefrequency-map.

It is likely that tree cover in the southern savannahs has been reduced considerably by frequent, hot fires. Similar effects have been observed in the same savannahs in Namibia just south of the lower Cuando where fires have progressively killed and cleared mature trees over decades from large areas of the Bwabwata National Park (Mendelsohn & el Obeid 2005) and in Bicuar National Park in Huíla province, Angola (Mendelsohn & Mendelsohn in press). The trees concerned were mainly *Burkea africana, Pterocarpus angolensis and Baikiaea plurijuga*, and they have been replaced by dense shrubland dominated by *Baphia massaiensis, Terminalia sericea, Bauhinia petersiana* and other shrubs.

Animal populations

Knowledge of animals in the catchments is sketchy, and generally thin. However, two recent sets of field work have collected substantial volumes of new information. The first is a survey of carnivores and other large mammals conducted by Panthera in 2015 and 2016 in Mavinga and Luengue-Luiana National Parks. The survey recorded the presence of animals using camera traps, spoor on roads and information provided by local residents.

A synthesis of the relative presence of large herbivores and carnivores shows that the diversity of species increases southward (Figure 36). The increase is substantial, rising from 0 to 10 species over a distance of less than 300 kilometres. Levels of persecution are probably similar across this gradient, and so the changes in diversity are likely due to factors other than disturbance or hunting. Likewise, the changes are probably not due to land degradation (which is similar across the gradient – see Figure 29) or burning (which is more frequent and intense in the species-rich south – see Figure 35).

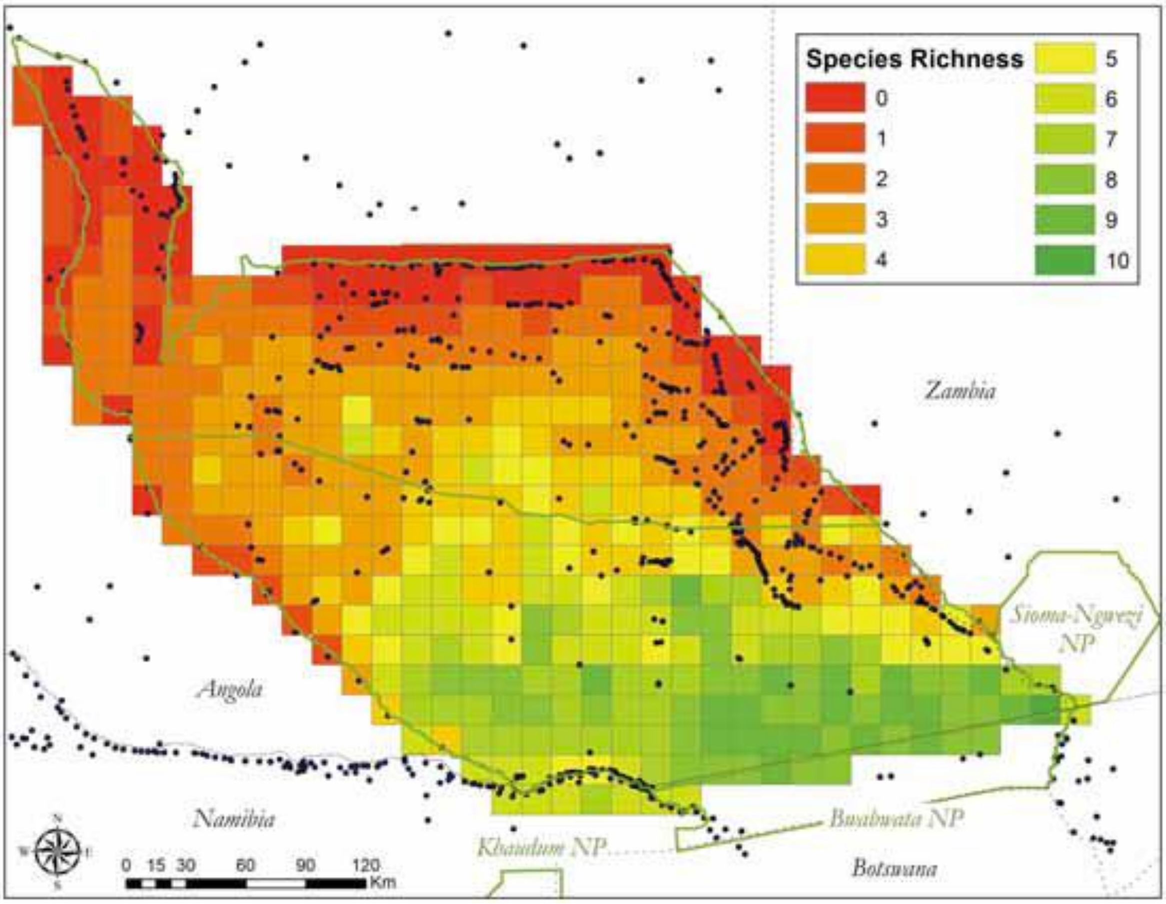


Figure 36. The number of 11 large carnivore and herbivore species predicted to occur across Mavinga and Luengue-Luiana National Parks (from Funston et al. 2017).

The increased density and diversity of large mammals towards the south may rather be a consequence of a general north-to-south increase in nutrient levels and productivity. Such a possibility and tendency is suggested by parallel increases in sightings of fish-eating birds along the Cubango, Cuito, Cuanavale and Cuando rivers (Figure 37). The birds comprise cormorants, darters, several species of herons, fish eagles and several species of piscivorous kingfishers.

These observations along rivers come from several National Geographic Okavango Wilderness Project surveys during the past 4 years. Apart from the results of surveys along and down the rivers, much information on animals has been collected in the Cuando and Cuito upper catchments, and to a lesser degree in the Zambezi west area and upper Cubango. While animal densities are low, largely as a result of the nutrient poor status of these habitats, a considerable diversity of mammals, birds, reptiles, amphibians and fish has been documented in the wetlands (rivers and source lakes) and miombo woodland of the Cuito and Cuando upper catchments. These include such iconic animals as lions, elephants, wild dogs, cheetahs and leopards, and considerable numbers of antelope that survive despite the pressures of bush meat hunting.

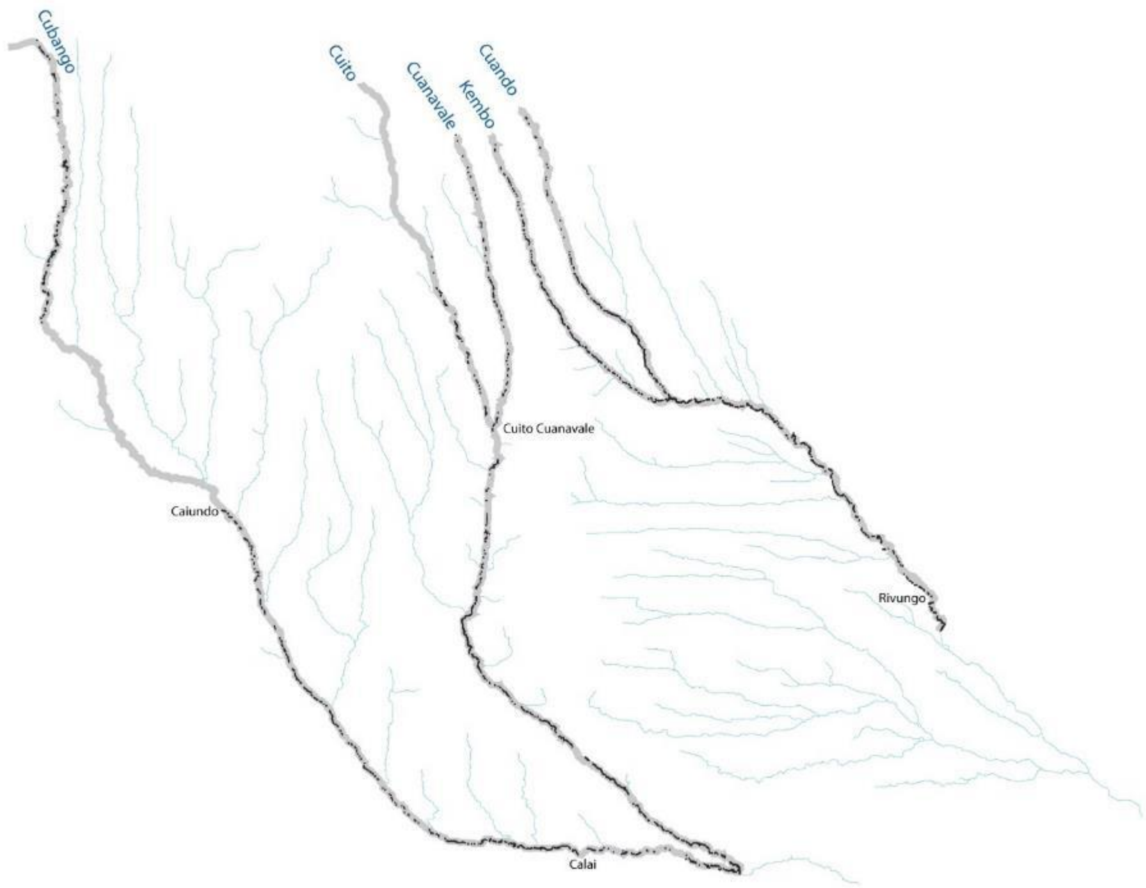


Figure 37. The locations of sightings of piscivorous birds during surveys along the Cubango River in 2017, Cuito in 2015, Cuanavale in 2016, and Cuando in 2018. All the surveys were between May and September each year. Fish-eaters included herons, fish eagles, cormorants, darters and piscivorous kingfishers. The data were collected and kindly made available by the National Geographic Okavango Wilderness Project.

6. People and socio-economic conditions in south-eastern Angola

Livelihoods in south-eastern Angola are divided between those in urban and rural areas. Residents in towns function in a cash economy, the majority engaged in informal trade and services, and public services. Cash also forms much of the income of peri-urban residents and rural residents who live close to major trunk roads where they sell vegetables, charcoal and bush meat.

Away from towns and trade routes, residents subsist largely in a food and bartering economy. Many of those in very remote areas have no cash incomes, while others have meagre incomes from the sale of a few commodities. Rural populations are generally sparsely distributed, most people being clustered in small, widely spread villages (Figure 38).

In summary, cash underpins the economy in and near towns and major roads, but it is less a feature the further away people live from markets and services. This is true for revenue or day-to-day needs. Much less is known about capital needs. Some cattle, goats, pigs and poultry are kept, very largely to serve as savings or security by rural residents in the western areas of the catchment zone. Livestock ownership decreases to the east and north, where many – perhaps most – families have little more than some chickens. The area immediately across the Cubango River in Namibia is something of an exception because residents often keep cattle, many of which belong to Namibian relatives.

To our knowledge, nothing is known about other capital resources, although access to family and other social networks are certain to be valuable. How these differ between long-established rural networks and those formed by recent urban immigrants needs to be understood. Likewise, there is a need to understand linkages between family members in rural and urban households, especially how those in rural areas increasingly benefit from goods and remittances supplied by their urban relatives.

This account is based largely on observations during field trips and aerial surveys of the catchment areas in south-eastern Angola; useful ideas and information provided by numerous informants; and study of high resolution satellite images. Other information came from Costa (2018), Mendelsohn & Weber (2016) and Mendelsohn & Mendelsohn (In press).

Patterns of distribution and economic activity

Approximately 2.7 million people now live in the catchments of the Cubango, Cuito, Cuando and western Zambezi within Angola. This is based on the mapping of households and villages described in Appendix 1.

The distribution and density of people in south-eastern Angola vary considerably. Among the catchment zones, the upper Cubango has the highest numbers and over half (54%) of all the people in the region. The Western Zambezi catchment also has large numbers of people, especially in and around Luena. About 32% of the whole catchment population is in Zambezi West. By contrast, the other catchments have rather small populations, as shown in Table 2.

Table 2: The number and percentage of people living in each catchment zone.

Zone	People	Percentage
Cubango upper	1,466,942	54.0%
Cubango lower	85,956	3.2%
Cuito lower	25,054	0.9%
Cuito upper	89,018	3.3%
Cuando lower	125,452	4.6%
Cuando upper	62,008	2.3%
Western Zambezi	861,510	31.7%
Total	2,715,940	100.0%

Source: mapping of households and villages in high resolution images (0.5 metre/pixel) taken between 2016 and 2018

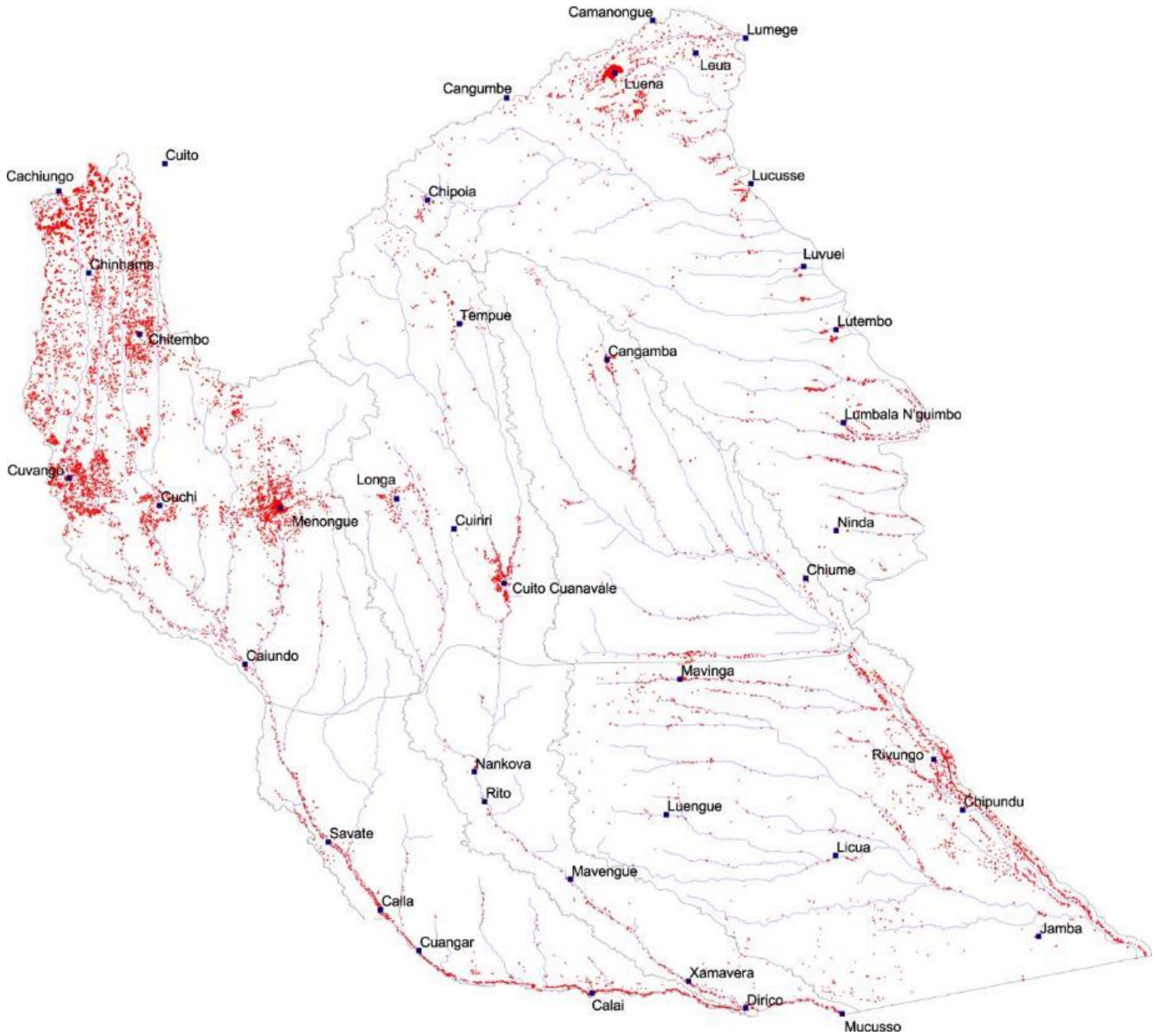


Figure 38. The locations of all households in the catchments.

Rural people live mainly in villages, each being a collection of households. Small villages consist of closely related families, while relationships are more diverse in bigger settlements. The number of small shops and churches in each village is proportional to its size, and the largest villages have schools and perhaps a clinic. There are some exceptions to families being aggregated in villages. The first is along the north bank of the Cubango River as it runs along the Namibian border. Most people here keep significant numbers of cattle and the homes are thus spread out, as is the case with agro-pastoralists elsewhere in Angola and Namibia. The second exception is among fishing communities who live along rivers on the margins of the Bulozi Floodplain. Why they choose to live in greater isolation is not known.

The patterns and characteristics of how people are distributed across the region are described in the following five categories.

1. Urban centres. The highest densities are in towns, and this is where most families now live. Thus 57% of all households are in urban areas, the remaining 43% in rural areas.[2] The two biggest towns or cities are Luena and Menongue. Population estimates for them and other large towns are as follows:

[2] These figures are affected by the criteria used to define urban and rural areas. For purposes of this project, aggregations of houses classified as urban were known administrative and/or commercial centres, and villages having more than 500 households.

Table 3: Population estimates for the biggest towns in the catchments in south-eastern Angola for 2017 or 2018.

City or town	Number of people
Luena	549,360
Menongue	280,458
Chinguar	42,306
Lumbala Nguimbo	39,678
Chitembo	39,264
Cachiungo	38,862
Cuito Cuanavale	22,332
Cuvango	17,064
Cuchi	13,332
Leua	10,554
Chicala Cholohanga	10,056

Source: mapping of households and villages in high resolution images (0.5 metre/pixel) taken between 2016 and 2018

Other smaller towns include Mavinga, Cangamba, Rivungo, Longa, Cuanguar, Caiundo, Savate, Chinhama, Licua, Mucusso, Nankova, Rito and Dirico, for example. While they are small, many of these towns are locally significant as the only administrative and commercial centres serving large surrounding rural areas.

Most urban residents live in low income, often informal houses in areas with few services. Potable, piped water is seldom available. Neither is solid waste removal, sewage systems, electricity or formal tenure. Roads are generally in poor repair. Formal housing is limited to the old colonial centres of the towns and to newly-built mass housing developments on the outskirts of towns. Nearby rivers are used by the majority of residents to wash their clothes, bedding and themselves. The effects of chemical contamination and risks of disease in the rivers have seemingly not been documented or published.

2. Peri-urban, broad concentrations around major towns embrace the many people in relatively dense populated swathes surrounding the largest towns. These zones are particularly evident around Menongue, Cuito Cuanavale, Rivungo, Cuvango, Chitembo, and the three towns of Chicala Cholohanga, Cachiungo and Chinguar. Rather than being urban residents, these are rural families that settled nearby to be close to markets and services in urban areas.

Some family members work and trade in the urban areas while others work on small-holdings to produce crops for themselves, and to sell in towns. These peri-urban residents also collect and sell firewood, chickens, homemade liquor and bush meat in towns.

3. Linear settlements along roads. Many rural homes are concentrated along certain trade and transport routes where there is substantial traffic of potential customers to buy local produce, and also transport to nearby urban centres. Such linear swathes are to be seen on the Cuvango-Cutato-Cuchi-Menongue axis, as well as around the major road running immediately south and along the Namibian border (Figure 38).

4. Linear settlements along rivers. Primarily for reasons of access to permanent supplies of water, most rural residents in more remote areas live along rivers. Gleysols and Fluvisol soils alongside rivers also offer better fertility for crops than the poor soils that predominate away from drainage lines.

Curiously, villages in the upper Cubango catchment are located on high ground quite some distance from the rivers where residents fetch water every day. Why they do not build their homes closer to water is not clear. Elsewhere in the region, most people live closer to the water, their villages spread ribbon-like along major rivers, such as the Cuando, Lomba, Cubia, Utembo, and Luengue rivers in Cuando Cubango, and the broad rivers near the Bulozi Floodplains, such as the Lungue-Bungo, Luanguinga, Luio and Mussuma rivers. About 370 households are on islands within the broad floodplain of the Cuando River where their owners live in isolated circumstances.

5. Scattered villages in sparsely populated areas are home to the relatively few people who live in isolated households or tiny villages in remote areas of the Zambezi west catchment and the lower Cubango, Cuito and Cuando sub-catchments. Many of those in the lower sub-catchments are !Xun and Khoe hunter-gatherers.

Urban migration and growth

It is clear that urban populations are increasing rapidly, as demonstrated by the annual growth rates in the sizes and/or populations of several towns and cities.

Table 4: Annual rates of growth or increase in the sizes of residential areas and/or the number of houses in various towns in the catchment areas.

Town	Years compared	Annual rate of change	Type of measurement
Calai	2004-2018	11%	Area
Chinguar	2002-2016	8%	Area
Chitembo	2002-2016	10%	Area
Cuchi	2011-2016	6%	Area
Cuito	2002-2018	9%	Area
Cuvango	2005-2016	12%	Area
Luena	2003-2013	16%	Area
Luena	2003-2013	14%	Houses
Luena	2003-2016	12%	Houses
Luena	2003-2018	13%	Area
Luena	2011-2018	11%	Area
Lumeje	2002-2014	16%	Area
Menongue	2003-2018	13%	Area
Menongue	2013-2018	7%	Houses

Source: mapping of households and villages in high resolution images (0.5 metre/pixel) taken between 2004 and 2018

Growth rates were normally above 10% per year, a rate at which towns would double in size every 7 years. Luena grew most rapidly, increasing 3.6 times over 10 years from 13,937 houses in 2003 to 49,900 in 2013. Now in 2018, Luena has an estimated 91,560 households.

The highest growth rates appeared to be in the biggest cities, while smaller towns, especially those in more remote areas away from major transport and trade routes seemed to grow at a slower pace. However, high resolution images were not available for most small, more remote towns to assess this trend more accurately.

Accounts by many residents in Moxico suggest that the very high rates of urban growth in Luena, Lumeje and other Moxico towns were driven by the large number of people returning from exile once the civil war ended in 2002. Other, more moderate growth in Moxico and elsewhere was, however, led by aspirations to have access to cash incomes and services.

Rural livelihoods:

Rural people spend much of their time producing food for domestic sustenance or sale. While the former is almost always a main occupation, time and effort spent on the latter varies according to what can be sold and proximity to markets.

As discussed in the account of soils, crop production in south-eastern Angola is not easy. The great majority of soils are extremely deficient in nutrients, and can hold little water. Many of the soils are also acidic.

Much of the land degradation and poverty in the catchments is a direct consequence of the poor soil. Soil conditions require virgin woodland to be cleared periodically to create new fields since nutrients are normally exhausted (i.e. mined) after a few years of cultivation. Fields that have been abandoned are seldom reused, and so the clearing of new fields is a continuous process, leaving more and more of the region denuded of woodland and forest. Yields and food production are limited by the poor soils, and surpluses are usually stored to survive possible future shortages, rather than being sold. Inadequate nutrition results in high mortality rates, small populations, little economic activity differentiation, few potential customers, and low purchasing power. Furthermore, social grants are seldom available to people in rural areas.

Manioc, sweet potatoes, maize and millet are the dominant staples. Millet is the main crop in the south, close to the Namibian border where rainfall is lower than elsewhere. Maize, together with smaller quantities of millet, sorghum and manioc, is most abundant in the west and north-west. Elsewhere, especially in high rainfall areas, manioc is the main crop supplemented with sweet potatoes and maize. Melons and beans are often inter-cropped with cereals. People living on islands in the Cuando River mainly grow maize, bananas and sweet potatoes.

All these staples are for domestic consumption. On *naca* fields on Gleysol soils in the northern parts of the Cubango catchment, most rural residents grow a variety of vegetables, green maize and sugar cane which is sold at nearby roadsides and urban markets. This production is very largely geared to generate incomes.

Other important sources of income are dried fish, honey (in miombo woodlands), bush meat, chickens, goats and cattle (along the Namibian border), charcoal, and traditional liquor. In certain areas, fair amounts of dryland staple produce are sold, such as maize, melons, beans and millet.

Production tasks are often divided between men and women. For example, men produce charcoal to sell along roads, while women collect firewood with which to cook at home. Likewise, men harvest and sell honey and bush meat, while crop production and collecting water is largely the preserve of women.

The great majority of households obtain their water from open sources throughout the catchments. These are normally rivers and streams, but shallow wells also often provide water, especially in towns and areas away from perennial water courses.

Soil conditions have always limited household welfare, but a lack of access to cash incomes is an additional and growing hardship as people seek to move away from a dependence on food subsistence and to benefit from purchased commodities. Access to cash explains much of the variance in wealth. Families with the means to pay for clothes, motorcycle taxi fares, oil and salt, school fees, medicines and cellular telephones are at a significant advantage compared to those who don’t, for instance.

Financial resources are particularly limiting in most rural areas where residents either have little to sell or have limited access to buyers or markets. Increasingly, every effort is made to obtain money and it is that impetus which drives people to towns (especially young people eager for modern living conditions and amenities). People who remain living in rural areas are more and more compelled to harvest any natural resources that may have financial value. In summary, two variables determine relative wealth: (a) the availability of potential goods to sell and (b) the presence of incentives or markets to produce and sell the goods. Both goods and incentives are rare in many parts of south-eastern Angola.

Most land in south-eastern Angola is formally owned by the state, while local residents have rights to its use. There are, however, no effective limits on use, either in terms of who may have user rights or in the quantity of resources that can be used, such as how much grazing, timber, water, land for cultivation, bush meat or fish is allowed. The same conditions of open access and maximisation of use hold in the two large national parks: Mavinga and Luengue Luiana National Parks.

Demographic features

As far as is known, no systematic and reliable information is available on demographic rates. However, several features of rural populations are clear: high fertility, infant and child mortality and immigration rates. Polygamy is widespread as a traditional practice and as a response to the skewed sex ratio caused by high war time male mortality. Mortality and fertility rates are lower in urban areas, where levels of education, health care and employment are considerably higher.

Services

The Angolan government has spent substantially on infrastructure in recent years. Perhaps proportionally more has been spent in the south-eastern areas than elsewhere to compensate for past circumstances. This area has long been considered to be neglected as the 'land at the end of the earth' (*terra do fim do mundo*), and it was severely disrupted by the civil war and hostilities related to the Namibian liberation war.

Substantial numbers of schools, health facilities, railway stations, new airports, police stations and offices for government departments have been constructed throughout the region. Many schools, health facilities and other infrastructure have not been equipped or staffed, however. The railway service running from Moçâmedes (on the coast) to Lubango and Menongue has been reinstated, several major roads have been refurbished and tarred. But transport across the region is hampered by the poor condition of some major trunk routes, especially Ondjiva to Caiundo, Katwitwi to Caiundo, Cuito to Luena, and Cuito Cuanavale to Rivungo and south to Luiana.

Administration

The catchments of south-eastern Angola fall into 6 of Angola's 18 provinces. From the north-west, the 6 are Huambo, Huíla, Bié, Cunene, Moxico and Cuando Cubango, which is the only province that lies entirely within the catchments. The capitals of the provinces are Huambo, Lubango, Cuito, Ondjiva, Luena and Menongue, respectively.

Provinces are divided into *municípios*. Their names and administrative centres are shown in Figure 39. And *municípios* are divided into comunas, which are the lowest levels of formal governance. Traditional governance is not prominent in Angola. There are few tribal chiefs, and tribes do not have the same prominence or identity often seen in other southern African countries. However, at local levels there are *sobas* (headmen) and *regedorias* (senior headmen) who receive stipends from the state.

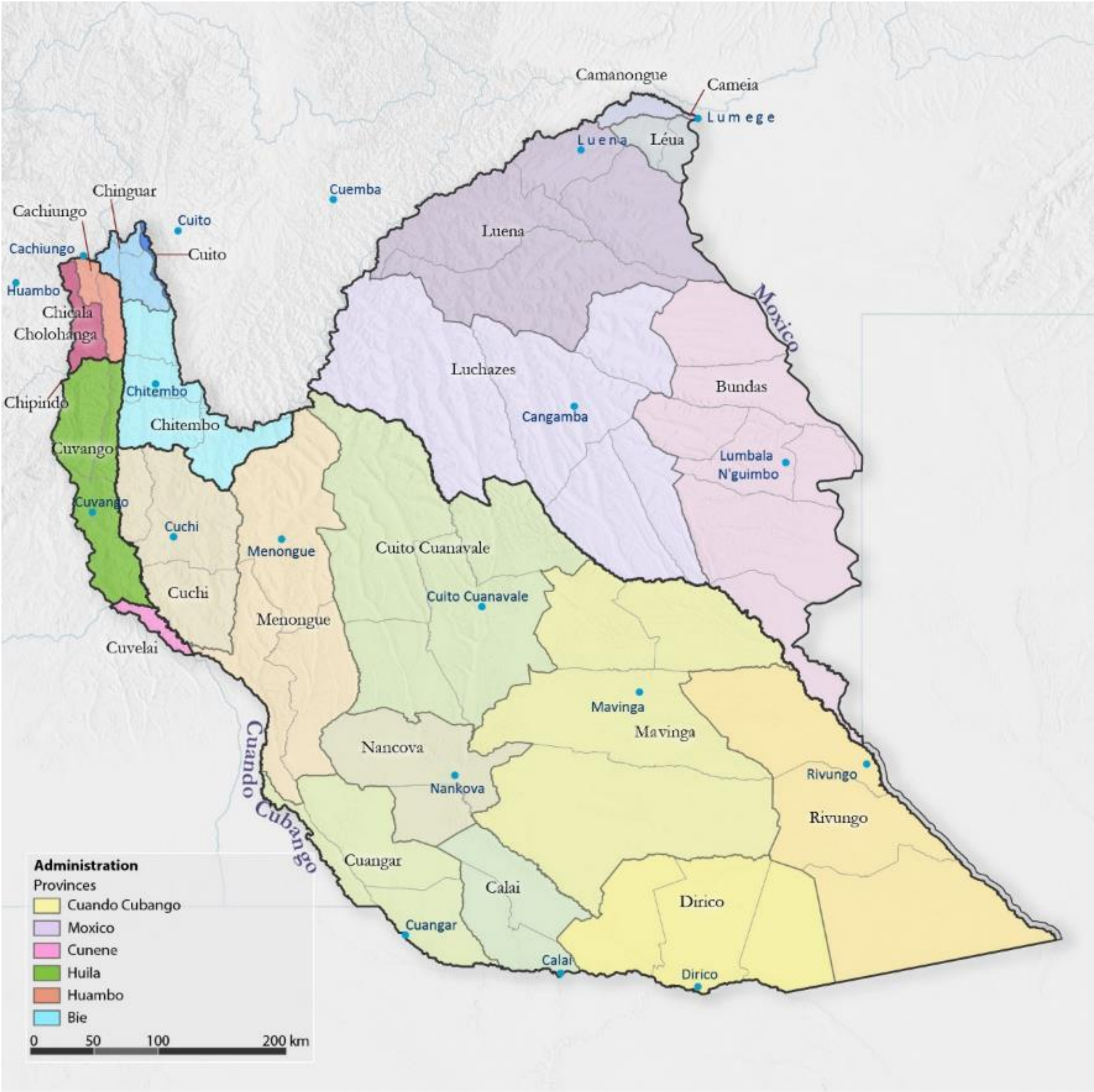


Figure 39. Administrative areas in the catchments of south-eastern Angola

7. Environmental losses and challenges

This chapter provides a synthesis of major existing and potential environmental pressures in the south-eastern Angola catchments. It is useful to distinguish the proximate or immediate drivers from those that have ultimate, longer-term or indirect effects. For example, pollution occurs when people wash in river waters, but is ultimately caused by the fact that many people are attracted to live alongside those rivers. Proximate factors generally cause environmental losses, while ultimate conditions drive the proximate factors that lead to losses.

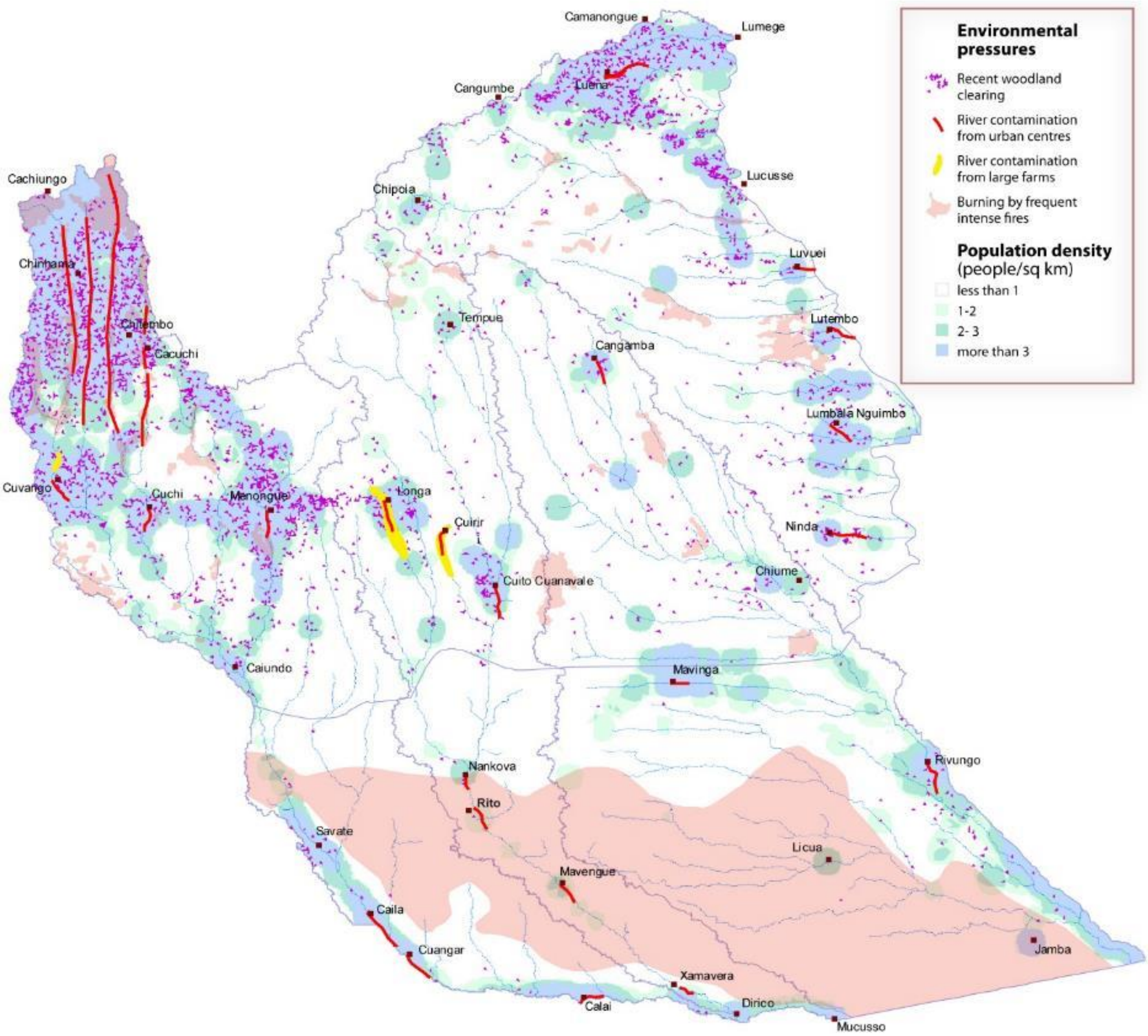


Figure 40. Areas in which environmental pressures are concentrated and most severe in the Cubango, Cuito, Cuando and Zambezi west catchments.

Areas and causes of major degradation

The major proximate and spatially identifiable causes of environmental degradation are the clearing of woodlands or forests for fields, the destruction of natural vegetation by large, frequent and intense fires, and the pollution of rivers by urban residents and industry. It is also likely that some rivers are, or can be contaminated by pesticides and fertilisers applied to large agricultural projects, as well as fish farms. Pressures from fires and the clearing of land have been increasing over many decades in tandem with population growth, while problems of river contamination are probably more recent.

Figure 40 shows the distribution of concentrations of these existing and/or likely environmental problems. Several additional pressures are severe in areas where rural residents are most concentrated: the use of wood for domestic building, fencing and fuel, and the harvesting of small mammals, birds and fish for domestic consumption. Charcoal is also produced here, but only in significant quantities along major roads frequently travelled by large trucks. Most large mammals were exterminated long ago from these densely populated areas.

Soil erosion was identified (in the form of erosion gullies seen in satellite images) as a serious problem in the northernmost parts of the upper Cubango (see page 20). That upper area of the Cubango is quite distinct from other parts of the catchments because it is so densely populated by rural residents (see page 53). It also has three major towns (Chicala Cholohanga, Cachiungo and Chinguar), as well as two large, nearby cities (Cuito and Huambo). The area also has a longer history of forest and woodland clearing, settling by small-holders, and farming than other parts of south-east Angola.

After so much clearing, little natural woodland has been left to clear in recent years (Figure 40). And some areas in the far north-west were probably always devoid of trees as a result of frost, fire and soil saturation (see page 44). The lack of woodland, intense farming by small-holders and the frequent fires create conditions that lead to the accumulation of eroded soil and ash in the four large rivers of the upper Cubango.

This is almost certainly the reason why river water in the upper reaches is relatively murky (see page 27). It is also probable that many suspended and dissolved solids are later removed by dense phragmites reed beds. However, their filtering services may be impeded when the reed beds burn, as they do in most years. For the future, studies are needed to document the exact sources and levels of upstream river contamination, and the roles of the phragmites in cleaning rivers downstream.

Figure 40 focuses on Angola, but the nearby presence of similar and perhaps exacerbating pressures alongside the Cubango River in Namibia should be noted. The most serious of these is waste from a number of urban centres and agricultural chemicals from several large irrigation schemes. Likewise, impacts from the riverside town of Shangombo, opposite Rivungo, on the east bank of the Cuando River should be considered.

Other kinds of degradation within Angola are hard to depict on a map. The harvesting of larger mammals, some birds and fish, either to be eaten or to be sold, occurs widely but unevenly. Fishing happens mainly in the lower reaches of the rivers, while large mammals or bush meat is harvested in areas sparsely populated by people, for example in the upper catchments of the Cuito, Cuando and the western Zambezi, as well in the Cuebe catchment upstream of Menongue, and in areas of the lower Cubango, Cuito and Cuando.

Figure 40 shows the location of stretches of rivers which may be polluted by large nearby towns. These are all reasonably substantial urban centres, but there are many other, smaller towns which may produce the same kinds of river contamination. A recent study by CETAC (2017) indicates that places used for washing by local villagers are often contaminated.

The loss of woodland to clearing and burning are arguably separate processes. However, the clearing of woodlands also opens them up to fire damage, especially where there are large contiguous areas of abandoned fields overgrown with combustible plant material. Fires in such lightly wooded areas will spread easily and rapidly, and are often intense, thus limiting the regrowth of the natural woodland. Ecological succession towards the restoration of the original woodland will require decades. Repeated burning slows the regeneration of trees and reforestation of old field areas. And very hot fires in old fields and more natural settings can kill off trees on the margins of woodlands and forests, thus progressively reducing the extent of wooded areas over time.[3]

Research on these and other factors leading to added fire damage is needed. There is also a question of why certain broad floodplains burn frequently while others that look structurally similar, seldom burn. Examples of the latter are the Cuebe upstream of Menongue, and the lower Cuito. The fact that they do not burn may be associated with water table depth, which keeps the grass green and moist, thus delaying the spread of fire. The same kind of question relates to sections of floodplains that burn much more frequently than others.

In addition to vegetation damage, bush fires cause the loss of certain soil nutrients, especially where they are frequent and/or intense. Nitrogen, phosphorus and organic carbon are commonly lost. Much lower nutrient levels were found in soils beneath open woodland near Savate, than in adjacent forest (Wallenfang *et al*. 2015). The open areas were burnt often and intensely, while the forested areas seldom burned (Stellmes *et al*. 2013). Moreover, the loss of organic carbon and dependent soil microorganisms impedes mineralization processes that restore nutrients.

It should be noted that there may be differences in the effects of fires, depending on their intensity. Thus, cooler fires may accelerate the release of nutrients from plant matter into the soil (Jain *et al*. 2008).

Environmental pressure zones

Most urban centres, and densely settled rural areas which are being cleared of woodland, are along major trade and transport routes linking parts of south-eastern Angola from north to south or east to west (Figure 41). Additional routes and zones of degradation are likely to develop when new roads are constructed, for example between Cuito Cuanavale and Rivungo and through Shangombo to Zambia, and from Chiume south to Rivungo and Namibia.[4]

With the exception of the upper Cubango, most of the existing and potential axes of severe environmental pressure are within fairly confined areas, which leaves large areas of the upper Cuito and Cuando, and the western Zambezi and its lower catchments, relatively free of widespread settlement and deforestation. Of concern are the consequences of a trade route being developed between Luena, Rivungo and Namibia. That might lead to major developments and an influx of people, especially in and around the rather pristine Cuando River.

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3 Interestingly, *Brachystegia bakeriana* may reduce such effects on miombo woodland. The trees grow commonly along forest edges where they apparently inhibit the growth of combustible grass and other plants, and therefore the intensity of fires (personal observation).

4 There are rumours of an intended SADC trade route to link the DRC and Namibia from Luau (on the DRC border) to Luena, Chiume and Rundu.

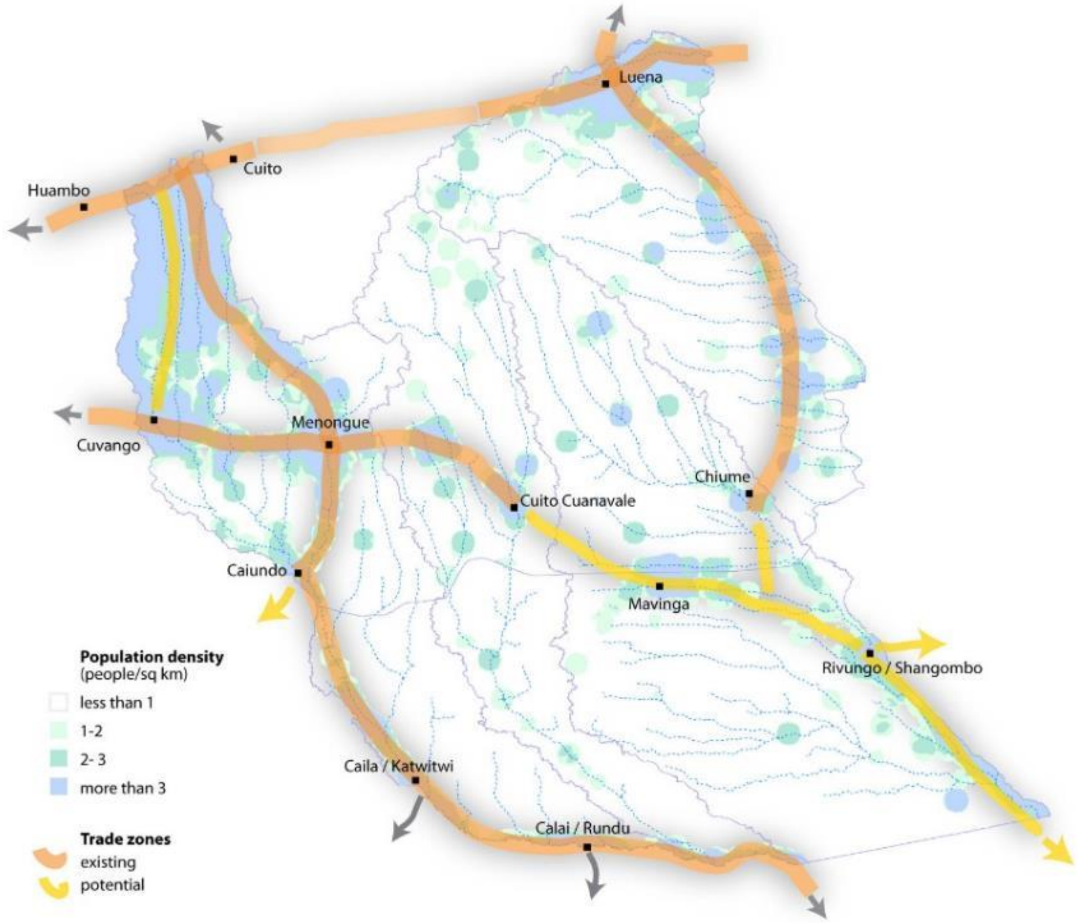


Figure 41. Major existing and potential trade routes in and out of catchments of the Cubango, Cuito, Cuando and western Zambezi.

Underlying drivers of degradation

The single most important condition responsible for much of the environmental degradation in south-eastern Angola is the poor quality of soils. Poor soil quality is also the root cause of most poverty.

As a result of the low yields produced by poor soils in south-eastern Angola (Asanzi et al. 2006; Ucuassapi & Dias 2006; Wallenfang et al. 2015), a low-input/low-output production strategy is adopted in dryland agriculture. 'Profit' incentives to invest in additional inputs, such as fertilisers or labour-expensive inputs, are therefore lacking, and farmers are obliged to clear new ground once the nutrients in their active fields have been mined. This occurs without exception, since nutrients are not replenished, nor is the pH or acidity of the soil corrected through fertilisation. Only in periodically flooded (*naca*) or colluvial (*ombanda*) fields are there some nutrient inflows. The extent of degradation increases progressively because supplies of nutrients are depleted rapidly (within 2 or 3 years normally), and replenished very slowly (especially phosphorus), and because trees are slow to regenerate on nutrient-deficient soils.

Low yields also mean that farmers seldom have surpluses to sell. In any event, it is prudent and preferable to keep surpluses for own use, for when food shortages occur during bad seasons. Low yields, poor nutrition and ensuing mortality (mostly infant and child) limits population sizes, and restricts social and economic differentiation. As a result, few people have the means to buy surpluses or other goods that might be for sale. Under such circumstances a cash economy cannot develop. There may be enough to eat, but little or no cash to earn.

Food-based economies may have been viable long ago. But nowadays everyone needs access to cash, and it is for this reason that rural residents in south-eastern Angola go to such lengths to sell goods that have cash value. Those sold most commonly are charcoal, bush meat, honey and fish. Some of these are exploited to an extent that is not sustainable. People in any particular area are faced with two challenges: to find and harvest marketable goods, and to reach customers. Life in many areas is constrained by one or both of these challenges.

These pervasive circumstances drive most of the environmental degradation and poverty in south-eastern Angola. Fortunately, they have been overcome to some extent in certain areas, most encouragingly along major roads and close to urban centres. This is where size counts: the busier the road and the bigger the town, the greater the market opportunities for local residents. And where profits are adequate, farmers have incentives to invest in measures that increase yields and production. Such conditions have enabled small-holders to become producers of vegetables and other durable crops, especially around major towns (such as Menongue and Luena) and along the major trade route that traverses the uppermost reaches of the Cubango catchment. Other goods – such as poultry, firewood, fruits and even goods from other places – which may have only marginal value elsewhere, become profitable in such areas.

The opportunities provided by markets have encouraged people from remote areas to move closer or into towns, or to settle near busy roads. These movements have several benefits. Pressures on areas left vacant by migrants, are reduced, potentially decreasing the extent of land degradation and hunting of wildlife. In their new homes, immigrants enjoy access to incomes and education, health and other services which they lacked before. However, it is evident that bonds with rural families are often maintained to a greater or lesser extent. This facilitates the movement of natural products harvested elsewhere to urban centres where they provide cash to urban relatives

While there are benefits that accrue from the concentration of people, there are also costs. Pressures on all natural resources increase greatly near large towns and busy roads, and rivers are usually contaminated. Methods are needed to manage these challenges, as well as to restore features that have been lost, such as woodlands, pastures and soils. Foremost, however, is the need to develop the economies of urban and peri-urban areas, and to encourage further movements away from areas where people will become trapped in perpetual poverty, exacerbated by the progressive degradation of the environment. For that reason, government should concentrate major investments in especially designed clusters, where it is easier to provide and manage public services and infrastructure, and where people have access to money and markets.

Three other recommendations might be considered. The first is to establish procedural systems for *sobas* (local headmen) to control the setting of fires and the clearing of land for new fields. Second is to encourage livestock *production* (active farming and the sale of livestock as commodities), which is to be distinguished from existing livestock *keeping* (practices that treat livestock as capital, not commodities). That will supply additional incomes to rural areas. Thirdly, wealthy citizens must be encouraged to protect and manage large areas of natural, pristine woodland and riverine areas for the long-term benefit of the country. In conjunction with such protection, they should rebuild wildlife populations, develop tourism resources, thus fostering national pride in Angola's outstandingly beautiful natural environment.

8. Knowledge gaps

The quantity and quality of information on the river catchments has increased substantially in recent years. The same is true of our understanding of processes, pressures, opportunities and challenges. However, more information and clearer interpretations are needed on many aspects, of which the following now seem important:

Circumstances in the uppermost, north-western areas of the Cubango catchment.

This is the most densely populated, intensively farmed and urbanised part of south-eastern Angola. Much of the area consists of grasslands and geoxylic communities or grasses and underground woody plants. Little natural woodland remains in the area. Several questions need to be answered, such as: was this area previously wooded; if so, how much has been cleared and how much was always open grassland; and what factors maintain this grassland and/or limit the growth of woodland? Answers to these and similar questions are needed before other, more practical questions can be tackled, for instance: what impacts have changes in land use and cover had on the functioning and water quality of the Cubango, Cuito, Cuchi and Cacuchi rivers? If hydrological processes have been degraded, what areas are most important to restore? What restoration measures are needed?

The upper catchment is clearly an economic magnet, and its further development should be encouraged to help draw rural people away from areas where they will remain poor and continue to clear forests and woodland. And so, how can economic development be promoted in ways that minimize environmental losses in that upper catchment area?

Role and functioning of phragmites reed beds in rivers of the upper Cubango

Probably as a result of clearing and intense use, considerable amounts of soil and ash are seemingly washed into these rivers in their uppermost reaches. It also seems possible that much of the soil, ash and perhaps other material is then removed by dense phragmites reed beds downstream. If so, their filtering services may be impeded when the reed beds burn, as they do in most years.

Among several questions: what are the sources and levels of river contamination, what are their impacts on the rivers, what roles do the reed beds play in maintaining clean rivers, and what impacts does burning have on the reed beds?

Water abstraction and quality

It is generally believed that little water is abstracted from rivers in south-east Angola, since there are few large-scale irrigation farms, no hydro-electricity schemes and few urban water supplies. However, no quantitative information is available to assess that belief. Likewise, it is assumed that significant water abstraction on the Namibian side of the Cubango/Okavango River is limited to several major irrigation schemes. Yet, a casual survey in 2017 found dozens of other piped water-offtakes along that river (OWP-Nat. Geo Survey, personal communication).

The same circumstances hold true for water quality. Most rivers normally look very clear and clean, and so we assume that levels of contamination are low, and remain that way. Yet, comprehensive quantitative information for rivers across south-eastern Angola is absent. Moreover, there are indeed strong suspicions and some evidence that some waters may indeed be badly polluted (CETAC 2017) around villages and downstream of major urban centres.

In the absence of good information on water offtake and quality, it is well-nigh impossible to assess the added or cumulative impact of any new developments. There is also no method of monitoring changes in offtake or contamination. Filling these information gaps and implementing monitoring mechanisms are major priorities.

The hydrology of the western Zambezi

It seems clear that rivers in the western Zambezi in Angola contribute significant volumes of water to the annual flooding of the Bulozi and Barotse floodplains, as well as to the entire greater Zambezi. But what are the quantities and fluctuations in these flows? That is not known.

It is also reasonable to assume that the sandy catchments and rivers of the western Zambezi provide steady supplies of water during the dry season when other rivers of the Zambezi system in Zambia are low. Those western rivers may therefore play crucial roles in maintaining perennial components of the Bulozi and Barotse floodplains and others downstream. Information on those roles should be acquired.

The hydrology of the western and eastern sub-catchments of the Cubango

The Cubango is divided into two quite separate groups of rivers. The first group is to the west and farthest north. From here, the Cubango, Cutato Nganguela, Cuchi and Cacuchi rivers flow southwards, parallel to each other and down gradients steeper than anywhere else in south-eastern Angola. Their levels and discharges rise and fall in fairly quick response to rainfall, and it is from these four rivers that most floodwaters downstream and in the Okavango Delta come.

To the east are five other rivers: the Cuelei, Cuebe, Cueio, Cuatir and Luatuta. They largely drain sandy substrates, and their flows are generally slower and probably vary less during the year than those of the western group. The chemistry of the eastern rivers probably differs as well, in all likelihood being more acidic but also cleaner with lower TDS and conductivity levels than in the Cubango and its associated rivers.

The two groups of rivers probably provide complementary supplies of water: fast, episodic, and rockier, probably with more minerals from the west; but cleaner, slower and more stable from the sandier eastern areas. The nature and implications of these complementary roles need to be assessed.

Relationships between rainfall and discharge

The sandy catchments of the eastern Cubango rivers, the Cuito, Cuando and western Zambezi all appear to provide steady, slow flows of very clear, clean water. This is seemingly all a result of rainwater percolating through, and being filtered by deep layers of inert quartz (i.e. sand) before seeping into the rivers and their tributaries. What is not known is how long it takes for rain water to find its way into river water?

Does it take weeks, months or years? How do recharge rates vary from one area to another, and what factors cause the variation? How might changes in rainfall affect recharges and discharges? These questions require answers to provide a clear understanding of the sponge-like functioning of the massive ridge of sand that has come to be called the Okavango-Zambezi Water Tower.

Answers to these questions should lead to another: what happens to all the water that does not find its way into river flow? The volumes of water beneath the sands of this part of the Kalahari Basin could or should be enormous. Where are they, can they be tapped, how might they serve people? The same thinking contributed to the recent discovery on a massive fresh water aquifer straddling the border between Cunene province in Angola and Ohangwena region in Namibia (see https://www.bgr.bund.de/EN/Themen/Wasser/Projekte/laufend/TZ/Namibia/ceb_fb_en.html).

Effects of fire

Field observations on the Namibian side of the border of the lower Cuando catchment show that large, intense and frequent fires have led to, and continue to cause substantial losses of woodland, much of it tall, mature, slow-growing hardwood species. The trees are killed by fires, regeneration and new growth is prevented by recurrent fires, and the affected areas become dense shrub-land. Savannah grassland is likewise lost in the process.

The same kind of large, hot fires burn in most years across much of the three lower catchments in Angola, and it is likely that similar damage to woodlands and grasslands is incurred. That possibility should be investigated and – if found to be correct – urgent steps should be taken to control burning over this very large expanse of savannah. Several other questions related to fires are discussed in the chapter on biological resources.

Movements from rural to urban areas

It is clear that settlement patterns, livelihoods and aspirations are changing rapidly in south-eastern Angola. The changes are doubtless mostly for the good, in reducing poverty and dependence on natural resources that are slow or unlikely to regenerate, and in providing incomes that allow people to participate in the economy of the 21st Century. How can these changes and improvements be encouraged, accelerated, and how can costs be minimized? Indeed, what are the major costs, and when and where are they most severe?

9. Synthesis on catchments in south-eastern Angola

This is a compilation of information and understanding about the Angolan catchments of four major rivers: the Cubango, Cuito, Cuando and western Zambezi (Figure 42). The first three rivers flow into, and no further than Namibia and Botswana, while rivers of the western Zambezi join Zambian tributaries to form the Zambezi on its way to the Indian Ocean in Mozambique.

Importantly, rivers flowing from these catchments contribute the great majority of water that sustains and drives production in three major, world-famous wetlands: the Barotse Floodplains, Linyanti Swamps and Okavango Delta. Similarly, large parts of the Bulozi Floodplains are inundated by water from south-eastern Angola. The Bulozi is probably the largest ephemeral wetland in Africa.

Figure 42: The catchments of rivers flowing through KAZA

Soils

Together with soils in the Lunda provinces and Moxico, most soils in south-eastern Angola are poor – much poorer than those elsewhere in the country. This is because they are less fertile, hold less water and are more acidic than other soils. It is, above all, the nature of the soils that is responsible for the relative paucity of people and wildlife in south-eastern Angola; for limited yields, for requiring farmers to clear fields every few years; and for impeding the regrowth of abandoned fields. Together, these features contribute to high levels of poverty, limited social and economic differentiation and the need for rural residents to harvest and sell charcoal, fish, bush meat and honey. And ultimately, it is because of south-eastern Angola's soils that river water is so clean and flows so slowly, and that the river catchments have remained in such pristine condition. Going forward, the future of the region and its people can only rest profitably in domains that acknowledge the limits and options afforded by soil conditions.

While soils in south-east Angola generally support limited production, small patches that are better suited to farming occur in places, especially in the uppermost reaches of the north-west Cubango catchment. Likewise, soils in some areas are much poorer, in particular those that are heavily leached and depleted in the sandy upper catchments of the other rivers.

Rivers

The great majority of water in the Cubango, Cuito and Cuando comes from their upper catchments, with little water being added in the lower catchments below about 15.5° South. The western Zambezi likewise gets much of its water from its upper catchment, although heavy seasonal rains in the Bulozi Floodplains may add large volumes to the Zambezi before it enters Zambia.

Discharges from most parts of the upper catchments are slow and steady, almost all river water emerging months after rain has fallen and the water has filtered through many metres of sand. Seasonal changes in these rivers are modest and gradual, and much of the upper catchment functions as a giant sponge of sand that slowly releases the supplies of water which go on to sustain year-round flows in downstream wetlands.

The discharges of four major rivers in the Cubango catchment are an exception. These are the Cubango, Cutato Nganguela, Cuchi and Cacuchi. Their flows are quite rapid, and rise and drop in quick response to changes in rainfall. It is these four rivers that produce most flooding of ephemeral and seasonal floodplains and therefore the production of new plant and animal life along rivers downstream and in the Okavango Delta. Their relatively episodic, catalytic contributions therefore complement the more gradual flows other rivers (mainly the Cuito, Cuelei, Cuebe, Cueio and Cuatir) that also feed the Okavango Delta.

Nothing is known about seasonal or annual changes in rivers of the western Zambezi. Likewise, there is no comparative information on volumes of water delivered down these rivers, the biggest of which are the Lungue-Bungo, Luio, Luena, Mussuma and Luanguinga.

The adjoining upper catchments of the Cuito and Cuando have very similar extents, elevations, soils, vegetation and rainfall. Yet, by the time these rivers exit Angola, the Cuito carries about 4 times more water than the Cuando. A likely explanation is that much of the Cuando's discharge is lost to the atmosphere via evapotranspiration from the river's broad floodplain and its abundance of macrophytic reeds. These plants are probably supported by nutrients produced by basalts along certain stretches of its major tributaries. Such nutrient sources are largely absent elsewhere in south-eastern Angola.

Water in all the rivers is normally clear and clean, being largely devoid of nutrients, dissolved solids, organic matter, suspended and bedload sediments. However, these compounds are increasingly abundant downstream, but nowhere do any of the rivers become naturally muddy or severely contaminated. Unlike the more neutral pHs of water in the north-western rivers of the Cubango, river water in the Cuando and Cuito's sandy catchments is extremely acidic, but downstream, it gradually becomes more neutral.

Biological resources

Most of the catchments are tree covered, largely in miombo woodlands or forests in the upper zones, and in open savannas - sometimes called Kalahari Woodlands or Burkea-Baikiaea woodlands - in the lower catchments. Grasslands and sedges dominate the margins and floodplains of rivers, while drier grasslands and underground geoxylic trees and shrubs grow in open areas above and away from drainage lines. These communities of grasses and underground woody plants are probably formed by various factors: regular fires, frost, soils being saturated as a result of underlying hardpan, and clearing for crops.

Such open grasslands and geoxylic woody communities cover the gentle hills of the north-western uppermost reaches of the Cubango catchment, creating an open habitat unlike anything elsewhere in south-eastern Angola. How much or what parts of that open habitat is natural or formed by human activity is not known. However, of late, more substantial and probably unusual quantities of soil and ash may be washed into the area's rivers.

Plant production is highest in the upper catchments, particularly in miombo woodland or forest in the Zambezi west area. By contrast, plant production is relatively low in the river valleys and floodplains, in the grass and geoxylic communities of the northern upper Cubango, in areas cleared for crops, and in large parts of the lower catchments

Most natural vegetation has been lost to clearing for fields, in particular along major truck and trade routes, around large towns and in the north-west of the Cubango catchment. New fields are cleared regularly and frequently, normally after 2 or 3 years of cultivation, and they are then seldom used again.

It is likely that large areas of open woodland and perhaps forest in the lower catchments have been degraded into shrubland by intense, large and frequent fires set by people, and which burn mainly in August and September. Logging for hardwood timber has increased rapidly in recent years, and its environmental impacts are hard to assess, but they are certainly far less severe than those due to shifting agriculture and bush fires.

Wildlife densities are very low in most of the catchments, mainly because of the low nutrient value of forage. However, small numbers of large, iconic mammals occur, and their densities increase from north to south in the Cuando catchment, and probably also elsewhere. Numbers of fish-eating birds similarly increase from the northern upstream reaches of the Cubango, Cuito and Cuando to their southern, lower reaches. These trends probably reflect changes in the supply of nutrients across south-eastern Angola.

People and socio-economic features

People and livelihoods in south-eastern Angola are divided between those in urban and rural areas. Urban populations have grown rapidly in recent years, doubling in size in different towns over periods ranging between 6 and 13 years. Rural populations are generally sparsely distributed, most people being clustered in widely spread villages, each home to a few hundred people.

Approximately 2.7 million people now live in south-eastern Angola. Over half (54%) live in the upper Cubango catchment and almost a third (31.7%) in the western Zambezi catchment. The other catchment zones are each home to less than 5% of all residents in this area of Angola.

People in towns function in a cash economy, the majority engaged in informal trade and services. To a lesser and varying degree, the same is true for peri-urban and rural residents living close to major roads. By contrast, rural people spend much of their time producing food for domestic sustenance or to sell. While the former is almost always a main occupation, time and effort spent on the latter varies according to what can be sold. Dryland yields of staples are low; normally less than 700 kilograms per hectare. Manioc, sweet potatoes, maize and millet are the dominant staples.

On *naca* fields in the northern parts of the Cubango catchment and around large towns, most rural residents grow a variety of vegetables, green maize and sugar cane which is sold at nearby roadsides and urban markets. Dried fish, honey (in miombo woodlands), bush meat, chickens, goats and cattle (along the Namibian border) charcoal, traditional liquor and some dryland staple produce (along certain roads) generate small incomes elsewhere.

Much of the land degradation and poverty in the catchments is a direct consequence of soil conditions which require shifting cultivation and limit food production. Occasional surplus harvests are normally stored to overcome possible future shortages rather than being sold. Inadequate nutrition contributes to high mortality rates, small populations, little economic activity differentiation, few potential customers and low purchasing power.

Financial resources are particularly limiting in most rural areas where residents have either little to sell or limited access to buyers. Increasingly, every effort is made to obtain money for modern living conditions and amenities, this being the main impetus for urban migrants. Those who remain in rural areas are increasingly compelled to harvest any natural resources that may have financial value. In short, rural environments offer some food security but limited income security.

The catchments of south-eastern Angola fall into 6 of Angola's 18 provinces: Huambo, Huíla, Bié, Cunene, Moxico and Cuando Cubango. The provinces are further divided into municípios, which are then further divided into comunas, the smallest unit of formal administration. More local, traditional governance comes from headmen (*sobas and regedors)* who receive stipends from the state. Most land in south-eastern Angola is formally owned by the state, while local residents have rights to its use. There are, however, no effective limits on use, either in terms of who may have user rights or in the quantity of resources that can be used. The same conditions of open access and resource use largely hold in the two large national parks: Mavinga and Luengue Luiana National Parks.

Environmental pressures

Four major processes lead to environmental degradation in south-eastern Angola:

- The clearing of woodland and forest and mining of soil nutrients for short periods of crop farming.
- The setting of frequent, large and often intense bush fires that lead to the loss of woodlands and certain soil nutrients, particularly in the lower catchments.
- Soil erosion in certain areas.
- The contamination of river water in and around large towns

Areas in which these pressures are most prevalent are shown in Figure 40. Additional pressures come from the harvesting of bush meat, timber, fish and charcoal, but these are not easy to map. Some of their impacts are also harder to imagine or assess.

Most urban centres, and rural areas which are densely settled and being cleared of woodland, are along major trade and transport routes linking parts of south-eastern Angola from north to south or east to west (Figure 41). Additional zones of degradation may develop when new roads are built, for example between Cuito Cuanavale and Rivungo and through Shangombo to Zambia, and from Chiume south to Rivungo and Namibia. The latter development along the relatively pristine Cuando River will be a major concern.

With the exception of the upper Cubango, most of the existing and potential axes of severe environmental pressure are within fairly confined areas, which leave large areas of the upper Cuito and Cuando, western Zambezi and lower catchments relatively free of widespread settlement and deforestation.

Noting that by far the greatest volumes of water flow from the upper catchments of the Cubango, Cuito, Cuando and western Zambezi, conservation efforts to protect the hydrological functioning of these catchments will be of major value. The upper catchments of the Cuito, Cuando, Zambezi and eastern tributaries of the Cubango (Cuelei, Cuebe, Cueio and Cuatir) are relatively pristine. This is unlike the western Cubango sub-catchment where the Cubango, Cutato Nganguela, Cuchi and Cacuchi rivers flow through large areas that have been degraded by dense settlement, intense farming, soil erosion and water contamination (Figure 40). Here, priority attention should be given to preventing further degradation, and to restoring natural vegetation, soil qualities and hydrological processes.

Such special attention on the western Cubango is necessary if these rivers are to continue to drive and maintain the productivity of downstream floodplains along the Cubango River and in the Okavango Delta. None of the other rivers flowing from south-eastern Angola can perform that function.

10. Perspectives on food production in Angola, and its south-eastern river catchments[5]

This brief review aims to assess levels of demand and supply for certain major crops; to identify geographic areas suited to the production of significant volumes of food; and to offer perspectives on how agriculture is conducted: at what scale, where, by whom, what for, and with what investments. In addition, food production in Angola's south-eastern catchments of the Cubango, Cuito, Cuando and Zambezi rivers is described.

The crops discussed are maize and rice (cereals), soybeans (legumes), cassava, sweet potatoes and potatoes (roots and tubers), meat (cattle and goats) and coffee. 'Agricultural hotspots' are areas where good agro-ecological conditions are present, where crops can be cultivated irrespective of the scale of production, and where the bulk of national production can be concentrated.

This information provides a background to guide the development of agriculture in the catchments of the Cubango, Cuito, Cuando and Zambezi rivers in Angola. Many people assume that the catchments are well suited to agriculture. Development is needed to redress a perceived neglect south-eastern Angola. Large areas of sparsely populated, undeveloped land are available, as well as river water for irrigation. Agricultural planners, politicians and investors therefore see opportunities to develop massive agricultural schemes in the catchments to produce the large amounts of food that Angola needs.

An absence of reliable data is a major challenge for a review of this nature. However, a good source of information is the CNC (*Conselho Nacional de Carregadores*), which has provided reliable data on licenced food imports that enter the country through the seaports. Regrettably, data on food products that come by road, from neighbouring nations, are not available. Comprehensive data on food produced in Angola is also lacking. As a result, knowledge is often inadequate concerning:

1) Areas of major crops under cultivation
2) The productivity of different farming systems
3) The total production volumes of different crops within Angola
4) Numbers of 'subsistence' and commercial farmers, and their employees
5) Numbers of families dependent on crop farming or cattle farming/keeping
6) And critically: to what extent is Angola food self-sufficient?

It should be clear that while some data provide measures of the volumes of food needed (and thus imported, at least by sea – see Table 5), it remains hard to assess Angola's exact needs to expand production.

Table 5: The most important food imports entering Angola via seaports, measured in tons, during the years 2013, 2014 and 2015.

Product	2013	2014	2015

5 This review is based on our experiences and observations throughout Angola, but specifically in areas where staple crops are produced commercially. That work was conducted for a large-scale production programme for cereals and vegetables in the productive Quibala region (KS46 funded by the Angola Development Bank). This programme can provide useful lessons on the viability and sustainability of large-scale investments, lessons which can usefully be applied to development similar models envisaged for south-eastern Angola.

Wheat flour	506,125	519,982	484,088
Maize flour	185,584	225,267	194,306
Rice	441,966	474,748	463,109
Maize (grain)	No data	37,073	54,000
Sugar	367,827	462,219	287,633
Frozen chicken	316,016	503,830	384,177
Pork (frozen)	57,261	34,291	No data
Beef (frozen)	51,929	15,914	No data
Frozen meat products (non-muscular)	37,274	19,173	No data
Eggs	17,861	7,578	No data
Palm oil	253,135	291,715	166,490
Soya oil	76,814	75,113	197,478
Beans and other dry legumes	59,280	71,908	52,004
Canned tomato products	44,771	24,571	24,707
TOTAL	2,415,843	2,763,382	2,307,992

Source: Conselho Nacional de Carregadores

Major crops

Maize

Table 6: Estimated requirements for maize and its substitutes per year, in Angola.[6]

Uses of maize	Tons of maize	Area needed (hectares) based on possible yield of 4 tons/hectares
Feed for 400,000 tons of chicken (now imported as frozen food)*	636,000	159,000
To feed 2,500,000 laying hens*	97,000	24,250
Needed for flour for human consumption**	1,500,000	375,000
Needed as a barley substitute for brewing	50,000	12,500
Total	2,283,000	570,750

* Because 636,000 tons of maize would be needed to raise 400,000 tons of chicken, which has now been imported. For laying hens, the assumed requirement is 84 grams of maize/day for a population of 2.5 million of layers.
** Assuming 25 million Angolans each consume 40 kg of maize flour/maize *'fuba'* per year.

Maize has particular strategic value because of its substantial demand and multiple uses. There are significant differences between the main maize producing areas in terms of the types of farming, degrees of intensification and capital investment. The differences concern both inputs and post-harvest production. The three major zones and types of farming are:

6 These data were compiled by Antonio Martins, Luanda

1. Large commercial companies along the Lucala/Cacuso axis
2. Small, medium and large farms along the Quibala/Waco Kungo axis
3. Peasant and small commercial farms in northern Huíla (Matala, Quipungo, Caluquembe) and the central Plateau (Chinguar, Cachiungo, Bailundo, Cáala, Huambo and Bié, etc).

Figures in Table 5 indicate that Angola is extremely dependent on maize imports, whether for direct consumption or in the form of products which require maize for production (of beer, frozen chicken and eggs). However, it is also clear that production within Angola can be increased substantially. Yields of 4 ton/hectare of rain-fed maize can be achieved on commercial farms. With irrigation, 11 tons/hectare is an attainable yield, yet the average productivity of the biggest irrigation scheme in Angola peaks at 6 – 7 tons per hectare. This scheme at Kibala (Cuanza Sul) has 41 centre pivots in a total of 2,000 hectares.

Good yields can be achieved after lengthy processes of trial and error, using a proper irrigation calendar and applying the right fertilizers in adequate quantities, at appropriate times, in the crop cycle. This requires experience and expert knowledge of the local soils and climate. The costs of irrigated production are high and competent management is required for the operation and maintenance of equipment. Formulas applied in one region cannot simply be applied elsewhere.

A variety of support services and technical assistance is required to support maize production, especially among small- and medium-scale commercial farmers. The following are examples of measures to improve productivity: post-harvest support services; mechanization for sowing, tillage, clearing, threshing and spraying; and support to acquire proper fertilizers and certified seed.

Soybeans

Soybeans are the most important source of protein for domestic animal production, especially for egg, chicken and even pig production.

Table 7: Estimated requirements for soya and its substitutes per year in Angola.[7]

Uses of soya	Tons of soya	Area needed (hectares) based on possible yield of 2 tons/hectares
Feed for chicken (now imported as frozen food)**	300,000	150,000
To feed 2,500,000 laying chickens*	27,700	13,8500
Soya oil imports**	595,000	297,500
Total	922,700	461,350

* This amount is considered consumption because of 300,000 tons of soya would be required to raise the 400,000 tons of chicken that are now imported. To feed 2.5 million laying hens 27,700 tons of soya oil are required.
** 595,000 tons of soya are needed to produce 100,000 tons of soya oil, currently imported. Note that of 1 ton of soybeans, 75% is processed into starch for animal food, and the remaining 25% into (mainly) oil for human consumption.

Domestic soybean production is largely confined to the Quibala/Waco-Kungo axis and is clearly insufficient to meet Angola's requirements.

Cassava

Cassava and maize are the staple foods in the northern regions of Angola. Despite its importance, only two large farms (Mandioko – Zaire and CAM – Malanje) are known to produce cassava on a combined area of

7 These data were compiled by Antonio Martins, Luanda

about 1,000 hectares. Both farms sell their produce as processed cassava *fuba* (flour) or *farinha musseque (*roasted flour). Traditional production by peasant farmers is greatest in Cuanza Norte, Uige, northern Cuanza Sul and Malanje provinces.

The introduction of varieties with shorter growing cycles and resistance to mosaic virus disease would increase production. Cassava growing would benefit from a network of local suppliers of improved seed material and services for planting, harvesting, fermentation, drying and milling.

Rice

Angola imports an average 450,000 tons of rice per year. Historically most rice has been produced in Bié and some parts of Moxico province. Publicly-funded state schemes have produced some rice, such as those at Gesterra – Sanza Pombo in Uige, and the Longa Farm in Cuando Cubango. There are also two private farms dedicated to rice production, but each with less than 200 hectares under cultivation.

Robusta coffee

Angola probably produces about 3,000 tons (peeled and polished) of Robusta coffee per year, of which approximately 1,500 tons is exported. The best quality and highly valuable Robusta for export purposes is the 'Amboim type' produced in Cuanza Sul.

Producers are concentrated in Gabela and Calulo municipalities (for the Amboim type), where there is a mix of traditional, small- and medium-scale commercial growers. Both municípios offer good potential for the increased production of Robusta coffee.

Arabica coffee

The production of commercial Arabica coffee (peeled and polished) is low, perhaps no more than 80 tons per year. However, the real figures are opaque and need confirmation in the field. Regions where production could be expanded lie in an arc extending from Ganda to Nharea, including Cassongue and Andulo municipalities. The highest potential for the expansion of production by traditional and medium-sized commercial farmers is in the areas between Andulo and Cassongue.

Measures to improve production include the provision of varieties resistant to fungi and technical support in planting, shade management, fertilization, pest treatment and pruning; and the construction of drying yards on small farms and post-harvest centres.

Sweet potatoes

Sweet potatoes are a significant and substantial source of food due to their disease resistance and productive potential in low-input conditions. Although grown throughout the northern two-thirds of Angola, two areas are best suited for expanded production. The first stretches across the provinces of Malanje, Cuanza Norte and Bengo, while the second covers the provinces Cuanza Sul and Huambo.

Irish potatoes

Irish potatoes are a popular food in Angola, with an estimated 600,000 tons being consumed each year. It is thought that less than half that amount is produced in Angola. Most production is in three zones: Quibala-Waco Kungo, Huambo-Bié (central Planalto), and around Matala. Production in each of these zones can be expanded, especially on small and medium-scale farms.

Potato production would benefit from a greater availability of high quality seed. A seed production centre somewhere near Huambo (in particular, Ecunha) would be close to the potato production zones in Cuanza Sul, Huíla and the central Planalto.

Beef

It is only possible to guess Angola's annual requirement for beef. In 2013 at least 52,000 tons of frozen meat where imported by ship. However, beef is also imported by road (from Namibia and South Africa) and produced by industrial abattoirs, of which at least four were functional in 2017. Informal 'bush' abattoirs provide most of the meat sold by informal markets. Although there might be as many as 2 million cattle in the country, most animals are kept as capital and are therefore not available for beef production. Moreover, productivity is hampered by multiple diseases, inadequate management and poor forage in many areas of the country.

The production of beef could benefit from measures to improve water provision, vaccination services, pastures and forage, and cross-breeding between indigenous and imported stock to improve local herds. There is also a need to encourage the commercial production of cattle for revenue.

Soil improvement

Although imported synthetic fertilizers cannot be totally replaced, it would be beneficial to establish some medium-sized organic fertilizer production units (15,000 tons/month each). They could use such raw material as poultry and livestock waste, agricultural limestone and vegetable matter compost (elephant grass, for example). Subsidising the provision of agricultural limestone (for liming) is desirable, especially to supply grain producers in certain areas, one reason being that the costs of transport now exceed the costs of the limestone itself.

Zones where production could further be developed on small- and medium-scale farms

Table 8: Areas in which the production of various commercial crops on existing small- and medium-scale farms could profitably be increased through the provision of technical assistance, the facilitation of the use of private mechanization services and by supplying inputs, post-harvesting services and facilitating commercialisation.

Province	Município	Main commercial crops
Cuanza Sul	Quibala	Cabbages, Irish potatoes, green peppers, maize
	Wako-Kungo	Maize, soya, vegetables, dairy, poultry
	Amboim	Bananas, papayas, plantains, pineapples, coffee
	Libolo	Cassava, coffee
Huambo	All municípios	Horticulture (onions, Irish potatoes, cabbages, carrots), maize
Bié	Chinguar	Horticulture (onions, Irish potatoes, cabbages, carrots), maize
Huíla	Northern municípios	Maize
	Humpata	Fruticulture, horticulture (potatoes, onions, cabbages)
Malanje	Cacuso, Malanje	Cassava, sweet potatoes
Bengo	Dande	Fruticulture (bananas, papayas, mangoes) horticulture (leaf crops, tomatoes, onions)
Benguela	Benguela and Baía Farta	Fruticulture (bananas, papayas, mangoes) horticulture (leaf crops, tomatoes, onions)
Cunene	Western municípios	Cattle
Namibe	Moçâmedes	Irrigated horticulture (tomatoes)
Uige	Southern municípios	Cassava, sweet potatoes, plantains

Cuanza Norte	Golungo Alto and Cazengo	Cassava, sweet potatoes, fruticulture, coffee

Farming systems in Angola

Farming in Angola is broadly divided into that concerned with providing food for domestic consumption (often called peasant, subsistence or traditional farming), and commercial agriculture. The following distinctions can be made within the commercial sector:

Small- to medium-scale farms are characterised by:

- their market-orientation, sometimes with systems for transporting produce to urban markets.
- some degree of mechanization to support agricultural operations.
- some use of irrigation, by means of pump systems.
- the general use of purchased, certified inputs (seeds, fertilizers, pesticides) to maximise production and income.
- their location, usually close to markets or at least near major transport routes to markets and urban centres.

Privately run large capital-intensive farms developed with funding from the private sector or public banks, which are:

- similar to medium-scale farms, but operate on a bigger scale with greater resources;
- exclusively market-oriented;
- normally produce crops that can be sold quickly;
- located as close as possible to market, to minimise transportation costs for their produce and inputs. Most such farms are near coastal centres;
- maximize the use of equipment available, only replacing equipment when needed;
- employ continuous processes of learning, adjustment and improvement;

Of a total of 27 such farms, 25 are currently functioning while 2 have stopped working.

Large farms established by the government and operated by private companies, and which have been funded by government, or through loans guaranteed by government from investment funds (for example, Aldeia Nova), foreign institutions (Gesterra farms, for instance) or parastatal companies (for example, Sonangol for the Biocom scheme). These farms[8]

- are usually over-equipped and over-staffed for the purpose;
- are often located inappropriately, frequently in places determined more by political considerations than factors associated with agriculture (crop viability, marketing, transportation or the presence of other farmers with whom to create synergies);
- Face challenges of weak management and unclear responsibility, normally because of a lack of accountability and/or incentives for managers and decision-makers;
- are large and the projects generate substantial profits for developers during the process of establishment, but that is not once – or if – the farms start to operate;

8 Investments that are completely foreign-owned are unknown in Angola, unlike elsewhere in Africa. Accusations of land grabbing are consequences of disputes between locally resident crop farmers or pastoralists and Angolan companies or influential individuals. Propriety is often linked to the use of land, and not in formal property deeds or rights. Unregistered traditional rights are therefore seldom recognised as legally binding.

- Incur costs and losses because loans are secured by the government or its parastatals, and the public is often required to cover these;

Of 21 such farms, 6 are currently functioning while 15 have stopped working.

Appendix 1 provides a list of farms that illustrate circumstances associated with both types of large farm enterprises, while the distribution of most of those farms is shown in the following map (Figure 43).

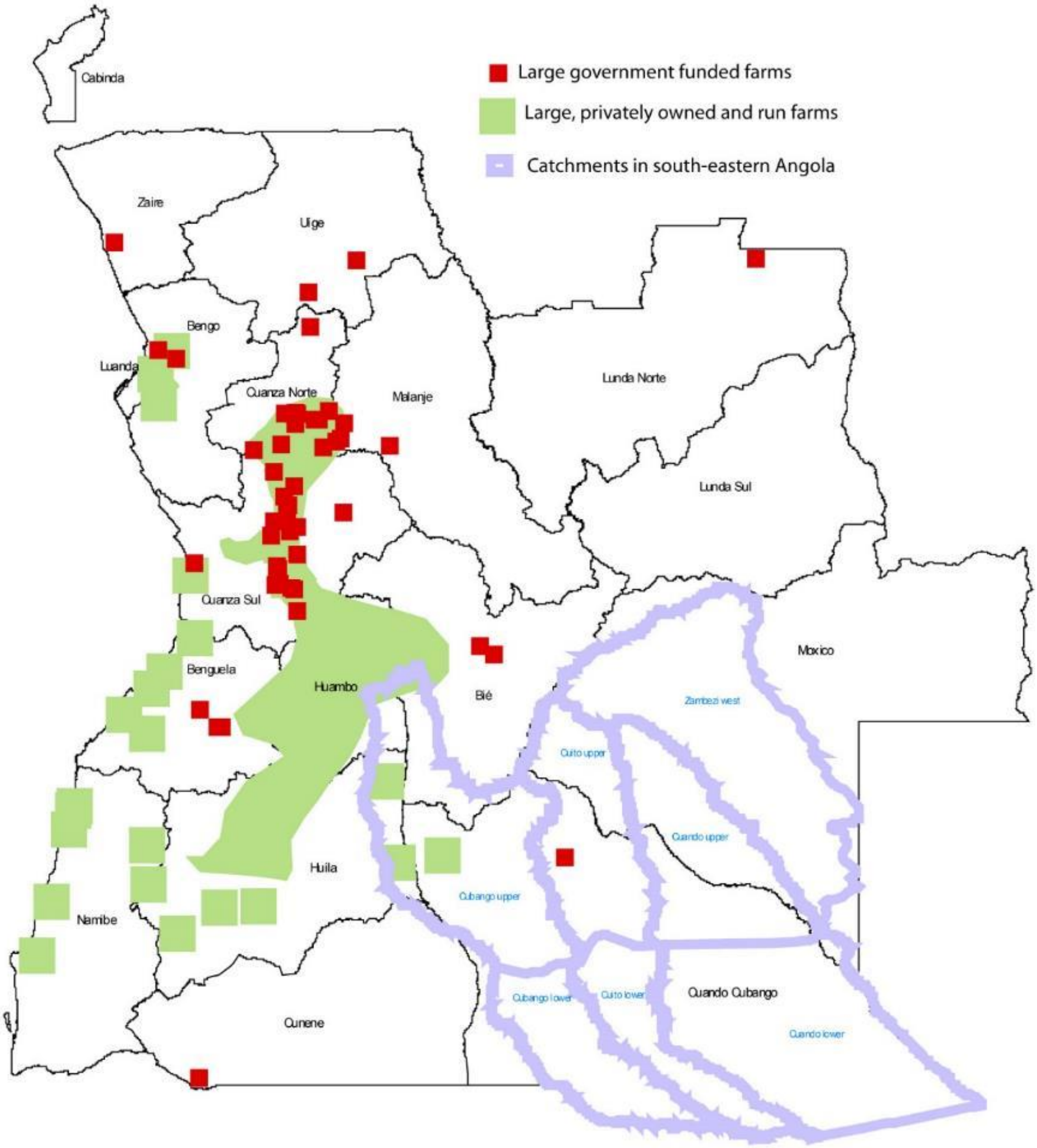


Figure 43: The general distribution of different commercial farming enterprises in Angola. Many other confined areas of commercial small-holder farming are to be found around larger towns and along certain major trunk routes.

Agriculture in south-eastern Angola

Farming in south-eastern Angola can be divided into five types.

1) **Large, Commercial Farms.** With capital-intensive activity, they often employ specialized labour. The farms are privately owned and usually funded with credit obtained from the private banking sector. Examples are Agrikuvango and Mumba described in Chapter 12 on development projects.

2) **Large State or Parastatal Investment Schemes.** They are usually funded directly by or through government institutions. They are also capital-intensive and are implemented with the help of specialized labour provided by private companies. There are two such farms in south-eastern Angola: Fazenda Agro-industria do Longa and Fazenda Modelo, the latter being developed as part of the large planned complex of Cuchi farms, again described in Chapter 12.

3) **Small Commercial Ventures**. These are all market-oriented enterprises, usually run by families with help from occasional labour. The farms use little technology and few purchased inputs, such as seeds and fertilisers. They generally produce vegetables that are sold at road-side markets or markets in local towns. The majority of small commercial farms are in the uppermost areas of the Cubango catchment and around towns, such as Menongue, Luena and Chitembo. The fields are typically on moist Gelysols or Fluvisols, the wettest soils in *naca* fields being used in the dry season, and conversely the drier soils in *ombanda* fields during the rainy summer.

4) **Medium-scale Agriculture**. Size, technology and labour are the main features that distinguish these bigger farms from Small Commercial Ventures. The farms are often 50 hectares and greater in size, they use tractors and pumps, buy seeds, fertilisers and pesticides in substantial quantities, and employ significant numbers of local people at different times of the year. They are much less capital intensive than the large private or government farms, and are infrequently funded by banks or the state. Most funds are supplied by farmers and land owners. The farms normally specialise in producing on one, two or three crops, at most. Although '*Agro-Pecuaria*' signs are often seen, there are few commercial farms of medium size in south-eastern Angola. Two examples described in Chapter 12 are Vinevala and Boa Esperanca at Bimbi.

5) "**Peasant" dryland farms.** The low-input agriculture practised on dry lands is the commonest type of agriculture in south-eastern Angola. Surpluses are generally stored for hard times, and thus seldom sold. Labour and other inputs are minimal. This kind of farming is 'traditional', remaining the same as it was hundreds of years ago. There is little or no horticulture, and few livestock are kept. All, or by far the greatest part of any meagre income is generated by non-farming commodities, such as charcoal, bush meat, honey or fish. Millet, manioc, maize, melons, beans and sweet potatoes are the most important dryland crops, the prevalence of each varying from one area to another. Most of the crops are grown on dryland fields that are cleared on a shifting or 'slash-and-burn' basis.

Cattle are rare in most areas, an exception being along the Namibian border. Likewise, sheep and goats are uncommon, while small numbers of pigs and chickens are kept in most villages. The animals are all used primarily as savings or capital. Factors limiting their numbers and health include diseases, poor nutrition and palatability of pasture, and a lack of water in certain areas.

Conclusion

Given its soil conditions (see Chapter 3) and remoteness, much of south-eastern Angola is poorly suited to most agriculture, and it has never supplied much food to Angola. The most productive agricultural areas in Angola are close to urban markets and the main roads that connect the country's five big cities (Luanda, Benguela, Lobito, Lubango and Huambo). Much of this area is in the central plateau stretching across western Bié, Huambo, far-eastern Benguela and northern and western Huíla; in Cuanza Sul; in the coastal valleys of Namibe, Benguela and Bengo provinces; in western Malanje and in some parts of Cuanza Norte. Almost all private companies have established themselves in these productive areas. This is where experienced farmers are concentrated, running private market-oriented, large-scale farms. And the only peasant farmers earning money in agriculture are in these same areas, where they mainly grow and deliver valuable fresh produce to urban markets.

The eastern provinces (Lundas, Moxico and Cuando Cubango) as well as the northern ones (Zaire and Cabinda) contribute little or nothing to Angola's food security. Large-scale investments in agriculture in these regions are almost exclusively driven by political motives and public funds, and most have not been functional. Many large, generously funded government farms are also located in productive farming areas, where inappropriate management is their main limitation. However, this is a weakness that can be remedied, and the farms recovered and reactivated.

It is fair to assume that the best areas for maize and legume production in Angola are already known and developed by small-, medium- and large scale farmers. With further development and improved techniques the same areas can provide most of Angola's food needs.

In the light of these potentials and circumstances, proposals to cultivate large new tracts of land in areas which are inappropriate for farming, should perhaps be reconsidered.

Appendix 1: A selection of major farms and agricultural schemes in Angola to illustrate the range of crops, production methods and types of funding.

Province	Município	Name	Main crops	Production	Type of funding
Cuanza Sul	Quibala	Santo Antonio	Maize, soya, animal fodder, pigs and maize flour	2,000 hectares of centre pivot irrigation; 600-900 reproductive sows	Private Angolan bank
Cuanza Sul	Quibala	Nova Agrolider	Greenhouse horticulture, feedlot cattle production, citrus	8 centre pivots, greenhouses (26 hectares). Post-harvest facilities	Private and parastatal Angolan banks
Cuanza Sul	Quibala	Kambondo	Maize, soya, beans, potatoes	6 centre pivots; Post-harvest facilities. Facing difficulties	Private and parastatal Angolan banks
Cuanza Sul	Quibala	Nuviagro	Potatoes, onions, carrots	8 centre pivots. Post-harvest facilities	Private Angolan bank
Cuanza Sul	Quibala	Terra do Futuro	Maize, soya, animal fodder, maize flour	Dryland irrigation. Project not functioning at the moment	Parastatal bank
Cuanza Sul	Wako Kungo	Aldeia Nova	Maize, soya, beans, millet, sorghum, animal fodder, dairy (400 cows), eggs (500,000 layers)	Biggest dairy in Angola and egg producer outside Luanda. Dryland crops. 3,000 – 4,000 hectares per year	Foreign investment fund
Cuanza Sul	Wako Kungo	SEDIAC	Maize, soya, beans	3,000 – 4,000 hectares of dryland crops	
Cuanza Sul	Wako Kungo	Agro-wako	Maize, potatoes	4 pivots. Post-harvest facilities for potatoes	
Kwanza Sul	Libolo	Cleomas	Citrus, mangoes, guavas	400 hectares of orchards	Private Angolan bank
Cuanza Norte	Cambambe	Rogério Leal	Maize and flour production	11 centre pivots. Milling 2.4 ton/hour	
Cuanza Norte	Lucala	Lucalagro	Maize, intensive horticulture	3 centre pivots; greenhouses	Private Angolan bank
Malanje	Malanje	CAM	Cassava and cassava flour	600 hectares	Private and parastatal Angolan banks

Malanje	Cacuso	Quizenga	Maize	Not functioning	Foreign loans
Malanje	Cacuso	Pedras Negras	Maize	Not functioning	Foreign loans
Malanje	Cacuso	Pungo Andongo	Maize	Not functioning	Foreign loans
Malanje	Cacuso	Pipe	Maize, beans	Functioning	Private and parastatal Angolan banks
Malanje	Cacuso	Biocom	Sugar cane	About 16.000 hectares of sugar cane. 50,000 to 60,000 tons of sugar per year	Foreign loans; Parastatal company investment
Benguela	Cubal	Vitor Alves	Sugar		Private Angolan bank
Benguela	Caimbambo	Vitor Alves	Sugar and alcohol		Private Angolan bank
Benguela	Cubal	Gesterra	Maize	Centre pivot irrigation. Project stopped	Foreign loans
Huíla	Humpata	Nossa Terra			
Bengo	Dande	Nova Agrolider	Mangoes, bananas, papayas, table grapes, passion fruit	> 200 hectares of orchards	Private and parastatal Angolan banks
Bengo	Dande	Turiagro	Bananas, mangoes, papayas	> 160 hectares of orchards	
Bié	Camacupa	Private	Rice	Sheet irrigation. Perhaps best rice producer in Angola	Private Angolan bank
Bié	Camacupa	Gesterra	Maize		Foreign loans
Cuando Cubango	Longa	Longa	Rice	Production stopped	Foreign loans
Uíge	Sanza Pombo	Sanza Pombo	Rice		Foreign loans
Uíge	Negage	Agricultiva	Greenhouse, poultry		Foreign investment loan
Zaire	Nzeto	Agricultiva	Manioc		Foreign investment loan

11. Major developments in the Cubango and Cuito River catchments in Angola

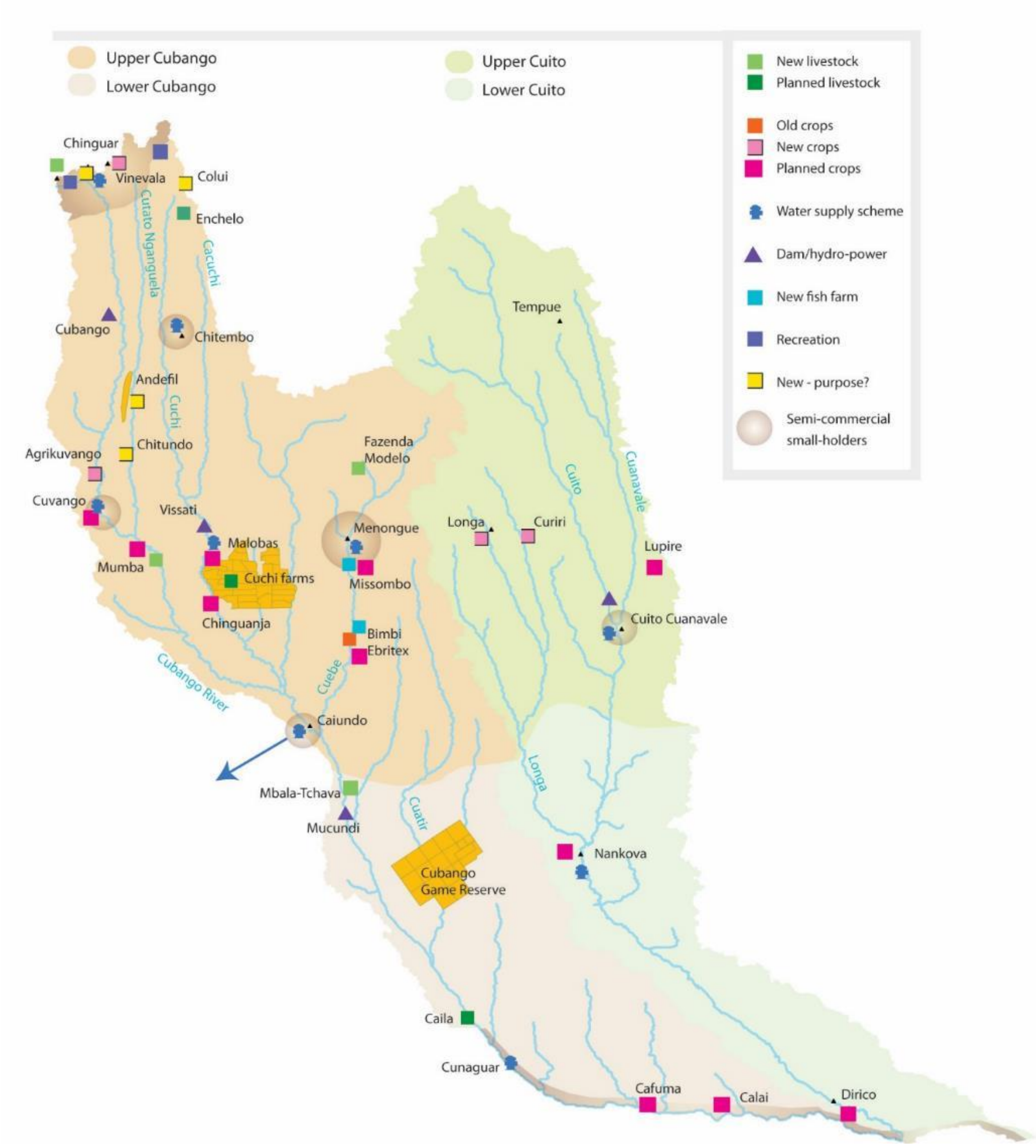


Figure 44: Old, new and planned developments for crop, fish and livestock production, water supplies, hydro-power and other enterprises. Based on field observations and informants, and COBA (2010), Consulprojecto et.al. (2012), Costa Afrika & I.Green (2014), Governo da Província do Cuando Cubango (2013), Governo Provincial do Cunene (2014), and World Bank (2017).

The document describes major commercial developments designed to produce food, hydropower and urban water supplies in the Cubango and Cuito catchments. These projects – and knowledge about them – is essentially divided in two categories. The first comprises projects announced by government in a variety of regional and sectoral development plans. These are all large projects, and a fair amount of knowledge about them is in the public domain. Most of these projects have not reached practical or feasibility planning stages, or been implemented, however (to our knowledge, the only exceptions being the Longa and Fazenda Modelo projects). The probable consequences of these large projects for the rivers' functioning is considered alarming, and concerns are often raised about their financial, technical, managerial, economic, social and other environmental dimensions.

The second category consists of existing projects that have been practically implemented by private enterprises and individuals. Little information about the projects is available, and their environmental impacts – individually or cumulatively – have not been assessed. In the absence of information or impact assessments, little alarm about their possible effects has been raised, again either individually or cumulatively. These projects are generally much smaller than those planned by government. Land and water used for the private projects is free, and occupation rights are obtained readily. The development of certain private projects has been supported with public funds

The following table summarises the information now available to us. It is, however, important to know that there are other planned but unknown projects, especially those conceived by private investors. And government officials are certain to conceive yet other plans.

Table 9: List of projects, organised by purpose, proponent or developer, when started, and size

NAME	TYPE	STATUS	Area (ha)	YEAR BEGAN	Planned size
Bimbi (Boa Esperanca)	Irrigation	Old	80		
Missombo	Irrigation	Old	332	1990	2,000 (planned expansion)
Enchelo	Livestock?	Old	1,465	2000	
Mbala-Tchava	Livestock	Old	740		
Bimbi fish farm	Fish farming	New		2016	
Missombo	Fish farming	New		2018	
Cachiungo	Fish farming/irrigation?	New	36	2016	
Agrikuvango (Tulumba)	Irrigation	New	530	2017	
Curiri	Irrigation	New	645	2017	
Longa rice	Irrigation	New	2,885	2014	8,500
Vinevala	Irrigation	New	250	2016	
Ukuni*	Irrigation/fish farming?	New	533	2016	
Fazenda Modelo	Livestock	New		2016	
Firma*	Livestock	New			
Omatapalo- Mumba	Livestock	New	900 +	2016	
Cubango Game Reserve	Conservation & tourism	New	240,000	2014	

Agropec	Recreation and farming	New	362	2010	
Cassenge	Recreation	New			
Chitundo	Unknown	New		2018	
Fazenda Andefil	Unknown	New			
Menongue	Urban supply	New		2016	
Cuito Cuanavale	Hydro-power	Planned			
Cubango	Hydro-power	Planned			
Malobas	Hydro-power	Planned			
Mucundi	Hydro-power	Planned			
Cafuma (private)	Irrigation	Planned			2,000
Chinguanja	Irrigation	Planned			40,000
Cuvango	Irrigation	Planned			35,000
Ebritex	Irrigation	Planned			25,000
Lupire	Irrigation	Planned			5,000
Dirico	Irrigation	Planned			20,000
Calai	Irrigation	Planned			5,000
Menongue	Irrigation	Planned			15,000
Mumba	Irrigation	Planned			27,500
Nankova	Irrigation	Planned			20,000
Chicala Cholohanga	Irrigation	Planned			22,000
Vissati	Irrigation	Planned			5,000
Caila	Livestock and abattoir	Planned			10,000
Caiundo/Cuvelai	Water supply to Cunene	Planned			
Cachiungo	Urban supply	Planned			
Chitembo	Urban supply	Planned			
Cuanguar	Urban supply	Planned			
Cuchi	Urban supply	Planned			
Cuito Cuanavale	Urban supply	Planned			
Cuvango	Urban supply	Planned			
Nankova	Urban supply	Planned			

*These projects lie and obtain their water very near the catchments, but are included here to provide additional information on the nature of recent developments in south-eastern Angola.

Figure 1 shows the locations of the developments described or mentioned here. Of note is the concentration of projects in the northern and western parts of the Cubango sub-catchment which are close to trunk roads, the Benguela Camino de Ferro railway, and major towns and cities. Few developments have been implemented or planned elsewhere, probably because the soils are generally poorer, and these areas are harder to reach, and/or more remote from markets and support.

Fish farming

At least two fish production farms are being developed in the catchment. One is about 18 kilometres south of Menongue at Missombo, which is a pre-independence irrigation scheme (see page 89). The farm is being developed for the Ministry of Fisheries, and will be used to produce a variety of fish species, some of which may be aliens. Annual production is planned to be 3 million fingerlings and 500 tons of fish. Missombo lies alongside, and obtains its water directly from Cuebe River. The risk of fish escaping into the Cuebe and thereby introducing alien species into the whole Cubango-Okavango system is a concern. Fish diseases could be spread in a similar fashion.

The other fish farm is small, and apparently experimental. This is Bimbi, and it lies about one kilometre north of the Cuebe River about 55 kilometres from Menongue on the road to Caiundo. The project has been developed by the Ministry of Environment & Tourism (MINAMB). It has four small ponds, and accommodation for visitors, as well as a *jango* for entertainment.

Aerial view of the Bimbi fish farm. The Menongue-Caiundo road is in the foreground, and the Cuebe river to the back.

Although its purpose is not quite certain, a third project is widely regarded as being for fish production. This is the small dam just south of Cachiungo. The impoundment was created by damming off a small tributary of the Cubango River (see page 96). (A lone hippopotamus was in the dam for several days in July 2018).

Crop production

Although commercial production is normally associated with large farms, the majority of farmers who produce crops for sale are actually small-holders who grow vegetables on *naca* fields. Almost all are located near major roads or around urban centres where produce can be sold. Their farming activities are actually semi-commercial, part of their production being for sale while the rest is used for domestic consumption. Dryland produce is usually eaten at home, while vegetables are mostly sold. Other small-holders produce some small quantities of dryland crops, mainly maize, melons and manioc. The distribution of most semi-commercial small-holders is shown in Figure 1.

Little mechanisation, and few fertilisers or improved seed varieties are used by small-holders. Their main inputs are in labour, each farming family spending considerable parts of each day managing irrigation and drainage channels, ploughing, planting, weeding, harvesting and marketing their produce. Much less labour is invested in dryland crop production, by contrast.

The rest of this account focuses on larger scale enterprises. They, too, vary in size, as well as in productivity and viability.

THE GRAIN SILO PROGRAMME

The construction of grain silos at various locations over the past five years is intended to support commercial crop production. This is part of the *Programa de Investimento Público* (Public Investment Program). The silos were to be collection and storage facilities for maize produced by local farmers, thus replicating the system that operated before independence in which small-holder growers would sell their harvests to traders who would transport the grain to silos in major towns. This silo was opened in 2014 at Cuvango. Like many others across the country, the silo has not been operated. Among a number of challenges, the system has suffered from the absence of a trading system that brings maize from producers to the silos, as well as money to pay producers timeously for their harvests.

COLUI (OR UKURI OR CURI)

While this development is strictly speaking not in the catchment (Figure 1), it lies very close and provides an example of recent land use changes in the area. Apparently developed by a Chinese enterprise, the farm is situated 18 km south of Desvio on the road to Chitembo. There are some recently planted citrus plantations, two dams have been built, and the beginnings of eucalyptus, aquaculture, dairy, cattle and dryland crops seem evident. The entire farm is probably about 1,500 to 2,500 hectares, and is in the headwaters of the Cuquema River, which is a tributary of the Cuanza River.

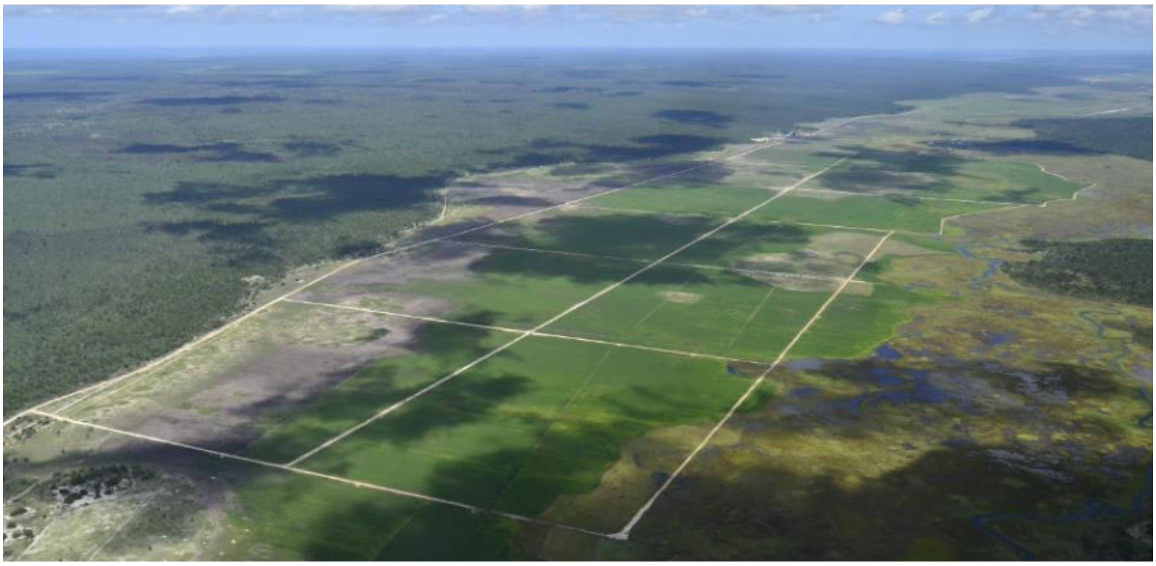
The photograph views Colui from the east, the main road between Chitembo and Desvio runs along the top of the image.

VINEVALA

This medium-scale farm is just east of Chinguar. It covers some 400 hectares, of which about 200 hectares are for maize, 15 hectares are for potatoes (as in this photograph) and a small area is for wheat. The farm is managed well, is of a manageable scale and is located close to transport and established markets, thus providing an example of effective commercial farming in the catchment. Other factors contributing to its relative success include rainfall of over 1,000 millimetres per year, the presence of a workforce drawn from nearby local residents, and nearby rivers to provide water for irrigation.

Vinevala was developed on land previously cleared of miombo woodland. Erosion is a pervasive problem, as is the ongoing depletion of soil nutrients (which require costly replacement in the form of fertilisers). Despite the constraints, these northern areas close to markets that have already been deforested, and that have soils that are at least marginally useful for agronomy, offer better potential for commercial development than most other parts of the catchment. In fact, this potential was developed historically when much of Angola's central plateau (the *Planalto*) produced large volumes of carbohydrates (maize and potatoes) as well as vegetables (onions, cabbages and carrots, *et cetera*).

LONGA



The Longa rice farm is a government project, first developed in 2012 on the west bank of the Longa River. Its development was accompanied by many expectations. However, after producing small crops in its first two years, the farm has ceased to function. A total of 1,500 hectares was cleared, ploughed, fertilised and equipped with irrigation equipment. The development also has a manufacturing plant for the processing, drying and packaging of rice, three laboratories and residential area for technical staff.

Fazenda Agro-industria do Longa farm is now widely regarded as an unfortunate example of oversizing and a lack of practical realism. Its development cost the public US$750 million dollars. Most soils on the farm are not suitable for rice cultivation. The gleysol and fluvisol soils are too acidic for rice cultivation, with pH values ranging from 4.8 to 5.5. Acidity will increase with the drainage, due to the decomposition of organic matter as it dries. It is now estimated that annual production can reach a maximum of only 2,500 to 3,000 tons, using 500 hectares that have some suitability for rice. Much of the remaining floodplain area developed for the project is too wet.

Despite the presence of new, modern equipment, only 300 to 400 hectares of rice could be planted by hand. Yields never exceeded the 3 tons per hectare, giving an annual production of about 1,000 tons. The manufacturing plant was however over-endowed with machines to process 7 tons of rice per hour, or 168 tons per day. Most of the lateral move irrigators, tractors and other machines have ceased to operate, or were never used. There was also a shortage of funds to buy seed.

The management of Longa has now been allocated to a private company, Cofergepo S.A., which intends to assist other, private farmers to produce rice which can be processed and marketed with Longa's assistance.

AGRIKUVANGO

This is the biggest irrigation scheme so far developed in the Cubango catchment. The project area covers some 3,000 hectares, and includes 12 centre-pivots, each irrigating 50 hectares. About 600 hectares will therefore be irrigated with water pumped from the Cubango River which forms the eastern boundary of the farm. The project lies roughly 20 kilometres north of Cuvango town, and belongs to the Tulumba Group.

It is understood that the farm plans to harvest two crops of maize each year. If a yield of 7 ton/hectare can be achieved, total production could amount to 8,400 tons each year. The investment costs reportedly require at least US$12,5 million for the first phase, this being advanced by the private banking sector. Agrikuvango is a private development and not listed in the government plans for irrigated agriculture.

CURIRI

Clearing of some 650 hectares for this private farm was done in 2016. The farm lies just west of the Cuiriri River and just north of the small town with the same name. The location and size suggests that the farm will be used for irrigation. The name of the developer is not known to us. The operators of the Longa rice farm – Cofergepo S.A. – now intend to collaborate with the Cururi development to produce rice.

BIMBI (Boa Esperanca)

This small farm covers some 80 hectares and was developed quite some years ago. Most of the farm was planted with citrus, and a small piggery forms part of the development. The nearby Cuebe River provides irrigation water for citrus. The farm apparently belongs to a previous governor of Cuando Cubango, General Eusebio. The farm lies about 63 kilometres from Menongue on the road to Caiundo.

MISSOMBO

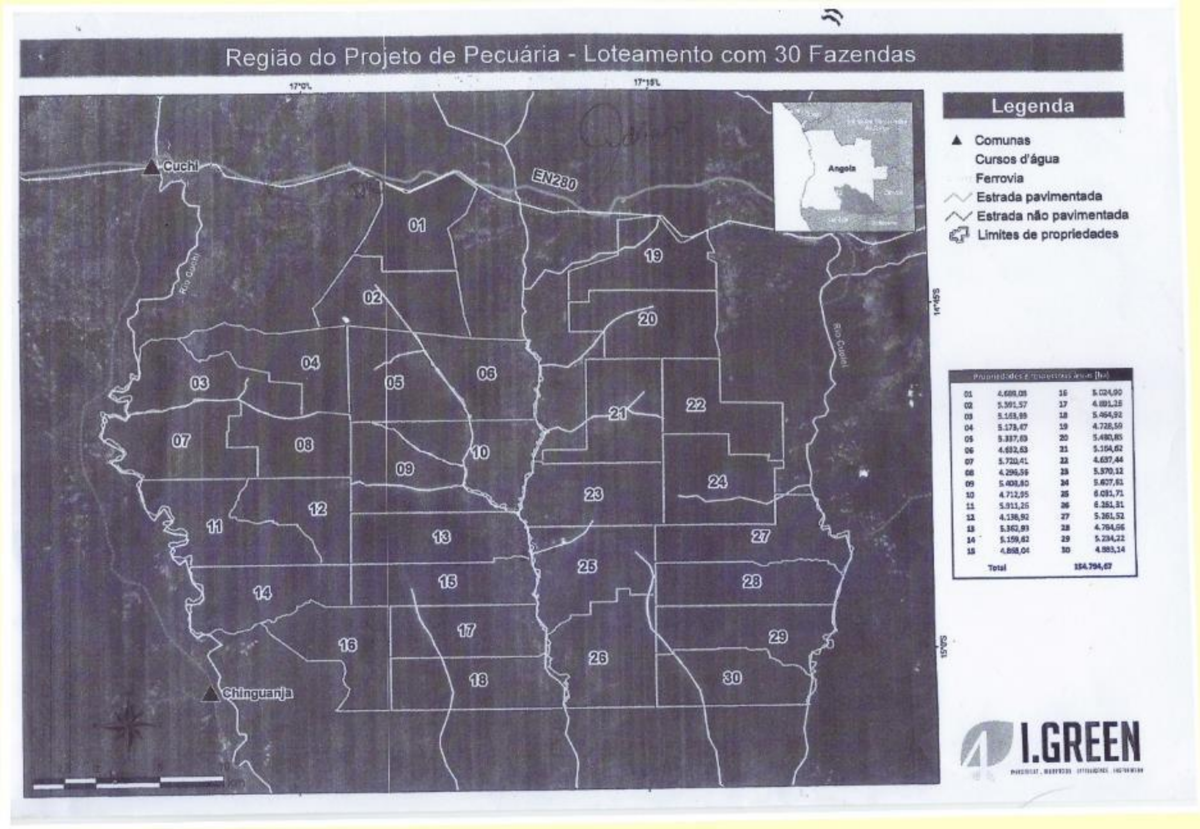
Missombo was developed as an irrigation farm covering some 300 hectares. Water was taken-off the Cuebe River and then led along a canal west of the river from where it could be released gravitationally to irrigate nearby fields. While the canal still carries water, most or all of the fields are no longer used for irrigated crop production.

It is not known why the irrigation scheme stopped working. This is the kind of farm that could serve the catchment well, as a result of several important attributes. It is close to a large market of more than 200,000 residents in Menongue who require fresh vegetables and other farm products. The soils (probably Lixisols or Calcisols) are seemingly more clayey and have more nutrients than most soils elsewhere in the catchment. And the Cuebe River provides a close source of water for irrigation

Missombo therefore presents positive opportunities for development. Its existing infrastructure can be used and refurbished where needed, and the now much larger population of Menongue residents provides a substantial demand for Missombo's products. The satellite image shows the major components of Missombo, including the Cwebe River Lodge and the site for the new aquaculture project (see page 85).

Livestock production

CUCHI FARMS and FAZENDA MODELO



Between 30 and 40 farms, each covering an average of 5,000 hectares are to be established south of the main Menongue-Cuvango road and between Cuchi and Cuelei towns (Costa Afrika & I.Green 2014). Their development for livestock production is to be guided by best practices on the model been farm of the Fazenda Modelo, recently developed by Oderbrecht north of Menongue. This model farm covers at least 2,500 hectares, large sections of which have been planted with an exotic improved pasture grass, probably *Brachyaria brizanta.*

Development of the Cuchi farms, is tied to the establishment of a smelter for the production of steel from iron ore mined at Jamba Mineire. Miombo woodland cleared off the farms will be used to fuel the smelter. Eucalyptus plantations would be established as the miombo is cleared, so that eucalyptus fuel wood can be harvested once all the miombo has been removed. The area covered by the 30 farms shown in Figure 1 extends over 153,000 hectares. That would increase to about 200,000 hectares if all 40 farms are established. Approximately 2,000 hectares of each farm would be planted with imported *Brachyaria brizanta* grass for grazing. Since all the farms lie close, or adjacent to the Cuchi and Cuelei Rivers they could also be used irrigated crop production. It is understood that US$800 million of public funds has been allocated for the development of these farms.

The iron mine at Jamba Mineire was refurbished in about 2008 but has yet to operate. Given the soils in the area in which the Cuchi beef farms are to be established, it seems doubtful that eucalyptus trees would grow rapidly enough to provide much timber within a reasonable period. If that is indeed the case, indigenous wood in other nearby areas would have to be harvested.

FIRMA and AGROPEC

This small livestock farm covering at least 160 hectares lies just east of Chicala Cholohanga and immediately north of the railway line and main road to Cachiungo, where strictly speaking it lies in the Cuanza catchment. Another, much larger farm lies nearby to the north-east. This is over 2,000 hectares in extent, and is also in the

Cuanza. That second farm is perhaps part of yet another nearby development, which is south of the road and railway line and in the Cubango drainage area. This is called AGROPEC, and has been developed as an upmarket resort and farm. While these are relatively small developments, they all began within the past five years and demonstrate the speed and extent to which developments are possible, especially in areas within easy reach of major centres, nearby Huambo and Cuito being the biggest examples.

MUMBA

This large farm has been established in the area during the colonial era. Recent development started there in early 2016 with the clearing of about 900 hectares of miombo woodland, most or all of it is now used for beef cattle. The farm belongs to the Omatapalo Group, and has recently been stocked with about 3,000 cattle imported from Namibia. Observations during the aerial survey in July 2018 suggested that irrigated agriculture is being developed. It was also clear that the newly developed project extends over much more than 900 hectares.

The Angolan government plan lists Mumba as the site for development of some 50,000 hectares of irrigated agriculture.

MBALA-TCHAVA

This 740 hectare farm was developed about 10 years ago, some 60 kilometres south of Caiundo just west of the Cubango River. The farm apparently belongs to General Eusebio, a previous governor of Cuando Cubango, but now seems dormant.

Recreational developments

Several recreational facilities have been developed along rivers in rural areas. Examples are at Tchilindo (about 70 kilometres upstream of Menongue on the Cuebe River, but since abandoned), Rio Cuebe Lodge just downstream of Menongue on the Cuebe River, the AGROPEC recreational complex just east of Chicala Cholohango, and the Cassenge dams and lodge about 2 kilometres west of Desvio. Several small recreational pavilions were seen along the Cuebe River downstream of Menongue in July 2018.

The Cassenge dams and lodge along the Cuchi River just west of Desvio on the road from Chinguar to Cuito. The dams impound water on two tributaries of the Cuchi River.

Other developments

Game reserves

A group of associates led by Stefan van Wyk acquired blocks of adjoining land east of the Cubango River and Savate. The Cuatir and Luatuta rivers run through the area. The development started in 2014, and is known as the Cubango Game Reserve. It now covers 240,000 hectares. A small lodge built on the Reserve now attracts tourists and scientists who use it as a base for studies in the area.

The main goal of those behind this development is to conserve the woodlands and the wildlife remaining in the area. Efforts are being made to restock and reintroduce certain large mammals, prevent slash-and-burn woodland degradation and reduce the intensity and extent of bush fires.

A similar development covering 30,000 hectares has recently begun immediately west of the Cubango River in the catchment of the Cuvelai and Cunene Rivers. The reserve is being developed by Fernando Matias, who also plans to restock and protect wildlife.

Timber

While not a formal development initiative or policy implementation, it is worth noting that the commercial harvesting of indigenous hard woods, especially of Angolan Rosewood *Guibourtia coleosperma* has expanded so rapidly and substantially that timber production could be seen as a 'development'. Much of the harvesting has been unregulated, with 'permits' being issued in dubious circumstances to harvest and export wood, even from national parks. The Angolan government has recently placed some limits and controls on the timber industry, but the extent and distribution of harvesting remains rampant.

Much of the timber is apparently exported to China and the 'Chinese' are widely blamed for the harvesting and its 'illegitimate' nature. However, all the foreigners harvesting timber in south-eastern Angola are business associates and employees of Angolans.

Purpose or use not known

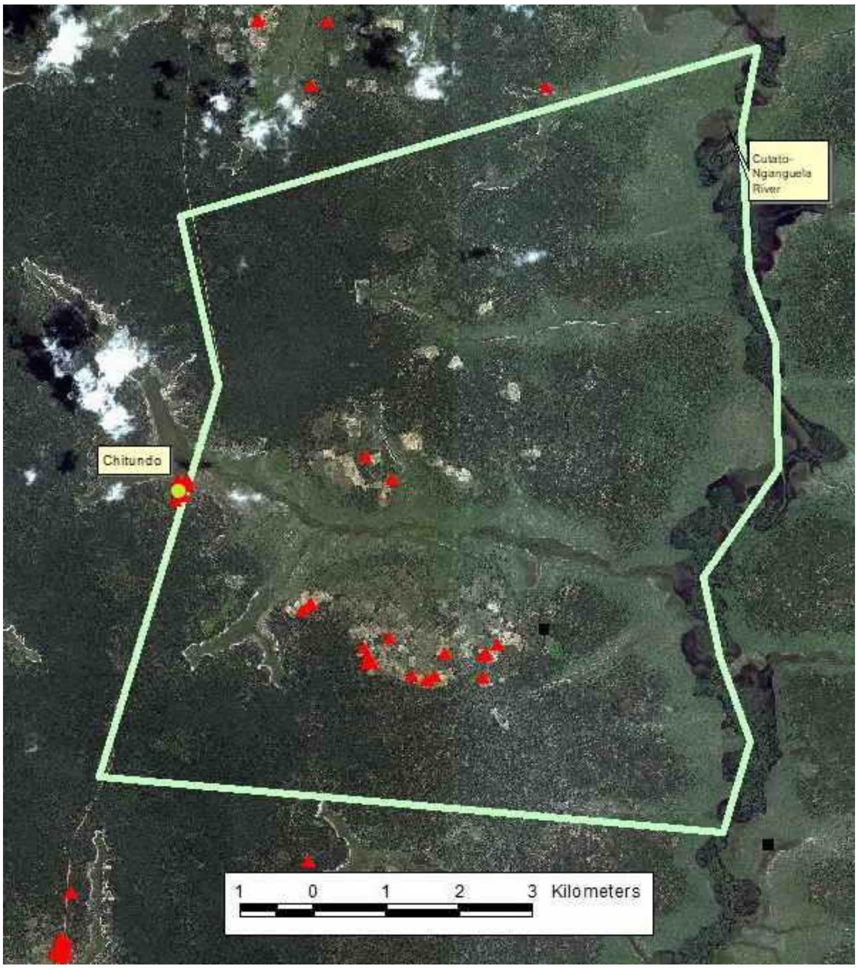
ANDEFIL

We have no information on the origins and plans for this development. Three well-placed signposts, respectively advertising Andefil *Fazenda* (farm) Sector 1, 2 and 3, are located along the road between Cuvango and Chinhama. The distance between southern- and northern-most sign is 33 kilometres, suggesting the intention to develop a substantial area.

ENCHELO

The Enchelo area lies about 40 kilometres south of Desvio on the road to Chitembo. There appears to be a combination of old colonial and newer farms in this area. Most of the farms are west of the main tar road, and extend west and down towards the Cuchi River. One or two newer farms are in the catchment of the Cacuchi River east of the main road. There are at least two small dams, and many sub-divided grazing camps for cattle. It is not known who owns the farms, what their main uses are, and what plans there are for future development. Cumulatively, the farms cover between 4,000 and 5,000 hectares. The area and farms are not listed in the MSIOA and *O Plano Geral de Utilização Integrada dos Recursos Hídricos (PGUIRH) da Bacia do Cubango* documentation.

CHITUNDO



Chitundo project, some 50 kilometres north of Cuvango on the road to Chinhama. Red triangles are houses of local residents. The green line shows the possible boundary of the project area, as explained by local residents. The area encloses about 6,000 hectares. According to local residents, the road between Cuvango and the project had been recently and especially repaired for this ‘Chinese’ development project.

CACHIUNGO

This dam is believed to have been developed as a fish farm, but there was no evidence of further development for aquaculture in July 2018. A canal has been dug downstream of the dam along the eastern margin of the valley. This appears to be for gravitational irrigation which would allow the watering of about 50 or so hectares below the canal. The canal is vaguely visible leading away from the open water to the right in the photograph. The dam captures water in a tiny tributary of the Cubango River.

Planned developments

Hydro-electricity

Several sites with the potential of being used to produce hydro-electricity were identified during the colonial era and in recent years. None have been developed, however. In the absence of engineering designs and feasibility studies, it is hard to assess the economic and environmental dimensions of each scheme. Large dams to generate electricity have been planned at Malobas (Cuchi), Mucundi, Cuito Cuanavale and Cuvango. Other hydro-electric schemes might work as 'run of the river' schemes.

The Cuchi River as it flows along a fault line that cuts through a hill eight kilometres north of the town of Cuchi. This is the site of the proposed Malobas Dam.

Urban water supplies

Intentions to construct water supply schemes for a number of large towns are noted in development plans. These include supplies for Chitembo, Cuito Cuanavale, Cuvango, Cuchi, Cachiungo, Nankova and Cuanguar. Plans for other tows are certair to follow, and the development of a water supply to Menongue has recently been started.

It should be noted that urban areas, and therefore demands for water, are growing rapidly. Currently, most urban residents obtain water from shallow wells, or nearby rivers and their tributaries. Many residents wash themselves and their clothes in the rivers. All these circumstances lead to substantial potentials for disease and water contamination.

Large-scale farming

The list of proposed irrigation schemes in Table 9 should not be regarded as comprehensive or authoritative. It is clear that many plans to develop these large agricultural schemes have come and gone, and more will surface and disappear. The scale of the developments is often impractical, as has been demonstrated by large state agricultural schemes elsewhere in Angola (see page 76). Preliminary feasibility studies will show the need to adjust certain intentions, and private developers will introduce other irrigation schemes.

The details of large-scale irrigation will thus change, but there are no indications that the intention to use large tracts of land and large volumes of water for irrigation will change. Moreover, a recent World Bank economic study has supported the general viability of the intention.

Cumulatively, the areas listed for irrigation in Table 9 amount to about 221,000 hectares. Water abstractions for irrigation, especially at the start of the growing season, will have major impacts on rivers since their discharges are then lowest. The massive volumes of fertilisers needed to create viable soil environments and pesticides may have significant impacts on downstream habitats, wildlife and human users of river water.

Technocarro, a large civil engineering developer, plans to establish 2,000 hectares of irrigation at Rio Cafuma along the north bank of the Cubango River between Cuanguar and Calai (J. Recio pers. comm., and http://www.angop.ao/angola/pt_pt/noticias/economia/2016/3/17/Cuando-Cubango-Projecto-Rio-Cafuma-produzira-mais-toneladas-soja-arroz-ano,f9331434-963e-4d00-93ec-81ae52b3e901.html). The project would produce maize and soya beans.

Government plans have largely focussed on crop production, but two significant plans for livestock production have been developed. The first is for the 30 or 40 farms south of Cuchi (see page 91; which could also be used for crop production). The second is to establish 10 cattle farms at Caila near the Namibian border at Katwitwi. Each would cover 1,000 hectares, and feed-lots on the farms could boost production. An abattoir to process up to 1,000 cattle per day would be established nearby (H. Carneiro pers. comm, (previous Cuando Cubango governor).

Water transfer schemes

Plans to pump water from Cubango River into the Cuvelai Bain have been mentioned repeatedly over the years. The pumping station would probably be Caiundo. The watershed between the Cubango and Cuvelai basins is 10-15 kilometres west of the Caiundo, and so once pumped over this divide the water could gravitate 100-200 kilometres towards the central Cuvelai. There, the water would be used irrigation and domestic and industrial purposes (Consulprojecto *et al.* 2012).

How much water might be pumped, at what times of the year, at for what economic cost and benefit has apparently not been determined or published.

12. Perspectives on developments and the future of the Cubango Catchment

The purpose of this chapter is to consider development options and challenges in the Cubango catchment, and to a lesser degree the catchments of the other three rivers. However, several fundamental aspects require explanation before suggesting prospects for development.

The Cubango Catchment: its particular value

Of all the rivers, the Cubango is singularly important because it delivers episodic pulses of floodwater to the ephemeral and seasonal floodplains in the Okavango Delta and the lower Cubango/Okavango River. Most production and reproduction of the Delta's plants and animals occurs in these floodplains (see page 27). Remove those periodic floods generated from the Cubango, and much of the Delta's rich biodiversity will disappear – as will much of the tourism industry that contributes a great deal to Botswana's economy.

Although nine major rivers make up the Cubango catchment in Angola, it is the main Cubango, Cutato Nganguela, Cuchi and Cacuchi that deliver most floodwater to the Delta. The upper catchments of these four rivers are also the most densely populated, supporting 54% of all people in south-east Angola (see page 52). As a result, they are also the most degraded areas in south-eastern Angola.

Circumstances in the upper Cubango are therefore complex, requiring careful thought on how competing interests for land and water can be accommodated. For example, what measures can be taken to limit further degradation, to enhance the livelihoods of residents, and to protect or restore processes vital to the functioning of the rivers? These are the sorts of challenges that need to be tackled if Angolans are to have improved livelihoods and Botswanans are to retain theirs.

Soils: the foundation of south-eastern Angola.

While much focus is placed on the value of its rivers, it is the soils of south-eastern Angola that fundamentally shape almost all aspects of plant, animal and human life. Harvests are limited by poor soil fertility, which is why the population is low. Long known as the land at the end of the earth (*terra do fim do mundo*), the area has always been ill-suited to settlement and development. The production of natural vegetation and abundance of wildlife is likewise restricted by poor soil, especially in its nutrient content, but also in its low water retention capacity.

The fundamental importance of soils requires emphasis. Few people believe that soils have such defining influences, many simply dismissing the idea that soils can limit agriculture. Rather, water is thought to be most crucial input for crop or pasture production, and there is the argument that soil deficiencies can be remedied by applying fertilisers. Technically, this is true, but fertilisers and other measures to improve fertility and water holding capacity come at a cost, indeed a huge cost if the soils are as poor as most of those in south-eastern Angola.

Crucially, low soil fertility results in high levels of poverty, and limited social and economic differentiation. With few or no options to earn incomes from farming, residents harvest and sell charcoal, fish, bush meat and honey or migrate in search of incomes to towns. The limited supplies of soil nutrients in new fields are rapidly depleted by farming, which means that farmers have to clear new fields every few years. The deforestation and degradation of extensive areas is thus a direct consequence of poor soils.

Future planning and development thus has to recognise the limits – as well as the options - presented by soil conditions. Small patches of soil slightly better suited to farming are to be found in places, often around major towns where farmers can sell their produce to make an income. Conversely, areas that have remained relatively pristine because their soils are extremely poor can be left that way to provide wilderness values for present and future generations. Presumptions that rural residents can have decent livelihoods in such infertile areas are simply false and harmful because they help maintain the status quo of poverty and more losses of woodland and soil fertility.

Large, publicly funded agricultural schemes: their viability, costs and benefits?

The multiple limits placed on farming by its poor soils is one reason why south-eastern Angola is generally not suited to large crop farming schemes. A second reason is concerned with the economics of these schemes. Large and frequent applications of fertilisers are major expenses. Others are the costs of equipment to plough the soils, and to pump substantial volumes of water to irrigate soils frequently because they retain little water. Transports costs for seeds, fertilisers, maintenance services and equipment purchased far from south-eastern Angola are substantial. So are the costs of taking harvests to markets in Luanda, Lubango and Lobito, for example.

Many costs would be lower if the equivalent farms were elsewhere in Angola. They would then be more profitable, less draining of public funds, and easier to design, establish and manage. Establishing programmes for food security will be more viable in agriculturally productive environments than in most areas of south-eastern Angola.

Third, experience has shown that large, state-sponsored agricultural projects are seldom practical or functional. Indeed, most have folded after a short time, or even before the farms were fully operational (see page 76). They are usually poorly designed, too large to manage properly, and often over-equipped and over-staffed. Managing the projects is then difficult, particularly in the absence of systems that provide for incentives or accountability.

Against this experience and logic, establishing new large government projects in south-eastern Angola is inadvisable. If such agricultural schemes can be viable, then it would be more prudent to reactivate, redesign and/or refurbish those schemes that now lie dormant. And new schemes could instead be developed where soils are more suited to agriculture, access to markets and inputs is easier, and greater economic viability can be achieved.

In any event, other ways of farming, improving food production and the quality of life in the Cubango catchment can be promoted and developed, as explained below.

From food security to income security

It is clear that rural societies are moving from subsistence livelihoods based on food to economies that depend on cash. 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 south-eastern Angola, and this is why urban centres are growing so rapidly, often doubling in size every 10 or so years (see page 55).[9]

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. In south-eastern Angola, encouraging urban migration will stem the prevailing processes of

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9 Despite arguments to the contrary, large agricultural schemes in south-eastern Angola and the Cubango catchment will 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 south-eastern Angola.

deforestation, bush-meat hunting, over-fishing, soil nutrient loss and expansion of areas damaged by bush fires, for example.

Recommendations

Six major points have been made above:

1. The upper Cubango catchment supplies the floodwaters that drive most of the production and reproduction of life in the Okavango Delta and downstream floodplains.
2. More than half the people in south-east Angola's catchments live in the upper Cubango catchment, which is more intensively used and degraded than other river catchments.
3. Soil qualities are the fundamental cornerstones governing almost all aspects of south-eastern Angola's life, 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. But certain small areas do have potential for commercial crop production because their soils are better suited to agronomy and they are relatively close to markets.
4. There are multiple reasons why large new publicly-funded agricultural schemes should not be developed in south-eastern Angola.
5. 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.
6. People are moving rapidly from food-based subsistence economies in depauperate areas to cash-based livelihoods in places where incomes are available.

Drawing on these points, development and practice in the Cubango and other south-eastern catchments might best be led by goals:

- That promote wealth 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 maximise the environmental and economic values of the Cubango and other catchments in ways that provide the critical naturally fluctuating flows of unpolluted river water to downstream users.
- 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 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.

Examples of centres which could be developed or expanded along the lines suggested here are: Chitembo, Caiundo, Menongue, Cuito Cuanavale, Lupire, Cuvango, Cuchi, Caíla, Cachiungo, Chinguar, Calai, Rivungo, Nankova, Licua, Maue, Cuanguar, Mavinga, Cangumbe, Luena, Lucusse, Tempue, and Lumbala Nguimbo.

Increasing food production

Intense, commercial agriculture can also be developed in areas away from urban centres, but preferably in places where farmers have ready access to sources of inputs (equipment, fertilisers, seed *et cetera*) and to markets. Much can be done to recreate conditions that held in the central plateau (including the upper Cubango) during colonial times when the majority of Angola's maize was grown by rural small holders and exported from there.[10] Similar processes work nowadays in places where small holders are close to major transport routes and markets.

The development of small holder agriculture offers three benefits: increased food production, incomes to enhance living conditions, and farming activities that reduce the need for shifting agriculture.

Among the best opportunities for agriculture lie in small-scale horticulture on moist, peaty Gleysols, on which *naca* and *ombanda* fields are used to grow potato, sweet potato, onion, carrot and cabbage in the upper Cubango.

The old 300 hectare irrigation scheme at Missombo, just south of Menongue, would be a good candidate for the kind of development suggested here. Much of the necessary infrastructure is in place, and its soils (probably Calcisols or Lixisols) are better suited than most to the commercial production of vegetables which could supply the majority or all of Menongue's needs. Other production could be transported and sold elsewhere.

Many areas not suited to arable agriculture might be able to support livestock production. Some private developers have established ranches, and the Angolan government is promoting the development of a massive block of cattle ranches near Cuchi (see page 91). However, it is not yet clear how successful these will, or can be. Possible or probable constraints include livestock diseases, the quality of forage and the availability of better pastures and climates elsewhere, especially in Cunene, Namibe, Huíla and Benguela.

All agriculture will benefit from technical assistance, of which there is now little available in south-eastern Angola. However, technical and other assistance should target developments that have financial value for farmers.

These suggestions for agricultural development seem sensible and viable, and thus merit further investigation and perhaps promotion. Other ways and places for farming should however be sought, and promoted when found to be viable. Appendix A provides notes which might guide further investigations of agricultural potentials.

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10 For example, 709,000 tons of maize were produced in Angola in 1970, almost all of which was grown on the central plateau by small-holder peasant farmers with some technical and market access support from local merchants. Tall grain silos used to store these maize harvests still stand in Chicala Cholohanga, Chinguar and Cachiungo.

What can be done to restore important areas, and to minimise further environmental losses?

Much of the upper catchment of the Cubango appears degraded by the loss of woodland cover, frequent fire, perhaps over grazing, and widespread shifting cultivation. At least to some extent, soil is lost to erosion, soil nutrients have been depleted, rivers are contaminated by ash and urban residents, and grasslands are burnt and heavily grazed each year.

Since this area has considerable potential for more commercial small-scale agriculture, further investigation of the degree and nature of degradation would be useful to guide measures that can curtail and even reverse losses.

Local *sobas* (headmen) may be willing and useful participants in helping to rally local residents and other support for restoration activities. *Sobas* might likewise be encouraged to play active roles in limiting fires and controlling the clearing of land. Indeed, community-based (or village organised) activities led initially by headmen, might be a viable way to manage and restore local resources. Such an approach is worth trying, especially so because there are no other controls on the use of natural resources and land. Not surprisingly, most environmental degradation is therefore very much a consequence of the well-known Tragedy of the Commons.

What about areas where few people live?

It is hard to avoid the harsh conclusion that most parts of south-eastern Angola are not fit for human occupation, certainly not by people who might make a decent living by living off the land as farmers, fishermen or even hunters. At best, residents can only have a decent life by selling particular commodities to people who are prepared to pay large amounts. What high value goods are available?

Those that come to mind immediately are heavily controlled, illegitimate or disreputable: some artisanal diamonds along certain rivers, ivory from perhaps a few thousand elephants, timber from slow growing hardwood trees, and bush meat. In any event, the volumes of these commodities and the number of buyers will always be limited.

What remains are two options or commodities: tourism and wilderness. Tourism certainly has potential, and a number of Angolan residents have recently established camps and lodges for visitors. The number of holiday makers has also grown rapidly over the last four years, accompanied by encouraging potential commitments by three southern African specialist tourism companies to build camps and guide their guests through the catchments. This is in stark contrast to just 10 years ago when hardly anyone – foreign or national – visited this remote area on holiday.

Tourism is thus growing, and many attractions are on offer.[11] Wildlife diversity and numbers can be increased which, together with increasing tourism and perhaps trophy hunting in due course, will all help put the last commodity 'on the map' – wilderness! It is for the preservation of wilderness that Angola can gain distinction, as well as national pride.[12] Combining wilderness values with the conservation of ecosystem services to maintain supplies of water to downstream wetlands of international importance will also bring Angola good neighbours. Further investment in tourism will follow, both from foreign sources and from Angolans who wish to protect vast tracts of wilderness, wildlife and water. It is important to remember that the South-eastern

11 Focussing on the Cubango catchment alone, several attractions deserve mention: impressive waterfalls (for example at Malobas, Cutato and Muculungongo), old forts (Menongue), missions (Cuvango, Capico, Mumbué), crystal clear rivers (on the Cuebe upstream of Menongue and elsewhere), the Cubango Game Reserve (near Savate), remote grassland pans (near the confluence of the Cuchi and Cubango rivers), dense Cryptosepalum forests, birdlife endemic to miombo woodland, and spectacular carpets of flowering underground trees.

12 A particularly relevant example of the development of Angolan pride comes from the films, articles and other publicity accorded the Cuito, Cubango, Cuanavale and Cuando rivers by the National Geographic-Okavango Wilderness Project expeditions. Few Angolans knew of those rivers previously, and almost no one in the world – let alone Angola – had any idea of their beauty and wilderness value.

corner of Angola has the potential to become part of the last big expanse of wilderness in Africa. The comparative value and competitive advantages of a vast wilderness will grow as other wildernesses in the world shrink.

Post script

1. Much is said nowadays about the virtues and potentials of community-based natural resource management (CBNRM). Other than the possible management and restoration of soils, pastures and woodlands in the **upper Cubango**, no immediate resources and/or communities were identified as candidates for CBNRM approaches. Further investigation is needed, especially in the field, to search for such possibilities, perhaps associated with more careful use and management of fish, timber and bush meat, for example.

2. Much is also said about conservation agriculture (CA), which seeks simultaneously to increase food production and the conservation of soils and/or natural plant and animal life. CA is, however, unlikely to bring major changes to livelihoods in areas with such poor soils. Even if yields were to double, farmers would not necessarily have markets or the wish to sell their harvests. Moreover, and in the absence of controls to limit land clearing, CA is likely to lead to even further losses of vegetation and soil nutrients. In essence, CA is unlikely to bring useful change in areas where soils are poor, markets are absent and land can be cleared at liberty. The principles of CA, however, apply usefully in peri-urban and other areas close to markets where commercial farming is possible.

Appendix A: Some agriculture potentials

This appendix lists several areas and agricultural enterprises that may have potential, some of which are expansions to suggestions made earlier in this report. Throughout, the emphasis is on supporting viable commercial agriculture. Subsistence farming is only to be supported where and when it can be converted into commercial production.

Dryland commercial maize production by small-holders

As mentioned, small-holders in the central regions of Angola (including the upper Cubango) previously grew much of Angola's maize production and exports. Two major factors made that possible: immediate payments or returns on harvests; and availability of transport to deliver harvests to buyers.

The Angolan government recently attempted to recreate these conditions by constructing silos (see page 86), but efficient mechanisms to transport and pay for harvests remain lacking. Private traders appear to be meeting these needs in certain areas, which is a welcome development that can be encouraged and expanded to other crops and livestock.

Large-scale, privately-funded and managed farms

Much has been said about large publicly-funded agricultural schemes being inadvisable, mainly because they are extremely expensive, large and hard to manage, and often planned for places poorly suited to farming. Of course, other big farms that avoid these difficulties can, and should be developed. However, farms should only be established if stringent assessments find that their environmental impacts are acceptable or can be mitigated.

Other cereals

Maize generally enjoys most focus as a preferred cereal crop because it is so widely and variously used. However, there is scope to expand the production of millet and sorghum, which can be grown without irrigation, and perhaps rice and wheat. Rice might be produced on Fluvisols in the Cubango catchment, and irrigated wheat could be grown along the lower Cubango.

Soya and other legumes

Soya and beans could be considered as rotation crops for maize. Beans are ideal for small-scale farming in the upper Cubango, while soya can be produced on alluvial, well-drained soils with good clay and silt contents.

Horticulture

There appears to be good scope for the production of citrus, passion fruit, avocado and guava in the upper Cubango where there are sandy soils and colluvial movements of water. And the upper Cubango has good potential for potatoes, onions, cabbage.

Small to medium size farms (Huambo area)

The upper Cubango catchment is well-suited to small and medium-scale farmers who typically each cultivate a few hundred hectares. A good example is the Vinevala farm, just east of Chinguar, which now produces maize on about 200 hectares, potatoes under irrigation (15 hectares per year) and a small quantity of wheat. This farm demonstrates what can be achieved by small and medium-scale entrepreneurs in areas with good rainfall (above 1,000 mm/year); abundant water for small areas of irrigation; good communications; and nearby markets (especially for fresh horticultural products). Access to funding and marketing agents are further assets.

Livestock

Relatively few livestock are kept in south-east Angola, probably because their numbers are limited by disease and the quality of pastures and browse. Moreover, livestock are generally kept as savings and thus not used for commercial production by subsistence or traditional farmers. However, ways of encouraging the production of poultry, goats and sheep for local sales should be investigated, especially in areas where local residents have ready access to markets.

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