*Communications of the Geological Survey of Namibia, **28** (2025), 16-33*

Enigmas of Angola's and Namibia's Cuvelai Basin and its Etosha Pan

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Abstract :- Southern Africa is host to two major inland river basins, the Okavango and the Cuvelai. Research on the landscape history of the Cuvelai has been patchy leaving many aspects of the basin's functioning and structure poorly understood. This paper offers a collection of observations and ideas highlighting unusual features that obscure our understanding of the Cuvelai and its Etosha Pan. Among them are questions concerning the basin's geographic limits, its sub-basins and their functioning, possible tectonic influences on deltas and the Kunene River, the effects of easterly winds, the settlement patterns of people, lunette dunes, springs and geomorphological processes around Etosha Pan, as well as environmental concerns. We hope that these questions whet the enquiring appetites of students and scientists to unravel more of the unusual structure and functioning of this rare environment.

Keywords :- Cuvelai, Dust, Etosha Pan, Kalahari Basin, Kunene River, Lunette dunes

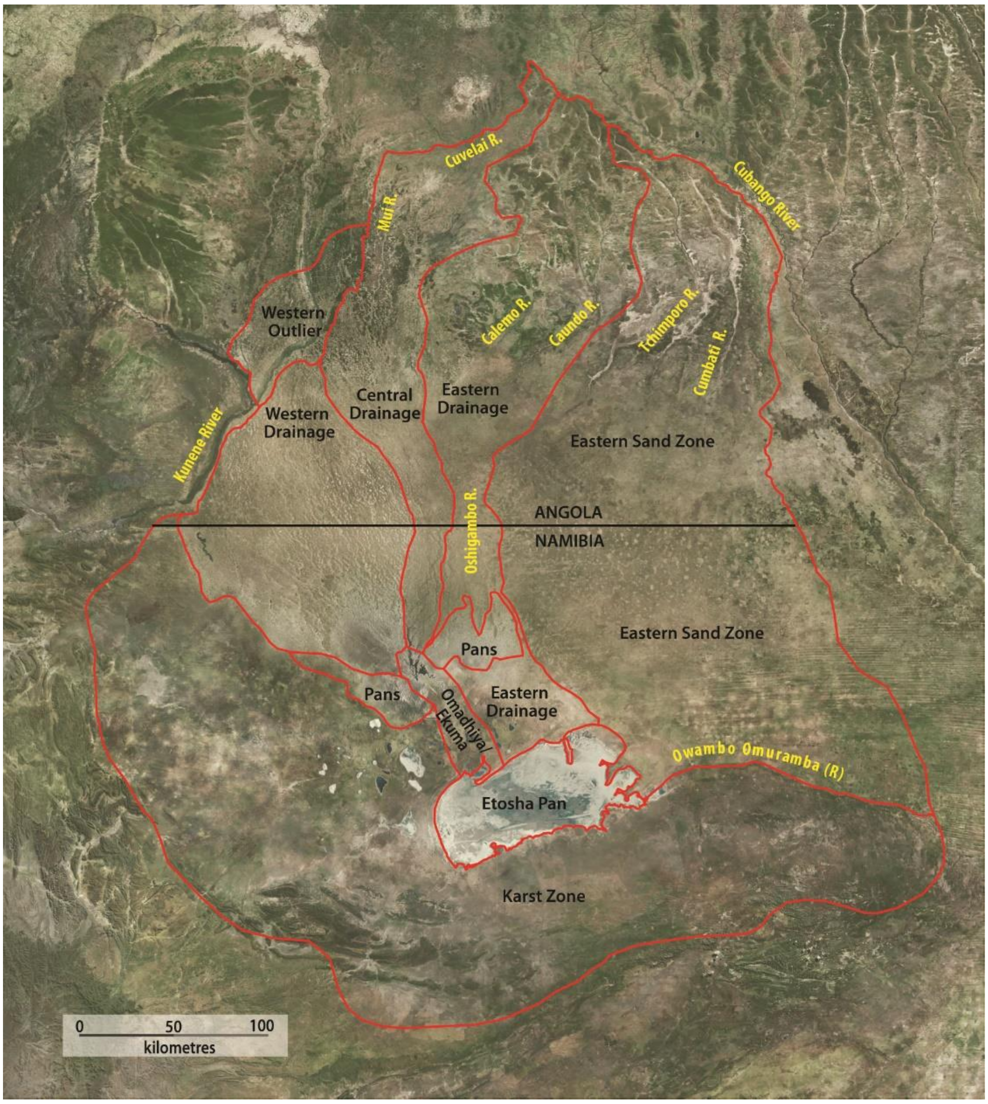

Figure 1. The Cuvelai Basin, its major zones and features, and a possible Western Outlier discussed below

Introduction

Inland deltas occur on all continents but relatively few formed recently during the last 65 million years (Bridgland *et al*., 2020). Southern Africa is host to two such global inland deltaic systems, the Okavango Basin in Angola, Namibia and Botswana, and the Cuvelai Basin in Angola and Namibia. Because of their recent geological history, both basins have good potential in providing examples of markers, integrators and actors of climate change at work on Earth. They also demonstrate ecosystem and environmental services that shape human settlement in the region. However, systematic and sustained studies of parts of the Cuvelai Basin and its functioning are lacking.

Research in the Cuvelai Basin dates back a century (e. g. Jaeger, 1926; Schwarz, 1920; Wellington, 1938) but it has been uneven. Collectively, we have spent some six decades exploring the Cuvelai Basin on the ground, in aerial surveys and with the use of satellite images and other data sets. This work has included studies of the basin's people, Etosha Pan, drainage systems, dust, fossils and geomorphology (e. g. Calunga *et al.,* 2015; Hipondoka, 2005; Hipondoka *et al.,* 2004, 2006, 2013; Hamunyela *et al.,* 2022; Kempf and Hipondoka 2003; Mendelsohn *et al.*, 2000, 2015; Mendelsohn and Weber, 2011; Mendelsohn and Mendelsohn, 2019; Pickford *et al*., 2009; Van der Waal *et al.,* 2021; Wanke *et al.,* 2018). Our explorations have yielded observations on peculiar features and raised questions that seem significant, curious, or surprising, and that highlight conditions and issues deserving enquiry and explanation. The purpose of this paper is to present these observations and questions in the hope that students and scientists will examine them so that the functioning of this unusual part of the world is better documented, understood and managed. We hope, too, that the paper provides a reasonable introduction to the Cuvelai Basin and its literature.

The Cuvelai Basin is an unusual feature of the African landscape, its combination of topographical, sedimentary, hydrological and socio-economic features probably giving it unique world status. Topographically, the basin extends west to east between the Kunene (called Cunene in Angola) and Cubango (also called the Okavango) rivers in Angola and across a shallow basin in Namibia, where its southern limits are bounded by a range of karst hills (Fig. 1). From north to south, elevations drop from 1450 m above sea level to 1080 m asl. Much of the basin has little or no surface drainage. The only water courses that flow with any frequency are those in the Western, Central and Eastern Drainage Zones, which consist of many channels that merge and diverge along their course from north to south. Most channels converge on the Omadhiya Lakes from where water may flow south along the Ekuma River into the Cuvelai's ultimate end – the Etosha Pan. The Cuvelai is thus endorheic, all surface water disappearing, as it seeps into the soil or evaporates from the channels, the Omadhiya Lakes and Etosha Pan. Tens of thousands of small pans, usually dry, which only fill with water sporadically after heavy local rains, dot the landscape across the middle of the basin between ~17° and 19° southern latitude.

The broad, shallow Cuvelai Basin described above is distinct from the more confined hydrological Cuvelai Drainage made up of the Western, Central and Eastern Drainage zones (Fig. 1.) This distinction should be born in mind throughout this article. Most of the Cuvelai Drainage's channels are in Angola, where they are called *chanas* as opposed to *iishana* in Namibia.

A Western Outlier?

To our knowledge, all geographers and other academics have described the Cuvelai Drainage as located east of the Kunene River in Angola. However, from fieldwork and studies of satellite imagery it now seems to us that a section of an original Cuvelai Drainage may lie west of the Kunene (Figs 1, 2). Surface water in this section flows along *iishana* first south and then south-east into the Kunene River. The vegetation, soils and structure of these drainage lines appear the same as in the adjacent main Western Drainage. Moreover, the location and number of *iishana* immediately west and east of the Kunene are similar, suggesting that they might once have been connected.

Similarities across the Kunene River are most obvious in the southern half of the area (Fig. 2). We are uncertain how far the similarities extend further north where the land is more wooded, drainage lines are more defined, and far fewer people reside. A tentative northern border is indicated by the dashed line in Fig. 2. If this supposition is correct, the Kunene River likely cut its way south across this section of the basin, perhaps ending its earlier flow to the south-east in the Cuvelai Basin, where it probably formed the Kunene mega-fan (Gärtner *et al*., 2023). Such a redirection of the Kunene's flow may be associated with uplift across a broader part of Angola, as postulated below (see page 22).

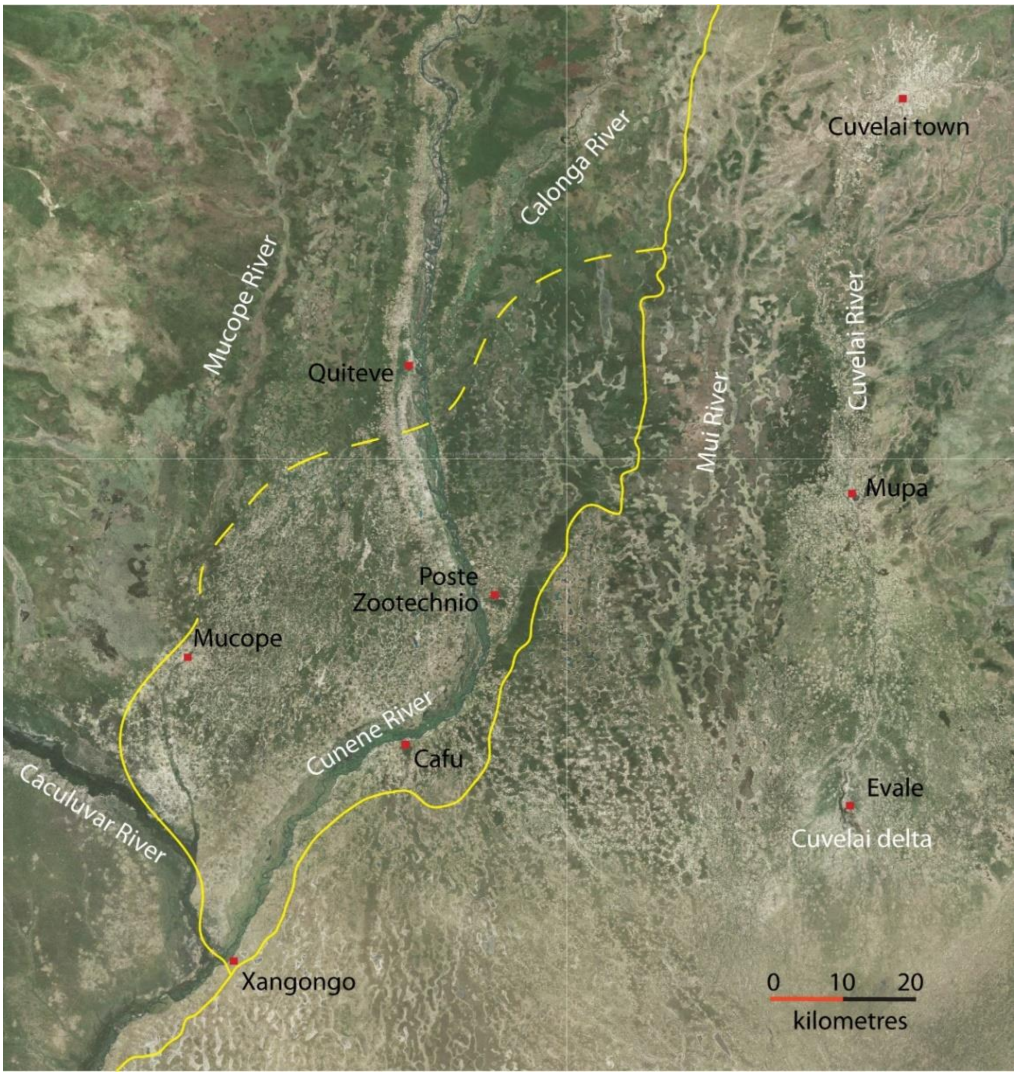

Figure 2. Probable section of the Cuvelai west of the Kunene (Cunene) River

Drainage zones

Of the three (western, central and eastern) major parts of the Cuvelai Drainage (Fig. 1), only two regularly carry water in *iishana* south into Namibia. These are the Western and Central Drainages, which differ in several ways. *Iishana* in the Western Drainage are broad, often several hundred metres wide, and the entire drainage collects water from an extensive area, about 100 km across at its widest. Water in the Western Drainage flows slowly, much of it flooding expanses alongside or away from *iishana*. Few trees line these *iishana,* which have more saline soils than those of the Central Drainage, where the *iishana* are narrow, often less than 100 metres across, less saline, and frequently bordered by riparian woodland, predominantly *eemwandi* or jackal berry *(Diospyros mespiliformis)*. Water flows are faster and the entire Central Drainage covers no more than 50 km at its widest point.

The sharpest transitions between the two zones are to be seen between Ongwediva and Oshakati and just east of Ongenga. The narrow, fast-flowing, freshwater *iishana* of the Central Drainage begin as small tributaries, which coalesce into larger channels that later diverge and merge repeatedly on their way south. By contrast and enigmatically, the *iishana* of the Western Zone begin immediately east of the Kunene River in broad pan-like channels, which continue to the south-east in that form, at times also merging with and again diverging from other broad, slow-flowing *iishana*. How water courses can begin and remain broad seems to us puzzling. This is the case all along the Western Drainage's margin just above and adjacent to the Kunene River (Fig. 1).

Some channels of the Western and Central Drainages merge to the west of Ondjiva. Reasons for the differences between the zones and how they reflect past events in the Cuvelai deserve study. We also encourage studies to examine the chemistry and structure of sediments in the *iishana* since they are likely to show the provenance of surface flows.

The Eastern Drainage is much more ephemeral than the drainages to the west. Its catchment consists largely of deep aeolian sands which absorb rainwater rapidly. Significant flows down its drainage lines are rare, perhaps occurring roughly every ten years. The two main water courses are the Calemo and Caundo rivers. Still further east is the Eastern Sand Zone, where surface water is limited to the narrow courses of the upstream reaches of the Tchimporo River. The Cumbati River is usually dry and not – or no longer – connected to any of the other watercourses in the Cuvelai Basin.

Seasonal wetlands and pans

The importance of Etosha Pan as an ephemeral wetland which sporadically supports thousands of breeding flamingos is well known (Lindeque and Archibald, 1991). Little, however, is known about the ecology of other ephemeral wetlands in the Cuvelai Drainage. These consist of hundreds of braided *iishana* channels and tens of thousands of small freshwater pans (Arendt *et al*., 2021; Fig. 3), sixty-six larger saline pans, and substantial expanses of saline grasslands that are flooded periodically (Fig. 3). At times these wetlands are used for breeding by at least sixty species of aquatic birds that move across southern Africa (Lindeque and Archibald, 1991; J. M. Mendelsohn, pers. obs., Fig. 4), but the extent of the contributions made by the pans to populations of African aquatic avifauna remains unknown.

Figure 3. Some of the thousands of pans that occasionally fill with local rain (photograph taken south of the Oshakati – Okahao road)

When filled, Arendt *et al*. (2021) estimated that some 190,000 pans may hold 1.9 km^3 of water. For the medium flood of 2017, Wanke *et al*. (2018) estimated a combined average discharge of over 200 m^3/s during the flood peak in *iishana*. At the time, this estimate was nearly half the discharge of around 500 m^3/s of the nearby Kunene River at Ruacana (Namibia Hydrological Services, 2017).

Figure 4. Thousands of cattle egrets (*Bubulcus ibis*) breeding in a temporary pan inundated during the huge flood (locally known as an *efundja*) in March 2011 (photograph: Helge Denker)

East Winds

While much of the Cuvelai has been moulded by its water courses, prevailing winds from the east have also done much to fashion the landscape and determine where people live. This is most evident in the lunette dunes that lie west of small pans in the central-eastern areas of the basin, mostly just north of the Angola-Namibia border (Fig. 5a). People predominantly live and farm immediately west of the pans, probably because the soils here are more fertile due to aeolian sands being mixed with fine alluvial sediments scoured off the pans by east winds (Mendelsohn and Mendelsohn, 2019). The same process likely explains why most people live and grow crops just west of old drainage lines in this area (Fig. 5b). In southern Angola areas immediately west of rivers are favoured for settlement to such a degree that most roads along major rivers were built directly to their west, for example, along the Kunene River between Matala and Quiteve, the Cubango from Kuvango to Katwitwi, and the Cuito and Longa Rivers from Cuito Cuanavale to Dirico, and from Longa to Nankova, respectively. A recent paper by Jolivet *et al*. (2023) explores the effects of east winds on rivers across south-east Angola and north-east Namibia.

Likewise, homesteads and fields are usually first established on higher ground immediately west of *iishana* (Fig. 5c), while subsequent houses and fields are started elsewhere on the raised ridges (*omitunda*). The practice of having the main entrance of Aawambo homesteads face east is rooted in the tradition that a 'virgin *omutunda* should be tamed by entering it from the east' (K. Hishoono, pers. comm.).

Deltas and the alignment of the Kunene and nearby rivers

Across the Cuvelai Basin between the towns of Xangongo and Caiundo is a line (Fig. 6), where rivers either spread into deltas (Mui – Fig. 7 - and Cuvelai) or into open expanses of grass-lands that are periodically inundated when fed by flows in the Calemo, Caundo, Tchimporo and Cumbati Rivers; the latter are visible as pale grey areas in Fig. 1. In very wet years water may flow from the grasslands south-westwards to form the Oshigambo River (Fig. 9).

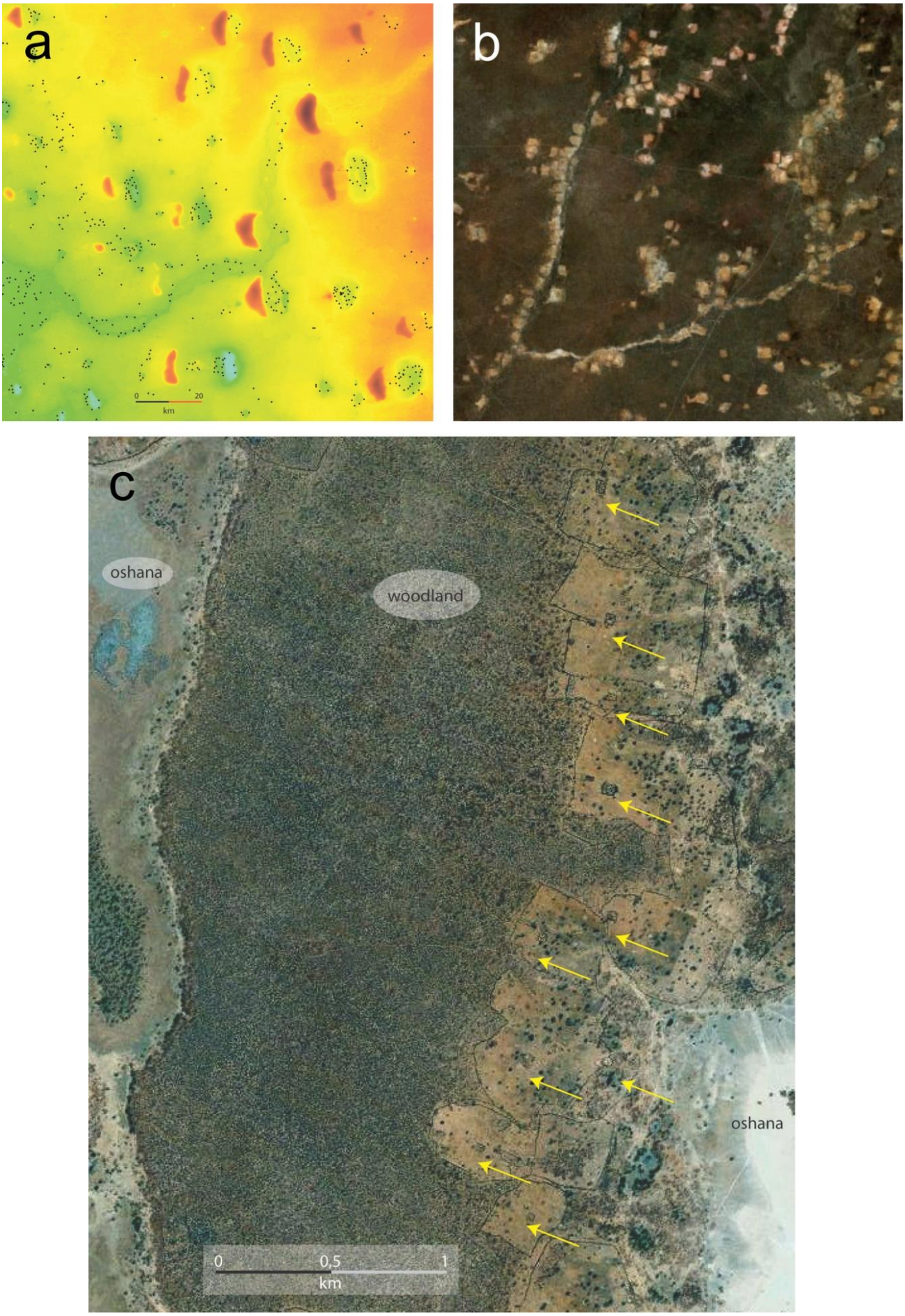

Figure 5. (a) Lunette dunes west of pans surrounded by houses (dots) (seen in Google Earth at 17.24° S, 16.64° E, (b) houses and fields west of drainage line (17.51° S, 16.93° E), and (c) houses (marked by yellow arrows) and fields west of an *oshana* (17.13° S, 15.33° E)

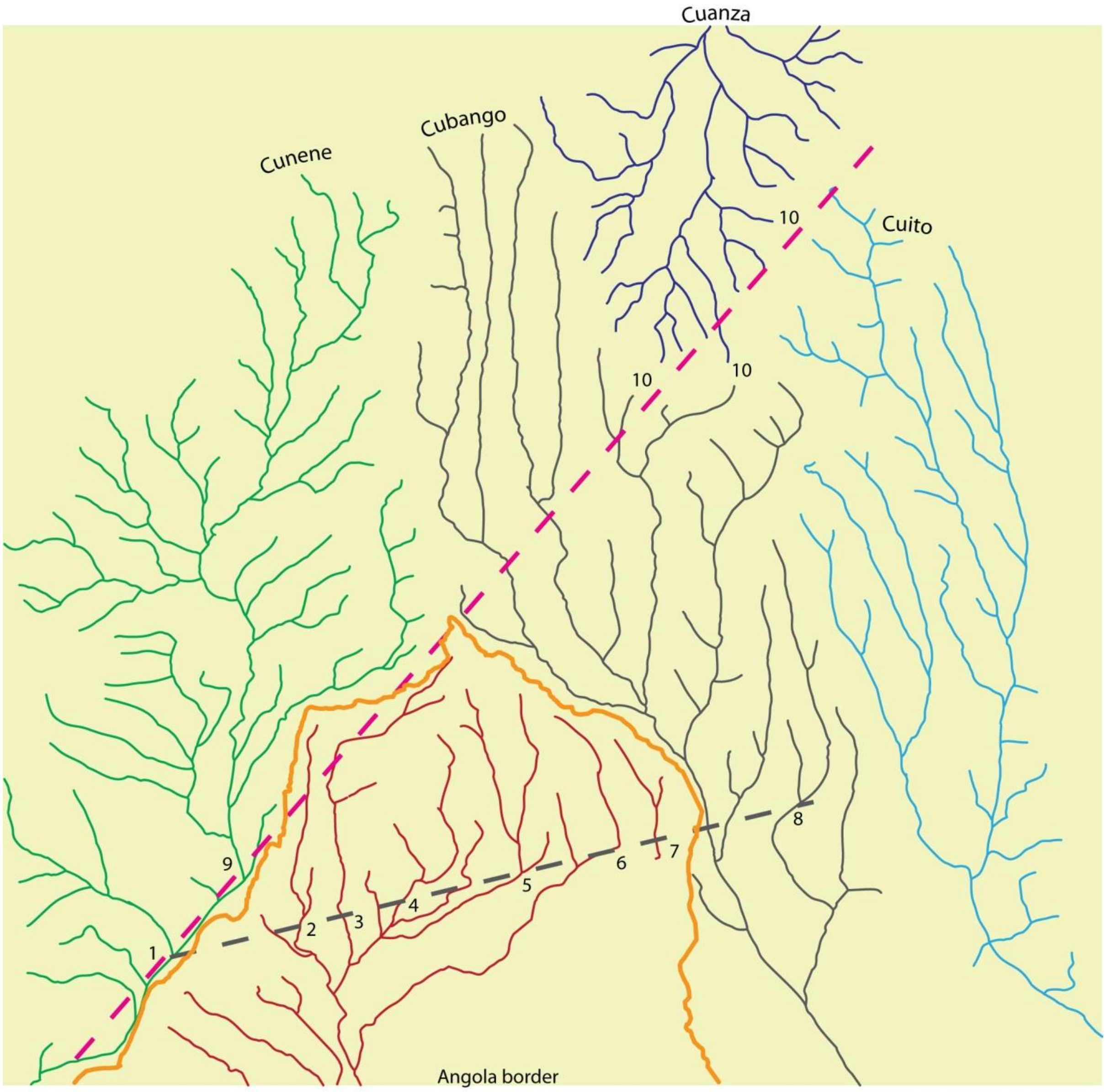

Figure 6. Deltas and axes in and around the Cuvelai Basin in Angola. The dashed grey line marks the axis from where the Caculuvar River joins the Kunene River at Xangongo (1) to the Mui River delta (2), Cuvelai River delta (3) and the flexures of the Calemo (4), Caundo (5), Tchimporo (6), Cumbati (7) and Cuatir (8) rivers. The dashed red line marks a possible flexure which may have diverted the Kunene River in a south-westerly direction (9), as well as breaking the drainage (10) between the Cuanza River (now flowing north) and the Cubango and Cuito Rivers which flow south.

An additional axis extends across this part of southern Angola, which runs along the course on to which the Caculuvar and Kunene Rivers appear to have been deflected, perhaps from their previous south-easterly trajectories. Notably, the same axis extends along the watershed that separates the north-flowing Cuanza River from rivers that flow south, the biggest being the Cuelei and Cuebe Rivers of the Cubango River Basin, and the Cuito and Cuanavale Rivers of the Cuito River Basin. The same appears to have happened further east to the Lungue-Bungo and Lumege Rivers of the Zambezi River Basin. The development of this watershed has been attributed to tectonic uplift (R. Swart, pers. comm.), which deflected the Cuanza northwards from its previous trajectory to the south.

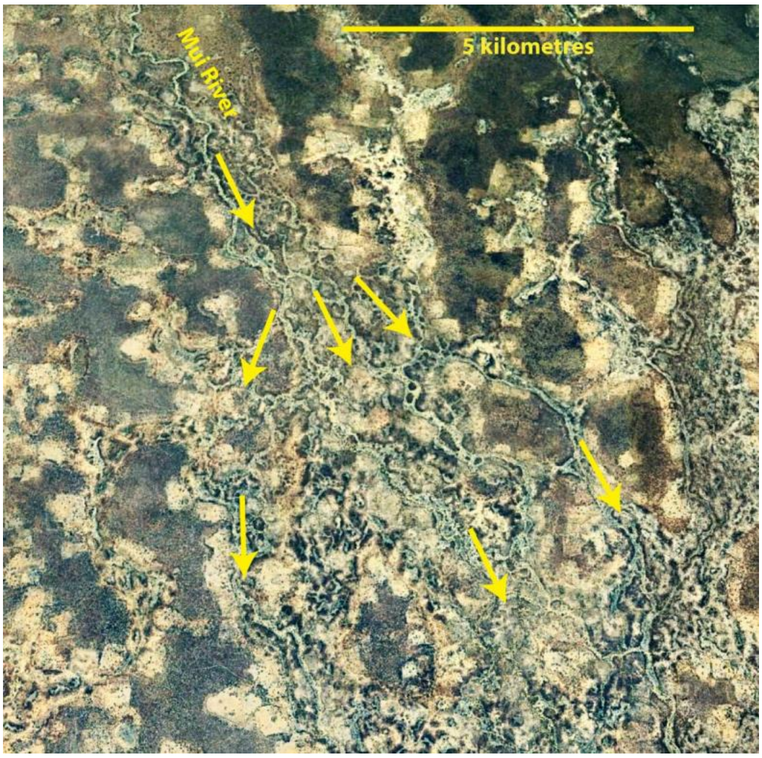

Figure 7. Delta of the Mui River as seen in Google Earth at 16.50° S and 15.55° E

A river on a ridge

Rivers normally flow in valleys. Like a normal river, the Cuvelai River runs from its source along the bottom of an incised valley, where tributaries join it on both banks. This is the Cuvelai's structure up to the town of Mupa. From there to the town of Evale the Cuvelai runs on top of a gentle ridge that drops away a few metres to the east and to the west (Fig. 8). South of Evale the Cuvelai branches into a delta. We surmise that the ridge was formed by the progradation of the Cuvelai River delta, which led to it progressively moving south as channels of the delta pushed south on top of alluvial sediments that had been deposited previously.

The channels that now flow off the sides of the ridge between Mupa and Evale merge further to the south with *iishana* coming from the Mui River delta (Fig. 7), the Cuvelai delta, and with *iishana* from the west and east (Fig. 8). Lying in the centre of this zone of convergence, Ondjiva often suffered major flood damage before embankments were built to force flood waters to flow around this large town (Calunga *et al*., 2015).

Palaeolake Kunene

It is widely agreed that the upper Kunene River once flowed into the Cuvelai Basin (e. g. Schwarz, 1920; Wellington, 1938). The same is true of the proto-Caculuvar River, and perhaps even some westerly flows of the Cubango River. All three of these large rivers may therefore have contributed sediments to fill and form today's Cuvelai Basin. In those times, much of the basin was probably a lake (Stuart-Williams, 1992).

Although Etosha Pan is the terminal sump of the Cuvelai System, the deepest point is actually in the Omadhiya Lakes, located 60 km upstream of Etosha Pan. The Omadhiya Lakes are some 2 m below the beds of the north-western section of Etosha Pan. As a result, water only flows into Etosha Pan in exceptional flood years. Surprisingly, water from Omadhiya Lakes may also spill-over and reach Etosha Pan through the Oshigambo River as captured in a satellite image taken 12 April 2011 (Fig. 9). Also, the depth of the lake beds regulates the funnelling of *iishana* from a maximum width of 150 km between Olushandja

Dam and Edundja, eventually to converge at Omadhiya Lakes. In turn, the Omadhiya Lakes are controlled by neotectonics (Kempf and Hipondoka, 2003), which are also considered responsible for the downstream section of the Oshigambo River being severed from its mid-section south of Onathinge, between ca. 18.17° S, 16.09° E and 18.26° S, 16.08° E. This severed section extends over 10 km.

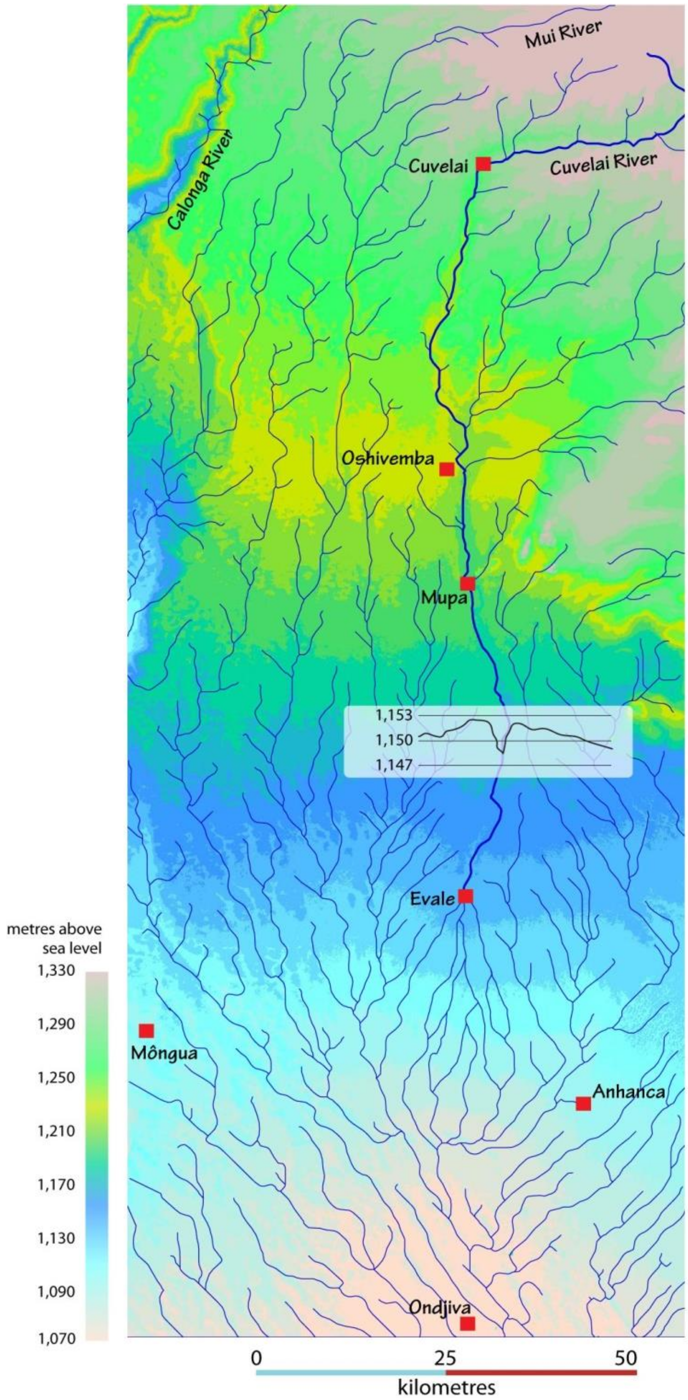

Figure 8. The course of the Cuvelai River from north of Cuvelai, to Mupa, Evale and Ondjiva. Drainage lines flow into the Cuvelai north of Mupa, while others flow away from the Cuvelai River between there and Evale. From west to east, midway between Mupa and Evale, elevations across the Cuvelai River rise from ca. 1150 to 1153 m a. s. l., then drop to 1147 in the Cuvelai River and rise again to 1152 m before sloping down to ca. 1148 m a. s. l. in the east.

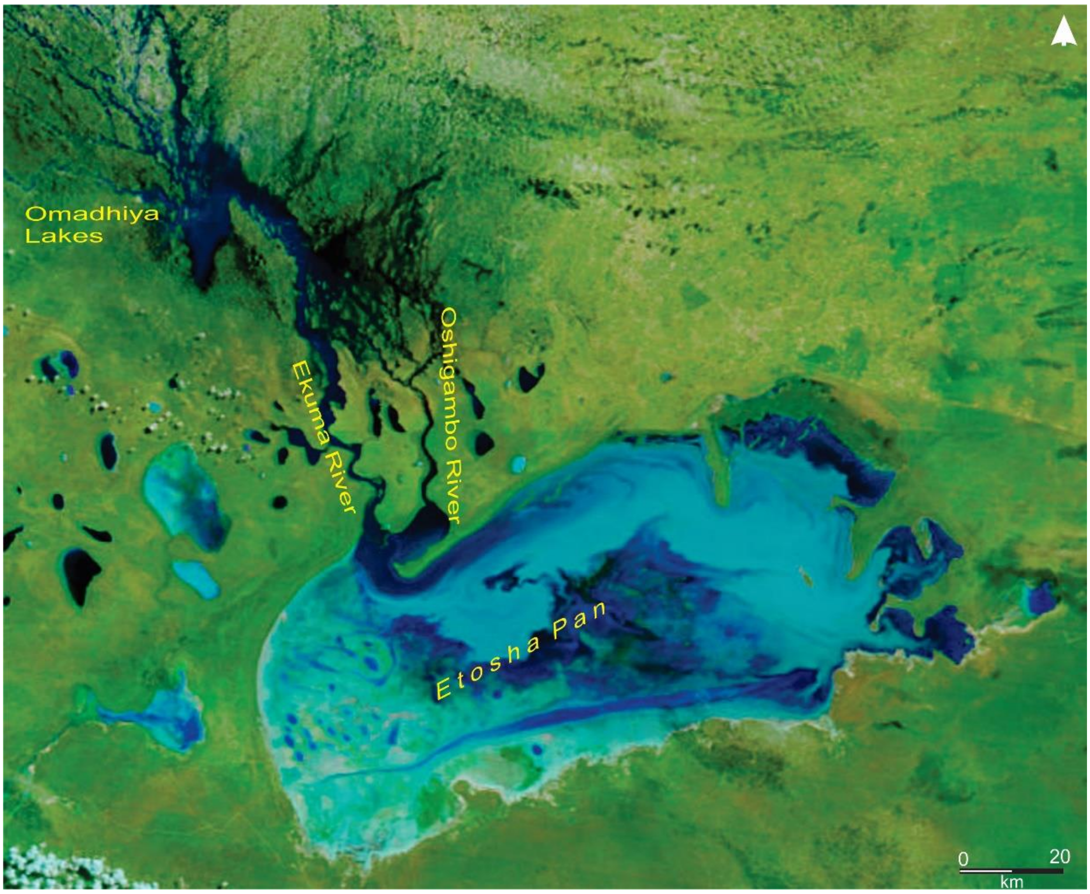

Figure 9. Water reaching Etosha Pan through both the Ekuma and Oshigambo Rivers from Omadhiya Lakes (image source: NASA. https://earthobservatory.nasa.gov/images/50100/flooding-across-northern-namibia)

Etosha's lunette dunes

The prevailing north-easterly wind at Etosha is assumed to have been in force for at least the last 140 ka (Buch *et al*., 1992). It is further assumed that the elliptical shape of Etosha Pan and the orientation of its main axis resulted from lake currents under the influence of this dominant north-easterly wind. However, the setting of the dunes fringing the western margin suggests that their sediments largely originated from the Ekuma Delta. Subsequently, the sediments were redistributed along the western beach face by counter-clockwise lake currents. Like in coastal environments, winds deposited these beach sediments along the shoreline as coastal dunes. In the process, Adamax Pan became separated by these dunes from Etosha Pan. Groundwater seepage beneath these dunes occasionally reaches Etosha Pan from Adamax north of Okondeka, which is a contact spring fed from the same source.

Dust plumes from Etosha Pan's surface add little to the formation of these dunes. This is inferred from the setting or characteristics of the i) current shoreline, ii) remnants of sand ridges rising as islands within the pan, and iii) clay sediment from the pan surface being transported further than the immediate surroundings. The base of the dune adjacent to the Ekuma Delta started as a composite feature with coarser material (Fig. 10). Within a short distance, the base splits into two major ridges, whose material becomes increasingly finer towards their tail-ends at Okaukuejo. The dune base thus starts north of the north-western pan margin and the ridges terminate before reaching the south-western margin of the pan. These two settings suggest that a significant proportion of the coarser material could not be transported further from its source in the Ekuma Delta. The position of the base of the sand ridge is also not aligned with the pan's surface or the dominant, north-easterly wind vector. In contrast, the sand ridge is absent to the south along the last 10 km of the western pan margin which lies to windward of the north-easterly wind.

Logan Island (Fig. 10) is the most

prominent remnant of the sand ridges located west in Etosha Pan. Because of its endorheic nature, the pan contracts and expands depending on the inflow. Logan Island is thus a remnant of an earlier shoreline that was eroded when the pan expanded. The sediments of Logan Island overlie the clay bed that characterises the rest of the pan. The clay layer under Logan Island is situated at the same elevation level as the adjacent clay of the pan.

Although fluvial input to the pan is known to regulate the availability of erodible sediment from the pan (Bryant, 2003), satellite images show evidence for dust uplifted from Etosha Pan and transported over tens of kilometres as far as the Atlantic Ocean by the north-easterly winds (Wiggs *et al.,* 2022). Some of the significant dust plumes pass over the dune-free south-western pan margin. The absence of a collective geomorphic imprint of the dust plumes also points to the limited influence wind has today on the development of these dunes.

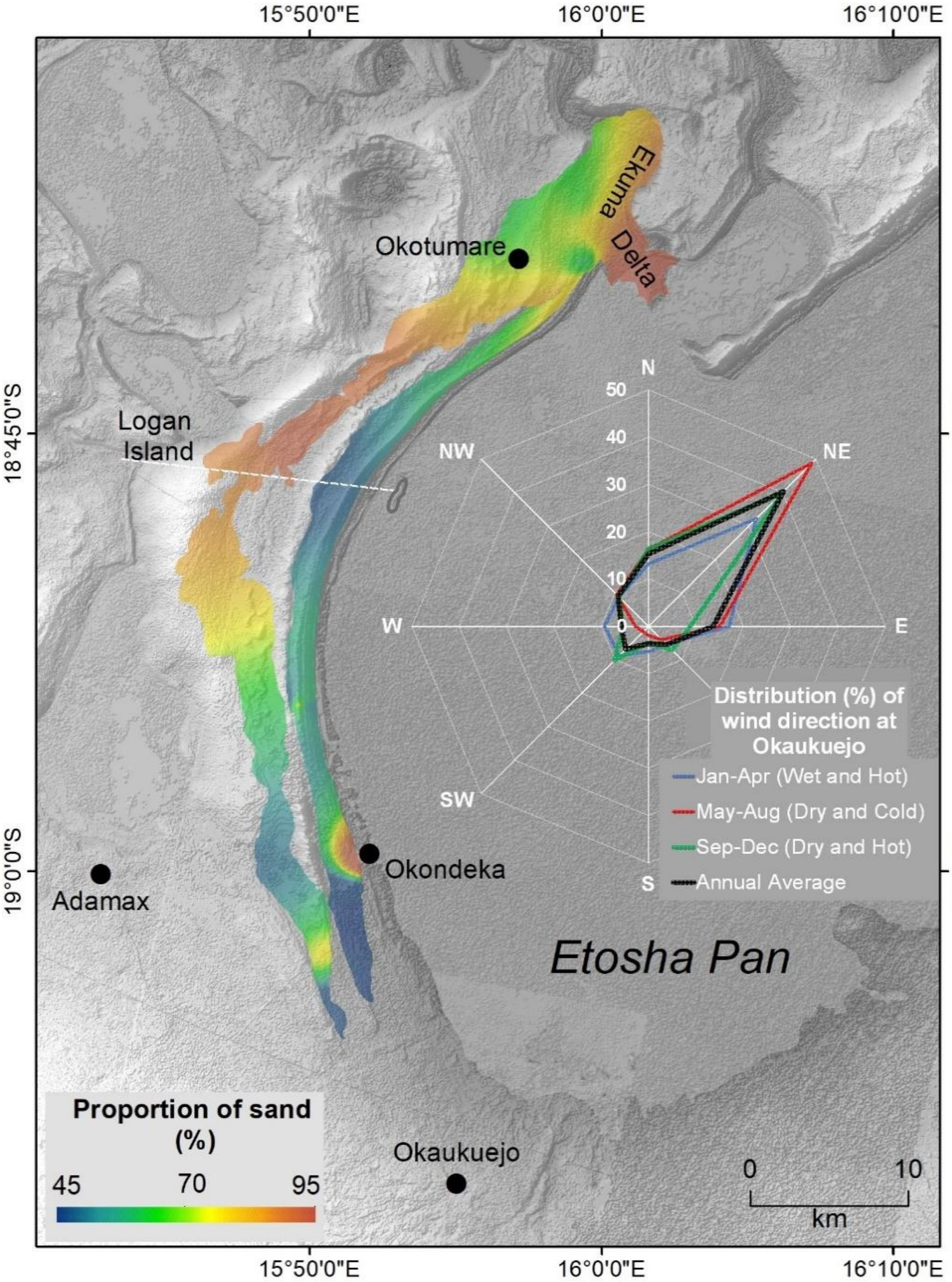

Figure 10. Proportions of sand in lunette dunes along the western margin of Etosha Pan

Raised artesian springs

A spring in the middle of Etosha Pan rests on a mound that rises about two metres above the surrounding pan surface (Fig. 11). The mound is built purely of mud, a result of dust being trapped in the moisture of the spring. Several other springs resting on mounds occur south of Etosha Pan, but these are built of carbonate precipitates from the springs' water (Miller, 2001). Of these the Gobaub spring south of Halali is a prominent example.

Figure 11. Spring in the middle of Etosha Pan a) from a distance, and b) up close from the top

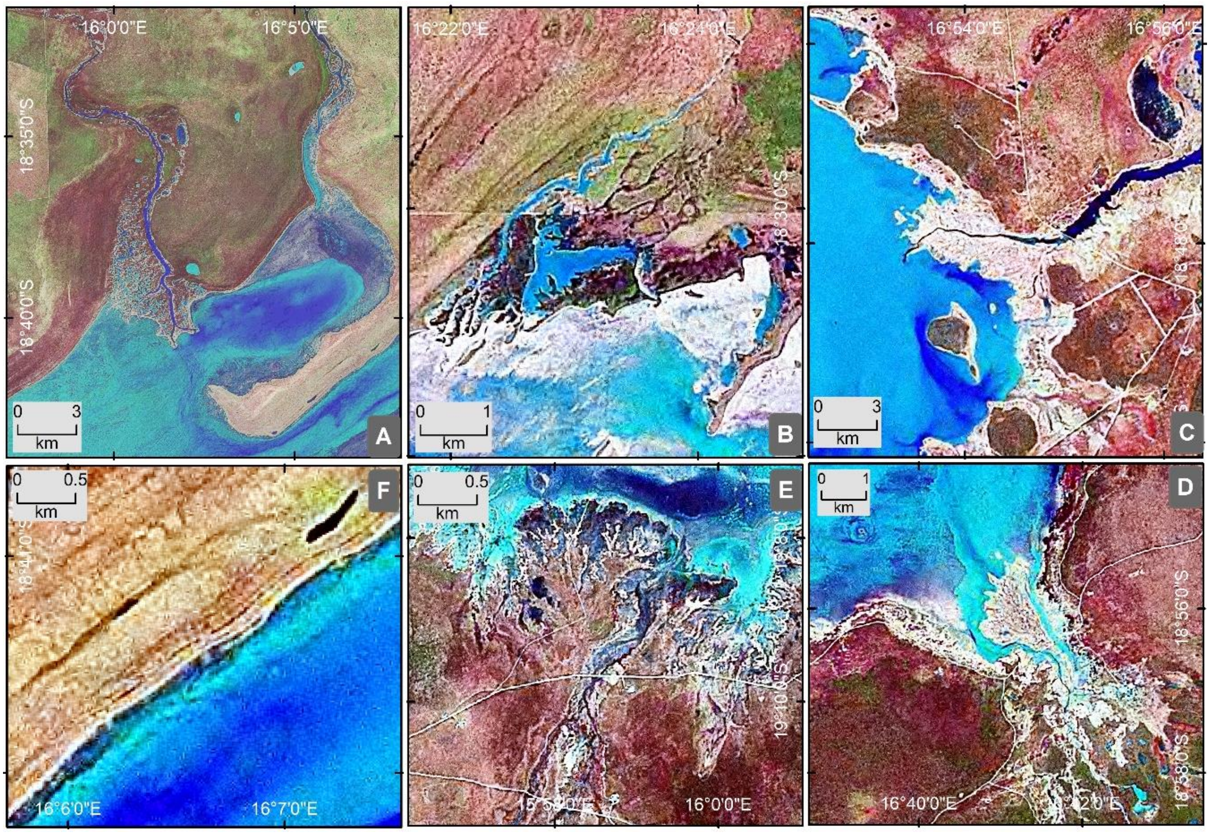

Figure 12. Selected deltas, fan deltas and a section of Oshigambo Peninsula. A) Ekuma Delta (left) and the absence of a delta at Oshigambo River (right), despite its prominence, B) Niipele, C) Fisher's Pan channel, D) Springbokfontein channel, E) Gaseb channel and F) beach sand ridges of the Oshigambo Peninsula. The illuviation of these sand ridges exposes a variety of fossils, including fragments of a sitatunga (Hipondoka *et al*., 2006) – the most amphibious antelope on the planet (Skinner and Smithers, 1990).

Geomorphological processes and footprints at Etosha Pan

Wave action eroded the rugged and steep scarps in the eastern and southern pan margins. Similarly, through deposition wave action shaped the northern Oshigambo Peninsula and western pan margin. Deposition of sediment in the west and eroding wave action in the east contributed to the eastward gradient of the pan.

Although Etosha Pan is one of the two (beside the Kuiseb River system) leading dust sources in Namibia (Vickery *et al.,* 2013), the river deltas, fan deltas and illuviation in the northern, eastern and southern margin of the pan give it more a fluvial footprint.

Ekuma is the only bird's foot delta, suggesting that it was formed under the influence of weak waves and currents, the river flow being stronger. The rest of the deltas in Fig. 12 bear hallmarks of modifications by waves and currents. For example, Niipele, Fisher's and Springbokfontein are all deflected counter-clockwise synchronous with the current direction. None of the sediments from these deltas have been dated to establish their chronology.

People of the Cuvelai

There is a notable and close relationship between the Cuvelai Drainage and the Aawambo (in Namibia) or Ambo (Angola) people who speak the same or closely related languages, have similar traditions, rules, farming and livestock keeping practices, villages and homes. Other groups living in low densities in the basin are !Xun, Hai‖Om, Aandongona, Damara, Herero, Ganguela and Nyaneka-Humbe. Many Aawambo have in recent decades moved to live and work elsewhere in Namibia or Angola, or from traditional rural villages to modern towns within the basin.

These emigrants generally maintain close associations with their rural family homes, to such an extent that many households can be termed trans-local, with family members living in quite different parts of the country contributing goods and money to their original family homesteads (Erkkilä *et al*., 2022). The relationships between these urban and rural household members appear to be stronger in Namibia than in Angola for reasons that are unknown and puzzling.

The close relations between Aawambo living either side of the Angola/Namibia border are another notable feature. Most Namibians are descended from grand-, great grand- or older Angolan parents, and many families retain links with members either side of the border. Many Angolan children school in Namibia, and many Angolans regularly visit Namibia for health care and to buy and sell goods. There are also great numbers of Angolans, many of them young, working informally for households on the Namibian side as domestic workers or tending livestock or crops. Conversely, it is estimated that tens of thousands of Namibian cattle belonging to Ovakwanyama owners graze seasonally or even permanently in Angola, especially in the Oshimolo area.

Some villages are bisected by the international border, where residents freely cross the cutline that separates Angola from Namibia (a good example is the village of Onehova visible on Google Earth at 17.393° S, 16.578° E). Most trade between residents of the two countries happens close to the border, especially in and around Santa Clara and Oshikango. Outapi, Onandjaba and Eenhana are other vibrant centres of cross-border trade, while smaller centres of trade are at Ongenga, Okongo and Ondobe. These examples demonstrate the close linkages between Aawambo in Namibia and Angola.

For many years satellite images revealed a conspicuous difference between the Angolan and Namibian sides of the Cuvelai, especially in its densely populated drainage areas (Fig. 13). The Namibian side was distinctly paler and brighter than the Angolan, because more trees had been cleared by the higher number of people resident in Namibia. The Angolan side appeared darker as it had more trees and fewer people and fields. The difference in population density began in the 1930s, when many Angolan Ambo began moving to Namibia (then South-West Africa), largely in response to harsh conditions levied on Angolans in the form of taxation and forced labour (Kreike, 1996; Hayes, 1992). Migration south continued, in later years due to civil war in Angola and the attractive services and economic conditions in

Namibia. At the same time, a large stretch on either side of the cutline was cleared of fields in the 1970s as the war for Namibia's liberation intensified.

In both countries most people cluster in and near the network of ephemeral drainage lines, at population densities much higher than in the surrounding areas (Mendelsohn and Weber, 2011). Historically, people settled among the *iishana*, where a mix of aeolian and alluvial sediments provided relatively fertile soils and because hand-dug wells provided access to fresh water year-round from shallow perched aquifers. Many people also live around arable soils and shallow aquifers amongst the thousands of small pans south-east and south-west of the major surface drainage zones (Arendt *et al*., 2021; Hamunyela *et al*., 2022). By contrast, potable water close to the surface is scarce in the poor aeolian soils that dominate the enclosing areas of the wider Kalahari Basin of which the Cuvelai is a part (Thomas and Shaw, 1991).

Figure 13. Satellite images taken in 1989 (left) and 2019 (right): the 1989 image shows a distinct difference between the darker Angolan and paler Namibian sides of the Cuvelai drainage zones. That distinction, caused by more land being cleared of trees in Namibia, has steadily diminished in recent years as Angola caught up with clearing its land for fields, while some woodland has recovered in Namibia (pers. obs.). The yellow arrow shows the grounds of the Ogongo Agricultural College, the only substantial area of the Cuvelai Drainage in Namibia not to have been cleared of woodland. Both images are from Google Earth with equivalent colour and contrast enhancement.

Environmental concerns

We use this opportunity to draw attention to some concerns regarding the environmental health of the Cuvelai Basin. The first is the accumulation of considerable volumes of human, plastic and other waste around major towns. Much of the waste lies in *iishana* from where it will be carried downstream during floods to be deposited around towns to the south and in the Omadhiya Lakes and Etosha Pan. A study of perennial and ephemeral rivers in Namibia found more micro-plastic particles in the Cuvelai's *iishana* system than in other rivers (Faulstich *et al.,* 2022).

Another concern requiring investigation is the use of dichlorodiphenyltrichloro-ethane (DDT) in mosquito control programmes to suppress the spread of malaria. This insecticide was first introduced in the basin in 1965 (Hansford, 1975; cited in Kamwi, 2005). Although DDT was banned in the 1970s due to its toxicity, it is still produced and given exemption for usage in controling malaria in Namibia (Burgos-Aceves *et al.,* 2021; Kamwi, 2005). The International Agency for Research on Cancer (IARC, 2015) classified DDT as a possible carcinogen in humans. More recently, exposure to DDT through pollution of water and soil resources has been documented to impact reproductive and immune systems with estrogen-disrupting action in humans and wildlife (Burgos-Aceves *et al.,* 2021).

During *efundja* floods great numbers of fish are found and often caught in *iishana* and the Omadhiya Lakes, which prior to the flood may have been dry for years. Where these fish come from is not fully known. Some come from the Kunene River (Van der Waal *et al.,* 2021), but others probably come from sources not connected with this river. Presumably these are fish that aestivate or hatch from eggs in the soil, perhaps in damp depressions. Identifying and protecting these refugia is important, not only for the survival of the fish but also for the nutritional and economic value provided by harvested fish.

Elderly residents often say that water flows in the Cuvelai are nowadays slower and wider than before, a possible consequence of sediments accumulating in the channels and making them shallower. Flood waters thus extend over larger areas and last longer than when these people were young. The sediments are said to have eroded off nearby fields and areas stripped of plant cover by livestock. These rapid changes reportedly have occurred because of the increase in land clearing, soil erosion accelerated by non-conservation tillage practices and livestock numbers. To our knowledge, these ideas have not been tested. If found to be correct, measures to alleviate flooding due to sediment accumulation could be investigated.

Some recent and little known literature

Useful information about the Cuvelai Basin is to be found in the following major, but often relatively unknown publications:

FISH: Van der Waal (1991), Van der Waal *et al.* (2021)

GEOGRAPHY: Feio (1966), SINFIC (2005), Mendelsohn *et al*. (2000, 2015), Mendelsohn and Weber (2011), Mendelsohn and Mendelsohn (2019)

GEOLOGY AND GEOMORPHOLOGY: Thomas and Shaw (1991), Buch *et al*. (1992), Miller (1997), Bryant (2003), Hipondoka (2005), Miller *et al*. (2010), Vickery *et al*. (2013), Wiggs *et al*. (2022), Gärtner *et al*. (2023)

HISTORY: Siiskonen (1990), Williams (1991), Hayes (1992), Kreike (1996, 2009), McKittrick (1996, 1997, 1998, 1999, 2002, 2003, 2006), McKittrick and Shingenge (2002), Gewald (2003)

HYDROLOGY and FLOODS: Stengel (1963), Lindeque and Archibald (1991), Kempf and Hipondoka (2003), Anon (2009), Shifidi (2014), Persendt *et al*. (2015), Wanke *et al*. (2018), Niipare *et al*. (2020), Arendt *et al*. (2021), Hamunyela *et al*. (2022)

LIVELIHOODS: Siiskonen (1990), Calunga *et al*. (2015), Erkkilä *et al*. (2022), Erkkilä (in press)

References

Anon. 2009. *Post-disaster needs assessment Namibia: Floods, 2009*. Government of the Republic of Namibia.

Arendt, R., Reinhardt-Imjela, C., Schulte, A., Faulstich, L., Ullmann, T., Beck, L., Martinis, S., Johannes, P., Lengricht, J. 2021. Natural pans as an important surface water resource in the Cuvelai basin—metrics for storage volume calculations and identification of potential augmentation sites. *Water,* **13**, 177.

Bridgland, D.R., Westaway, R. and Hu, Z. 2020. Basin inversion: a worldwide Late Cenozoic phenomenon. *Global and Planetary Change,* **193**. https://10.1016/j.gloplacha.2020.103260

Bryant, R.G. 2003. Monitoring hydrological controls on dust emissions: Preliminary observations from Etosha Pan, Namibia. *Geographical Journal*, **169(2)**, 131–141. https://doi.org/10.1111/1475-4959.04977

Buch, M.W., Rose, D. and Zoller, L. 1992, A TL-calibrated pedostratigraphy of the western lunette dunes of the Etosha Pan/ northern Namibia: A reconstruction of the depositional implications for the last 140 ka. *Palaeoecology of Africa,* **23**, 129–147.

Burgos-Aceves, M.A., Migliaccio, V., Di Gregorio, I., Paolella, G., Lepretti, M., Faggio, C. and Lionetti, L. 2021. 1, 1, 1-trichloro-2, 2-bis (p-chlorophenyl)-ethane (DDT) and 1, 1-Dichloro-2, 2-bis (p, p'-chlorophenyl) ethylene (DDE) as endocrine disruptors in human and wild life: A possible implication of mitochondria. *Environmental Toxicology and Pharmacology,* **87**. https://doi.org/10.1016/j.etap.2021.103684

Calunga, P., Haludilu, T., Mendelsohn, J., Soares, N. and Weber, B. 2015. *Vulnerabilidade na bacia do Cuvelai / Vulnerability in the Cuvelai Basin.* Occasional Paper No. 12, Development Workshop, Luanda, Angola, 152 pp.

DAR Angola. 2013. *Plano de Gestão Integrada dos Recursos Hídricos da bacia Hidrográfica do rio Cuvelai (Integrated Water Resources Management Plan for the Cuvelai River Basin)*. Provincial Government of Kunene, Angola.

Erkkilä, A. In press. *Trees of Life: Cultural Landscape Change in North-Central Namibia*. University of Namibia Press, Windhoek, Namibia.

Erkkilä, A., Indongo, N. and Siiskonen, H. 2022. Translocal livelihoods in southern Africa: A case study from north-central Namibia. *Journal of Namibian Studies: History Politics Culture,* **31**, 31–53.

Faulstich, L., Prume, J.A., Arendt, R., Reinhardt-Imjela, C., Chifflard, P. and Schulte, A. 2022. Microplastics in Namibian river sediments–a first evaluation. *Microplastics and Nanoplastics,* **2(1)**, 24. https://doi.org/10.1186/s43591-022-00043-1

Feio, D.M. 1966. A evolução do relevo da bacia endorreica do Cuanhama (Angola). *Finisterra,* **1(1)**, 33-59.

Gärtner, A., Houben, G.J., Sitnikova, M.A., Mille, R. McG., Wang, F., Zieger-Hofmann, M., Zieger, J. and Linnemann, U. 2023. Multiproxy sediment provenance analysis of two megafans in the Owambo Basin, northern Namibia. *Journal of the Geological Society (London),* **180**. https://doi.org/10.1144/jgs2022-065

Gewald, J.B. 2003. Near death in the streets of Karibib: famine, migrant labour and the coming of Ovambo to central Namibia. *Journal of African History,* **44**, 211–39.

Hamunyela, E., Hipondoka, M., Persendt, F., Nghiyalwa, H.S., Thomas, C. and Matengu, K. 2022. Spatio-temporal characterization of surface water dynamics with Landsat in the endorheic Cuvelai-Etosha Basin (1990–2021). *ISPRS Journal of Photogrammetry and Remote Sensing,* **191**, 68–84.

Hansford, C.F. 1975. *Malaria: Report on visit to South West Africa*: 17-28 February 1975. Department of Health, Welfare and Pensions, Tzaneen, RSA.

Hayes, P. 1992. *A history of the Ovambo of Namibia 1880-1935*. PhD thesis, University of Cambridge, UK.

Hipondoka, M.H.T. 2005. *The Development and Evolution of Etosha Pan, Namibia*. Dr. rer nat. thesis, Julius-Maximilian-Universität, Würzburg, Germany.

Hipondoka, M.H., Busche, D. and Kempf, J. 2004. Source of Lunette Dune Sediments: A Geomorphic Terrain Analysis Approach in Etosha National Park. *Erdkunde,* **1**, 212–220.

Hipondoka, M.H., Jousse, H., Kempf, J. and Busche, D. 2006. Fossil evidence for perennial lake conditions during the Holocene at Etosha Pan, Namibia: news and views. *South African Journal of Science*, **102**, 93–95.

Hipondoka, M., Kempf, J. and Jousse, H. 2013. Palaeo and present ecological value of the Etosha Pan, Namibia: an integrative review. *Journal* of the *Namibia* Scientific *Society,* **61**, 67–85.

IARC (International Agency for Research on Cancer) 2015. IARC monographs evaluate DDT, lindane, and 2,4-D. Press Release, no. 236 (2015).

Jaeger, F. 1926. Die Etoschapfanne. *Mitteilungen aus den Deutschen Schutzgebieten,* **34**, 1–22.

Jolivet, M., Dauteuil, O., Dia, A., Davranche, M., Pierson-Wickmann, A.C., Barrier, L., Murray-Hudson, M., Mazrui, N., Marsac, R., Cheng, F. and Li, X. 2023. Highly contrasted geochemical pattern in sediments of the Okavango Delta, Botswana driven by dust supply, hydrological heritage and biogeochemical reactions. *Geochemistry, Geophysics, Geosystems*, **24(6)**. https://doi.org/10.1029/2023GC010978

Kamwi, R.C. 2005. *Malaria situation in Namibia: A study of vector species and effectiveness of the past and current control strategies in selected parts of Namibia.* Ph.D. thesis, University of Namibia.

Kempf, J. and Hipondoka, M. 2003. Regenzeitliche Hydrodynamik im Bereich der

Etoschapfanne, Namibia. *Petermanns Geographische Mitteilungen*, **147**, 4–5.

Kreike, E.H. 1996. *Recreating Eden: agro-ecological change, food security and environmental diversity in Southern Angola and Northern Namibia, 1890-1960*. Ph.D. thesis, Yale University, Connecticut, USA.

Kreike, E. 2009. De-Globalisation and Deforestation in Colonial Africa: Closed Markets, the Cattle Complex, and Environmental Change in North-Central Namibia, 1890–1990. *Journal of Southern African Studies,* **35**, 81–98.

Lindeque, M. and Archibald, T. 1991. Seasonal wetlands in Owambo and the Etosha National Park. *Madoqua,* **17**, 129–133.

McKittrick, M. 1996. The 'Burden' of Young Men: Generational Conflict and Property Rights in Ovamboland. *African Economic History,* **24,** 115–129.

McKittrick, M. 1997. Reinventing the Family: Kinship, Marriage and Famine in Northern Namibia, 1948-54. *Social Science History,* **21(3)**, 265–295.

McKittrick, M. 1998. Generational Struggles and Social Mobility in Ovamboland, 1915 to 1950. *In:* P. Hayes, J. Silvester, M. Wallace and W. Hartmann (eds) *Namibia Under South African Rule: Mobility and Containment, 1915-1946,* Ohio University Press, Ohio, USA, 312 pp.

McKittrick, M. 1999. Faithful Daughter, Murdering Mother: Transgression and Social Control in Colonial Namibia. *The Journal of African History,* **40(2)**, 265–283.

McKittrick. M. 2002. *To Dwell Secure: Generation, Christianity and Colonialism in Ovamboland, Northern Namibia.* Social History of Africa Series. Heinemann, Portsmouth, New Hampshire, USA, 320 pp.

McKittrick, M. 2003. Forsaking their Fathers? Colonialism, Christianity and Coming of Age in Ovamboland, Northern Namibia. *In*: *Men and Masculinity in Africa.* Heinemann, Portsmouth, New Hampshire, USA.

McKittrick. M. 2006. The Wealth of These Nations: Rain, Rulers and Religion on the Cuvelai Floodplain, 449-470. *In:* T. Tvedt, E. Jakobsson, R. Coopey and T. Ostigaard (Eds) A History of Water: Series I, Vol. 3: *The World of Water*. Bloomsbury Academic, London, UK, 528 pp.

McKittrick, M. and Shingenge, F. 2002. Faithful Daughter, Murdering Mother: Transgression and Social Control in Colonial Namibia, 205-229. *In:* W. Woodward, P. Hayes and G. Minkley (eds) *Deep Histories: Gender and Colonialism in Southern Africa,* Series Cross Cultures, Vol. 57, Brill Publishing, Leiden, The Netherlands, 404 pp.

Mendelsohn, J.M. and Weber, B. 2011. *Povos e águas da bacia do Cuvelai em Angola e Namíbia / The Cuvelai Basin: its water and people in Angola and Namibia*. Occasional Paper No. 8, Development Workshop, Luanda, Angola, 122 pp.

Mendelsohn, J.M. and Mendelsohn, S. 2019. *Sudoeste de Angola: um retrato da terra e da vida / South West Angola: a portrait of land and life.* Arte & Ciência, Porto, Portugal, 423 pp.

Mendelsohn, J.M., El Obeid, S. and Roberts, C.S. 2000. *A profile of North-Central Namibia.* Gamsberg Macmillan, Windhoek, Namibia, 84 pp.

Mendelsohn, J.M., Robertson, T. and Jarvis, A. 2013. *A profile and atlas of the Cuvelai-Etosha Basin.* RAISON & Gondwana Collection, Windhoek, Namibia, 170 pp.

Miller, R.McG. 1997. The Owambo Basin of northern Namibia, 237–268. *In*: R.C. Selley (ed) *Sedimentary Basins of the World*, Vol. 3. Elsevier, Amsterdam, The Netherlands, 394 pp.

Miller, R.McG. 2001. Geology. *In*: G. Christelis and W. Struckmeier (eds) *Groundwater in Namibia: an explanation to the Hydrogeological Map*. Ministry of Agriculture, Water and Rural Development & Ministry of Mines and Energy, Windhoek, Namibia, 128 pp.

Miller, R., Pickford, M. and Senut, B. 2010. The geology, palaeontology and evolution of the Etosha pan, Namibia: implications for terminal Kalahari deposition. *South African Journal of Geology*, **113**, 307–334.

Namibia Hydrological Services. 2017. *Daily Flood/Hydrological Drought Bulletin*, **17 March 2017**. Ministry of Agriculture, Water and Forestry, Windhoek, Namibia.

Niipare, A.M., Jordaan, A. and Nguza, S. 2020. Flood Impacts in Oshana Region, Namibia: A Case Study of Cuvelai River Basin. *Journal of Geography and Geology,* **12**, 8-24. https://dx.doi.org/10.5539/jgg.v12n1p8

Persendt, F.C., Gomez, C., Zawar-Reza, P. 2015. Identifying hydro-meteorological events from precipitation extremes indices and other sources over northern Namibia, Cuvelai Basin. *Jàmbá: Journal of Disaster*

Risk Studies, **7**, 1–18.

Pickford, M., Senut, B., Hipondoka, M., Person, A., Segalen. L., Plet, C., Jousse, H., Mein, P., Guérin, C., Morales, J. and Mourer-Chauviré, C. 2009. Mio-plio-pleistocene geology and palaeobiology of Etosha Pan, Namibia. *Communications of the Geological Survey of Namibia*, **14**, 95–139.

Schwarz, E.H.L. 1920 *The Kalahari or Thirstland Redemption*. Maskew Miller, Cape Town, 196 pp.

Shifidi, V.T. 2014. *Socio-economic assessment of the consequences of flooding in Northern Namibia.* MSc thesis, University of Stellenbosch, South Africa. https://hdl.handle.net/10019.1/96066

Siiskonen, H. 1990. *Trade and socio-economic change in Ovamboland, 1850-1906*. Studia Historica 35, Societas Historica Fennica (Suomen Historiallinen Seura), Helsinki, Finland, 269 pp.

SINFIC SARL. 2005. *Plano de Urbanização da Cidade de Ondjiva (Urbanization Plan for the City of Ondjiva).* Report for the Government of Kunene Province, Angola.

Skinner, J.D. and Smithers, R.H.N. 1990. The mammals of Southern African subregion. 2nd ed., University of Pretoria Press, Pretoria, South Africa, 769 pp.

Stengel, H. 1963. Die Cuvelai, 'n bydrae tot die Waterkunde van 5uidwes-Africa, 218-232. *In: Waterwese in Suidwes Afrika*. Africa-Verlag Der Kreis, Windhoek, Namibia.

Stuart-Williams, V. 1992. Etosha: third largest lake in the world. *In*: Marsh A, Seely M (eds) *Oshanas – sustaining people, environment and development in central Owambo, Namibia.* Windhoek, Namibia, 52 pp.

Thomas, D. and Shaw, P.A. 1991. *The Kalahari Environment*. Cambridge University Press, UK, 298 pp.

Van der Waal, B.C.W. 1991. Fish life of the Oshana Delta in Owambo, Namibia, and the translocation of Kunene species. *Madoqua*, **2**, 201–209.

Van der Waal, B.C., Hipondoka, M.H. and Ekandjo, M.N. 2021. Towards understanding the presence of abundant fish in running iishana. *Namibian Journal of Environment*, **5**, B–10.

Vickery, K.J., Eckardt, F.D. and Bryant, R.G. 2013 A sub-basin scale dust plume source frequency inventory for southern Africa, 2005–2008. *Geophysical Research Letters,* **40**, 5274–5279. https://doi.org/10.1002/grl.50968

Wanke, H., Beyer, M., Hipondoka, M., Hamutoko, J., Gaj, M., Koeniger, P. and Himmelsbach, T. 2018. The long road to sustainability: integrated water quality and quantity assessments in the Cuvelai-Etosha Basin, Namibia, 75-83. *In*: R. Revermann, K.M. Krewenka, U. Schmiedel, J.M. Olwoch, J. Helmschrot and Jürgens, N. (eds) *Climate change and adaptive land management in southern Africa – assessments, changes, challenges, and solutions. Biodiversity & Ecology,* **6**. Klaus Hess Publishers, Göttingen & Windhoek, 497 pp. https://doi:10.7809/b-e.00307

Wellington, J.H. 1938. The Kunene River and the Etosha Plain. *South Africa Geographical Journal,* **21**, 21–32.

Wiggs, G.F.S., Baddock, M.C., Thomas, D.S.G., Washington, R., Nield, J.M., Engelstaedter, S., Bryant R.G., Eckardt, F.D., von Holdt, J.R. and Kötting, S. 2022. Quantifying mechanisms of aeolian dust emission: field measurements at Etosha Pan, Namibia. *Journal of Geophysical Research: Earth Surface*, **127**. https://doi.org/10.1029/2022JF006675

Williams, F.N. 1991. Precolonial communities of south-western Africa. A history of Owambo kingdoms 1600–1920. *Archeia,* **16**. National Archives of Namibia, Windhoek, 204 pp.