DINTERIA

Namibia Scientific Society
Namibia Wissenschaftliche Gesellschaft

Contributions to the Flora and Vegetation of Namibia
Beiträge zur Flora und Vegetation von Namibia

Number
Nummer **35**
NOVEMBER
2015

DINTERIA

Number 35, NOVEMBER 2015

[Editor: Peter Cunningham, Environment & Wildlife Consulting, Namibia – E-mail: pckkwrc@yahoo.co.uk]

Original articles

Cover Illustration: *Hermania stricta* (desert rose; Wűstenrose). Photograph by Peter Cunningham

DINTERIA No. 35: 13-42 Windhoek, Namibia – NOVEMBER 2015

An overview of grass species used for thatching in the Zambezi, Kavango East and Kavango West Regions, Namibia

Ben J. Strohbach[1] & H.J.A. (Wally) Walters[2]

[1]School of Natural Resources and Spatial Sciences, Polytechnic of Namibia
P/Bag 13388
Windhoek
Namibia
E-mail: bstrohbach@polytechnic.edu.na

[2]Oshikango Thatching and Building cc
P. O. Box 6058
Uniedal
7612
Stellenbosch
South Africa

Abstract
The trade with indigenous plant products has increased over the past years, contributing considerable to the household economies of rural people. Likewise, the trade with thatch grasses in north eastern Namibia has grown to a multi-million dollar industry, with a considerable amount being exported to neighbouring Angola. However, confusion still exists as to which grass species are harvested, where they grow, and in what quantities. With this paper, the main thatching species, Eragrostis pallens*,* Cymbopogon caesius *and* Hyperthelia dissoluta*, together with other potential thatching species, are shortly described according to characteristics important for the thatching industry. Recommendations are made to improve the sustainability of the industry.*

Key words: *Cymbopogon caesius, Eragrostis pallens, Hyperthelia dissoluta*, indigenous plant product trade, thatch grass, thatch quality

Introduction

The indigenous plant product sector has developed in recent years to become an important contributor to income generation in the rural economies of Namibia (Cole 2014). The thatch grass industry is but one of these: An annual sales volume of 1.2 million bundles is estimated for the Kavango, and in many years the demand is greater than the supply. Thatch grass is sold at between N$7 and N$10 per bundle by the local harvesters (Walters 2014). A project is currently initiated by the Ministry of Trade and Industry (MTI), through the Namibia Development Corporation (NDC), to establish a thatch grass hub in Rundu, with the aim to formalise and stabilize the trade with thatch grass in the north-eastern Regions of Namibia (NDC 2013).

Considerable confusion exists on the species used for thatching, with e.g. *Aristida stipitata* (a short, much-branched grass) being praised as a prime thatching grass under the name 'nangondwe' (cf. NDC 2013; Walters 2014). Such confusion can be attributed to the initial incorrect capturing of local names during specimen collection for herbarium purposes, and was over time multiplied in various publications taken as authorative for the Namibian Flora (Müller 1984, 2007; Klaassen & Craven 2003; Craven & Kolberg 2012). In many cases, the grasses are only known by their local names, or an incomplete identification (e.g. Gunson 1999).

At the same time, the habitat of the grasses in question, as well as the abundance/availability of these, is greatly unknown. Identification guides (Gibbs Russell *et al.* 1990; van Oudtshoorn 1999; Müller 2007) generally provide only a very sketchy overview of the habitat, whilst vegetation descriptions aim at giving a general description of dominant and characteristic species as well as structure of the vegetation, rather than the full composition and abundance of species (e.g. De Sousa Correia & Bredenkamp 1986; Burke 2002; Strohbach & Petersen 2007; Lushetile 2009; Strohbach 2013a, 2014). In many cases, including the Zambezi Region, only an overview description is available, lacking detailed phytosociological descriptions (Mendelsohn & Roberts 1997; Burke & Strohbach 2000; Strohbach 2001; Mendelsohn & el Obeid 2003).

The purpose of this study was to ascertain the identification of thatch grasses collected, sold and used in the Kavango West, East and Zambezi Regions, and to present some basic characteristics of these grasses. Furthermore, general comments and recommendations towards the development of a sustainable thatch grass industry are presented.

Natural Environment

Eastern and especially north-eastern Namibia are dominated by sands of the Kalahari basin. Riverine systems of the Okavango, Kwando, Zambezi and Chobe River systems locally define the landscape (Mendelsohn & Roberts 1997; Mendelsohn *et al.* 2002; Mendelsohn & el Obeid 2003, 2004).

In the Kavango West and East Regions, the Okavango River forms a deep ravine cutting through the landscape (Schneider 1986; Gröngröft 2013; Strohbach 2013a). Most of the population lives near the Okavango River, with easy access to water, and natural resources provided by the riverine and wetland ecosystems (Mendelsohn & el Obeid 2003). The thatching grass industry developed along the B8 tarmac road towards Rundu as well as nearby Divundu (Walters 2014). The people living here are more impoverished than those living along the river, and are highly dependent on living from various forest products (timber as well as non-timber products). Here the main habitat for collecting thatch grasses is the Kavango woodlands. Detailed descriptions of this vegetation are presented by De Sousa Correia & Bredenkamp (1986), Burke (2002), Strohbach & Petersen (2007) and Strohbach (2013). The Bwabwata National Park, now entirely part of the Kavango East Region, is covered by a dune - interdune mosaic with Kavango woodlands (Mendelsohn & Roberts 1997).

The Zambezi Region is strongly influenced by the riverine systems of the Kwando, Zambezi and Chobe Rivers. These form extensive floodplain systems in the eastern and southern parts of the Region. Only the far northern part of this Region is dominated by pure Kalahari sands with associated woodlands. The central parts (between Kongola and Katima Mulilo) form a transition between these Kalahari sands and the wetland systems, and are dominated by various forms of Mopane savanna. Only limited detailed vegetation descriptions, mainly of the Kalahari Woodlands at Sachinga Livestock Development Centre, are available (Lushetile 2009).

Thatch quality characteristics

No formal quality criteria exist for thatch grass or thatch reed (Long 1978; Horn 2006). The length of the culm would be an obvious criteria; for Cape thatching reed (*Thamnochortus* spp.) a culm length of 2 m is regarded as a standard quality characteristic (Horn 2006). The durability of the thatch is considered as a major factor by owners and producers, and is

influenced by the hardness of the culm, the ripeness of the culms at the time of harvesting, but also chemical components like tannins (Van Voorthuizen & Odell 1976; Horn 2006).

During discussions with several harvesters, but also with other stakeholders, the following possible criteria for thatch grass quality were developed:

Length

Grass culms are to be at least 1 m long, preferably longer than 1.5 m

Diameter

Extremely thin culms would mean a lot more material need to be collected. Thinner culms also have a higher surface: volume ratio, resulting in a higher risk for fungal attack and rotting. Thick culms, on the other hand, would mean less effective water-proofing, requiring a thicker thatch layer.

Straightness of the culms

The straighter, the easier to thatch with. Bent, knotty or branching culms are unsuitable for effective thatching.

Is the culm hollow or not?

Hollow culms can easily be flattened, or can splinter and break. This will make the roof loose, and highly susceptible for rot or loss of material. Related to this would be factors like how easily the culm bends or breaks, as well as the general hardness (degree of lignification) of the culm. Especially snapping at nodes has been observed at some species.

Does the culm contain essential oils or not?

From observations and anecdotal evidence by the harvesters it became evident that e.g. *Cymbopogon excavatus* provides a highly durable thatch, most likely due to the fact that it contains essential oils. These essential oils are also insect-repelling (Bissinger & Roe 2010; Nerio *et al.* 2010; Maia & Moore 2011; Kalita *et al.* 2013).

Methods

During a field visit between 13 and 17 May 2015, a large number of thatch grass collectors were visited in the Zambezi, Kavango East and Kavango West Regions. At each collector, available grass bundles were inspected and the different species collected identified. For this purpose, samples were taken and pressed for further identification in the National Herbarium of Namibia (WIND). Identification in the herbarium was done with the aid of the available collection, as well as standard reference books available (Merxmüller 1966; Launert 1971; Gibbs Russell *et al.* 1990; Müller 2007).

Whilst inspecting the grass bundles, the collectors were asked for the vernacular names of different grasses found in the bundles. In many cases, they were also asked to point out these grasses in the veld. Questions were also asked regarding the availability of these grasses, the quality of these grasses and preferences for use.

Additional information to the grass species, including English (E), Afrikaans (A), Silozi (L), Rukwangali (R), Shishambyu (Sh) and Thimbukushu (T) vernacular names, were obtained from the literature (Klaassen & Craven 2003; Müller 2007; Craven & Kolberg 2012; Clayton *et al.* 2014). Care was taken that the vernacular names provided by the literature did not contradict names provided by the collectors in this report. Abundance and distribution data (as far as available) was obtained from the Namibian phytosociological database (Strohbach & Kangombe 2012), in particular sub data sets collected/used for Strohbach & Petersen (2007), Lushetile (2009) and Strohbach (2011, 2012, 2013a).

For a number of species a few culms were harvested and dried in an oven at 50°C. After drying, the diameter of these culms was determined with the aid of a veneer calliper. For this

purpose, repeat measurements were done on the internodes of several sections of these culms. In several cases, where no samples were taken, measurements were taken from specimens at the National Herbarium of Namibia.

Grass species used for thatching

Several grass species have been indicated in the past as thatching species from the north-eastern parts of Namibia. Not all are suitable or actually used as thatch. In the discussion below, these species are discussed in relation to some of the basic characteristics important for the thatching industry. A comparison of culm diameter is presented in Figure 1. Nomenclature follows Klaassen & Kwembeya (2013).

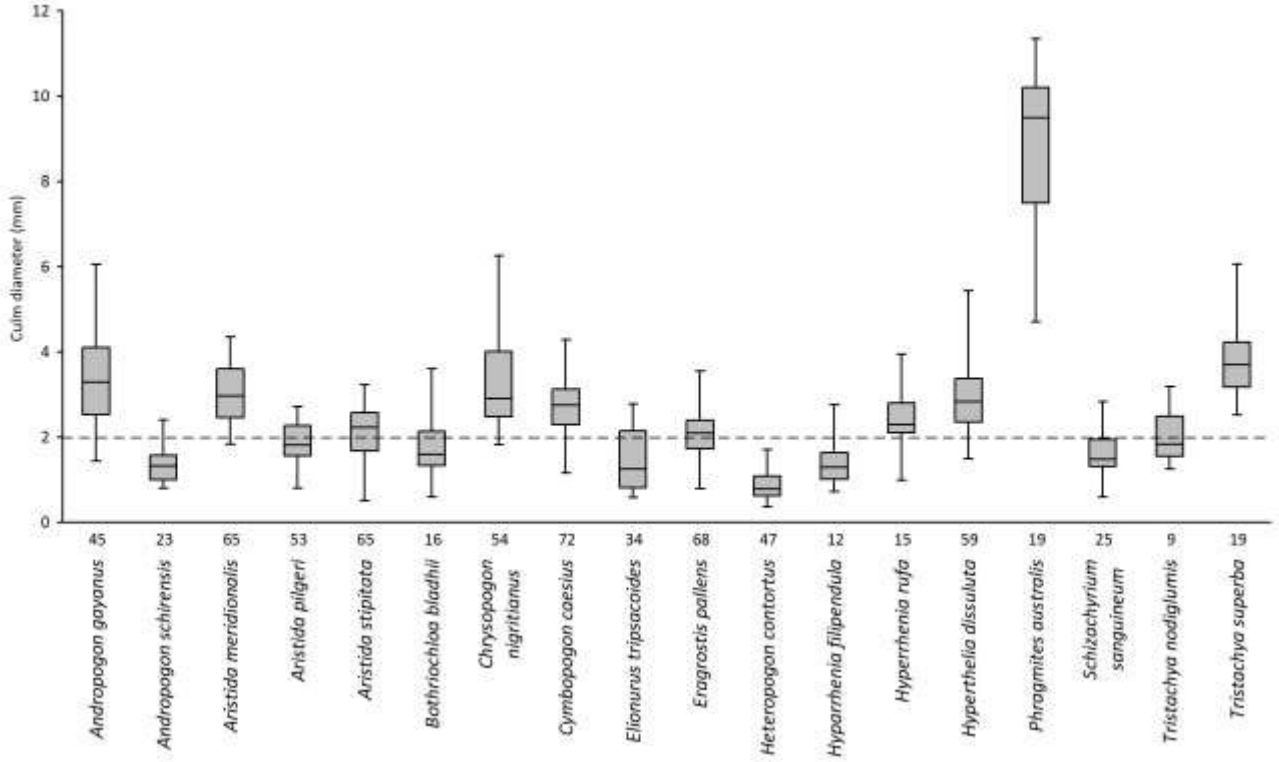

Figure 1. Comparative culm diameter of 18 grass species used for thatching purposes in Kavango West, East and Zambezi Regions. The number of measured samples is indicated next to the x axis, before the species name. The dotted line at 2 mm diameter indicates an arbitrary ideal minimum culm thickness for thatching.

Andropogon gayanus
Blue-grass (E); ngumbe (Sh); nengere (T)

Perennial grass, up to 3.6 m high. The culm diameter ranges between 1.4 and 6.1 mm, averaging at 3.4 mm (± 1.08 mm) (measured on herbarium specimens).

The straight culms are used by San for arrow shafts (Müller 2007). It has been found occasionally on heavier soils, often associated with calcrete, but never at great abundance (Strohbach & Petersen 2007; Strohbach 2013a). It has not been reported by Lushetile (2009).

This grass was very seldom found in collected bundles in the Zambezi Region, and is generally not exploited for thatch.

Andropogon schirensis
hairy blue-grass (E)

Perennial grass, with unbranched culms, ca 1.8 m high (Müller 2007). Culm diameter ranges between 0.8 and 2.4 mm, averaging at 1.4 mm (± 0.41 mm) (based on herbarium specimens).

Often confused with the branching *Andropogon chinensis* (Figures 2a & b). It has not been reported by Lushetile (2009).

This grass is seldom seen and was only occasionally found in the collected bundles in the Zambezi Region. It is generally not targeted as a grass for collection as thatch.

Figures 2a & b. Inflorescence (left) and habitat (right) of *Andropogon schirensis*.

Aristida meridionalis
Giant bristle-grass (E); leeusteekgrass (A)

Tufted perennial, with basal leaves, up to 2 m high (Müller 2007). Average observed height is ca 1.5 m. The culm is remarkably straight, unbranched with a very smooth appearance (Figure 3). Culm diameter ranges between 1.8 and 4.4 mm, averaging at 3.1 mm (± 0.68 mm). In the field it was observed that the culm easily snaps at the nodes.

Aristida meridionalis occurs widespread in sandy and loamy soils, often in dense patches, but is not dominant (Lushetile 2009; Strohbach 2013a). A considerable amount of this species was observed along the road verges in Zambezi Region and to a lesser extend in Kavango East, Kavango West and Otjizondjupa Regions.

This grass is not harvested for thatch.

Figures 3 a & b. Inflorescence (left) and habitat (right) of *Aristida meridionalis*.

Aristida pilgeri
Pilger's bristle-grass (E); murkankumbu (T)

A tufted perennial grass, with unbranched culms ca 1.5 m tall (Müller 2007) (Figures 4a & b). Culms range between 0.8 and 2.7 mm in diameter, averaging at 1.9 mm diameter (± 0.45 mm). The grass is regarded as a very brittle grass, easily breaking when trampled (Müller 2007).

Aristida pilgeri occurs occasionally in sandy soils, often washed sandy soils of *omirimbi* or on dry floodplains, but never in great abundance (Strohbach 2011, 2012, 2013a).

The grass is occasionally harvested for thatch in the Zambezi and Kavango East Regions, but not in great quantities.

Figures 4a & b. Inflorescence (left) and habitat (right) of *Aristida pilgeri*.

Aristida stipitata
Dune/sandveld bristle-grass (E); tjoke-tjoke (R)

This species is incorrectly referred to as 'nangondwe' in current literature (Klaassen & Craven 2003; Müller 2007; Craven & Kolberg 2012).

A much-branched, woody grass, referred to as perennial in the literature (Gibbs Russell *et al.* 1990; Müller 2007), but generally assumed to be annual (Strohbach & Strohbach 2004; Strohbach 2013b). The many branches result in a strongly zigzagged culm, up to 0.6 m tall (Figures 5a & b). Culm diameter ranges between 0.5 and 3.2 mm, averaging at 2.1 mm (± 0.58 mm).

Aristida stipitata is a wide-spread pioneer species in especially the sandy soils of the Kalahari basin in eastern and north-eastern Namibia. It often dominates under over-grazed conditions (Strohbach & Strohbach 2004; Strohbach & Petersen 2007; Strohbach 2013a, 2014).

Due to its short growth, and much-branched culms, it is not regarded as a good thatching grass. However, the woodiness of the culms, and the ease of collecting it in great quantities, makes it a much-used grass for covering temporary shelters, even hut roofs, by the local population in Kavango East and West Regions. The grass is packed onto the roof in dense mats, rather than properly thatched.

Figures 5a & b. Inflorescence (left) and habitat (right) of *Aristida stipitata*. Habit picture from the Dordabis area.

Bothriochloa bladhii
Smelly grass (E); vleistinkgras (A); namunuka (L)

A tufted perennial grass, often with bent culms, up to 1.5 m tall (Gibbs Russell *et al.* 1990; Müller 2007; Clayton *et al.* 2014) (Figures 6a & b). Culm diameter ranges between 0.6 and 3.6 mm, averaging at 1.8 mm (± 0.78 mm) (based on herbarium specimens). The leaves have a strong phenolic smell when rubbed, indicating a possible resistance to rotting in the culm. Due to its smell, the grass is generally regarded as unpalatable to grazers (Müller 2007).

Bothriochloa spp. is known to occur in water-logged soils like vleys and pans. They however avoid standing water (Müller 2007). Their distribution is thus patchy, localized, but very dense in such patches. It has not been reported by Lushetile (2009).

This species has been reported to be used for thatching at Ibbu village in the southern Zambezi Region. It was not observed in any grass bundles for sale.

Figures 6 a & b. Inflorescence (left) and habitat (right) of *Bothriochloa bladhii*.

Chrysopogon nigritanus
(synonym: *Vetiveria nigritiana*)
Vetiver (E); sivamba (L), iskaka, zikaka

A tufted perennial grass, growing to 2 - 3 m tall (Gibbs Russell *et al.* 1990; Clayton *et al.* 2014). The culms are unbranched, and on average 3.4 mm in diameter (± 1.23 mm) (range: 1.8 - 6.3 mm) (Figures 7a & b).

Chrysopogon nigritanus is a wetland grass species, growing on fringes of inundated floodplains and in shallow water. It forms a valuable winter grazing once the floods have receded. During the flooding period it forms part of the refuge for fish fry and for species breeding on these seasonally inundated floodplains and is thus a keystone species in these aquatic ecosystems (Bethune 1991).

This species is used for thatch and palisades mostly by people living close to the Okavango River in the Kavango East and West Regions. It is not sold commercially, and should, due to its keystone function in the aquatic ecosystem, also not be commercially developed as thatch grass.

Figures 7a & b. Inflorescence (left) and habitat (right) of *Chrysopogon nigritanus*.

Cymbopogon caesius
(synonym: *Cymbopogon excavatus*)
Broad-leaved turpentine grass (E); kasisi (L)

A tussocky, tufted perennial, with many broad leaves along the culm. The culms generally grow up to 1.5 m tall (Müller 2007; Clayton *et al.* 2014), but have been observed along road verges to reach up to 1.8 to 2 m height (Figures 8a-d). The culm diameter ranges between 1.2 and 4.3 mm, averaging at 2.7 mm (± 0.64 mm). The genus *Cymbopogon* is know for it's essential oil content (an oil similar to citronella oil), which is strongly insect-repelling (Nerio *et al.* 2010; Maia & Moore 2011; Kalita *et al.* 2013; Rehman *et al.* 2014).

Cymbopogon caesius occurs occasionally in the veld, never at high quantities (Lushetile 2009). It was observed in patches along the road verges. According to local grass harvesters in the Zambezi Region, it occurs in abundance in the southern parts of this Region, most likely in the Liambezi-Linyanti grasslands (Mendelsohn & Roberts 1997). This could not be ascertained during the field visit.

Kasisi has been described as a long-lasting, high quality thatching grass by the local community. It does not seem to be generally available in the thatch industry market – likely as a result of restricted availability and high local demand. A thatched roof at Omega (in the Bwabwata National Park) was said to have lasted for well over 30 years, before recently being replaced by a tin roof. The grass material which was taken from the roof indicated a 50/50 mixture of *kasisi* (*Cymbopogon caesisus*) and *mahengehenge* (*Hyperthelia dissoluta*). It seemed that the essential oils in *Cymbopogon caesius* helped to prevent rot including the other grass culms in the mixture.

Should the production of thatch grass from *Cymbopogon caesius* be further developed, the possibility to harvest the leaves, and produce oil similar to citronella oil as a by-product should be investigated. As this grass does not seem to occur in great abundance, it should be investigated whether this species can be planted for commercial production, making use of numerous fallow fields in the area.

Figure 8. Inflorescence (a and b) and habitat (c) of *Cymbopogon caesius*. (b) Inflorescence as it appears stripped and is found in thatching bundles. (d) A roof of a hut at Ibbu being thatched with *kasisi* (*Cymbopogon caesius*).

Elionurus tripsacoides

A tufted perennial grass, ca 1.2 to 1.5 m tall (Clayton *et al.* 2014). The culm diameter ranges between 0.6 and 2.8 mm, averaging at 1.5 mm (± 0.69 mm) (measured on herbarium specimens). This species occurs occasionally in the deep sandy soils of the Kavango woodlands (Strohbach & Strohbach 2004) (Figures 9a & b). No record is known from the Zambezi Region (Lushetile 2009), but it is likely to occur here.

Elionurus tripsacoides has been found once in a mixed bundle of thatch for sale near Katima Mulio, but does not seem to be generally harvested for thatch.

Figures 9a & b. Inflorescence (left) and habitat (right) of *Elionurus tripsacoides*.

Eragrostis pallens
Broom grass (E); besemgras (A); nangondwe (R)

A tall, densely tufted perennial grass, growing to between 1.5 and 1.8 m tall. The culms are straight and unbranched (Müller 2007; Clayton *et al.* 2014) (Figures 10a-d). Culm diameter ranges between 0.8 and 3.6 mm, averaging at 2.1 mm (± 0.53 mm).

Eragrostis pallens is a wide-spread grass in the Kavango woodlands (Strohbach & Strohbach 2004; Strohbach & Petersen 2007; Strohbach 2013a), but never in dense stands. It has also been reported from the Zambezi Region (Lushetile 2009; Strohbach 2011, 2012), as well as from further south in the Kalahari ecosystems (Strohbach 2013b, 2014). The fact that this grass occurs wide-spread means that there is a considerable resource available; at the same time, due to its low density, it also means a considerable effort to walk to collect these grasses.

Nandongwe (*Eragrostis pallens*) is harvested as the prime thatching grass in the Kavango East and West Regions (including San communities in the Bwabwata National Park). It has also been reported as one of the main thatching grasses of northern Botswana in the sandy areas (Van Voorthuizen & Odell 1976). It is not harvested in Zambezi Region at all. The local population in Kavango also do not use this grass for thatching as this grass can be sold, and is thus more important as a source of income than to be used as building material.

Harvesting of this species starts as early as April each year, continuing to late winter, even spring (July to NOVEMBER). Of great concern is the fact that the grass is still green in April and May (being the bulk harvesting season), meaning that both the culms and the seeds have not ripened fully at the time of harvesting. The unripe culms mean that lignification of the cells has not been completed, making the grass soft and potentially susceptible to easy rotting (Van Voorthuizen & Odell 1976; Dabo *et al.* 1997). Unripe seeds mean that these (a) do not fall easily from the inflorescence when harvesting, and (b) are basically unripe and likely not viable for germination during the next season.

As this grass forms the bulk of the thatch grass industry in Namibia, and is also exported to neighbouring Angola, it should be investigated whether it is not feasible to cultivate this grass. For this purpose fallow (or abandoned) fields on the upper river terrace (with nutrient-poor sandy soils) could be utilised.

Figures 10a & b. Inflorescence and habitat of *Eragrostis pallens* (a & b). (c) Cleaning of *nangondwe* bundles at Omega; (d) Approximately 700 bundles of *nangondwe* (*Eragrostis pallens*) ready for sale along the B8 tarmac road to Divundu.

Heteropogon contortus
Spear grass (E); assegaaigras (A); ehege hege (R)

A short tufted, perennial grass, growing ca to 50 cm tall (Müller 2007). The culms are generally straight, but depending on genotype and age of grass, could be branched. Culm diameter ranges between 0.4 and 1.7 mm, averaging at 0.9 mm (± 0.32 mm).

Heteropogon contortus occurs widespread and in great densities along the roads in the Zambezi Region. The species occurs also in the Kavango Regions, mainly in loamy soils. However, it is not common in the veld, neither in the Zambezi nor the Kavango Regions (Strohbach & Strohbach 2004; Strohbach & Petersen 2007; Lushetile 2009; Strohbach 2011, 2013a).

As the grass leaves are more or less as long as the culms (up to 30 cm long), the culms cannot be cleanly cut without a large number of grass leaves. The very short and very thin culms are also not very suitable for thatching. The species is not used by the local population for thatching purposes.

Hyparrhenia filipendula
Fine Thatching Grass (E); fyn tamboekiegras (A); tengenya (L)

An upright, perennial grass, ca 1.5 to 1.8 m tall. Culm diameter ranges between 0.7 and 2.8 mm, averaging at 1.4 mm (± 0.54 mm) (measured on herbarium specimens). It is of limited distribution in the Zambezi Region and mainly associated with the floodplain areas around (especially to the south) Lake Liambezi (Strohbach 2011) and occasionally also along road verges.

It is not known to be used as a thatch grass in the Zambezi Region.

Hyparrhenia rufa
Yellow-spike thatching grass (E); geelaar tamboekiegras (A); mutengenya (L), latengenya

A tall, perennial grass, growing between 2 and 3 m tall. The culms are generally straight and unbranched (Müller 2007) (Figures 11a & b). Culm diameter ranges between 1.0 and 4.0 mm, averaging at 2.4 mm (± 0.77 mm). This species is easily confused with *Hyperthelia dissoluta*.

Like *H. filependula*, this grass is limited to the heavier soils in the southern Zambezi Region around Lake Liambezi, possibly also within the Liambezi-Linyanti grasslands (Mendelsohn & Roberts 1997). It occurs at higher abundance than *H. filipendula*, but is still not wide-spread. Because of its length and relative higher abundance, it is used occasionally for thatch, although limited.

Figures 11a & b. Inflorescence (left) and habitat (right) of *Hyparrhenia rufa*.

Hyperthelia dissoluta
Yellow thatching grass (E); geel tamboekiegras (A); tengere (R), mahengehenge (L)

A tall, perennial grass, growing between 2 and 3 m tall. The culms are generally straight and unbranched (Müller 2007) (Figures 12a & b). Culm diameter ranges between 1.0 and 5.4 mm, averaging at 2.9 mm (± 0.70 mm). This species is easily confused with *Hyparrhenia rufa*.

Hyperthelia dissoluta occurs widespread, often at high densities, along road verges throughout Zambezi, Kavango East and West as well as Otjozondjupa Regions. Within the Kavango, it is often limited to the lower parts of the landscape in/nearby *omirimbi*, etc., indicating that this species favours heavier loamy soils rather than the pure sands of the Kalahari. Its abundance in the veld could not be ascertained. It has not been reported by Lushetile (2009) and infrequently by Strohbach (2011).

H. dissoluta (*Mahengehenge*) is collected widespread throughout the Zambezi Region, and is the main commercial thatch species in this Region. From a quality point of view, however, it is not highly regarded by the local population as it does not last as long as *Cymbopogon caesius* (*kasisi*).

Figures 12a & b. Inflorescence (top) and habitat (bottom) of *Hyperthelia dissoluta*.

Phragmites australis
Common reed (E); mbu (R)

A bamboo-like species (also belonging to the Poaceae, or grass family), the common reed grows in shallow water along the margins of the Kavango River and other permanent rivers like the Zambezi and Chobe mostly in areas which are more or less permanently inundated (Strohbach 2013a). It grows between 3 and 4 m tall, and the hollow culm ranges between 4.7 and 11.3 mm in diameter (Figure 13). Average culm diameter is 8.7 mm (± 1.95 mm). A related species, *Phragmites mauritanica*, also occurs here, but is less common, generally shorter and the culms are not as straight (more geniculate).

Phragmites australis is generally not used for thatch, but rather for palisades around huts, due to its length. The very thick culm means that water proofing with this species is difficult, requiring an extra thick layer of material for effective thatching. The culms are hollow, meaning that they splinter easily, or collapse if tightened too hard on a thatch roof.

Another concern is that the reed beds in the Kavango, Zambezi and Chobe Rivers are the breeding grounds for fish in these aquatic ecosystems and reducing this will mean a reduced fish population, which is under threat by overfishing (Bethune 1991; Hay *et al.* 1996).

Figure 13. Habitat of *Phragmites australis*.

Schizachyrium sanguineum
Red autumn grass (E)

A slender, perennial grass, ca 1.2 m tall (Müller 2007). The grass has a conspicuous copper-red to maroon appearance (Figure 14). The culms range in diameter between 0.6 and 2.8 mm, averaging at 1.6 mm (± 0.56 mm) (measured on herbarium specimens).

The distribution is limited to the moister, loamier soils near riverine systems in the Zambezi Region. The abundance of this grass could not be established. It has occasionally been found in bundles of thatch grass (mixed thatch) near Linyanti.

Figure 14. Inflorescence of *Schizachyrium sanguineum*.

Tristachya nodiglumis
Mwange, mwangetonga

A tufted perennial grass, growing between 0.6 and 2 m tall (mostly below 1.5 m) (Clayton *et al.* 2014) (Figure 15). The culm diameter ranges between 1.3 and 3.2 mm, averaging at 2.0 mm (± 0.69 mm) (measured on herbarium specimens). The culm is hollow.

Tristachya nodiglumis has been observed on sandy soils within the Mopane habitats in the Zambezi Region. The habitat preferences and abundance of this species could not be determined during the field trip. This grass has been found a number of times in bundles collected near the Gunkwe mulapos in Central Zambezi, as well as the Kwando valley woodlands of the western Zambezi Region.

Figure 15. Inflorescence of *Tristachya nodiglumis* as seen in the thatch bundles.

Tristachya superba
Giant russet grass (E)

A tufted perennial grass, with culms growing up to 2.5 m tall (Clayton *et al.* 2014). The culms are very straight, generally leafless and hollow (Figures 16a-c). The culm diameter ranges between 2.5 and 6.1 mm, averaging at 3.8 mm (± 0.95 mm) (measured on herbarium specimens).

Tristachya superba occurs in the Kavango woodland habitats on very sandy soils. It is widespread, but less abundant than *Eragrostis pallens*. This grass is used for making sleeping mats and as drinking straws by the local communities around Omega. It is generally not used as thatch.

Figures 16a-c. Inflorescence (top) and habitat (middle) of *Tristachya superba* (a and b) and examples of sleeping mats made with this grass species (bottom).

General observations

Grass quality

Most grass species have a culm diameter of between 2 and 4 mm, and are thus relatively thin compared to the industry standard of between 3 and 4 mm (Long 1978; CSIR 1998; Horn 2006). *Andropogon schirensis, Aristida pilgeri, Bothriochloa bladhii, Elionurus tripsacoides, Heteropogon contortus, Hyparrhenia filipendula, Schizachyrium sanguineum* and *Tristachya nodiglumis* are very thin (mostly <2 mm diameter), whilst *Phragmites australis* is extremely thick (Figure 1). *Andropogon gayanus, Chrysopogon nigritanus* and *Tristachya superba* have a very broad range of culm thickness (varying on a single culm), thus making them relative unsuitable for thatching purposes. *Aristida stipitata* and *Heteropogon contortus* are also too short for thatching and *Aristida stipitata* is also heavily branched without straight culms.

The strength of the culms could not be tested within the scope of this paper. In terms of general observations, it is felt that *Eragrostis pallens* is harvested too early in the season (it is still green at the time of harvesting), indicating that lignification of the culm has likely not been completed. This makes the culm weak, weaker than what it could have been. A longer growth/ripening period for this grass will possibly also result in somewhat thicker culms – many of the harvested material was less than 2 mm in diameter. *Aristida pilgeri* is known to be a brittle grass (Müller 2007), making it also potentially unsuitable for thatching. A similar tendency has been observed from *Aristida meridionalis*, which is not used for thatching at all by the local community.

Harvesting practises

In most cases, the grass is cut with a sickle. In some cases, grasses with roots attached were found in the grass bundles, which is an unsustainable practise (Figures 17a & b).

During interviews with the harvesters, it was indicated that the harvesting is done very low, just above ground level. This, coupled to the fact that harvesting in the Kavango Region starts very early during the season (during mid April), is potentially also an unsustainable practise. Perennial grasses store their nutrients in rhizomes and roots near or below the soil surface during the dry season. With the onset of the rainy season, these nutrients are released and can facilitate growth. As the growing season ends (normally with the onset of the first cold in May), nutrients are translocated back to the root system (Danckwerts *et al.* 1989; Tainton 1999). If harvested too early, the translocation of nutrients has not been completed (if it has started), and coupled to a very low cutting, means that the grass tuft is subject to severe defoliation equivalent to severe overgrazing. Such heavy defoliation has been proven to damage the grass sward, meaning that grass plants die (Danckwerts & Stuart-Hill 1988; Danckwerts *et al.* 1989; O'Connor 1991, 1993) and are replaced by unsuitable/unpalatable annual grasses. This is especially so for the Kavango Region, where *Aristida stipitata* could become dominant and cannot be commercially exploited for thatch (and is also used only for short-term/temporary structures by the local population).

Figures 17a & b. Unsustainable harvesting practises include (a - top) pulling out the grasses with their roots, rather than cutting the grasses with a sickle, as well as (b - bottom) harvesting these grasses too early, in an unripe stage, before seeds have fallen. Here a bundle of *Eragrostis pallens*.

Another concern of harvesting the grasses too early is the fact that the seeds are generally not ripe when harvesting. This is evident from the fact that most flower packets are still attached when cleaning commences, and many of these flower packets remain even within the cleaned grass bundles when ready for sale. This could affect propagation and production of the particular grass species while unripe seeds are also highly unlikely to germinate.

The possibility to cultivate thatch grass as an alternative crop has not yet been investigated. Cultivation of Cape *dekriet* (*Thamnochortus insignis*) has been successful in the southern Cape, and has in this way increased the production and sustainability of the industry dramatically (Horn 2006). Such a practise could increase the yield of high-quality grasses like *Cymbopogon caesius*, which is not known to grow in high abundances within their typical habitat. In both the Zambezi and Kavango East Regions, a number of abandoned/fallow fields are available, which can be exploited for the cultivation of such thatch grasses. In the Kavango East Region, *Eragrostis pallens* should be considered for planting, as it occurs on the nutrient-poor soils of the Kavango woodlands.

Additional, related products

Cymbopogon caesius contains an essential oil, which is likely to have insect-repelling properties. Collecting the leaf matter during thatch harvesting could potentially be used for further processing for such oil. This could develop into a considerable side-industry to the thatch industry although the feasibility of this still need to be determined, including the quality and quantity of such oils.
Many communities in the harvesting area also harvest wood in various forms – e.g. droppers, poles, fire wood are the most common timber products offered for sale in the area. The poles are mainly harvested from *Baikiaea plurijuga* (Rhodesian teak) – the preferred timber species in the area – although the poles on offer are generally short (2-3 m long) and not very straight. Droppers seem to be sourced from *Terminalia sericea* (as indicated by the intense yellow colour of the wood), and range between 1.2 and 1.5 m in length which could be suitable for fencing purposes, but are also both too short, and not straight enough, for construction purposes.

Threats

The development of the wood industry in conjunction with the thatching grass industry is viewed as highly problematic. Both *Baikiaea plurijuga* and *Pterocarpus angolensis* (teak / kiaat) are classified as near-endangered due to continuous overexploitation in Namibia (Loots 2005). Deforestation on the predominantly sandy soils could result in severe nutrient loss (specifically denitrification through the excessive heating of soil surface) (Schlesinger & Peterjohn 1991; Schlesinger & Pilmanis 1998). This in turn could lead to desertification, potentially influencing the production of grasses (not increased as by popular belief) (Schlesinger *et al.* 1990). Such processes would accelerate the ongoing desertification processes due to global climatic change, which in turn could lead to the remobilisation of the sand surface (wind erosion and wind deposition) (Thomas *et al.* 2005).

Fire is a threat to the grass harvesting industry. Several harvesters indicated that neighbouring villages threaten their grass harvesting operations when setting early fires. The fire season starts during late May/early June each year, but the most fires (and most intense fires) only occur during August and September each year (Le Roux 2011).

Recommendations

In conclusion, a number a recommendations can be made to assure the sustainable development of this industry for the benefit of the rural population. These recommendations are grouped as general recommendations, based on observations made during this study, as well as known grassland and ecosystem management principles. The second group of recommendations are recommendations for further research topics, where information needs have been identified.

General recommendations

(i) **Register trade names, and set industry standards for these:** Three grasses have been identified as the most important grasses for thatch: *Cymbopogon caesius* (*kasisi*)*, Hyperthelia dissoluta* (*mahengehenge*) and *Eragrostis pallens* (*nangondwe*). These three vernacular names lend them ideally as trade names and should be registered as such – i.e. as part of access and benefit sharing efforts (Cole 2014). At the same time, basic industry standards can be set for these – i.e. purity of the collection; specific minimum lengths of culms; harvesting standards; etc. A second obvious step would be to determine quality standards – this would be a research task to determine the quality (e.g. physical strength, durability, susceptibility to decomposition, etc.). With time, other grass species (e.g. *Hyparrhenia rufa*, *Tristachya* nodiglumis) could also be branded while mixed species bundles should be avoided as far as possible.

(ii) **Harvesting of wetland grasses:** Harvesting of *Phragmites australis*, *Phragmites mauritanica*, *Chrysopogon nigritanus* and *Bothriochloa bladhii* should be limited and definitely not commercialised. This is recommended in order to protect the wetland habitats, and ultimately the fish resource in the river systems, which form an important protein source for the local population.

(iii) **The trade in wood products:** This should not be encouraged. The Directorate of Forestry has a control function in this regard, but is battling to effectively implement this function due to the vastness of the area. Further commercialisation of this trade will mean that it will become difficult to control and will result in extensive desertification of the Kalahari sands. Due to their general lack in nutrients, these sands are already highly susceptible to desertification (Schlesinger *et al.* 1990; Thomas *et al.* 2005).

(iv) **Sustainable harvesting techniques need to be implemented:** These include: (a) cutting culms with a sickle (or other mechanical means), but not pulling tufts from the soil; (b) cutting between 5 and 7 cm above the ground, not at ground level; (c) harvesting later in the season – i.e. earliest from mid-May onwards and (d) removing as many as possible seed packets at the place of cutting. With time, a community-driven monitoring system (similar as has been implemented with the devil's claw harvesting – see e.g. Strohbach 2003) should be implemented to monitor the resource availability, and to allocate harvesting areas to particular families.

(v) **Community awareness and training of harvesters:** This is necessary to successfully implement the above recommendation, especially regarding industry standards and sustainable harvesting. This will include community capacity building in order to establish trader's associations.

Recommendations for further research

(i) **The resource availability needs to be determined:** This includes both determining the preferred habitat of particular species, especially in the Zambezi Region, as well as quantifying the resource in terms of density and extent. A second step will be to develop a simple monitoring procedure which can be applied by the community to monitor and manage their resource.

(ii) **The sustainability of harvesting, including seedling establishment:** This needs to be determined and is closely linked to the previous recommendation – i.e. how healthy is the grass population; how is it affected by repeated (annual)

harvesting; how well is recruitment of seedlings taking place; and how viable are seeds, especially if harvested too early?

(iii) **Quality characteristics of different grass species needs to be determined:** This includes the average and minimum culm length with and without the inflorescence (values presented in this report are based on available literature); the culm strength in terms of bending, snapping and splintering under normal thatching procedures; as well as the susceptibility of these culms to rot and decomposition effects by sun and rain. Part of these characteristics will be regular material quality testing procedures as applied in the building industry (or at least applied to grass culms), part will be anatomical studies in order to determine the degree of lignification, and a large part will be decomposition studies both in the laboratory as well as on simulation thatch frames. It is also advisable to repeat these tests with both unripe (early harvest) and ripened (late harvest) culms.

(iv) **The potential to mix sources, or to treat culms with specific chemicals, in order to prevent rotting and/or reduce fire risk:** Evidence from the Omega thatch roof indicates that a mixture of two grass species (including *Cymbopogon caesius* culms) considerably extended the life time of the grass roof (Figure 18). It needs to be empirically tested whether this observation is valid, and if, what the ideal mixture ratios would be to ensure maximum durability at minimal costs (considering that *Cymbopogon caesius* is presently only harvested in the southern Zambezi Region, and has thus the greatest transport cost). The use of chemicals as fire retardants on thatch roofing is still controversial, yet the technology is available. Similar chemicals will be available to prevent rot, and the grasses are in any case chemically treated to prevent the spreading of foot-and-mouth disease (Namibia Development Corporation 2013; Walters 2014). Empirical studies are needed to determine the effect of these different treatments on the durability of the grasses.

(v) **The feasibility to establish secondary industries with essential oils from *Cymbopogon caesius*:** Essential oils derived from *Commiphora* spp. and *Colophospermum mopane* are well developed elsewhere in Namibia (Cole 2014). The fact that *Cymbopogon caesius* contains similar oils related to citronella oil is however little known in Namibia. This oil has known insect repellent properties and could lead to an important secondary industry to the thatch grass industry especially when considering that the leaves of this grass are currently treated as a waste product (and likely to be burned after cleaning of the culms).

(vi) **The possibility to plant specific grass species, as an alternative cash crop, needs to be determined:** At present, the grass harvesting relies on cheap labour, often school children during their April/May school holidays (the reason why harvesting is starting in April already). Furthermore, these rural areas have a large impoverished jobless population; marginal fields, and no other source of income but collecting and selling grass. Due to the sparse growth of these grasses, the harvesting of grass is very slow and labour intensive. The current availability of cheap labour is bound to change over time, eventually resulting in less thatch grass available to the industry. It thus is advisable to start experimenting early with the planting of especially the high-value grasses to ensure a continued, sustainable production. The availability of land for this purpose should not be a problem, as numerous fields in marginal soils (e.g. along the river terrace of the Okavango River) are lying fallow. Planting of grass will stabilise these fallow lands again. However, the clearing of new fields for the purpose of planting thatch grass should be avoided.

Figure 18. A community hall at Omega (Bwabwata National Park) thatched with a mixture of *kasisi* and *mahengehenge* (*Cymbopogon caesius* and *Hyperthelia dissoluta*) in the 1980's. Except for loss of material due to improper maintenance, the condition of the thatch is suprisingly good.

References

BETHUNE, S. 1991. Kavango River Wetlands. *Madoqua* 17: 77–112.

BISSINGER, B.W. & ROE, R.M. 2010. Tick repellents: Past, present, and future. *Pestic. Biochem. Physiol.* 96: 63–79.

BURKE, A. 2002. Present Vegetation of the Kavango. *J. Namib. Sci. Soc.* 50: 133–145.

BURKE, A. & STROHBACH, B.J. 2000. Review: Vegetation Studies in Namibia. *Dinteria* 26: 1–24.

CLAYTON, W.D., VORONTSOVA, M.S., HARMAN, K.T. & WILLIAMSON, H. 2014. RBG Kew: GrassBase - The Online World Grass Flora. URL http://www.kew.org/data/grassbase/index.html

COLE, D. 2014. The commercialisation of indigenous natural plant products in Namibia. Venture Publications, Windhoek, Namibia.

CRAVEN, P. & KOLBERG, H. 2012. A provisional list of local names for Namibian plants. (Unpublished report). Windhoek.

CSIR, 1998. A Guide to Good Thatching Practice. Boutek Report, No. BOU/E9806. Division of Building and Construction Technology of the CSIR, Pretoria.

DABO, S.M., TALIAFERRO, C.M. & COLEMAN, S.W. 1997. Anatomical and histological factors affecting the ruminal degradation of stem tissues in Bothriochloa species. *Anim. Feed Sci. Technol.* 67: 299–309.

DANCKWERTS, J.E. & STUART-HILL, G.C. 1988. The effect of severe drought and management after drought on the mortality and recovery of semi-arid grassveld. *J. Grassl. Soc. South. Afr.* 5: 218–222.

DANCKWERTS, J.E., TEAGUE, W.R. & HOBSON, F.O. 1989. Plant growth and response to defoliation. Grazing Management: A strategy for the future. Department Agriculture and Water Supply, Pretoria.

DE SOUSA CORREIA, R.J. & BREDENKAMP, G.J. 1986. A reconnaissance survey of the vegetation of the Kavango, South West Africa. J. *SWA Wiss. Ges.* XL/XLI: 29–45.

GIBBS RUSSELL, G.E., WATSON, L., KOEKEMOER, M., SMOOK, L., BARKER, N.P., ANDERSON, H.M. & DALLWITZ, M.J. 1990. Grasses of southern Africa. *Memoirs of the Botanical Survey of South Africa* No. 58. National Botanic Gardens / Botanical Research Institute, Pretoria.
GRÖNGRÖFT, A. 2013. Mashare - Landscape. *Biodivers. Ecol.* 5: 101.
GUNSON, K. 1999. The sustainability of use and economic valuation of wetland plant resources in the Eastern Caprivi floodplains, Namibia. University of Cape Town.
HAY, C.J., VAN ZYL, B.J. & STEYN, G.J. 1996. A quantitative assessment of the biotic integrity of the Okavango River, Namibia, based on fish. *Water SA* 22: 263–283.
HORN, J.A.M. 2006. Volhoubaarheid van die kommersiële benutting van inheemse dekriet (*Thamnochortus insignis*) in die Suid-Kaap. Masters Thesis, Department Agricultural Management, Nelson Mandela Metropolitan University, Port Elizabeth.
KALITA, B., BORA, S. & SHARMA, A.K. 2013. Plant essential oils as mosquito repellent-a review. *Int. J. Res. Dev. Pharm. Life Sci.* 3: 741–747.
KLAASSEN, E.S. & CRAVEN, P. 2003. Checklist of grasses in Namibia. Southern African Botanical Diversity Network report No. 20. National Botanical Research Institute and SABONET, Windhoek : Pretoria.
KLAASSEN, E.S. & KWEMBEYA, E.G. (Eds.). 2013. A Checklist of Namibian Indigenous and Naturalised Plants. *Occasional Contributions* No. *5.* National Botanical Research Institute, Windhoek.
LAUNERT, E. 1971. Gramineae. Flora Zambesiaca 10.
LE ROUX, J. 2011. The Effect of Land Use Practices on the Spatial and Temporal Characteristics of Savanna Fires in Namibia (Ph.D. thesis) Universitätsbibliothek der Universität Erlangen-Nürnberg, Erlangen.
LONG, K. 1978. Introductory Guide to Thatching. National Building Research Institute of the CSIR, Pretoria.
LOOTS, S. 2005. Red Data Book of Namibian Plants. Southern African Botanical Diversity Network Report, No. 38. SABONET, Pretoria and Windhoek.
LUSHETILE, K. 2009. Vegetation description of Sachinga Livestock Development Centre and Surroundings, Caprivi, Namibia (B.Sc.Honours Mini Dissertation), University of Pretoria, Pretoria.
MAIA, M.F. & MOORE, S.J. 2011. Plant-based insect repellents: a review of their efficacy, development and testing. *Malar. J.* 10: 11.
MENDELSOHN, J., JARVIS, A., ROBERTS, C. & ROBERTSON, T. 2002. Atlas of Namibia. David Phillips Publishers, Cape Town.
MENDELSOHN, J. & OBEID, S. EL. 2003. Sand and Water. A profile of the Kavango Region. Struik Publishers & RAISON, Cape Town & Windhoek.
MENDELSOHN, J. & OBEID, S. EL. 2004. Okavango River. The flow of a lifeline. Struik Publishers & RAISON, Cape Town & Windhoek.
MENDELSOHN, J. & ROBERTS, C. 1997. An environmental profile and Atlas of Caprivi. Directorate of Environmental Affairs, Namibia.
MERXMÜLLER, H. (Ed.). 1966. Prodromus zur Flora von SWA. J. Cramer Verlag, Lehre.
MÜLLER, M.A.N. 1984. Grasses of South West Africa/Namibia. Directorate of Agriculture and Forestry, Windhoek.
MÜLLER, M.A.N. 2007. Grasses of Namibia, 2nd ed. Ministry of Agriculture, Water and Forestry, Windhoek.
NAMIBIA DEVELOPMENT CORPORATION 2013. Kavango Thatch Grass & Home Industry Hub Project Document. Ministry of Trade and Industry, Windhoek.
NERIO, L.S., OLIVERO-VERBEL, J. & STASHENKO, E. 2010. Repellent activity of essential oils: A review. *Bioresour. Technol.* 101: 372–378.
O'CONNOR, T.G. 1991. Local Extinction in Perennial Grasslands: A Life-History Approach. *Am. Nat.* 137: 753–773.
O'CONNOR, T.G. 1993. The influence of rainfall and grazing on the demography of some African savanna grasses: a matrix modelling approach. *J. Appl. Ecol.* 30: 119–132.

REHMAN, J.U., ALI, A. & KHAN, I.A. 2014. Plant based products: Use and development as repellents against mosquitoes: A review. *Fitoterapia* 95: 65–74.
SCHLESINGER, W.H. & PETERJOHN, W.T. 1991. Processes controlling ammonia volatilization from Chihuahuan Desert soils. *Soil Biol. Biochem.* 23: 637–642.
SCHLESINGER, W.H. & PILMANIS, A.M. 1998. Plant-soil interactions in deserts. *Biogeochemistry* 42: 169–187.
SCHLESINGER, W.H., REYNOLDS, J.F., CUNNINGHAM, G.L., HUENNEKE, L.F., JARELL, W.M., VIRGINIA, R.A. & WHITFORD, W.G. 1990. Biological feedbacks in Global Desertification. *Science* 247: 1043–1048.
SCHNEIDER, M.B. 1986. Notes on Terrace Soils of the Kavango River, northern SWA/Namibia. *J. SWA Wiss. Ges.* XL/XLI: 199–213.
STROHBACH, B. 2011. Environmental Impact Assessment on the proposed 330 kV Power Line from Katima Mulilo to Ngoma: Impact on the Vegetation. Unpublished report. Enviro Dynamics cc and NamPower, Windhoek.
STROHBACH, B. 2012. Environmental Impact Assessment on the proposed irrigation scheme and water supply canal: Impact on the Vegetation. Unpublished report. Colin Christian Associates and Namibia Agriculture & Renewables, Windhoek.
STROHBACH, B.J. 2001. Vegetation Survey of Namibia. *J. Namib. Sci. Soc.* 49: 93–124.
STROHBACH, B.J. 2013a. Vegetation of the Okavango River valley in Kavango West, Namibia. *Biodivers. Ecol.* 5: 321–339.
STROHBACH, B.J. 2013b. Vegetation of the Eastern Communal Conservancies in Namibia: III. Annotated checklist. *Dinteria* 33: 3–42.
STROHBACH, B.J. 2014. Vegetation of the Eastern Communal Conservancies in Namibia: I. Phytosociological descriptions. *Koedoe - Afr. Prot. Area Conserv. Sci.* 56.
STROHBACH, B.J. & KANGOMBE, F. 2012. National Phytosociological Database of Namibia. *Biodivers. Ecol.* 4: 298.
STROHBACH, B.J. & PETERSEN, A. 2007. Vegetation of the central Kavango woodlands in Namibia: An example from the Mile 46 Livestock Development Centre. *South Afr. J. Bot.* 37: 391–401.
STROHBACH, B.J. & STROHBACH, M.M. 2004. An annotated plant specieslist for the Mile 46 LDC and surrounding area in central Kavango, Namibia, with some notes on species diversity. *Dinteria* 29: 55–78.
STROHBACH, M., 2003. National Devil's Claw Situation Analysis - Resource Survey. Internal report. CRIAA SA-DC, Windhoek.
TAINTON, N.M. (Ed.). 1999. Veld Management in South Africa. University of Natal Press, Pietermaritzburg.
THOMAS, D.S.G., KNIGHT, M. & WIGGS, G.F.S. 2005. Remobilization of southern African desert dune systems by twenty-first century global warming. *Nature* 435: 1218–1221.
VAN OUDTSHOORN, F. 1999. Guide to Grasses of southern Africa, 2nd ed. Briza, Pretoria.
VAN VOORTHUIZEN, E.G. & ODELL, M. 1976. Thatching in Botswana: The Social-Ecology of Traditional Construction. *Botsw. Notes Rec.* 165–174.
WALTERS, H.J.A. 2014. Kavango Thatch Grass Logistics Centre Reports. Oshikango Thatching and Building cc for NDC, Windhoek / Stellenbosch.