Status quo of sustainable forest management in Namibia

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STATUS QUO OF SUSTAINABLE FOREST MANAGEMENT IN NAMIBIA

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'Promoting Sustainable Forest Management in the Kavango-Zambezi-Region in Namibia'

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FOREWORD

Namibia has a broad variety of vegetation types including deserts, savannahs and dry woodlands; with the north and north-eastern regions characterised by large plains of hardwood forests.

Forest resources are of essential importance to Namibia; as woodlands stabilises the fragile environment and prevent soil erosion, especially in the flood-prone areas along the river streams in the northern part of the country. Moreover, forests are homes to Namibia's rich biological diversity. They also play a vital socio-economic role especially in the rural areas of Namibia, as a large population depends directly or indirectly on the availability of forest resources for their livelihoods. The forests are a major source of building materials for homesteads, fuel wood for cooking, lighting and heating, medicines and browsing for livestock amongst others.

The wide variety of ecosystem services that forest provides are not only critical for the local environment, but are also important global goods. Forest plays a critical role in the context of climate change since they are one of the biggest reservoirs of carbon, helping to maintain the carbon cycle and other natural processes. They are key to reducing climate change.

In 2000, 8.1 million hectares of Namibia were covered by forests (down from 8.7 million hectares in 1990). By 2020, Namibia's total forest area has significantly decreased to only 6.6 million hectares. During the 1990's, the estimated forest area was at 10.6% of the total land area; however, recent estimates indicates a major decline in forest cover, down to roughly 8.1% in 2020. These figures verifies that Namibia's forests are under threat. Major risks associated with accelerated loss of forestry include, inter alia, the expansion of land for agricultural purposes, the cutting down of trees for fuel woods and for domestic use, clearing for infrastructural development, uncontrolled wildfires, selective logging through timber concessions, legal and illegal timber harvesting for exporting as logs to international markets and unlicensed curio carvings. Deforestation does not only lead to the loss of resources important for human survival; it also results in desertification and severe permanent degradation of the land and other important natural process.

The concept of sustainable forest management stems from the need to protect Namibia's natural resources, but while also ensuring the sustainable use for the benefit of the people. Protection of Namibia's forests is one element

of the broader sustainable development agenda, and it means collaborative initiatives must be at the heart of our development. Therefore, civil society organisations, government, political decision-makers, traditional authorities, community forest members, media and farmers are unified, to discuss, disseminate and create awareness for sustainable forest resources management within their respective communities and the broader public.

I wish to thank the author, coordinators and all who have contributed to this publication for their valuable insights and hard work to serve the Namibian nation. Let us all make sustainable forest resources management a reality for today and the future generations.

H.E. Sinikka Antila

Ambassador of the Delegation of the European Union to the Republic of Namibia

Windhoek, April 2023

LIST OF ABBREVIATIONS

α-ESA	α-Eleostearic Acid
AFIS	Advanced Fire Information System
AVHRR	Advanced Very-High-Resolution Radiometer
BIOTA	Biodiversity Monitoring Transect Analysis in Africa
BIS	Bush Information System
BMZ	German Federal Ministry for Economic Cooperation and Development (Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung)
CBNRM	Community Based Natural Resource Management
CF	Community Forest
CFN	Community Forestry in Namibia Project
CLB	Communal Land Board
CNES	French Space Agency (Centre national d'études spatiales)
CO_2	Carbon dioxide
CONINFO	Conservancy information (database)
CRIAA SA-DC	Centre for Research, Information and Action in Africa – Southern Africa Development and Consulting
DBH	Diameter at Breast Height
DoF	Directorate of Forestry
DRFN	Desert Research Foundation of Namibia
ESA	European Space Agency
FAO	Food and Agriculture Organisation
FINNIDA	Finnish International Development Agency
FMC	Forest Management Committee
FRA	Forest Resources Assessment
FSC	Forest Stewardship Council
Gt	Giga tonnes
GTZ	German Agency for Technical Cooperation (Deutsche Gesellschaft für Technische Zusammenarbeit)
ha	Hectare
HSF	Hanns Seidel Foundation
IFTT	Indigenous Fruit Task Team
INPs	Indigenous natural products
IPTT	Indigenous Plant Task Team
IRDNC	Integrated Rural Development and Nature Conservation
ITTO	International Tropical Timber Organization
KfW	German Development Bank (Kreditanstalt für Wiederaufbau)
kg	Kilogram
LDC	Livestock Development Centre

List of Abbreviations

LiDAR	Light Detection and Ranging
m	Metre
m^3	Cubic metre
MAWF	Ministry of Agriculture, Water and Forestry
MEFT	Ministry of Environment, Forestry and Tourism
MLR	Ministry of Land Reform
MODIS	Moderate Resolution Imaging Spectroradiometer
N$	Namibia Dollar
NACSO	Namibian Association of CBNRM Support Organisations
NASA	National Aeronautics and Space Administration (United States)
NBRI	National Botanical Research Institute
NCE	Namibian Chamber of Environment
NDVI	Normalised difference vegetation index
NFI	National Forestry Inventory
NFFP	Namibia-Finland Forestry Programme
NFRC	National Forestry Research Centre
NGO	Non-government organisation
NNF	Namibia Nature Foundation
NRSC	National Remote Sensing Centre
NSI	Namibian Standards Institution
NTFP	Non-Timber Forest Products
NUST	Namibia University of Science and Technology
NWFR	North-West Forestry Region
PSP	Permanent Sample Plot
Radar	Radio detection and ranging
REDD	Reduction in Emissions from Deforestation and Forest Degradation
SAR	Synthetic Aperture Radar
SFM	Sustainable Forest Management
SPOT	Satellite for earth observation (Satellite Pour l'Observation de la Terre)
TAO	Total Allowable Offtake
UAV	Unmanned Aerial Vehicle
UNAM	University of Namibia
UNFCCC	United Nations Framework Convention on Climate Change
WWF	World Wide Fund for Nature
ZAR	South African Rand

1 NAMIBIA'S FORESTS

1.1 WHERE ARE NAMIBIA'S FORESTS?

Namibia is an arid country, covered mainly by grass and shrublands in the western and southern parts, which are desert and semi-desert. There are however forests in the north-eastern part of the country (Figure 1). The extent of these dry forests is only vaguely known. The main reason is that different definitions of forest and woodlands have been used in Namibia. Local vegetation maps refer to Namibia's forests as tree savanna or woodlands (Edwards 1983, Giess 1998, Burke *et al.* 2002). The classification used by the Directorate of Forestry in Namibia defines forest as areas with forest cover higher than 75% (Edwards 1983, FAO 2020).

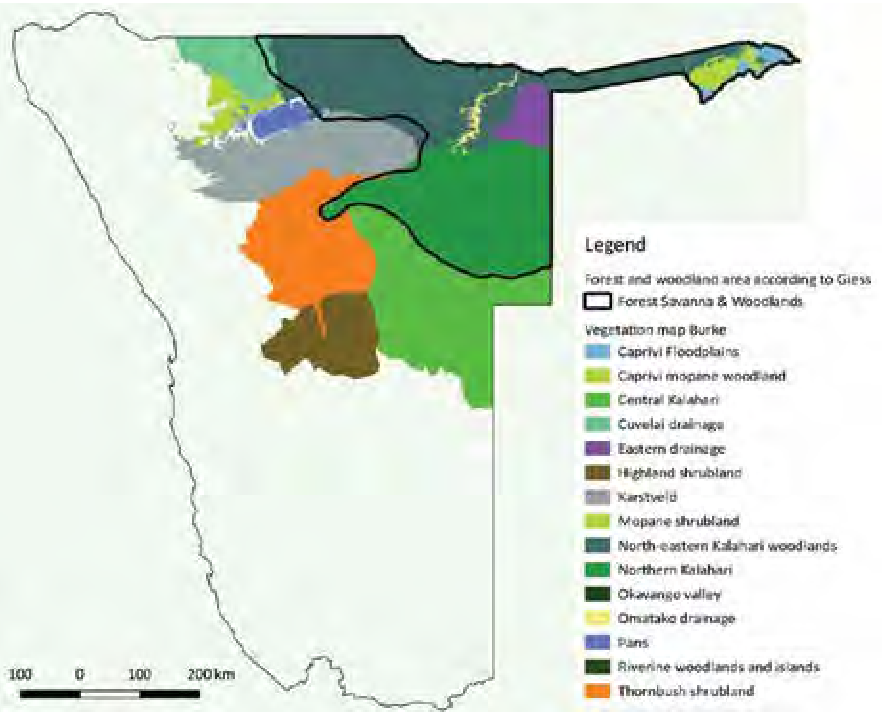


Figure 1 - Forest and woodland in Namibia according to the vegetation maps of Giess (1998) and Burke *et al.* (2002)

The Namibian 'forest' definition is very different from the internationally most used definition, that of the Food and Agricultural Organization (FAO) (Box 1), which most countries use to report their forest resources. When Namibia reports to FAO, it has to convert data based on the Edwards classification to that of the FAO. According to the FAO definition (Box 1), Namibia's forests extend much further westward and southward than on the preliminary Namibian vegetation map of Giess (1998). The riverine vegetation found along the perennial rivers and the larger ephemeral rivers of Namibia are also forested according to this definition.

The terms 'woodland' and 'savanna' used in the Namibian classifications are often used on the African continent, for example for mopane or miombo woodland (Timberlake and Chidumayo 2011, Chirwa *et al.* 2014). However, there is no internationally accepted definition for woodland (Putz and Redford 2010), making the term difficult to use for management purposes. Woodland in the regional context has a wider meaning than the FAO term 'other wooded land'. The canopy cover can be higher than 10%, up to 60% (Hirota *et al.* 2011, Kutsch *et al.* 2011). The understorey, the layer of vegetation beneath the main canopy of a forest, is characterised by C4 grasses (warm season grasses) (Putz and Redford 2010, Ratnam *et al.* 2011, Oliveras and Malhi 2016). The C4 photosynthetic pathway makes these grasses tolerant to higher temperatures and drought but less tolerant to shade compared to C3 grasses (cool season grasses) (Ratnam *et al.* 2011, Oliveras and Malhi 2016). This woodland definition overlaps with that of savanna in the more heavily 'treed' versions of the spectrum (Ratnam *et al.* 2011). The characterising presence of C4 grasses in woodlands, and savannas in general, is, however, difficult to monitor as they are not always present during long droughts, after fires, or because of overgrazing by livestock or game.

The FAO definitions appear to be well aligned with the quantitative definition given for the tree and shrub savanna biome of Namibia given by Thuiller *et al.* (2006) and based on a vegetation model: the biomass of deciduous broad-leaved trees is higher than 0.94 tonnes per hectares (ha), or the biomass of the C4 pathway plant functional types is higher than 49.5 tonnes per ha.

BOX 1: FOREST MONITORING BY FAO

The Food and Agricultural Organization (FAO) has been monitoring the world's forests at 5-to-10-year intervals since 1946. The Global Forest Resources Assessments (FRA) are now produced every five years in an attempt to provide a consistent approach to describing the world's forests and how they are changing. The FRA is a country-driven process, and the assessments are based on reports prepared by officially nominated National Correspondents. If a report is not available, the FRA Secretariat prepares a desk study using earlier reports, existing information and/or remote sensing based analysis (FAO 2020, p. 2).

FAO introduced definitions that are applied at a global scale (FAO 2004):

- Forest is "land spanning more than 0.5 ha with trees higher than 5 m and a canopy cover of more than 10%, or trees able to reach these thresholds in situ".
- Other wooded land refers to land that is not classified as "Forest" and spanning more than 0.5 ha with trees higher than 5 m and a canopy cover of 5 to 10% or trees able to reach these thresholds; or with a combined cover of shrubs, bushes and trees above 10%.

Canopy cover or crown cover is defined as the proportion of the forest ground covered by the vertical projection of the tree crowns. It cannot exceed 100% (Jennings et al. 1999).

1.2 HOW MUCH FOREST DOES NAMIBIA HAVE?

The accurate forest area of Namibia is not known since there is no regular national land or forest cover mapping (FAO 2020). The most comprehensive forest map of Namibia was established from 1992 to 1997 and covers Namibia north of latitude 20° S (Erkkilä and Löfman 1999, Graz, pers. comm. 2022). Multispectral SPOT (Satellite for earth observation) data obtained in 1993 were used to map the most eastern areas and Landsat data obtained in 1993 and 1996 for the remaining parts. The map covered Kavango West, Kavango East, Zambezi, Ohangwena, northern Kunene, Omusati, Oshana, Oshikoto and northern Otjozondjupa. Data for Omaheke and Khomas is lacking. This map is the basis of the five-yearly reporting of Namibia to the FAO (FAO 2005) and applied the term 'forest' similarly to the FAO (Box 1). Figure 2 shows that most forests were concentrated in the north-eastern parts of the country in 1992. Western Ohangwena and northern Omusati used to

have a much higher forest cover, but there was a lot of deforestation before Independence (Erkkilä and Löfman 1999).

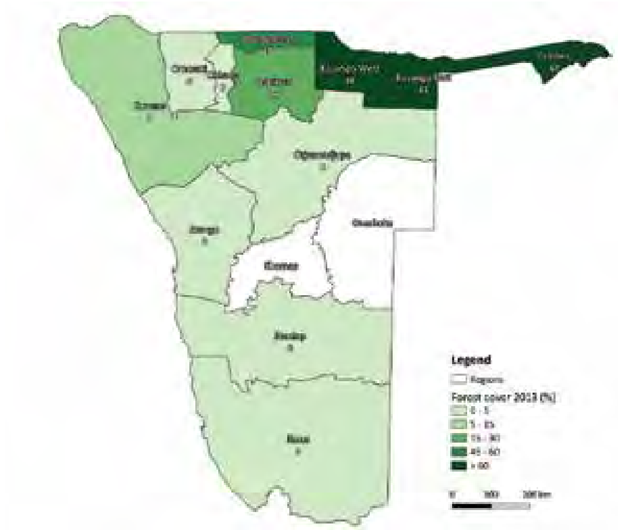


Figure 2 - Forest in Namibia according to the forest cover mapping of northern Namibia (Holm and Graz, 1992 in FAO 2005). Forest cover includes only the dense, medium, open forest classes. The forest cover map only covered Namibia north of latitude 20° S. Areas south of this were assumed to have no forest, although there is forest in Khomas, southern Otjozondjupa and Omaheke.

All areas reported to the FAO are based on desktop studies with rough extrapolations of the 1992 data. A deforestation rate of on average 1% is used and some savannah classes were converted to forest classes (FAO 2005). The forested area reported for 2020 was 6,638,900 ha or 8.1% of the total land area, considerably less than the 9.8% reported in 2000 (FAO 2020). A global forest assessment based on high-resolution satellite data (Landsat 7) showed that Namibia had only 13,000 ha of forest with canopy cover of 25% or more (Hansen *et al.* 2013). Hence, nearly all of Namibia's forest has a canopy cover ranging between 10% and 25%.

The recently established Bush Information System (BIS) (MAWF and NSA 2020) provides a unique opportunity to create an updated forest map for Namibia. Thompson (2021) determined the extent of Namibia's forest and woodland according to FAO definitions based on two layers of the BIS (Figure 3). The *Canopy Cover* layer was used to identify a canopy cover of more than

5% per ha and the BIS *Tree Height* layer was used to identify an average tree height of more than 5 m per ha. The resulting forest and woodland area is the area where both these layers intersect. The same process can be followed to obtain the Namibian forest area by extracting areas with a canopy cover of more than 10% and an average tree height of more than 5 m per ha. Taking into account Figure 3 and the author's field knowledge, it is more than likely that this forest area will be much larger than the forest area determined by Giess (Figure 1).

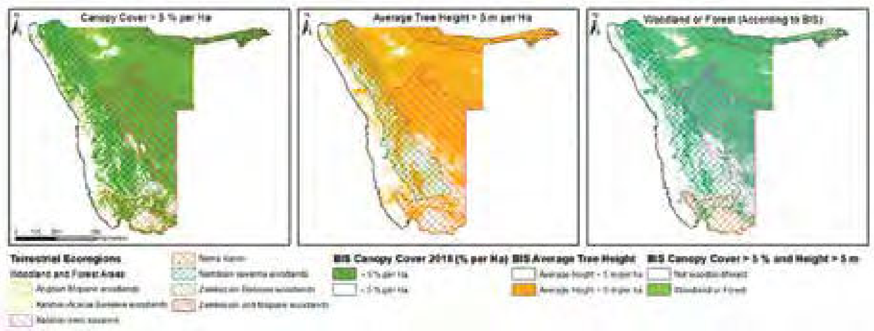


Figure 3 – Forest and woodland of Namibia based on data of the BIS compared with the WWF Ecoregions for woodland and forest (Thompson 2021): (a) 2018 BIS Canopy Cover greater than 5% per ha, (b) 2018 BIS Average Tree Height taller than 5 m per ha, (c) Overlap of (a) and (b).

1.3 FOREST TYPES IN NAMIBIA

Namibia's forests are at the southern edge of the forest biome in southern Africa (FAO 2012). They are tropical dry forests consisting mainly of mopane woodlands and open *Burkea, Pterocarpus,* and *Terminalia* forests (Figure 4). Towards the north-east average rainfall increases, and the forest gradually changes to Zambezian Baikiaea forests, which are considered part of the miombo ecoregion. The miombo ecoregion is an extension of White's Zambezian regional centre of endemism and is characterised by semi-deciduous woodland composed of trees of the legume subfamily Detarioideae (previously Caesalpinioideae) (Timberlake and Chidumayo 2011, LPWG 2017).

The western edge of Namibia's forest and other wooded land is semi-arid and formed by mopane woodland, which is also found in the south of the Zambezi region. There is no gradual transformation towards miombo

woodlands; boundaries are rather distinct, although there are patches of Baikiaea woodlands up to Omusati (Kanime and Laamanen 2003). Further south, where annual rainfall decreases, the woodlands become progressively more intermingled with species of the legume subfamily Caesalpinioideae (formerly Mimosoideae), and gradually change into semi-arid scrublands (Burke *et al.* 2002). In general, the forest can be characterised by six main types (Figure 4):

- Zambezian Baikiaea woodlands;
- Mopane woodlands: Angolan and Zambezian;
- Kalahari Acacia Baikiaea woodlands;
- Karstveld (Figure 1);
- Acacia woodlands: northern and eastern parts of Kalahari xeric savanna;
- Riverine woodlands.

All forest and woodland areas are characterised by three seasons: cold dry from May to August, hot dry from September to December, and (relatively) wet from January to April. There is great variation in temperature between winter and summer, and between day and night during winter. Many areas get frost during winter, while day temperatures may rise above 35°C during summer, causing severe stress for plants (Verlinden and Dayot 2005).

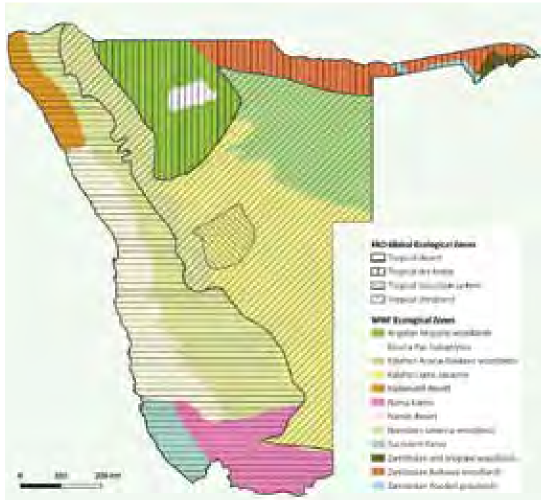


Figure 4 - Global ecological zones for Namibia according to FAO for forest reporting (FAO 2012) and WWF (Olson et al. 2001)

1.3.1 ZAMBEZIAN BAIKIAEA WOODLANDS

The Zambezian Baikiaea woodlands are found on the deep, nutrient-poor Kalahari sand soils of the Omusati, Ohangwena, Kavango East, Kavango West, and Zambezi regions. The terrain is fairly flat and situated at elevations of 900 to 1100 m above sea level. Mean annual rainfall ranges from 350 mm in the west to approximately 650 mm in the east. The woodlands extend more westwards than indicated in Figure 4, with Uukolonkadhi Community Forest (CF) the most westward representation of this woodland type, where it is called Omuthitu/Omufitu (Kanime and Laamanen 2003, Verlinden and Dayot 2005). The Hamoye and Caprivi State Forests and many CFs – such as Okongo, Omufitu Wekuta, and Likwatera - are covered by this type of woodland.

The Zambezian Baikiaea woodlands are open forests with canopy coverage of 10% to 30% and an average canopy height of about 10 to 12 m in Namibia. The woodlands are dominated by tree species of the Fabaceae family and are named after one dominant species; *Baikiaea plurijuga*, the Zambezi teak, an important timber tree (see 2.2.1). Forest inventories show that the species is less dominant in the Kavango regions than in the eastern parts of the Baikiaea woodlands, which extend into northern Botswana and southern Zambia (Childes and Walker 1987, Mitlöhner 1993, De Cauwer *et al.* 2016, De Cauwer, Knox, *et al.* 2018). Several authors, therefore, refer to the Kavango woodlands as Burkea (Frost 1996, Burke *et al.* 2002), Burkeo-Pterocarpetea (Strohbach and Petersen 2007), Baikiaea-Burkea (Stellmes *et al.* 2013a), or Baikiaea-Pterocarpus (De Cauwer *et al.* 2016) woodlands, because red syringa (*Burkea africana)* is the most dominant canopy tree, with the Zambezi teak and kiaat (*Pterocarpus angolensis)* as co-dominant species (Table 1).

Table 1 - Canopy tree composition based on sample plots (n = 1333) in the Kavango regions and represented as a proportion (%) of the total basal area (De Cauwer *et al.* 2016)

Species	**Contribution (%)**
Burkea africana	22.9
Baikiaea plurijuga	16.4
Pterocarpus angolensis	16.1
Schinziophyton rautanenii	11.7
Guibourtia coleosperma	11.4
Dialium englerianum	5.8
Combretum collinum	2.2
Erythrophleum africanum	0.6
Acacia erioloba	0.4

Westwards, in Omusati, the Zambezi teak dominates again, together with *Commiphora mollis*. There is hardly any red syringa or kiaat and no mangetti (*Schinziophyton rautanenii)* (Kanime and Laamanen 2003). However, the tree layer has disappeared in most of the Zambezian Baikiaea woodlands of the Omusati region due to overharvesting, resulting in a shrub layer (Selanniemi *et al.* 2000).

Woody species in the understorey of the forest include mainly silver cluster-leaf (*Terminalia sericea), Combretum zeyheri*, *Commiphora angolensis*, and *Ochna pulchra* (Kanime and Laamanen 2003, De Cauwer *et al.* 2016). In the Kavango regions, understorey species also include *Combretum psidioides*, *Diplorhynchus condylocarpon, Strychnos cocculoides*, *Commiphora africana,* and *Strychnos pungens* (De Cauwer *et al.* 2016). In Omusati *Mundulea sericea* and *Ozoroa paniculosa* are common (Kanime and Laamanen 2003).

Common shrubs include sand camwood (*Baphia massaiensis*), white bauhinia (*Bauhinia petersiana)* and raisin bush *(Grewia)* species (Kanime and Laamanen 2003, De Cauwer *et al.* 2016). The ground layer consists mainly of grasses, although the dwarf jackal-berry (*Diospyros chamaethamnus*) is also common in Kavango. In Namibia plant species richness is highest in the Kavango region, probably because of a variety of habitats, including the wetlands near the Okavango River, and the incursion of tropical species from Angola down the river (Maggs *et al.* 1998).

Total stem densities in the Baikiaea woodlands are in the order of 100 to 444 stems per ha (Kamwi 2003, Kanime and Laamanen 2003, De Cauwer, Knox, *et al.* 2018). Wood volume varies between 14.3 m^3 per ha for Uukolonkadhi CF in Omusati (Kanime and Laamanen 2003), 23.1 m^3 to 38.4 m^3 per ha in Zambezi (Geldenhuys 1991, Kamwi 2003), to 43.2 m^3 per ha in Okongo CF, Ohangwena (Angombe *et al.* 2000). Basal area was 5.6 m^2 per ha in the Kavango regions (De Cauwer, Knox, *et al.* 2018). While the wood volume is much lower than in 'true' miombo woodland, stem diameters are larger on average, with a mean diameter at breast height (DBH) of about 29.9 cm (De Cauwer, Knox, *et al.* 2018).

1.3.2 MOPANE WOODLANDS

Mopane woodlands are strongly dominated by the species *Colophospermum mopane*, commonly known as mopane, which can occur either as a tree up to 20 to 25 m tall (Kamwi and Laamanen 2002, Geldenhuys and Golding 2008) or a shrub. Canopy cover ranges between 10% and 25% but can be as high as 60% according to Musvoto *et al*. (2007). The distribution range of mopane woodland covers areas with an annual rainfall of 400 to 700 mm (Chirwa *et al.* 2014) and little or no frost incidence in winter (Siebert *et al.* 2003). They are often found on fine-textured soils, such as the Angolan mopane woodlands on the alluvial clays in the Cuvelai system or the Zambezian mopane woodlands on fossil wetlands with shallow sands (Erkkilä and Siiskonen 1992, Mendelsohn and el Obeid 2005). CFs dominated by mopane woodlands include amongst others the Ehi-Rovipuko CF in the Kunene, the emerging Ongandjera CF in the Omusati Region, and Sikanjabuka CF in Zambezi (Chakanga *et al.* 1998, Kamwi and Laamanen 2002, Directorate of Forestry 2004).

The average canopy height is much lower than in the Zambezian Baikiaea woodlands, ranging between 5.5 m and 9 m (Chakanga *et al.* 1998, Kamwi and Laamanen 2002, Directorate of Forestry 2004, De Cauwer, Knox, *et al.* 2018). The average tree diameter is not more than 20 cm (De Cauwer, Knox, *et al.* 2018). Tree densities are similar to those in the Baikiaea woodlands, varying from 100 to as many as 440 stems per ha in the more protected and least populated areas (Kamwi and Laamanen 2002, Musvoto *et al.* 2007, De Cauwer, Knox, *et al.* 2018). The basal area can reach 5.2 m^2 per ha (De Cauwer, Knox, *et al.* 2018), while wood volume can be as low as 3.6 m^3 per ha in Ehi-Rovipuko CF (Directorate of Forestry 2004) and as high as 52 m^3 per ha in Sikanjabuka CF (Kamwi and Laamanen 2002).

Other tree species than mopane are in the minority. In the Angolan mopane woodlands, they consist mainly of *Commiphora*, *Acacia,* and *Combretum* species, as well as *Terminalia prunioides, Albizia anthelmintica*, *S. guerichii,* and *Elephentorrhiza elephantina* (Chakanga *et al.* 1998, Siebert *et al.* 2003, Directorate of Forestry 2004). In the Zambezian mopane woodlands, silver-cluster leaf, named muhonono in Zambezi, is the main tree next to mopane (Kamwi and Laamanen 2002). Shrub species can include *Bauhinia petersiana*, *Dichrostachys cinerea, Grewia* species, *Combretum* species, *Maerua juncea, Rhigozum brevispinosum,* and *Euclea divinorum* (Kamwi and Laamanen 2002, Siebert *et al.* 2003, Directorate of Forestry 2004). The grass in well-developed mopane stands is very sparse, possibly the result of the dense shallow lateral root system of mopane (Erkkilä and Siiskonen 1992).

1.3.3 KALAHARI ACACIA BAIKIAEA WOODLANDS

This forest type is a transition from the Zambezian Baikiaea woodlands to the Acacia shrublands further south. It is found in areas characterised by Kalahari sand soils and longitudinal, east-west orientated dunes. The dunes

are less than 10 m high due to erosion but the remnants of the dune fields are still visible in satellite images (Graz 1999, Strohbach and Petersen 2007).

Most of the tree layer of the Acacia Baikiaea woodlands is similar to that of the Zambezian Baikiaea woodlands, although canopy coverage and *B. plurijuga* and *G. coleosperma* trees are in a southward direction. The shallower and slightly heavier sand to loamy sand soils from dune depressions and drainage channels are dominated by *Acacia* species, especially *Acacia luederitzii* and *A. fleckii*. Shrub species include *Croton gratissimus, Dichrostachys cinerea,* and *Bauhinia petersiana* (Strohbach and Petersen 2007). This vegetation type contains the Kanovlei State Forest and several CFs such as M'kata and Nyae Nyae.

1.3.4 KARSTVELD

The Karstveld is an area south of Etosha National Park which is characterised by underlying limestone rock, dolomite hills, and underground caves (Figure 1). The mountainous savanna vegetation has a much higher species diversity than the surrounding areas (Maggs *et al.* 1998). Typical trees include tamboti (*Spirostachys africana),* marula *(Sclerocarya birrea),* strangler fig (*Ficus burkei*), common kirkia (*Kirkia acuminata), Commiphora mollis,* Propeller Tree *(Gyrocarpus americanus),* Leadwood (*Combretum imberbe), Securidaea longepedunculata, Olea europaea* subsp. *africana*, and *Moringa ovalifolia*. The flatter, sandier areas are mopane woodland intermingled with *Acacia* species, *Combretum apiculatum, Terminalia sericea,* and *Terminalia prunioides* (Giess 1998, Mannheimer and Curtis 2018). Some areas have a tree layer that is high and dense enough to form a forest or which formerly met this criterion. There are no CFs in this forest type.

Figure 5 Karstveld in Ongava Game Reserve (Photo: V. De Cauwer)

The Karstveld is the area closest to the copper mine of Tsumeb for which a lot of wood, especially of tamboti, has been harvested for energy and mine props since the early 20th century. The consumption of tamboti wood went up with the deepening of the mine, up to 13,000 m^3 per year by the 1950s (Erkkilä and Siiskonen 1992), a very large amount of wood compared with recent harvest rates. For example, the mean volume harvested for the period 2010 – 2016 was 2,138 m^3 per year (Nott *et al.* 2019). By the early 1990s most of the area was dense shrubland (Erkkilä and Siiskonen 1992), caused amongst others by overgrazing.

1.3.5 ACACIA WOODLANDS

Some of the northern and eastern parts of Kalahari xeric savanna have a tree layer that is high and dense enough to form a forest or which formerly met this criterion. Those areas are characterised by *Acacia recifiens, A. tortilis, A. erioloba, Ziziphus mucronata,* or *Combretum apiculatum*. Examples of this woodland type are some of the dense *Acacia erioloba* stands near Rehoboth. In the more sandy areas *Terminalia sericea* is common, sometimes with *Philenoptera nelsii* or *Burkea africana* (Giess 1998, Directorate of Forestry 2008), with a canopy layer 5 to 7 m high. This vegetation type is found, for example, near the road from Windhoek to Gobabis and Botswana. Otjombinde CF and the emerging Otjinene CF are situated in this forest type. Only one known forest inventory is available (Directorate of Forestry 2008). The Acacia woodlands are not indicated on most forest maps, although it should be possible to derive them from the BIS, as discussed in section 1.2.

1.3.6 RIVERINE WOODLANDS

All river valleys in Namibia support shrub or woodlands that are taller and denser than in the areas around them, often with a different species composition (Mendelsohn and el Obeid 2005). Riverine vegetations form linear forests along all perennial rivers of Namibia, as well as along most ephemeral rivers in the semi-arid zones. Vegetation composition varies with the rainfall zone.

Along the Kavango River, knob thorn (*Acacia nigrescens*) trees of more than 20 m high are found, intermingled with species such as *Peltophorum africanum,* safsaf willow (*Salix mucronata* subsp. *mucronata*), and *Ziziphus mucronata* (De Cauwer 2013). The ana (*Faidherbia albida*) tree dominates in the Kuiseb valley. Along the Orange River there are mainly *Searsia* species, cape willow (*Salix mucronata* subsp. *capensis*), wild tamarisk (*Tamarix usneoides*), and sweet thorn (*Acacia karroo*) (Mendelsohn and el Obeid 2005). The riverine forest along ephemeral rivers is dominated by *Acacia* species, especially camelthorn (*Acacia erioloba*), *Ziziphus mucronata*, and to a lesser extent *Combretum imberbe*, *Euclea pseudobenus*, and wild tamarisk (Giess 1998).

Riverine woodland along the perennial rivers is the most threatened forest type of Namibia as it is often cleared for agricultural fields, many forming form part of large irrigation schemes. Regeneration becomes near impossible as livestock overgraze the areas along the river. It is not known to what extent regeneration is still possible in national parks situated along perennial rivers, such as Mahango along the Kavango River, because of the high densities of game. Only robust measures, such as fencing off areas, will protect this vegetation type.

1.4 FOREST DYNAMICS IN NAMIBIA

Forest dynamics encompass the environmental and biological processes that shape and change a forest ecosystem. An understanding of forest dynamics is required to plan forest management interventions. However, the dynamics of natural tropical forests are difficult to understand because of the many natural disturbances, the high species diversity, and because the ecology of many of those species is not well known (Gourlet-Fleury *et al.* 2005, De Cauwer 2016). Relevant ecological parameters that are needed for each species include the tolerance for tree competition, diameter growth, regeneration, and mortality rate (Gourlet-Fleury *et al.* 2005, Seifert *et al.* 2014). Lack of such data hinders the development of predictive dynamic models, essential for forest managers to simulate logging scenarios for sustainable exploitation (Gourlet-Fleury *et al.* 2005). In Namibia, the data available are not sufficient to give a full picture of Namibia's forest dynamics.

1.4.1 TREE REGENERATION

Few efforts have been made to understand the natural regeneration in Namibia's woodlands. In general, the dry conditions are associated with poor and erratic natural regeneration, particularly in the nutrient-poor deep Kalahari sands. Hence, the rate of tree recruitment is relatively slow and is probably a disincentive to public and private investment in forest management (Ministry of Agriculture, Water and Forestry 2011).

There is research evidence that the natural regeneration of several important timber and fruit species is problematic, especially in the Zambezian Baikiaea woodlands. The natural regeneration of kiaat is limited compared to other woody species (De Cauwer 2016, Kabajani 2016), which is similar to findings in other parts of southern Africa (von Malitz and Rathogwa 1999, Caro *et al.* 2005). Reasons suggested for the lack of regeneration include high fire frequency, grazing and browsing pressure, climate change, and lack of light because of plant competition (von Malitz and Rathogwa 1999, Caro *et al.* 2005, De Cauwer *et al.* 2016). The Zambezi teak also showed limited regeneration compared to the number of mature trees in Kwando CF with 232 seedlings per ha (Kamwi 2003). This timber species is known to have regeneration problems in Zambia (De Cauwer, Chaka, *et al.* 2018).

Figure 6 - Manketti (Schinziophyton rautanenii) and Kiaat (Pterocarpus angolensis) at Kanovlei State Forest (Photo: V. De Cauwer)

There is also limited regeneration of the highly valued timber tree *Guibourtia coleosperma*. Forest inventories show that the tree is not abundant (< 10%), especially in the smaller size classes. The important fruit trees *Schinziophyton rautanenii* (manketti, mungongo) and *Strychnos cocculoides* (monkey orange, uguni) also show limited natural regeneration in northern Namibia (Kabajani 2016). The major reason may be the overharvesting of the fruit and, for *S. rautanenii*, harvesting of the tree for its wood.

Natural tree regeneration in mopane woodland appears good as long as young trees are not overharvested (Erkkilä and Siiskonen 1992). Good regeneration of mopane was observed in Ehi-Rovipuko CF with 457 seedlings per ha (Directorate of Forestry 2012) and in Sikanjabuka CF with 5,316 seedlings per ha (Kamwi and Laamanen 2002).

1.4.2 FOREST DISTURBANCES

Tree growth and forest health can be affected by many environmental and anthropogenic factors, often referred to as disturbances. Long drought periods, frost, fungi and insects, and a high fire frequency can affect tree growth, forest health, and increase tree mortality in Namibia's forests. Heavy browsing by livestock and wildlife can also affect tree growth and cause seedling mortality. Elephants not only browse trees but also push them over. Large elephant populations can be a major disturbance in and near national parks, such as Khaudum, or in the southern Zambezi Region, which borders Chobe in Botswana (Ben Shahar 1998).

The unsustainable or illegal harvesting of woodland resources is also a major disturbance in Namibia's forests. If timber is sustainably harvested, it should not affect forest structure and composition over the long term. Mopane is sometimes overharvested in the most populated areas, such as central Omusati (Musvoto *et al.* 2007), especially because mopane wood is widely used for a range of purposes. Timber is the main woodland resource that is illegally harvested. In some cases, it is legally but unsustainably harvested because there is no adequate management plan, or the plan is not followed or monitored. Unfortunately, there are rarely sufficient quantitative data to assess sustainability levels of harvesting. Roads, and especially tar sealed roads, are the major vectors along which both timber harvesting and deforestation take place, especially in areas with low population density (Kamwi *et al.* 2015, Schneibel *et al.* 2016).

Figure 7 - Hamoye state forest after a fire in October 2008 (Photo: V. De Cauwer)

Fires occur regularly in Namibia's forests; on average 7% of the land area burned annually in Namibia during the period 2003 to 2012 (FAO 2015). Although fire was a major driver of the southern African woodlands long before humans existed (Bond and Zaloumis 2016), most fires in the Baikiaea woodlands have an anthropogenic origin. Fire is used by subsistence farmers and hunters to clear the land or improve grass quality, which is important for the rapid regeneration of grass. In addition, fires can break physical dormancy in the hard-coated seeds of fire-adapted tree species. However, the ecological effects of fire on vegetation are dependent upon many factors such as timing, weather conditions, fuel load, and frequency (Ministry of Agriculture, Water and Forestry 2011).

The fire season in north-eastern Namibia is in August and September, the late dry season, when hardly any natural ignitions take place (Archibald *et al.* 2008, Stellmes *et al.* 2013b). Unfortunately, at that time of the year, there is a large amount of dry biomass resulting in hotter and larger fires, not only affecting the understorey, but also the trees. Mid- to late dry season fires result in significantly higher stem mortality compared to early burning or no burning (Geldenhuys 1977) and increase bush encroachment. Early dry season fires on the other hand can reduce the rate of bush encroachment and assist the growth of tree saplings, as observed in Bwabwata National Park for Kalahari podberry (*Dialium engleranum)*, silver cluster-leaf, and red syringa (Eastment *et al.* 2022). A single fire may not affect tree layer composition, but the accumulation of damage caused by recurring fires in the late dry season can result in shifts in species composition and forest degradation (De Cauwer and Mertens 2018). With northern Namibia projected to become warmer and drier, fire frequency is expected to increase (Pausas and Ribeiro 2013, Enright *et al.* 2015, De Cauwer *et al.* 2016). A limitation of fire frequency in the late dry season is needed to protect certain socioeconomically important species such as Kalahari podberry and false mopane (De Cauwer and Mertens 2018).

1.4.3 FOREST DEGRADATION

Forest degradation is a process during which biomass, wood volume, and carbon sequestration decrease, and changes in species composition take place as a consequence of severe or long-term disturbances. Shifts in species composition can for example be towards more fire resistant (De Cauwer and Mertens 2018) or drought-resistant species, or by removal of species targeted for timber or other purposes. Climate change is likely to accelerate the rate of woodland degradation (see 1.4.5).

Forest degradation is difficult to quantify as it requires comparison with an undegraded condition and often entails repeated measurements over time. Long-term studies in the Zambezian Baikiaea woodlands have been very limited (De Cauwer and Mertens 2018). One study of an annual burning experiment over 16 years in northern Namibia illustrated how fire negatively affected woody regeneration, especially of species such as *Baikiaea plurijuga* and *Commiphora spp.* (Geldenhuys 1977). The lower representation of *B. plurijuga* in the Kavango regions may be caused by its higher fire sensitivity. The most fire-resistant timber species of the Zambezian Baikiaea woodlands appear to *be Pterocarpus angolensis* and *Terminalia sericea*, and the least resistant *Guibourtia coleosperma* (De Cauwer and Mertens 2018).

1.4.4 DEFORESTATION

Unlike forest degradation, deforestation is a loss of forest; the area is no longer forest because land-use has changed (active deforestation), for example, the forest has been cleared for agriculture, or because, after a period of forest degradation, canopy coverage is no longer 10% (passive deforestation). The rate of passive deforestation is probably much greater than that of active deforestation in Namibia; however, there are insufficient data to determine this. Passive deforestation may, for example, lead to the deforestation of large areas in the Bwabwata National Park.

According to the reporting of Namibia to the FAO, forest loss was 11,130 km^2 or 16.1% of the forest area from 2000 to 2015 (FAO 2014). However, this is a rough estimate as stated earlier (see 1.2). It does seem to correspond with the estimate of 13% forest loss for the period 2000 to 2012 based on Landsat satellite data (Hansen *et al.* 2013).

Active deforestation in Namibia is mainly for subsistence or commercial agriculture (Wingate *et al.* 2016, De Cauwer, Knox, *et al.* 2018). The area covered by the Zambezian Baikiaea woodlands and associated shrublands decreased by 4,607 km^2 (4.3% of the area) during the period 1975 – 2014 because the agricultural area doubled (Wingate *et al.* 2016). Forest cover in Kavango East decreased from 58% in 1990 to 55% by 2016, while cropland increased from 3% to 6% (Muhoko *et al.* 2020). Local farmers remain on the same fields, resulting in permanent clearings (Erkkilä and Löfman 1999, Pröpper *et al.* 2010), or temporary fallows in the Kavango regions (Hilukwa 2018). An increasing population causes the expansion of clearings, even into areas with very marginal cropland, as on the Kalahari sand soils of the Zambezian Baikiaea woodlands. These sandy soils are generally unsuitable for crop production because of their low water-retention capacity and limited nutrients. The relatively low rainfall means that rain-fed crop production is risky and with low yields (Jones and Barnes 2009), for example, only 250 to 600 kg per ha for maize (Pröpper *et al.* 2015).

The Kavango and Zambezi regions are considered the breadbaskets of Namibia and the government has stimulated commercial agriculture through the development of green schemes near perennial rivers. Forest is sometimes cleared (Jones and Barnes 2009, De Cauwer, Knox, *et al.* 2018), for example at the Liselo scheme (Figure 8). There were also plans to start plantations of *Jatropha curcas*, a biofuel crop, in north-eastern Namibia. These plans have not been realised because potential yields were unknown and because of a concern that biofuel would displace food crop production (Jones and Barnes 2009).

In the most populated areas of the Angolan mopane woodland the forest was extensively converted to agricultural fields and in the western part to grazing land in the decade before Independence (Erkkilä and Löfman 1999, Verlinden and Dayot 2005).

Considering that the main driver of deforestation is the conversion to agricultural land, one of the best ways to stop deforestation is to intensify and diversify agricultural production on the existing fields that have the best soils and that have access to water, such as the green schemes. The most important will be to invest in soil improvement (Jeremy Ford, pers. comm.) and apply recent agricultural research, such as plant growth-promoting bacteria (Haiyambo *et al.* 2015) or planting of drought-resistant cultivars.

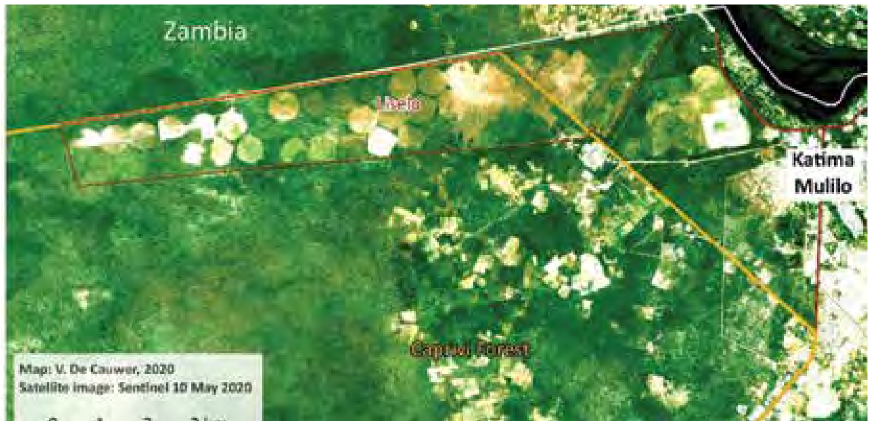


Figure 8- Liselo Farm in Caprivi State Forest, Zambezi (Photo: V. De Cauwer 2020)

1.4.5 EFFECTS OF CLIMATE CHANGE

The rate of surface temperature increase caused by human-induced climate change has generally been more rapid in Africa than the global average, which has caused an increase in aridity and droughts. A decrease in the mean precipitation in south-western Africa has been observed (IPCC 2021). Satellite data have shown that there has been a decrease in rainfall in October for north-eastern Namibia and that both the wettest and driest of the last 40 years in Namibia occurred in the last decade (Thompson 2021).

Global warming and the observed increases in hot extremes are projected to continue throughout the 21st century. Predictions include an increase in dryness from 1.5°C, increased wind speed, and a decrease in rainfall of up to 30% for south-western Africa (IPCC 2021). Namibia's forests may receive 100 mm less rain annually by 2080 (De Cauwer *et al.* 2016). This will increase fire weather conditions and fire frequency is expected to increase (Enright *et al.* 2015, IPCC 2021).

The increasing evapotranspiration caused by the rising temperatures, increased fire frequency, and increasing droughts will cause more plant stress (Munalula *et al.* 2016), a decrease in tree growth (Fichtler *et al.* 2004), decreasing tree recruitment (Enright *et al.* 2015), and ultimately a potential increase in tree mortality (Allen *et al.* 2010). This will decrease the distribution ranges of many tree species in Namibia (Thuiller *et al.* 2006). De Cauwer *et al.* (2014) predicted a decrease in the distribution area of Namibia's most important timber tree, kiaat. By 2080 the tree may almost have disappeared from the country.

As a result, ongoing climate change will cause Namibia's dry forests to shift towards the north-east. This is consistent with the study of Thuiller *et al.* (2006) that predicted a decrease in tree cover in northern and north-eastern Namibia by 2080. While it is difficult to observe a reduction of tree cover over time, considering the many other factors that affect this, other early warning signs can be monitored. Decreasing tree regeneration and increasing tree mortality, especially for the major timber species, can be monitored in Permanent Sample Plots (PSPs) (see 3.1.4). This would assist natural resources managers to put mitigation plans in place to bridge the period during which the worst effects of climate change are likely to manifest themselves.

1.4.6 FOREST SUCCESSION

Forest succession is the process by which a forest community evolves over time. The term is especially used for the recovery process of the forest after a severe disturbance, as it is assumed that a natural forest community is in equilibrium. The type of disturbance, the climatic conditions, the presence of potentially colonising species, and the interactions among species all influence the path that succession will take.

Species composition and forest structure fluctuate throughout succession. Certain species are better equipped than others to deal with more light, wind, higher temperatures, and disturbed soils. These species are referred to as pioneer species. They generate more easily and tend to grow fast, outcompeting other species, and hence they appear early in the forest succession. However, they are short-lived so that other species that can better handle shade and that can grow under the cover of the pioneer species replace them in later forest succession stages. Pioneers among tree species include *Terminalia sericea* and *Burkea africana* (De Cauwer *et al.* 2016). Both can invade deforested and other disturbed or degraded areas. *T. sericea*, together with shrub species such as *Dichrostachys cinerea* and *Acacia fleckii*, can form dense thickets on deep sand (Erkkilä and Siiskonen 1992, Strohbach and Petersen 2007).

Pterocarpus angolensis is a light-demanding species; however, research has shown that it is not a pioneer species as it is long-lived with weak competitive abilities, especially during the juvenile phase. It is a late-successional or climax species that forms part of the canopy in a forest that is in equilibrium. That is why *P. angolensis* is doing relatively well in the Zambezian Baikiaea woodlands compared to its cousins in the wet miombo woodlands (De Cauwer 2016).

In general, there is too little known of forest succession in Namibia, especially how long it takes for the different forest types to recover, and which species have the best competitive abilities.

1.5 PLANTATIONS IN NAMIBIA

Plantation forestry is limited to a few remnants of experiments with exotic species dating back to the German colonial time. Attempts were made to establish trial plantations during the 20th century as local wood production was not sufficient to satisfy local demand. It was decided that indigenous species were too slow-growing to be planted for wood production and

exotic species should form the basis of large-scale plantations (Erkkilä and Siiskonen 1992). The species trials concentrated on *Casuarina*, *Eucalyptus,* and *Prosopis*, as well as ornamental species for planting in the cities and around farm dwellings, such as *Cupressus sempervirens, Pinus radiata, Schinus molle, Tecoma stans,* and *Morus alba* (Erkkilä and Löfman 1999, Ministry of Agriculture, Water and Forestry 2011). Species trials were based in Okahandja and Grootfontein (Ministry of Agriculture, Water and Forestry 2011). Several of the trial species were then planted in experimental plantations, for example, near Brakwater, Grootfontein, Rundu, and Ngoma, and mainly with *Casuarina* and *Eucalyptus* (Erkkilä and Löfman 1999, Ministry of Agriculture, Water and Forestry 2011).

Plantations of neither *B. plurijuga* nor *P. angolensis* have been attempted in Namibia; trial plantings have been limited to neighbouring countries (Piearce 1986, DFSC 2001, Caro *et al.* 2005). In general, there is much less plantation forestry in southern Africa than in the rest of the world. However, this may change in the future considering the increasing wood demand and an emphasis on renewable, carbon-friendly commodities (De Cauwer, Knox, *et al.* 2018).

2 FOREST SERVICES AND RESOURCES IN NAMIBIA

Namibia's forests provide valuable forest products and ecosystem services, despite the relatively low tree density. Forest products include both timber and Non-Timber Forest Products (NTFPs) such as firewood, thatching grasses, and fruits. The products and services benefit not only the local communities but also the Namibian population and economy, while ecological services have an impact at a global level. Hence, the value of Namibia's forests is much more than just the wood, and includes the ecological and socio-economic value, which is much broader and more difficult to quantify.

Multifunctional forests provide multiple services and products to the users, as Namibia's forests do. Managing a multifunctional forest is complicated because management interventions targeting a single product or service may affect the forest's capacity to provide for others. Intense timber harvesting may affect a forest's value as a habitat for wildlife. Decisions on trade-offs in the provision of various goods and environmental services are best made using processes that involve the full range of stakeholders. Forest managers applying Sustainable Forest Management (SFM) must continually balance various management objectives that inevitably change over time as social, and community needs, and values change; this is the challenge of multipurpose forest management. Although embedded in the laws of many countries, multipurpose forest management has proven to be a complex endeavour that faces a range of economic, social, and institutional barriers. Nevertheless, success stories around the tropics, particularly in community-based initiatives, show that it can be made to work—for the benefit of communities and the forest (ITTO 2015b).

2.1 ECOSYSTEM SERVICES

Ecosystem services are the contributions of the natural world that people value (Domptail and Mundy 2013). Namibia's forests are ecologically important for carbon storage, soil erosion control, climate regulation, water storage, providing a habitat or movement corridor to a range of species, including commercially important game, and maintaining biodiversity; these are all services valued by people. Additionally, people value forests for recreational, spiritual, and cultural reasons. During a project in the Kavango regions stakeholders were asked to rank the ecosystem services of the Okavango River and neighbouring forests according to their perception. After the provision of water, species diversity was given the highest priority,

especially by the national and district stakeholders. This was followed by mitigation of hazards (floods, fires, drought) and climate regulation, while environmental setting (sense of place and respect for landscape) got the lowest ranking, especially by local stakeholders (Domptail and Mundy 2013).

While all ecosystem services are valuable, it should be noted that the recreational value is currently underused or not valued. Only a small proportion of tourists visit the forested areas of Namibia.

2.1.1 CARBON POOL, EMITTER, AND SINK

Carbon dioxide (CO_2) is the most common greenhouse gas. Globally, tropical and subtropical forests store the largest amount of carbon in terrestrial ecosystems, approximately 600 Gt, and are thus the major terrestrial carbon pool (Foley 1995). The global carbon pool for tropical dry forests and savannas is estimated at 220 Gt, with almost 60% stored in the soil (Foley 1995). Hence, in Namibia, it is safe to state that most carbon is stored in the tree and shrub savannah of north-eastern Namibia and especially in its soils. There are only very rough estimates for Namibia's total carbon pool in forests and woodlands, because the forest area for Namibia is not known, while accurate biomass and carbon data are lacking in scientific literature. There are a few studies that have determined the above-ground woody volume or biomass in Namibia's forests (De Cauwer *et al.* 2020, Kindermann *et al.* 2022). They allow estimating the above-ground carbon pool at approximately 25 to 35 t C ha^{-1} (total soil organic carbon per hectare) in Kavango and Zambezi, depending on the level of forest degradation. A study for the thornbush shrublands estimates the total above- and below-ground carbon pool at 90 t C ha^{-1} of which 35 t C ha^{-1} was soil carbon (Musekiwa *et al.* 2022), which seems very high. Unfortunately, the carbon pool is decreasing because of land conversion and climate change. Net removals at national level for the Agriculture, Forestry and Other Land Use sector are estimated to have increased from 86,725 Gg CO_2 eq (gigagrams CO_2 equivalent) in 2010 to 100,497 Gg CO_2 eq in 2015 (Republic of Namibia 2020).

CO_2 is globally also the most emitted greenhouse gas (82%). Forest degradation and deforestation are major contributors to carbon emissions in Namibia (see 1.4.2 and 1.4.4). While the extent of woodland degradation is difficult to assess, it is estimated that it is a much larger contributor to carbon emissions than deforestation in sub-Saharan Africa (Bombelli *et al.* 2009).

Next to being a carbon pool, Namibia's forests also act as a carbon sink as they remove atmospheric carbon. Rough estimates at the national level indicate that Namibia's land sector is currently a sink but will become CO_2 neutral under the scenario of increased harvest and use of the invader bush (Republic of Namibia 2020). Hence, encouraging natural forest regeneration, expanding forests, and planting trees will mitigate climate change. Accurate data on annual carbon sequestration in Namibia's forests are lacking but are needed to encourage these initiatives. While increasing the carbon sink by tree planting is important, it is more important and efficient to maintain the current carbon pool through pro-active forest and fire management and fulfilling international agreements.

Namibia has ratified the Paris Agreement and, as a Non-Annex I Party, has to submit national reports on the implementation of the United Nations Framework Convention on Climate Change (UNFCCC) on a five-yearly basis. The reports are known as (intended) nationally determined contributions and give information on greenhouse gas emissions, carbon storage, and especially on actions to address climate change and facilitate adequate adaptation to climate change. Namibia's last report indicated that it aims to reduce deforestation to a strict minimum with an annual loss of 7500 ha while 2500 ha per year is estimated to be converted to forest (Republic of Namibia 2020).

Proactive agronomic and sustainable forest management will assist to mitigate climate change. Examples include assisting subsistence farmers to increase agricultural yield without clearing more forest and managing forests for sustainable production of more firewood and better timber. Once concrete steps have been taken towards reducing emissions, the reductions become eligible for carbon trading. Namibia can consider taking part in the carbon market, which includes, for example, REDD+, the UN Programme for Reduction in Emissions from Deforestation and Forest Degradation with the "plus" signifying the role of conservation, sustainable management of forests and enhancement of forest carbon stocks. REDD is based on the idea that funds are provided to developing countries for reducing emissions from deforestation or forest degradation through various policies and measures (Peskett *et al.* 2008).

A study by Jones and Barnes (2009) assessed the possibility of REDD for forests in the Zambezi Region. Although no legislation specifically provides local communities with rights over carbon, it can be inferred from the Forest Act that the CF does have such rights. The study concluded that REDD is

not appropriate in Zambezi, primarily because the potential for alternative uses of the woodlands in this region is poor. It argued that the woodland had value while other land uses in Zambezi are not entirely economic. The cost of implementation of the REDD system in Zambezi was at the time estimated at some N$ 33 million per annum (Jones and Barnes 2009). However, history has shown that deforestation in Zambezi has continued. Moreover, the application of the REDD system was approached only from a community angle, with the use of community structures. As the REDD application is very complex, it would be much more efficient and less costly if an NGO like the Integrated Rural Development and Nature Conservation (IRDNC) or WWF were to apply on behalf of a group of CFs. This would then be a kind of outsourcing of the REDD application. There is, however, a limited understanding of the opportunities and challenges for pro-poor payments for avoided deforestation and degradation in Namibia (Jones and Barnes 2009), explaining why there is as yet no Namibian participation in the carbon market.

2.1.2 SOIL PROTECTION AND IMPROVEMENT

Forests and woodlands have the capacity to retain soil and prevent erosion, with riverine forests protecting riverbanks. Moreover, many tree species belonging to the Fabaceae family can fix nitrogen from the air and enhance the nutritional status of the soil. This is very important as most of Namibia's forests and woodlands are on Kalahari sand, or arenosols. Sandy soils are always low in nutrients because they consist largely of quartz sand and thus contain little humus (Mendelsohn and el Obeid 2005). Namibia's arenosols are deficient in most major nutrients, but especially phosphorous, which limits the nitrogen content of the soil (Mendelsohn and el Obeid 2005, Verlinden and Dayot 2005). The soils are also deficient in micro-nutrients such as manganese, iron, and zinc (Verlinden and Dayot 2005).

2.1.3 MAINTAINING BIODIVERSITY

Forests contain a wealth of biodiversity, both flora and fauna. Many species would disappear if their forest habitat were removed. Forest managers can also establish measures to improve biodiversity, such as better control over fires and leaving (some of the) dead wood to attract insects, spiders, and reptiles (Mannheimer and Curtis 2018). Many bird species specifically look for insects in dead trees. The National Botanical Research Institute's (NBRI) incorporation into the Directorate of Forestry contributes to the recognition of the biodiversity component of Namibia's forests.

2.2 TIMBER AND POLES

Timber and wood from smaller-sized trees, often referred to as poles, are a major woodland resource for both local and commercial users in Namibia, even though Namibia's open forests do not produce much wood. This section describes the main species harvested for wood in Namibia and their main uses.

2.2.1 MAJOR TIMBER SPECIES

Pterocarpus angolensis is considered the most valuable timber species in Namibia. It is a deciduous tree, reaching a height of 10 m to 18 m in Namibia and growing in mixed stands of open forest (Figure 9). Its wood - known as kiaat, bloodwood, mulombe, or mukwa - is sought after for furniture and decking because of its beautiful grain, colour, durability, and good stability. It is also used for woodcrafts. The density is about 620 kg per m^3 (12% moisture content) (ITTO 2015a), similar to that of European oak. The species is commercially interesting only when the bole is large enough to obtain planks of the dark heartwood. Despite its economic importance, there are no estimates for the growing stock of the species on a national level (FAO 2010a). This makes it hard to determine if the current harvest is sustainable. The mean stem diameter growth of kiaat is 5.5 mm per year in Namibia (De Cauwer 2016).

Figure 9 - Left: Kiaat (*Pterocarpus angolensis*) during the dry season near Rundu, Right: Kiaat during the rainy season near Cuangar, Angola, just north of the border with Namibia at Nkurenkuru (Photos: V. De Cauwer)

2 Forest Services and Resources in Namibia

Zambezi teak (*Baikiaea plurijuga)* – known as mukusi/mukusu or umgusi in the timber trade - is the second most harvested timber species in Namibia and has a reddish, harder wood with a wood density of 900 kg per m^3 (12% moisture content) (ITTO 2015a). The tree can reach a height of 20 m in Namibia, but its average height is much lower and decreases toward the south and west. For example, the tree has an average height of 12 m in the Kavango regions and 8 m in the most western parts of its distribution area, Omusati (Kanime and Laamanen 2003). Namibian Zambezi teak grows a bit more slowly than kiaat with a mean stem growth rate of about 3.9 mm per year (Van Holsbeeck *et al.* 2016).

The wood of false mopane (*Guibourtia coleosperma)* is known by the tradename of rosewood or local names ushivi (Namibia), musivi (Angola), and muzauli (Zambia). Its harvest is on the rise (IRDNC 2015a) because of the high demand for hongmu wood, a Chinese term for the timber of dense tropical hardwood species with a reddish hue. Namibia's rosewood is very similar to Zambezi teak, which has the same wood density. The local market for rosewood consists mainly of poles, for which young trees are cut (De Cauwer 2020). The tree occurs in the Zambezian Baikiaea woodlands but is not very common, representing on average 2% of the trees (Angombe *et al.* 2000). No data are available on the growth of rosewood, but it can be assumed that the growth rate will be similar to that of Zambezi teak.

The yellow wood of the silver cluster-leaf (*Terminalia sericea)* - mugoro in Rukwangali and muhonono in Silozi - is mainly used for poles. This pioneer species is a small tree in Namibia, reaching an average height of 5 m in Omusati and Kunene (Kanime and Laamanen 2003, Directorate of Forestry 2004) and about 8 m in the Zambezi Region (Kamwi and Laamanen 2002). The species tends to deploy its roots near the soil surface, which enables it to compete for water and nutrients with other shallow-rooted plants, such as grasses (Hipondoka and Versfeld 2006). The mean diameter growth of silver cluster-leaf ranges from approximately 4.2 mm in Oshikoto to 8.9 mm in Kavango (Van Holsbeeck *et al.* 2016). The wood of *Terminalia* species is termite-proof (Rothauge 2014).

Mopane reaches an average tree height of 5.5 m and a maximum height of 9 m in Omusati and Kunene (Kanime and Laamanen 2003, Directorate of Forestry 2004). The dense wood provides good quality firewood and is suitable for construction, especially as it is resistant to beetles and fungi (Mannheimer and Curtis 2018), and termite-proof (Rothauge 2014). Young regeneration of mopane is often removed for fencing and constructing kraals (Directorate of Forestry, 2004). Roots are sometimes used for artwork or aquaria. The mean growth rate for mopane in north-central Namibia is about 3.6 mm per year (Cunningham and Detering 2017).

The softwood of *Schinziophyton rautanenii* or mangetti is used for dug-out canoes, the main form of transport in the Okavango area, but also as fuel (De Cauwer, Knox, *et al.* 2018). The tree has a high mean stem growth rate of approximately 7.6 mm per year in Kavango (Van Holsbeeck *et al.* 2016).

Red or wild syringa (*Burkea africana*) - musheshe, or mukarati in the timber trade - is one of the most common tree species in Namibia's forests but is hardly used as timber, although it is a stable and durable wood with high density (850 kg per m^3) (12% moisture content) and resistant to termites (ITTO 2015a). This is mainly because the trees are difficult to saw and work with, requiring powerful and specialised equipment, and because the trunk of mature trees is often hollow (De Cauwer 2020). Red syringa has a mean stem growth rate of approximately 4.2 mm per year in Namibia (Van Holsbeeck *et al.* 2016).

2.2.2 LOCAL USE

Local users harvest mainly smaller trees for construction purposes, fencing, or cash. Communal farmers will build houses and fence their homesteads and kraals with poles. According to the Forest Regulations, poles are trees with DBH between 15 and 30 cm. For example, people living near M'Kata CF in Otjozondjupa need an average of about 54 poles per household to construct or renovate a house and every third year a house is constructed or renovated (Otsub *et al.* 2003). Other wood uses include woodcraft and domestic tools such as axe handles, pestles and mortars, cooking sticks, and slingshots (De Cauwer, Knox, *et al.* 2018). Commercial farmers will produce fence droppers and straining posts for own use or for informal sale to other farmers (Rothauge, 2014).

The most preferred timber species for local use are kiaat and Zambezi teak (see 2.2.1). The wood of silver cluster-leaf, mopane, and false mopane is used mainly for poles. For carvings and other handicrafts only the most suitable species for the purpose is targeted, which includes amongst others sand corkwood (*Commiphora angolensis*), Kalahari apple-leaf (*Lonchocarpus nelsii*), red syringa, and peeling plane (*Ochna pulchra*). Carving in the North-West Forestry Region is not as common as in Kavango, where some CFs earn their income from carvings, such as Ncumcara and Mbeyo (Hilfiker 2011).

2 Forest Services and Resources in Namibia

2.2.3 COMMERCIAL USE

The commercially most important timber species of Namibia are kiaat, Zambezi teak, and false mopane, all indigenous species, as there are no timber plantations in Namibia. Only the merchantable or squared logs are traded, with the remaining harvested wood being underutilised. For kiaat, which has a large portion of sapwood, this is approximately 28% of the utilisable timber wood volume (Moses 2013). Even then, the timber use-value of kiaat, estimated at ZAR 485 for a tree of harvestable size, surpasses the carbon value (Moses 2013).

Untreated poles are sometimes sold by private farmers on a commercial scale. The supply and quality vary depending on the extent of bush control activities on the farm (Rothauge 2014).

BOX 2: GROWING STOCK, THE AMOUNT OF WOOD IN A FOREST

According to FAO, the growing stock is the "volume over bark of all living trees more than X cm in diameter at breast height (DBH)". This includes the stem from ground level or stump height up to a top diameter of Y cm, and may also include branches up to a minimum diameter of W cm. Each country defines their X, Y and W values. In Namibia, the growing stock is calculated with volume equations for all trees of more than 5 cm in DBH (=X) and includes all branches. The equations were established as part of the Namibia–Finland Forestry programme and are based on trees felled in four regions (De Cauwer 2015). Forest inventories from before Independence used 10 cm for X (Geldenhuys 1975).

Growing stock and wood volume are measured in m^3.

Tree diameter is measured at breast height, which is 1.3 m from the ground, and referred to as diameter at breast height or DBH.

Basal area (BA) is often used as a proxy for wood volume and biomass; it is the sum of the cross-sectional areas of tree stems at DBH in a stand.

2.2.4 HISTORICAL HARVESTING

The commercial harvesting of indigenous hardwoods in Namibia dates back to the German colonial period at the end of the 19^{th} century when much wood was needed for the operation of mines and the construction of railways. This is also the period when the first harvest permit systems were introduced to limit overharvesting. Based on data in Namibia's archives, the timber volume harvested during the period 1959 – 1987 was on average 1,360 m^3

per year, while permits for 8,850 m^3 were granted in 1990 (De Cauwer 2020). More information on timber harvesting before independence is given in the book of Erkkilä and Siiskonen (1992).

In the most recent decades local and regional timber has increasingly been exported via Namibia to South Africa and China. The timber comes from Angola and Zambia, and sometimes the Democratic Republic of Congo (DRC). The most-traded wood was that of kiaat, followed by Zambezi teak. The mean volume harvested for the period 2010 – 2016 was 2,138 m^3 per year (Nott *et al.* 2019). In 2018 there was a peak in the harvest of Zambezi teak and *Guibourtia coleosperma*, partially illegal as no clearance certificates were obtained. The exact number of trees that were harvested in 2018 is not known, but the media reported 60,000 to 100,000 logs. Considering that a tree of harvestable size can provide approximately 0.5 m^3 timber wood, this would result in 30,000 to 50,000 m^3 wood harvested in 2018, which is considerably more than historical harvest rates (De Cauwer 2020) (Figure 10).

All the timber harvested in 2018 was in communal areas. It is therefore surprising that in the past many statements (e.g. Hilfiker 2011) were made to the effect that the timber harvest in the many CFs is hardly commercially justifiable.

The Karstveld is closest to the copper mine of Tsumeb, for which a lot of wood, especially of tamboti, has been harvested for energy and mine props since the early 20th century. The consumption of tamboti wood went up with the deepening of the mine, up to 13,000 m^3 per year by the 1950s (Erkkilä and Siiskonen 1992).

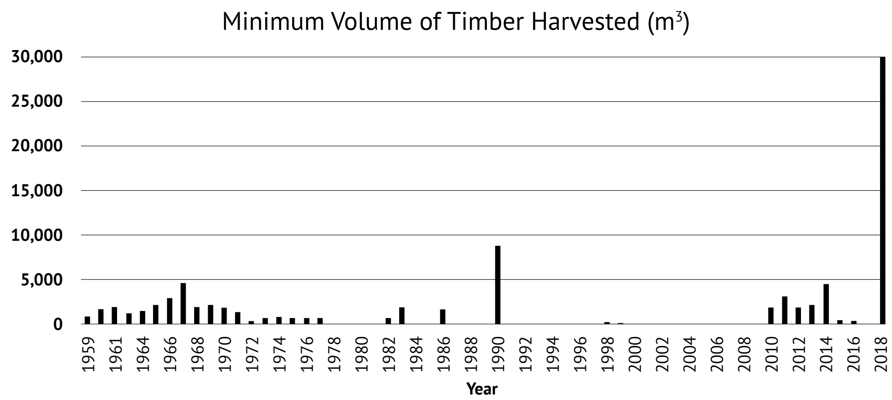


Figure 10 - Estimates of the minimum volume of wood harvested in Namibia in the past 60 years. The values represent wood volumes declared on harvest permits and are based on data of Namibia’s Archives (1959 – 1977, 1982 – 1983, 1986), Hilbert (1990), Chakanga (1998 – 1999), and Nott et al. (2019). The value for 2018 is an estimate based on the number of logs reported in the media. No data are available for the other periods.

2.3 NON-TIMBER FOREST PRODUCTS

The most important NTFP is firewood, a primary source of domestic energy, especially for cooking (Mendelsohn and el Obeid 2005). Deadwood or smaller branches are collected in the vicinity of settlements and fields. More community members collect firewood than those that harvest timber. For example, a study in central Angola showed that annual consumption of wood amounted to 484 kg per person, of which 78% or about 370 kg was for firewood and the remainder for house construction (Kissanga Vicente da Silva Firmino 2016). Annual firewood consumption in M’Kata CF in Otjozondjupa amounted to about 160 kg per person (Otsub *et al.* 2003). Good fuelwood species include mopane (see 2.2.1) and purple-pod terminalia (*Terminalia prunioides*). Purple-pod terminalia is common in Kunene and reaches an average height of 5 m (Kanime and Laamanen 2003). The mean growth rate for *T. prunioides* in north-central Namibia is about 3.8 mm per year (Cunningham and Detering 2017).

Charcoal production occurs mainly on commercial farms further south to combat bush encroachment. However, it can also be a side product of logging agreements, such as has happened in Kwandu CF (Hilfiker 2011).

The forest also provides grazing and browsing for livestock and game, which is regulated by the Forest Act for protected forests. Browsing game include economically important species such as impala, black rhinoceros, elephant, and kudu. Bark and leaves are browsed, with some species more preferred than others. At the end of the dry season, when there is no grass, many grazers, including cattle, will also browse.

Wild fruits and vegetables form an important source of nutrition and cash income, especially towards the end of the dry season, or during droughts when crops fail and the forest resources act as a safety net (Jones and Barnes 2009, Chidumayo and Gumbo 2010). In the Zambezian Baikiaea woodlands the fruits of ushivi, Kalahari podberry (*Dialium englerianum*), marula, monkey orange or maguni (*Strychnos* spp.), the dwarf jackal-berry (*Diospyros chamaethamnus*), and raisin bush (*Grewia* spp.) are eaten fresh or used to make alcoholic beverages (De Cauwer, Knox, *et al.* 2018).

The seeds of white bauhinia and mangetti yield oils of high nutritional quality (Yeboah *et al.* 2017). The oil yields for mangetti are high (60%), and comparable to those of sunflower and peanut oils (45–55%), indicating their potential for the commercial production of cold-pressed (virgin) oil. White bauhinia oil yields are lower (19%) but comparable to those of soybean oil (17–22%) (Yeboah *et al.* 2017). The amount of unsaturated fatty acids in both species is 73–80%, comparable to good quality oils like olive oil, which has about 72% unsaturated fatty acids. The presence of α-eleostearic acid (α-ESA) was also detected in mangetti oil. Studies have shown that α-ESA is a tumour-suppressing agent and can inhibit breast cancer (Tsuzuki *et al.* 2004, Grossmann *et al.* 2009), thus demonstrating the potential suitability of the oil as a health food supplement (De Cauwer, Knox, *et al.* 2018).

The fruits of several tree and shrub species of Namibia's forests and woodlands – especially marula, blue sourplum (*Ximenia americana*), baobab (*Adansonia digitata*), mangetti, and mopane - produce oils that are used commercially in cosmetic applications.

The list of forest products with traditional medicinal uses is too long to add here. More information can be found in reference books such as those of Mannheimer and Curtis (2018) and von Koenen (2001). One product is harvested at a commercial level: devil's claw or wool spider (*Harpagophytum procumbens* and *H. zeyheri*), a creeping plant of which the tuber has medicinal qualities, especially against arthritic conditions (von Koenen 2001). The tuber is harvested mainly in north-eastern Namibia, although it is also present in the north-western parts (Hilfiker 2011).

Honey collected from wild bees is a major source of cash income in the wetter miombo woodlands (Shackleton and Gumbo 2010), but less so in Namibia. It appears to be one of the most promising forest products in north-eastern Namibia. Initiatives in northern Namibia seem less successful as communities show only limited ownership of apiary sites installed mainly by the Directorate of Forestry. Despite less favourable environmental conditions such as the availability of water and vegetation, the Directorate of Forestry continues to promote beekeeping as an agent for pollination and income opportunity for communities (Hilfiker 2011).

As long as local houses and lodges require thatching grass, this raw product will have local markets. The construction of a house needs on average 150 to 200 kg of grass (Otsub *et al.* 2003). Usually, CFs benefit in the form of revenue from harvesting permits or sale (Hilfiker 2011). It is an important source of income in the Kavango regions (Domptail and Mundy 2013).

In the mopane woodlands mopane plays an important socio-economic role in the life of the communities as it has many uses. Besides timber, mopane provides medicines, fodder for game and domestic animals, young bark for ropes, and it is a food plant for mopane worms (Madzibane and Potgieter 1999, Mannheimer and Curtis 2018). The mopane worm (*Imbrasia belina*) is the caterpillar of a moth of the Saturniidae, which feeds primarily on the leaves of mopane. The caterpillars are dried before consumption or sale in both rural and urban centres and provide an important source of protein (61% of dry matter) (Headings and Rahnema 2002). Unfortunately, the supply of mopane worms varies from year to year, depending on rainfall.

Figure 11 - The fruits of the corky monkey orange provide an important source of cash in north-eastern Namibia. (Photo: V. De Cauwer)

3 SUSTAINABLE FOREST MANAGEMENT

SFM aims to balance the various uses of forests while ensuring their ecological functioning and the provision of benefits and functions into the future (ITTO 2015b). The International Tropical Timber Organization (ITTO) developed a set of criteria and indicators that can be used to guide forest management and assess its sustainability. The seven criteria constitute the basis for the assessment of SFM (ITTO 2015):

1) Enabling conditions for SFM
2) Extent and condition of forests
3) Forest ecosystem health
4) Forest production
5) Biodiversity
6) Soil and water protection
7) Economic, social, and cultural aspects.

For the first criterion one of the main enabling conditions for SFM is a good legal framework. Another important enabling condition is a large pool of well-trained forest technicians, managers, and researchers. This is lacking in Namibia. This chapter explains tools that allow the assessment of most of the other criteria needed for SFM and how they are applied in Namibia, especially forest monitoring, forest management, silviculture, and research.

3.1 FOREST MONITORING

Forest monitoring aims to obtain comprehensive information on forest resources, which is needed to manage forest ecosystems sustainably. Hence, it especially addresses criteria 2 to 5 for the assessment of SFM. Information that needs to be collected can be quantitative data, including the extent of the forest area and the amount of timber, and qualitative, such as tree health and damage. Assessing forest extent is done with remote sensing data (see 3.1.3).

3.1.1 FOREST INVENTORIES

The main tools of forest monitoring are forest inventories, which need to be repeated regularly because forest disturbances (see 1.4.2) constantly affect

forest resources and can cause forest degradation (see 1.4.3). A common interval between inventories is 5 or 10 years, as in the FAO reporting (Box 3). The focus of a forest inventory is assessing wood biomass, especially timber and the carbon pool, but also forest health and ecosystem functioning (Köhl *et al.* 2006). The principle of an inventory mirrors the annual game counts carried out in communal conservancy areas; the counts are analysed before quotas are set for the sustainable use of game (NACSO 2022). However, instead of counting, forest inventories are based on tree measurements in sample plots that represent the total forest area.

BOX 3: FOREST INVENTORY METHOD IN NAMIBIA

The national inventory system uses a systematic sample design; plots are placed at equal distances. For the regional inventories, a stratified systematic sample design was used with the density and structure of the woody vegetation used as criteria for the stratification.

Plots consist of three nested circles in which all woody species with a diameter at breast height (DBH) exceeding 5 cm are tallied. Trees with DBH > 45 cm are measured within a circle with 30 m radius. Trees with DBH > 20 cm are measured with a circle with 20 m radius, and all woody vegetation with DBH > 5 cm are measured in the circle with 10 m radius. In two subplots with radius 5 m all woody vegetation with DBH < 5 cm is tallied (Directorate of Forestry 1997).

The intensity of an inventory varies according to the scale and purpose. At a national and regional level, inventories provide strategic information for policy and decision-makers, such as forest extent and composition, the size of the carbon pool, and potential uses of forest resources. At the local level, for example for a state or community forest, inventories provide detailed information for the planning of forest management operations at stand level (Geldenhuys 1991, Selanniemi *et al.* 2000). A forest stand is a community of trees sufficiently uniform in composition, structure, site quality, or location, to distinguish it from adjacent communities (Nyland 2016).

Almost all forest inventories will collect data on tree species and the stem diameters within the sample plots. Tree height, damage, and timber quality are also important measurements, especially for local inventories. At the plot level, information on the site needs to be collected, such as the exact location, topography, and vegetation cover. Canopy cover is an important parameter affecting the forest micro-climate (see 3.3.1).

Forest inventories are upscaled to the total forest area by extrapolation of the plot data, and often with the assistance of remote sensing data (see 3.1.3). The forest inventory results feed into forest management, especially planning of harvest or silvicultural measures, and thus the management plan. As there are many forest disturbances, forest inventories need to be repeated over regular intervals of time.

The Directorate of Forestry recognises that '*the protection, management and use of forest ecosystems to provide commercial products and also vital ecosystem services require a comprehensive monitoring, reporting and verification system of the forest resources'* (Ministry of Agriculture, Water and Forestry 2011, p. 4). However, no comprehensive national forest monitoring has yet been done for Namibia. The total forest extent is not known, nor are national deforestation rates (see 1.2). The need for repeated forest inventories is not recognised in Namibia. This is the case for the whole southern African region, where none of the countries has a repeated national forest monitoring system in place (Morales-Hidalgo 2015). Regional forest inventories are incomplete, outdated, and were never repeated. Monitoring at a local level is much better with the forest inventories for the CFs.

The inventory of Namibia's woodlands started in 1975, during colonial times (Geldenhuys 1975, 1976). In 1995 the Directorate of Forestry in cooperation with the Finnish International Development Agency (FINNIDA) started a National Forest Inventory (NFI) as part of the Namibia-Finland Forestry Programme (NFFP), to produce regional inventories for northern Namibia (Kamwi and Kätsch 2009). Four regions were covered by the regional forest inventory: Oshikoto, Zambezi (then Caprivi), Omusati, and Oshana (De Cauwer 2015, FAO 2020). Of these four regions, Omusati and Oshana had almost no forest cover (Selanniemi *et al.* 2000, FAO 2005). Forest inventory data were also collected for the eastern part of the Otjozondjupa Region (Korhonen *et al.* 1997a, 1997b). The regions with the largest amount of forest cover (Kavango East and West), as well as four other regions with potential forest cover, were not included in the national forest inventory.

Since 2000 there has been a shift from regional to local-level forest inventories (Kamwi and Kätsch 2009). The German Development Service, through the Community Forestry in Namibia project, assisted with the inventories of the first CFs. They developed a forest inventory technique and assisted with the implementation and funding of ten Participatory Natural Resource Assessments (Schusser 2012), in which community members themselves conducted the inventory. Nowadays the National Forestry

Inventory Department provides technical guidance, analyses the data, and compiles inventory reports (NACSO 2022). To date forest inventories have been carried out for all the registered CFs and some of the state forests, but these data do not represent larger areas of the country (FAO 2020).

The WWF also coordinates annual vegetation surveys with the communities in selected conservancy and CF areas, which are collated into the Namibian database for conservancy information (CONINFO) and can assist with the management of NTFPs (NACSO 2022). Forest inventories have also been conducted by the research community, targeting specific research problems.

3.1.2 ALLOMETRIC MODELS FOR NAMIBIA'S TREES

The tree measurements of forest inventories are used in determining the amount of wood (wood volume), above ground biomass, or sequestered carbon of the plots or stands sampled with the assistance of allometric models (Figure 12). Allometric models are formulas that calculate tree volume or biomass using, for example, tree diameter and height. Accurate models are required to provide reliable estimates of growing stock and carbon sequestration; model choice can lead to large differences in such estimates. Often models are developed for a specific tree species or a specific site to explain most differences in tree height to diameter relationships. However, site-specific models are labour intensive and expensive to develop for trees of natural tropical forests and woodlands, especially when using destructive methods which require harvesting of trees and weighing of wood samples. Moreover, there is little quality control of the models developed, and often they are developed with too few sample trees and for relatively small study areas (De Cauwer *et al.* 2020). Henry et al. (2011) showed that at least 22% of the allometric equations reported for Sub-Saharan African forests resulted in inaccurate estimates of biomass or volume.

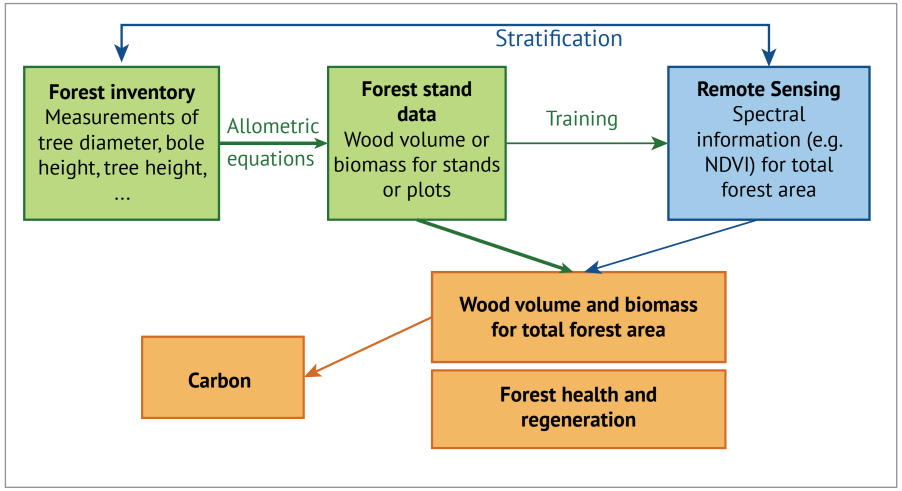


Figure 12 - The use of forest inventories and remote sensing data to determine wood volume, biomass and regeneration in a forest

A set of allometric models to calculate the total wood volume and above-ground biomass have been developed for the main timber trees of Namibia through the NFFP, and through university research (Verlinden and Laamanen 2006, Moses 2013, Nott 2018, De Cauwer *et al.* 2020). Of those, the best performing model to estimate the total wood volume of kiaat was that of De Cauwer *et al*. (2020) with 22% relative error, followed by the NFFP model with 30% relative error (De Cauwer *et al.* 2020). Ideally, quality control should be performed for all other NFFP models.

For some of the other trees equations of neighbouring countries can be used (Tietema 1993, Abbot *et al.* 1997, Hofstad 2005, Smit 2014). A generic volume model developed for Tanzania (Mauya *et al.* 2014) and a generic biomass model developed for Zambia (Ngoma *et al.* 2018) also appear to work well for some of Namibia's tree species (De Cauwer *et al.* 2020). However, the pantropical models for aboveground biomass of Chave *et al.* (2014) can perform as well as many local and regional models if accurate height and wood density data are used. The models have the advantage that they are calibrated with a large number of sample trees. Hence, the collection of more accurate height and wood density data in Namibia, rather than the development of new models, is advised (De Cauwer *et al.* 2020).

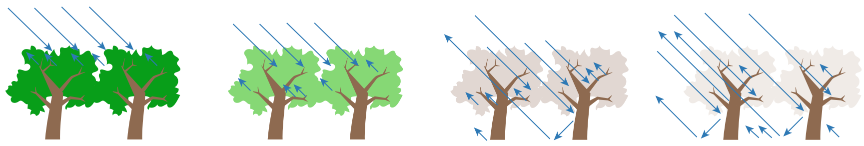
3.1.3 USE OF REMOTE SENSING

An important prerequisite for regional and national forest monitoring is the availability of a consistent remote sensing database (De Cauwer, Knox, *et al.* 2018). Remote sensing data allow the preparing of efficient forest inventories, especially by creating strata for a stratified sampling design. Strata represent forest areas with similar properties, for example, a vegetation type or forest cover. Afterwards, remote sensing data assist in upscaling the forest inventory data to the total forest area monitored. Hence, most university curricula for foresters will include GIS and remote sensing courses.

Before the seventies aerial photos were the only type of remote sensing data available. Over the recent decades a wide range of remote sensing data that is suitable for forest monitoring, especially low to medium resolution multispectral satellite data, has become freely available. The most commonly used data were acquired by the AVHRR (Advanced Very-High-Resolution Radiometer), Landsat, and MODIS (Moderate Resolution Imaging Spectroradiometer) sensors of NASA (National Aeronautics and Space Administration, United States), the Sentinel satellites of the European Space Agency (ESA), and SPOT satellites of the French Space Agency (CNES). These satellite sensors all acquire optical data, also called passive data, because they measure the energy of sunlight reflected from a surface. Examples of forest studies in Namibia using such imagery include the detection of forest cover change (Erkkilä and Löfman 1999, Wingate *et al.* 2016, Kamwi *et al.* 2018), monitoring net primary or biomass production (Palmer *et al.* 2016), and the modelling of forest cover, stand density, biomass, or stand volume (Verlinden and Laamanen 2006, Kamwi and Kätsch 2009, De Cauwer *et al.* 2017). All these studies rely largely on vegetation indices derived from the satellite data, especially the normalised difference vegetation index (NDVI).

However, forest cover estimated with traditional optical remote sensing methods tends to underestimate the surface covered by dry tropical forests (Naidoo *et al.* 2016, Bastin *et al.* 2017). The open and deciduous forest canopy cover makes it difficult to distinguish shrubs from trees with optical satellite data; this is further complicated by fires and highly variable annual rainfall, resulting in non-consistent NDVI time series for Namibia. Other promising methods have been explored, such as object-based classification (Muhoko *et al.* 2020), phenology and biodiversity descriptors derived from long-term MODIS or AVHRR time series (Revermann *et al.* 2016, Thompson 2021), or by active remote sensing as was done for the BIS (Mathieu *et al.* 2018). Active remote sensing sensors actively emit radiation directed toward a target and measure the reflectance from the target, such as radar (radio detection and ranging) and LiDAR (Light Detection and Ranging) scanners. Synthetic Aperture Radar (SAR) penetrates vegetation canopies to varying degrees, allowing a better accuracy and measurement of physical attributes such as biomass or canopy height (Figure 13).

Lately, Unmanned Aerial Vehicles (UAVs), or drones, have been introduced in forest monitoring, also in Namibia (Knox *et al.* 2018, Morgan *et al.* 2020).



Sensitivity of SAR measurements to forest structure and penetration into the canopy at different wavelengths used for airborne or spacebonre remote sensing pbservations of the land surface. Credit NASA SAR Handbook.

Figure 13 – Sensitivity of SAR measurements to forest structure at different wavelengths (Flores-Anderson *et al.* 2019)

3.1.4 PERMANENT SAMPLE PLOTS

The most common method for monitoring and understanding tree population dynamics and ecosystem functioning is through the establishment of permanent sample plots (PSPs) (Picard *et al.* 2010, SEOSAW partnership 2021). PSPs are large sample plots, often 1 ha or larger, that are repeatedly measured over a long period. Early warning signs of climate change (see 1.4.5) can be detected by forest researchers who monitor tree regeneration and mortality in PSPs.

Tree population dynamics are described mainly by determining tree diameter distribution, diameter growth, regeneration, and mortality, as well as the variables that influence them such as competition, soil, and climate (Namaalwa *et al.* 2007, Seifert *et al.* 2014). Additionally, it is necessary to monitor tree health and damage to get an insight into the potential drivers of mortality. Consequently, a range of plot and tree variables needs to be collected in PSPs, requiring much manpower and time to establish and measure.

There are few PSPs in Namibia where quantitative measurements are done. The Namibia University of Science and Technology (NUST) established three plots in 2006 covering a total of 2.5 ha. Two plots are situated at the forestry research station of Hamoye (Kavango East), one within a fenced area and one outside, and a third plot is at the research station of Kanovlei (Otjozondjupa Region) (De Cauwer 2006). The first complete remeasurements started in 2021 (Figure 14). The sample plots used for the regional inventories and the inventory of Okongo CF were regarded as PSPs and marked in the field with aluminium poles (Angombe *et al.* 2000, Selanniemi *et al.* 2000). To the author's knowledge, the plots have not been revisited and many of the poles may have been lost by now. The oldest PSPs known in Namibia were established before Independence as part of fire trials, of which no results have been published since the study of Geldenhuys (1977). The establishment of 20 PSPs for Namibia's woodlands is planned for 2023 as part of the SECO[1] project (https://blogs.ed.ac.uk/seco-project/).

Since 2001 there are also biodiversity observatories established in Namibia for the BIOdiversity Monitoring Transect Analysis in Africa (BIOTA) Southern Africa project, as part of an observation network extending from the Cape Peninsula in South Africa to the Kavango regions. The observatories are 1 km^2 in size and aim at the long-term monitoring of vegetation. Some of these observatories are situated within the forest, for example, the Mile 46 observatory at the Livestock Development Centre (LDC) in the Kavango West Region (Strohbach and Petersen 2007). Vegetation surveys do not, however, collect the quantitative measurements needed for forest management.

1 SECO is not an acronym but means 'dry' in Spanish.

Figure 14 - Left: Tagging of trees at approximately 1.5 m tree height. Right: Assessing the cause of tree mortality (Photos: V. De Cauwer)

3.1.5 TREE GROWTH AND DENDROCHRONOLOGY

Next to the long-term monitoring of tree diameter in PSPs (see 3.1.4), tree growth can also be determined by tree ring analysis or dendrochronology. This is possible if trees have annual tree rings, as is the case in climates where there is a seasonal growth interruption because of cold temperatures or a lack of rainfall. Although many tropical trees do not have annual growth rings, trees in areas with distinct dry and wet seasons do, as in Namibia. This was proven through radiocarbon dating for several Namibian hardwood species (Worbes n.d.) and through cambial wounding for kiaat (De Cauwer *et al.* 2017).

Tree ring analysis allowed determining that the mean stem diameter growth of kiaat is 5.5 mm per year in northern Namibia and southern Angola. This is relatively high compared to the growth of the species in other parts of southern Africa (De Cauwer 2016). Taking into account that kiaat seedlings go through a long dying off–resprouting phase (Kayofa 2015), it takes about 80 years to reach a stem DBH of 40 cm (De Cauwer 2016).

Most trees do not grow at a constant rate; they grow more slowly as they get older. Hence tree-ring chronologies get detrended to compare growth between different sites and for a better comparison with climate data (Worbes 2002). The growth of kiaat appears however almost constant up to a DBH of 60 cm, a tree size that is now becoming difficult to find (De Cauwer 2016). We do not know the maximum age of a mature kiaat tree, except that it is at least 150 years (Fichtler *et al.* 2004, Worbes n.d.).

Tree ring analysis has shown that the Namibian Zambezi teak has a mean stem growth rate of 0.39 cm per year, similar to *B. africana* (Van Holsbeeck *et al.* 2016). This means that Zambezi teak is approximately 100 years old when it reaches the minimum harvestable DBH of 40 cm (De Cauwer 2020).

Figure 15 - Increment borings allow to determine the number of tree rings. (Photo: V. De Cauwer)

3.2 FOREST MANAGEMENT

At Independence, the dry woodlands were not under any systematic forest management, other than the exploitation of kiaat, Zambezi teak, and false mopane. A renewed focus on forest management came after Namibia's Independence when a dedicated Directorate was created. This was soon followed by new forest policies and plans (Ministry of Agriculture, Water and Forestry 2011). Since 2006 attempts have been made to introduce SFM in the CFs based on forest management plans. However, while policies and

CF declarations support SFM, the actual forest management and control of forest operations have been neglected over the past decade, both at a national level and on the ground.

3.2.1 FOREST MANAGEMENT PLANS IN NAMIBIA

Forest management plans are a requirement for all protected forests in Namibia and aim to support SFM. According to the Forest Act and Regulations, the forest management plans are 'an agreement between the Minister and a management body which contains all operational work and administration' of a protected forest. The management plan needs to state the management objectives and include a description of the area covered by the classified forest and the forest resources it contains. Subject to the management plan, the Director of Forestry determines the maximum quantity of forest produce which may be harvested in the protected forest; the 'allowable harvest'. The allowable harvests should be guided by the principles of SFM: not to deplete, but to maintain and improve the resource base (NACSO 2022).

However, there are no detailed guidelines on what information the management plan should give so that the maximum allowable harvest can be determined by the Directorate of Forestry, nor do the Forest Act and Regulations indicate the minimum and maximum period the management plan should cover. Management plans should be revised after each repeated forest inventory (see 3.1.1) as sustainable yield will have changed.

3.2.2 SUSTAINABLE TIMBER HARVEST

Many consider timber harvesting to be the same as deforestation. This is not correct when SFM practices are followed. Sustainable timber harvesting aims to harvest a specific number of trees of specific sizes in a forest stand so that those trees can easily be replaced by regeneration and the growth of smaller trees before the next harvest (De Cauwer 2020). This should ensure a constant supply of wood resources with future timber yields unaffected or improved. The amount that can be sustainably harvested over a period is referred to as sustainable yield, Total Allowable Offtake (TAO), allowable cut, or allowable harvest. To determine the sustainable yield, it is necessary to know the amount of timber available, the growth rate of timber trees, the tree regeneration rate, and the tree mortality caused by disturbances (De Cauwer 2020). Unfortunately, little is known about the sustainable harvest rates, tree mortality, or tree regeneration in Namibia (Graz and von Gadow 2005).

There are several ways to regulate sustainable timber yield for natural forests. The easiest way is to remove trees of a minimum stem diameter, the minimum harvestable diameter. This method is often used in Namibia; a DBH of 40 cm is the minimum harvestable diameter of timber trees according to the harvesting licence conditions of the Forest Regulations. The minimum harvestable diameter method assumes that sparing medium and small diameter tree classes will ensure a sufficient supply of timber in the future. This method is cost-efficient only if there are enough trees that have the minimum harvestable diameter (Lamprecht 1989). Moreover, it will be sustainable only if the minimum harvestable diameter is large enough, if tree mortality is low in all diameter classes, and if there is good regeneration.

Another method is to determine harvest rates for diameter classes. This method is often used in Namibia for what are called 'poles', trees with DBH between 15 cm and 30 cm, creating a loophole for overharvesting young trees in the forest. Ideally, sustainable timber yield should be based on tree populations (Graz and von Gadow 2005).

Sustainable timber harvest also entails harvesting timber with minimum waste, using as many parts of the harvested tree as possible. For example, the saw log is often the only part used of commercially felled kiaat trees (Moses 2013), while the larger branches have many potential uses. Local communities often use non-mechanised tools, and to minimise the effort they saw the log at about one metre or higher above the ground. Mechanised saws assist, for example, in cutting logs closer to the ground.

As stated by the Directorate of Forestry (Ministry of Agriculture, Water and Forestry 2011), 'with no tradition for active stand management, Namibia's woodlands have suffered what is typically described as the "tragedy of the commons". Essentially common ownership and unregulated access without proper recognised rights of local people, has inadvertently fuelled a tendency to "mine out" available merchantable timber with no due regard or responsibility regarding regeneration for future harvesting products.'

3.2.3 COMMUNITY FOREST MANAGEMENT

Although CF members can use wood and non-wood products for subsistence and commercial purposes, this is subject to the applicable management plan. Ideally, the management plan should indicate sustainable yields for all the natural resources that are harvested. In practice, harvest levels for the first CFs were set through block permits issued by the Directorate of Forestry. The block permit is an official document that allows the communities to harvest certain timber species. It was introduced because forest inventory and management plans were not finalised by the time of gazetting, and to obtain community support for the CFs. Communities started to ask for new block permits when the old ones expired. However, neither the Forestry Act nor the Community Forest Guidelines of 2005 describe this system (Schusser 2012).

Management plans are valid for a certain duration; the length of this period is not indicated in the Forest Act but appears to be 5 to 10 years (NACSO 2022). Many CF management plans are currently outdated and no longer applicable, as required by the Forest Act. When no management plan is applicable, persons who reside in a CF can harvest forest produce for household uses and do not have to stick to a management plan.

The quality of forest management plans is a major concern. Forest Management Committee (FMC) and Directorate of Forestry staff members concede that in many cases forest management plans are either absent or incomplete (Benkenstein *et al.* 2014). Their format varies greatly and often the forest inventory report is used as a management plan. Estimates of allowable TAOs are either not specified or, if indicated, it is not clear whether standardised processes have been used to calculate the allowable harvest levels of timber (Nott *et al.* 2019).

The use of permits ensures that much of the decision-making on the use of forestry resources remains with the Directorate of Forestry rather than the relevant FMC. For example, commercial harvesters who have been issued a permit by FMCs to harvest in CFs are still required to secure transport and marketing permits from the Directorate of Forestry (Benkenstein *et al.* 2014).

Many NTFPs (see 2.3) have an economic and local subsistence value, and grazing also needs to be included in the inventory and management plan to allow sustainable utilisation. For example, the FMC can issue forest-use permits for grazing (Benkenstein *et al.* 2014, FAO 2020); however, overgrazing should be prevented to avoid land degradation and bush encroachment. With the commercialisation of products such as marula and sour plum (*Ximenia* spp.) oils, growth and yield of various products could help in resource management plans and yield predictions (Ministry of Agriculture, Water and Forestry 2011).

CFs still face many challenges. Overlapping mandates in the management or use of forest areas can result in conflicting land uses. For example, land within CFs has in the past been allocated for small-scale commercial

livestock farming, promoted by the Ministry of Lands and Resettlement, or crop growing with the permission of the traditional authorities (Jones and Barnes 2009).

Another problem is that most FMCs lack the incentives and technical skills to develop or implement forest management plans or to meet elementary requirements on reporting, accounting, and forest monitoring, for which they need external support (Ministry of Agriculture, Water and Forestry 2011, KFW 2013, Benkenstein *et al.* 2014). Moreover, the CF area to be managed is often so large that there are insufficient resources for monitoring, even for well-organised forestry committees. The Directorate of Forestry is understaffed and hardly in a position to offer effective support to the FMCs (KFW 2013). Self-financing of the FMCs out of CF revenues often seems unfeasible; small CFs especially do not provide an adequate economic basis (KFW 2013).

The CFs appear often to have become a tool for harvesting more trees, rather than harvesting sustainably and protecting the forest resources, the capital. Stronger partnerships between CFs and conservancies appear to be one way in which their viability may be enhanced (Benkenstein *et al.* 2014).

3.2.4 MONITORING OF HARVEST

The Forest Act states that no one can clear more than 15 ha of wooded land or cut more than 500 m^3 of forest produce from any piece of land in one year without the approval of the Directorate of Forestry. It also states that no forest produce can be harvested in protected forests unless authorised by the management plan or a licence if not for household use. The Directorate of Forestry uses permits as tools to control tree harvesting and transport. After the Forest Regulations of 2015 were published, new permit books were printed in 2016 and issued to the regional offices. The system is however lacking a system for report-back on the permits issued. There is also a need for all permit data to be collated and summarised in a format that can be easily shared and used to inform management decisions (Nott *et al.* 2019).

The harvesting licences indicate several conditions to ensure SFM, such as, where two or more stems grow from the ground, no more than half of the stems may be felled. Harvested timber logs must be marked by a forest officer, using a special hammer, before they are transported from the place of harvesting.

In 2015 Namibia gazetted new forest regulations and in 2016 the new permit books were printed and issued to the regional offices. However, according to Minister Shifeta, monitoring of harvesting and enforcement on the ground has been minimal due to limited manpower at the Directorate of Forestry and because timber operations are often undertaken at night. Control of transport is difficult to implement due to the high volumes of trucks and timber and the variety of routes taken. Trucks should be weighed at the weighbridges, while timber harvesting needs to be restricted and carried out during the day (Shinovene 2019).

Fines for noncompliance with regulations are however no deterrent; they cannot exceed N$ 5000 and there is no discrimination based on the size of the tree harvested (Mannheimer and Curtis 2018). For the financial year 2017/2018 the Directorate of Forestry reported that 22 fines were issued to those who contravened the laws and regulations. Many forest products were confiscated, notably 39,575 tonnes of charcoal, 11,945 tonnes of firewood, 91,229 droppers, 22,895 poles, 175 tonnes of mopane roots, and 469 wood carvings (Ministry of Environment and Tourism 2018).

3.2.5 CERTIFICATION

Forest certification is a tool to promote SFM. The certificate informs buyers of forest produce that the product was produced in a socially beneficial, economically viable, and environmentally responsible way. Certification of forest produce, specifying conditions of production and harvesting, is done voluntarily by companies in Namibia. The Forest Act Regulations indicate that any company accredited by the Forest Stewardship Council (FSC) may certify forest produce to be traded within or outside Namibia. Most of the certifier assessments are done by South African experts.

The FSC certification is used mainly by the charcoal industry and is demand-driven; 1.6 million ha of Namibian wood- and shrublands were under FSC certification by June 2020. Namibia is the first country in Africa that has obtained an FSC group chain of custody certificate. The FSC group certificate holders have also included NTFPs, such as venison, into their scope of forest management certification (FSC 2020). FSC labelling is not yet done for timber and poles.

3.2.6 FIRE CONTROL

Fire management of protected forests and areas is a responsibility of both the Directorate of Forestry and the Directorate of Wildlife and National

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Parks, although this is often shared with regional governments, communal forest managers and other stakeholders. Fire management includes both fire prevention and firefighting. Fire prevention is done mainly by reducing the fuel load through the establishment of fire breaks or, sometimes, the application of early burning. Fire breaks are referred to as fire cutlines in the Forest Regulations and should have a minimum width of 15 m. Maintenance of the fire breaks is mainly outsourced to the communities. In the period 2016 to 2017 communities constructed 2,011 km of firebreaks in fire-prone areas of the Oshana, Omusati, Kunene, Otjozondjupa, Omaheke, Ohangwena, Kavango East, Kavango West, and Zambezi regions. This created jobs for 961 people (70 women and 891 men) at a cost of N$3,458,060 (Republic of Namibia 2017).

Although the Directorate of Forestry rarely uses early burning, it has been applied by the Ministry of Environment and Tourism in Bwabwata National Park. Fire management in the National Park was dominated by fire exclusion; however, this resulted in uncontrolled wildfires (Figure 16). In 2007, Bwabwata National Park started an integrated controlled burning programme in the Zambezi Region that included early burning (Ministry of Environment and Tourism 2016).

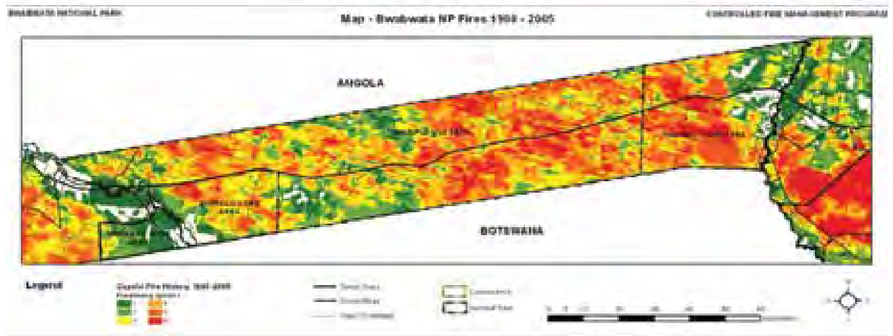

Figure 16 – Fire history of Bwabwata National Park in the period 1998 – 2005 (Ministry of Environment and Tourism 2016)

Firefighting is increasingly resource-intensive, as the number of active fires shows a rising trend and poses an ever-greater threat to the expanding population (Pricope and Binford 2012). Resources are often lacking to maintain the fire breaks or extinguish fires, making early fire alert systems such as the Advanced Fire Information System (AFIS) (http://afis.meraka.org.za) futile. An alternative to manual clearance of fire breaks could be controlled grazing. The scale, complexity, and urgency of the situation has encouraged the ministry to establish a Fire Management Strategy for Namibia's Protected Areas in close consultation with stakeholders (Ministry of Environment and Tourism 2016). It would be good if this strategy were expanded to the forest areas, especially now that the DoF is part of the MEFT.

The Forest Act has several provisions regarding the management of fire. In areas adjoining or close to a classified forest the minister may declare a fire management area and appoint a fire management committee that should draw up a fire management plan for the area. In terms of the Act it is an offence to light a fire in a CF unless the fire has been authorised by the management authority and is in accordance with the management plan for the CF (Jones and Barnes 2009). In reality, most fires start during the clearing of the fields adjacent to community forests and run out of control. The author knows of no cases where fire management is undertaken by communities.

3.3 SILVICULTURE IN NAMIBIA

Silviculture is the practice of tending a forest or woodland for specific purposes, for example, timber, charcoal, bark, or pole production, and includes interventions such as thinning, planting, pruning, and the use of rotations (De Cauwer, Knox, *et al.* 2018). The distinction between forestry and silviculture is that silviculture is applied at the stand-level, while forestry is a broader concept. Forest areas are divided into spatial units that form the basic entities for management, referred to as stands or blocks. Adaptive management is common in silviculture, while forestry can include natural land without stand-level management and treatments being applied.

Many silvicultural methods depend on the manipulation of the forest canopy to create conditions favouring the survival and growth of desirable trees. The structure of the canopy controls the quantity and quality of light, the local precipitation, and air movement in the forest; these affect, for example, air temperature and soil moisture (Jennings *et al.* 1999).

The first step toward introducing silviculture in previously unmanaged forests is domestication. Domestication includes all measures for improving the economic performance of stands at least to a level that can ensure that the costs of management for sustained yield are covered. It involves a restructuring of the original growing stock so that the domesticated stands are more botanically and structurally homogenous. This will ensure larger supplies of timber of higher quality in the desired size classes. This does not

mean that non-marketable species should be eradicated; they need to be retained to maintain biodiversity, the supply of NTFPs, and maintain forest stability (Lamprecht 1989).

3.3.1 APPLICATION OF SILVICULTURE IN NAMIBIA

There are virtually no silvicultural guidelines for forest management at stand level; in particular, interventions and regulations to aid the natural regeneration of key species are lacking (Ministry of Agriculture, Water and Forestry 2011). This will be further discussed in the following sections. Hence, woodland management in Namibia is restricted to the bare extraction of resources and can thus rather be compared to a mining operation where no actions are taken to invest in future resources (Lamprecht 1989, Dewees *et al.* 2011). The decreasing forest area and the increasing urbanisation may change attitudes and approaches in the future. A study in the mopane woodlands of Namibia and Zimbabwe showed that communities living in well-wooded areas were less interested in managing woodlands than those in areas where woodland resources were less abundant (Musvoto *et al.* 2007).

3.3.2 NURSERIES

There are tree nurseries at many of the Directorate of Forestry's regional offices, Hamoye Research Station, and the National Forestry Research Centre (NFRC) in Okahandja. The NFRC houses a Tree Seed Centre with cold storage facilities and a laboratory that is among others used for seed testing. Hamoye has high mortality among seedlings because of frost conditions (Ministry of Agriculture, Water and Forestry 2011).

Many species in private nurseries and the Directorate of Forestry are however non-indigenous and consequently should be avoided for afforestation. Tree growing of drought-resistant, indigenous species needs to be promoted on a national scale. The harvesting of wood or fruits of indigenous tree species cannot continue sustainably if the future of the species' populations is not ensured (De Cauwer, Chaka, *et al.* 2018). A first step would be to raise greater public awareness on which tree species are indigenous and most suitable for the different regions of Namibia. Another way to achieve this would be to create tree nurseries at the community level as a way of generating a regular income (Hilfiker 2011).

Genetically improved seedlings need to be cultivated. These are seedlings resulting from a strict selection process for specific traits, such as growth rate, fruit production, stem length, and shape (De Cauwer 2020). Some work has been done for marula, with the identification of 'ideotypes' based on fruit size, kernel versus flesh proportion, and dry matter contents (Leakey *et al.* 2002).

More documented nursery experiments are needed with indigenous species, which are often difficult to cultivate, with problems arising at several stages (De Cauwer, Chaka, *et al.* 2018). Seed germination experiments have been done by the Directorate of Forestry and researchers (Moses 2012, Vander Heyden 2014, De Cauwer and Younan 2015, Heita 2015), but this has to be expanded to more tree species and include seedling survival and protection, while more results need to be published in popular literature. Another problem is that many tree species of the Zambezian Baikiaea woodlands, such as kiaat, develop deep taproots during the seedling phase, which makes it difficult to transplant the species.

3.3.3 TREE PLANTING

Tree planting in Namibia is mainly limited to orchards with exotic fruit trees or planting of a few trees on special occasions, such as Arbor Day. A total of 438 ha of orchards, mainly of mango, citrus, guava, and paw-paw, and woodlots are maintained by the DoF (Republic of Namibia 2017). There is no afforestation; the term used for planting of trees in forest areas. This is reflected in the reports of Namibia to the FAO (FAO 2015) and a global forest assessment with high-resolution satellite data (Hansen *et al.* 2013). A common view is that the Namibian forest is non-exhaustive and does not need assistance to regenerate. However, natural forest regeneration is slow and erratic for most species (see 1.4.1). Many seedlings die because of drought, browsing, or fires in the late dry season, and in most years and especially during long drought periods conditions are not good enough for seedlings to reach the sapling stage. In contrast, the harvesting of timber and NTFPs often increases during periods of drought when there is limited food and income. Moreover, timber harvest targets the best timber trees which results in the removal of the best genetic material of the forest. The most desirable mother trees will get less chance to propagate, and this human selection results in a degradation of timber quality of the remaining trees. Active intervention is needed to support the regeneration of seedlings with superior timber qualities.

Forest regeneration is also slow on abandoned fallows, which consist mainly of shrubs and resprouting trees. A study in northern Namibia showed that the tree seed density in the soil seed bank of fallows was low (0.04 seeds

per m^2) with low species diversity (Hilukwa 2018). Reforestation projects in northern Namibia cannot rely on a quick natural restoration of the forest, especially when no tree-root systems remain that allow coppice growth (De Cauwer, Chaka, *et al.* 2018).

The Directorate of Forestry encourages the establishment of community-based orchards, for which they received support from donor organisations, such as the Community Forestry in Namibia project of the German Ministry for Economic Cooperation and Development (BMZ). By 2011, 151 out of 207 established orchards were still being successfully operated (KFW 2013). However, communities are struggling to manage the orchards properly. Among the reasons for this are high investment costs, reluctance in maintaining orchards by the community, and weak management skills, including benefit-sharing mechanisms. Hence, planting may be more successful if done by individuals who take ownership of the planted trees and nurture them. Planting near homesteads is advised, as well as the promotion of agroforestry and public-private partnerships (Ratnam *et al.* 2020).

If afforestation projects are planned in the future, they will be affected by the low number of indigenous tree seedlings available at government and private nurseries, while most available tree species are non-indigenous. When planting a forest, it is necessary to plant at least five times the number of trees that will be required in a mature forest. Natural selection will make sure that the strongest and fastest growing individuals will survive. The lack of indigenous tree seedlings in nurseries is one of the reasons why assisted natural regeneration may be more successful.

3.3.4 ASSISTED NATURAL REGENERATION

Assisted natural regeneration refers to low-cost methods that can be applied to natural forest stands to enhance natural regeneration, especially through the reduction of barriers to tree regeneration and preferably by involving local people (Ganz *et al.* 2003, Shono *et al.* 2007). It is a less expensive technique for landscape restoration (Ministry of Agriculture, Water and Forestry 2011), but is rarely used in Namibia. Techniques to assist natural regeneration include exclusion of grazing, controlling of fire (including patch burning), the use of pioneer shrubs as nurse plants, the removal of plant competition, and enrichment planting (Ganz *et al.* 2003, Aerts *et al.* 2007, Chazdon and Guariguata 2016). Few experiments have been undertaken in Namibia, although they offer exciting research possibilities with direct applications for Namibia's forests.

Enrichment planting of nursery seedlings in Kanovlei State Forest in the Otjozondjupa Region was compared with direct seeding for kiaat, Zambezi teak, and false mopane in several seasons. Regeneration from seeds covered with a layer of soil was much better compared to that of broadcast seeds and planted nursery seedlings. After one year, the seedling survival rate from seeds covered with a layer of soil was 11%, while that from noncovered seeds was only 1.3%. No plants survived of a late rainy-season direct seeding and planting of seedlings. All planted seedlings were destroyed by small mammals within six weeks unless protected by individual sleeves (Chaka 2019).

The effect of browsing, plant competition, and fire on the natural regeneration of woody species was studied in Onkumbula CF in northern Namibia. Browsing protection did not affect seedling density, species richness, or seedling survival, but it improved the growth of seedlings both in height and diameter after one year. Plant competition removal did not have any significant effects within that period. The effect of fire on woody species regeneration was observed five months after a fire by comparison with neighbouring forest areas unaffected by the fire. While burning favoured germination of seeds, shoot production, and species diversity of the regeneration, it had a strongly negative effect on tree sapling survival (Amutenya 2020).

3.3.5 TISSUE CULTURE AND GRAFTING

Tissue culture is a vegetative means of *in vitro* propagation from small plant parts. It entails a systematic procedure for the establishment and multiplication of shoots from plant material, root formation, and seedling acclimatisation under aseptic conditions. The technique allows the rapid production of high quality, disease-free, and fast-growing plants; it is, however, not easily implemented. Very few experiments have been done with tissue culture on Namibian tree species, although a laboratory was built for this purpose at the NFRC in Okahandja.

One study evaluated the technique for Namibian kiaat and monkey orange. The results show that germination of the species using tissue cultures is more successful and faster in comparison to seedling cultivation. Up to seven plantlets could be produced with tissue culture methods within seven days, while traditional nursery methods produced only two and seven seedlings from kiaat and monkey orange, respectively, after 30 days. The study developed a tissue culture protocol for both species (Heita 2017). *In vitro* ensures rapid multiplication of plant production material on a defined solid or liquid medium under aseptic conditions. Through tissue culture, plants can be regenerated from small parts, such as cells and tissues.

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Grafting is another way of vegetatively propagating plants with desired tree attributes and thus superior genetic quality, for example fruit trees that produce larger than average quantities of fruit. In 2009 and 2010 GTZ organised training in marula grafting for members of the Eudafano Women's Cooperative and 14 Directorate of Forestry staff of the North-West Forestry Region, including 10 nursery staff from Ongwediva. Scions from 21 recorded superior mother trees were collected and 187 marulas grafted. Of these, 48 marulas had survived by March 2010 (corresponding to a survival rate of 25.7%) (Hilfiker 2011).

3.3.6 THINNING

Thinning is often done in tree plantations to avoid competition among trees. However, thinning can also be done to liberate the best trees for the production of high-quality timber (Lamprecht 1989). These improvement thinnings remove tree competition around the most promising timber trees so that there are no competing neighbours within a circle with a radius of at least 7 m. Shrubs and much smaller trees are not considered as competition; rather, they can assist in keeping the stem of the timber tree branch-free. Thinnings allow intermediate wood harvests which, although of low-quality timber, can be used for wood carving, droppers, poles, or firewood.

Thinning has little impact on tree height in mopane woodland but can result in the redistribution of basal area increment among fewer stems. Although reducing the total production per hectare, thinning results in faster achievement of the desired pole sizes and speeds up vegetative growth and seed-bearing for the remaining trees (Musvoto *et al.* 2007).

In western Omusati only 20% of households were interested in thinning and coppicing, with the majority perceiving woodlands as being managed by nature. Men ranked thinning higher than women and children as the technique was perceived as having a high likelihood of improving the supply of thick poles (Musvoto *et al.* 2007).

3.3.7 PRUNING

Trees in open forests often develop strong branches, which negatively affect the timber quality. Pruning aims systematically to remove those branches, dead and alive, during tree development to obtain a longer branch-free bole.

The bole is the main stem of the tree and the part that is commercially the most useful for timber.

Only trees with the desired timber characteristics should be pruned. Pruning saws rather than hatchets or machetes are advised as the wounds heal better when cuts are smooth. For species with a pagoda-type crown, such as *Terminalia* sp., at least two 'storeys' should be left. Many *Eucalyptus* species do not need pruning, although *E. camaldulensis* does (Lamprecht 1989). No examples of pruning in Namibian woodlands and forest stands were known to the authors, although it would be highly beneficial for kiaat (Figure 17).

Figure 17 – Kiaat (*Pterocarpus angolensis*) with undesired bole qualities. The stem would have been straighter if the side branch had been removed when the tree was younger (Photo: V. De Cauwer).

3.3.8 COPPICING

Coppice is woody vegetation that has regrown from stump sprouts, shoots, and root suckers, mainly after the harvest of the original trees. Coppice is used as a forest management system to produce fuel, pulp, or other low-quality wood. In the dry tropics, such as in Namibia, it can be a natural evolution of the vegetation when harvesting and browsing pressure is high. Some species coppice much more easily than others, for example, mopane coppices readily.

Coppice management is easy and well adapted to the situation in the dry tropics. According to Von Breitenbach (1965, in Cunningham and Detering 2017) mopane coppices so vigorously that an entirely cleared area regenerates fully to a dense forest within 15 years, while regeneration from seed to a pre-cleared state could take up to 40 years. Active coppice management is rarely done in Namibia but has a lot of promise. In central Omusati, where tree harvesting is intense and woodland resources relatively scarce, 40% of households expressed interest in using coppicing in mopane woodland given the opportunity, as this was perceived to result in more firewood (Musvoto *et al.* 2007).

3.4 SUSTAINABLE FOREST MANAGEMENT VALUE CHAINS

3.4.1 EXISTING VALUE CHAINS IN NAMIBIA

Currently, only registered CFs are allocated an annual TAO for the harvesting of timber. These amounts are low for CFs with only a small portion of forest or where major timber species are not well represented. Small TAOs are not always used because they are not economically viable for commercial logging. The areas with the highest percentage of kiaat are CFs in eastern Ohangwena, western Kavango, Okongo, and Katope. It is especially in these areas that harvesting is still taking place. For example, the TAO for kiaat in Katope CF is 720 trees per year and in Okongo CF 916 trees per year. The TAOs for Zambezi teak are larger with 7,727 trees in Okongo CF and 2,654 in Katope CF (Nott *et al.* 2019).

Droppers are produced for own use or informal sale (see 2.2.2), although one building warehouse sells raw fence droppers produced in Namibia, without guarantee, at its Windhoek branch as part of a low-cost housing project (Rothauge 2014).

CFs have proven to have less revenue potential than conservancies, which generate funds primarily through tourism and hunting (Schusser 2012, Benkenstein *et al.* 2014). CF revenue depends to a large extent on available resources and social dynamics. While more densely wooded areas have a higher revenue potential for firewood, the availability of other NTFPs can provide local communities with a more important source of income. In certain CFs, harvesting of the devil's claw plant (*Harpagophytum procumbens*) contributes significantly to local incomes, as there is a high demand for this product from international pharmaceutical companies (Benkenstein *et al.* 2014). It is one of the first NTFPs that was commercialised and its export earnings are estimated to be in the region of N$ 20 to 30 million per annum (Cole 2014).

Seed oils derived from marula and sour plum (*Ximenia* spp.) have functional supply chains in Namibia as well as recognised market demand. Namibian indigenous lipid oils are commonly marketed in international markets as cosmetic ingredients but can be used for other purposes as well. Marula oil, in particular, is popularly used as a condiment in food, and is sold in both traditional and more formalised national markets in Namibia. Sour plum oil has attracted keen interest from the international market, mainly due to its anti-ageing properties (Cole 2014).

Mopane seeds are harvested, and steam distilled at the Opuwo Processing Facility to extract the essential oil. The resource is abundant and the technology for extraction is locally available. The challenge is to develop the market (Cole 2014).

Mopane worms sometimes provide an important cash injection to CF members in the mopane woodlands. This income is however highly variable, as the supply of mopane worms depends on rainfall. Despite distinct processing methods to increase storage characteristics, products usually perish within half a year.

Currently, the socio-economic benefits of most CFs lie primarily in their ability to enhance rural livelihoods by providing fuelwood, building materials, grazing, medicinal plants, and other resources (Benkenstein *et al.* 2014), especially during droughts.

3.4.2 POTENTIAL VALUE CHAINS FOR NAMIBIA

The Namibian government recognises that the full economic potential of natural products harvested within CFs is not reached. This is mainly because there are inadequate value-adding efforts for both wood and NTFPs. For example, most commercial timber harvested in Namibia is exported as raw or squared logs and planks. Treated poles mainly come from South Africa. More forest products could be brought to the market and contribute directly to rural development (Ministry of Agriculture, Water and Forestry 2011).

To create more value-addition to hardwood_within Namibia, more technologies need to be adopted that could lead to the utilisation of a broader range of species. For example, species such as red syringa can yield flooring or furniture if powerful, specialised equipment, such as stellated blades for sawing and carbide tools for machining, were to be used (Ministry of Agriculture, Water and Forestry 2011, ITTO 2015a).

Even more interesting technologies exist to make reconstituted wood products such as fibreboards, onto which high-quality veneer can be bonded to produce high-quality wood-based panels for both local and export markets (Ministry of Agriculture, Water and Forestry 2011). Several factors hamper the establishment of such a pressed wood industry. Probably the biggest problem is that no standards exist to enable the manufacturer to procure a steady supply of wood of desired and uniform quality. The quality of the wood supplied varies tremendously and the likelihood of procuring the wrong type of wood is a risk which the manufacturer would have to

take. Secondly, while Namibian hardwood yields coarse chips of acceptable quality, the resins in the wood result in an uneven consistency of the pressed wood product. Thirdly, the high sand and ash content adds an expensive pre-processing procedure. It is much easier and more economical to make chip- and press-wood products from softwood such as pine, grown uniformly under controlled conditions in huge plantations, than to struggle with a highly variable, unaccommodating indigenous resource. The De-Bushing Programme might assist in developing norms and supply chains that can feed these latent building materials industries with the assistance of the Namibian Standards Institution (NSI) (Rothauge 2014).

There is a huge demand for raw, farm-made droppers; however, large agricultural input suppliers do not buy them up for resale to customers. Poles are not treated against decay and termites and are not normed to any standard, which can expose input suppliers to claims for damages if they sell raw droppers (Rothauge 2014). Standardisation of droppers, rafters, and poles, and potential treatment, will help commercialisation.

A better-regulated wood market, with fair prices for wood, can increase the revenue collected through timber harvesting and provide greater incentive to protect the forest. The Forest Act Regulations indicate a price of only N$ 200 for protected commercial trees, although the ongoing revision of the Forest Act provides an opportunity to change this (De Cauwer 2020).

In conclusion, a lack of technical and pricing standards within the timber industry, barriers to technology transfer, and accessing markets, are the serious challenges that Namibia must overcome.

Indigenous Natural Products (INPs), including NTFPs, have the potential to contribute significantly to improving food security, alleviation of rural poverty, and conservation. Eight years ago it was estimated that the annual value of the contribution to Namibia's Gross Domestic Product of INPs was between 30 and 50 million Namibia dollars, with the potential to increase considerably (Cole 2014). It is for this reason that the Ministry of Agriculture, Water and Forestry supported the creation of the Indigenous Fruit Task Team (IFTT) in 2000, which evolved in 2003 into the Indigenous Plant Task Team (IPTT), a multi-stakeholder forum to develop a coordinated approach and strategy for the promotion of the commercialisation of INPs in Namibia. The Ministry of Agriculture, Water and Forestry has also established the Plant Product Development Section at the NBRI (Joseph S. Iita in Cole 2014). Because of the complexity of governance systems relating to INPs, the IPTT has adopted a 'pipeline approach' with flexible support to INP development, both for production and marketing.

Many challenges however remain to be overcome for the INP sector to realise its full potential. These challenges include aspects such as resource-based sustainability, management and technical capacity of producers, managing supply and demand, undertaking local research and development, attracting appropriate investment, and consolidating and increasing local and international markets (Joseph S. Iita in Cole 2014).

Promising NTFPs include honey, manketti nuts, and mopane worms. Honey collected from wild bees is a major source of cash income in the wetter miombo woodlands (Shackleton and Gumbo 2010), but less so in Namibia. It is one of the most promising NTFPs in north-eastern Namibia (Hilfiker 2011). Manketti oil could be produced in larger quantities, but the demand has been limited (Cole 2014). A pilot project in cooperation with a CF in mopane woodland and research institutions could assess opportunities for domestication, storage, and value addition of mopane worms.

4 MAIN STAKEHOLDERS OF SUSTAINABLE FOREST MANAGEMENT IN NAMIBIA

4.1 GOVERNMENT

A large proportion of Namibia's forests is vested in the state, including those in communal areas. As a consequence, a range of institutions is involved in the regulation and management of forests in communal areas (Table 2) (Jones and Barnes 2009). At the national level the Ministry of Finance plays an important role regarding the import and export of wood.

Table 2 – Authorities involved in regulating and managing forest resources on communal land (Adapted from Jones and Barnes, 2009).

Resource	Line ministry	Regional government	Traditional authority	Forest Management Committee
Land	MLR (control) is responsible for land-use planning. CLBs allocate title, registration, and leases	Development planning including land-use planning	Allocation of residential and grazing land, endorsement of leases, and establishment of CFs	Broad management rights over CFs within gazetted boundaries
Grazing	MAWL (advisory)	/	Allocates grazing	Authority over grazing
Forest	MEFT (control); DoF manages state forest reserves	Development planning including land-use planning	Management authority	Devolved authority

MLR = Ministry of Lands and Resettlement; CLB = Communal Land Board; MAWL = Ministry of Agriculture, Water and Land Reform; MEFT = Ministry of Environment, Forestry and Tourism; DoF = Directorate of Forestry.

The Directorate of Forestry was established as part of the Ministry of Environment and Tourism shortly after Independence to manage and develop Namibia's forest sector (Benkenstein *et al.* 2014). Later it became part of the Ministry of Agriculture, Water and Forestry. The Directorate's mandate was expanded in 2008 to include the entire country and to integrate newly established CFs into the overall programme (NACSO 2022). The National Botanical Research Institute (NBRI) was merged with the Directorate of Forestry at a later stage. In 2020 the Directorate of Forestry was incorporated into the Ministry of Environment, Forestry and Tourism. This decision allows Namibian plant resource management to be more closely integrated with the conservation of other natural resources (NACSO 2022).

The Directorate was created with two divisions, for management and research respectively, each led by a Deputy Director, and supported by regional and field offices (Ministry of Agriculture, Water and Forestry 2011). The Division Forest Management is responsible for (FAO 2020):

- the development of policy and legal framework,
- protection and management of classified forests,
- promotion of community and environmental forestry,
- provision of extension services,
- maintenance of an efficient sector-wide management information system.

It has four subdivisions representing regional offices of four forestry regions: North-West, Central, North-East, and South. The North-West Forestry Region (NWFR) is administrated through the Ongwediva regional Forestry Office. It covers the four forestry districts that coincide with the political regions: Oshana, Omusati, Ohangwena, and Oshikoto. Each forestry district is headed by a District Forest Officer, who is responsible for different forestry stations (Hilfiker 2011).

The Division Forestry Research is responsible for conducting forestry research and disseminating forestry research information (FAO 2020). It has two subdivisions, one for Research Programmes and Stations, and one for Forest Monitoring and Mapping. The Subdivision Research Programmes and Stations has its research headquarters in Okahandja, at the National Forestry Research Centre (NFRC), which dates back to 1902 (Erkkilä and Siiskonen 1992, Ministry of Agriculture, Water and Forestry 2011). The NFRC houses a Tree Seed Centre with cold storage facilities and a laboratory. The NFRC is headed by a Chief Forester, who also manages three field stations: Hamoye (Kavango), Kanovlei (Otjozondupa), and Ngoma (Zambezi). Ngoma Forestry Research Station was transferred to the Directorate of Forestry

in 2003 (Ministry of Agriculture, Water and Forestry 2011). Both Hamoye (Figure 18) and Kanovlei are situated next to state forests and near CFs. The subdivision maintains several field-based research trials. These trials are the Makambu and Kanovlei fire trials, a silver-cluster leaf coppicing trial, a trial with the exotic *Ziziphus mauritiana* (Chinese apple / Indian plum), a marula germplasm multiplication trial, and phenological studies of African custard apple (*Annona senegalensis*) (Ministry of Agriculture, Water and Forestry 2017).

Figure 18 - View of eastern border of Hamoye state forest (Photo: V. De Cauwer)

The second subdivision is that for Forest Monitoring and Mapping, which includes the National Remote Sensing Centre (NRSC) and the National Forestry Inventory (NFI) Department (Ministry of Agriculture, Water and Forestry 2011). The NRSC was established in 1995 to provide technical services to the Directorate of Forestry in particular, and other line ministries and the Namibian public in general. The NFI Department carries out forest resource assessments across Namibia (Government of Namibia n.d.).

The DoF struggles to fill all its positions with well-trained foresters. For example, there were 33 vacant positions for Forestry Technicians, as well as for Chief Foresters, Principal Foresters, and Chief Forest Technicians that could not be filled in 2015 (Republic of Namibia 2016). The total budget of the DoF was N$ 88 million for 2016/2017 (Republic of Namibia 2017), down from 160 million for 2014/2015 (Republic of Namibia 2016). The total research budget, excluding salaries, was N$ 7 million in the 2009/2010 financial year; no later data was found. Most of the research budget was for the maintenance of research facilities, construction, and the purchase of capital goods. However, a detailed overview of research expenditures is hindered by the use of one cost centre for the Directorate of Forestry (Ministry of Agriculture, Water and Forestry 2011).

4.2 COMMUNITIES AND COMMUNITY FORESTS

In northern Namibia the communities are the main forest users. Traditionally, they have had relatively unhindered non-commercial use rights regarding resources such as grazing, forest products, and fish. Some areas of forest have even been illegally fenced by wealthy individuals for their use (Jones and Barnes 2009). Community rights were expanded with the introduction of CFs through the Forest Act of 2001. Community forestry is a relatively new mode of participatory forest governance, giving local communities rights to manage forest resources owned by the state. It is based on the assumption that the buy-in of the community will provide an incentive to use forest resources sustainably to conserve forests, while improving the community's living standards (Schusser 2012).

Namibia is a pioneer in community-based natural resource management, with community management of wildlife starting before Independence in 1990 (Owen-Smith 2010). From the mid-1990s the new Namibian government adopted a strong policy of devolving use rights over renewable natural resources to local communities. This approach was first adopted in the wildlife and tourism sectors. A national policy on use rights over wildlife in communal conservancies was approved in 1995 (Jones and Barnes 2009) and the first communal conservancies were established in 1998. Community forestry is an extension of this Community-Based Natural Resource Management (CBNRM) Programme.

The Community Forestry programme makes the communities involved important stakeholders in SFM. The programme aims at supporting and empowering local communities through transferring rights to manage forest resources and benefit from related income and employment opportunities (Government of Namibia n.d.). Local people are encouraged to take responsibility and to become actively involved in forest management. Most of the CFs overlap with a communal conservancy. However, CFs differ from conservancies in one fundamental respect: all residents within a CF are

members of the forest, and have members' rights, whereas not all residents of conservancies are members (NACSO 2022).

The first 13 CFs were proclaimed in 2006 and included, amongst others, Okongo CF (Hilfiker 2011, Schusser 2012). In 2013 a further 19 CFs were declared. The last declarations were made in 2018 and 2019. By early 2022 Namibia had 43 registered and 27 emerging CFs. The 43 declared CFs are in ten regions spread across northern Namibia (Figure 19), covering approximately 8,730,000 ha or 10.6% of the country (NACSO 2022). This is much more than the official amount of forest in Namibia (see 1.2); however, many of the CFs have very little forest according to the FAO definition (Box 1). For example, Ongandjera CF consisted of 77% shrubland and 14% bare land in 1998 (Chakanga *et al.* 1998).

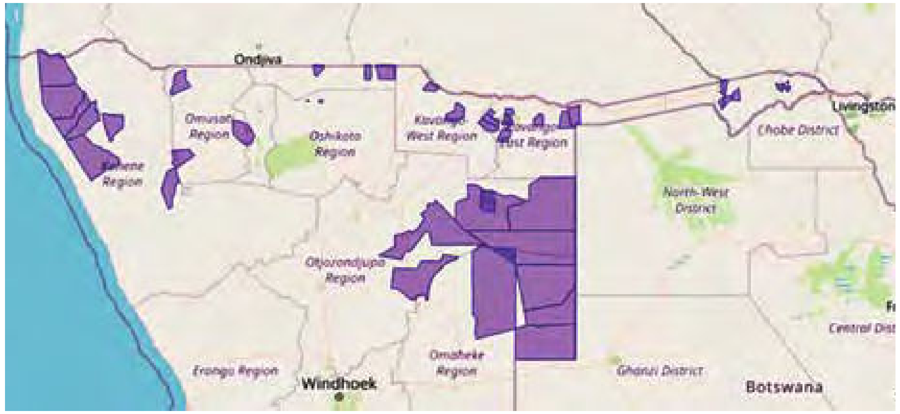

Figure 19 - Community Forests of Namibia (NACSO 2022)

Significant support from the government and the donor community has helped to establish CFs, to build capacity, and to promote more sustainable harvesting practices (Hilfiker 2011, Benkenstein *et al.* 2014).

Through the involvement of the communities, the Directorate of Forestry has now better control over deforestation and illegal harvesting in large forest areas (Schusser 2012, KFW 2013). For example, illegal harvesting of all harvestable trees was discovered in Mbeyo after it became a CF. Before community forestry started in Mbeyo, the area was known as a hotspot for illegal harvesting activities, but no illegal activity was ever officially reported (Schusser 2012).

More information on the management of CFs is given in section 3.2.3.

The Forest Act specifies that CFs can be established through a written agreement between the minister responsible for forestry and the representatives of those who have rights over the relevant area of communal land. This is subject to the provision that the consent of the chief or traditional authority is secured (Jones and Barnes 2009). The act also sets out the conditions that need to be met before an area can be declared a CF, which includes, for example, the election of a body that is representative of the community. This can, but does not have to, take the form of an FMC.

The establishment of the first CFs did not however always run smoothly (Schusser 2012, Benkenstein *et al.* 2014). It was a learning process both for communities and the Directorate of Forestry (Hilfiker 2011), and attempts were made to facilitate the process based on the first experiences (Ministry of Agriculture, Water and Forestry 2005). In 2012 a standardised implementation process that was legally correct, integrative, and pragmatic was designed by the Directorate of Forestry and a range of stakeholders. This agreed standardised process is reflected in two documents, the Community Forestry Manual, and the Community Forestry Toolbox (Directorate of Forestry 2012).

The Toolbox explains the necessary process to implement the official declaration or gazetting of a CF in ten implementation steps or milestones. It also details further milestones for forest management (Directorate of Forestry 2012). The toolbox can be found on the Forestry Data Portal: https://forestry.gov.na/web/community-forestry/general-documentation.

4.3 TRADITIONAL AUTHORITIES

Traditional authorities are important stakeholders in SFM as they allocate land, endorse leases, and their support is needed for the establishment of CFs (Table 2). Often they are the driving force behind the establishment of CFs, as in the Zambezi Region (Jones and Barnes 2009).

4.4 PRIVATE SECTOR AND CIVIL SOCIETY

There are many stakeholders in the private sector, such as companies and individuals involved in harvesting timber or forest derived products, carpenters and cabinet-makers, commercial farmers on forested land, and those wanting to invest in tree planting and carbon sequestration.

There are not many NGOs in Namibia. Those most involved in SFM are the Namibia Nature Foundation (NNF), the Namibian Chamber of Environment

(NCE), IRDNC, the Centre for Research Information and Action in Africa (CRIAA), and the DRFN.

4.5 ACADEMIC SECTOR

Specialised forestry degrees are not offered in Namibia and must be obtained abroad. From 1998 to 2008 the Ogongo campus of the University of Namibia (UNAM) offered a 3-year National Diploma in forestry. This diploma evolved from a forestry training programme that was established in 1992 at the then Ogongo Agricultural College with the assistance of the Finnish government. The aim was to produce sufficient qualified technical forestry and resource management personnel who could, for example, work in forest extension. New forestry students were taken in only every third year due to the low demand in Namibia (Louw 2007). However, while the National Diploma was abolished, the need for technical and computer skills within the Directorate of Forestry remained (Chakanga and Nyambe 2003, Ministry of Agriculture, Water and Forestry 2011).

Currently, a forestry option is offered in year 4 of the Bachelor in Integrated Environmental Science (Honours) at the Ogongo campus. The NUST offers a course in forest management in year 4 of its Bachelor of Natural Resources Management Honours. There is no vocational training for forest technicians. The most important role of the academic sector in SFM is forest research. Academics publish almost all forest research in Namibia.

5 KEY MESSAGES AND RECOMMENDATIONS

A SWOP analysis, based on all information collected in the previous chapters, was used to describe the status quo of the forestry sector and the challenges faced by SFM.

5.1 STRENGTHS

- Namibia has a policy framework that strongly supports SFM.
- There are many local forest inventories for the community forests with a treasure of information on Namibia's vegetation and natural resources.
- The recently established Bush information System (BIS) has detailed, nation-covering information on the woody cover and canopy height for Namibia.
- Many forests and woodlands in Namibia are so far from roads and population centres that they are most likely not overharvested yet.

5.2 WEAKNESSES

- No comprehensive forest monitoring has been done for Namibia yet, while regional forest inventories are incomplete, outdated, and never repeated.
- The three state forests are not declared yet.
- There is no reforestation/afforestation in Namibia, despite a declining total forest area.
- The Forest Act and Regulations are not sufficiently specific, especially regarding the definition of forest, the "protected plant" status, the information the management plan should contain, and how the allowable harvest should be determined.
- The pole size indicated in the Forest Regulations is too big (15 – 30 cm), creating a loophole for overharvesting young trees in the forest.
- The permit system used by the Directorate of Forestry lacks a system to report back on the permits issued and summarise this in a way that can inform management decisions.
- A lack of skills and resources in the forestry sector is a major obstacle to SFM; the Directorate of Forestry has a very small budget and a small pool of well-trained forest technicians and managers. CFs have very

little forestry knowledge, while forest researchers are very few and scattered over several institutions.
- Forest policies are not always well known and applied, even by Directorate of Forestry staff.
- The CFs appear to have become a tool for harvesting more trees, rather than harvesting sustainably. Common ownership fuels a tendency to "mine out" available wood.
- There is no independent quality control of forest inventories, management plans, and allometric equations, which can lead to incorrect estimates of sustainable harvest (TAO).
- The management plans of most CFs are outdated or incomplete.
- No silviculture is applied in Namibia; forest management is restricted to the bare extraction of resources with a trend of overharvesting young trees for droppers and poles.
- There are not enough indigenous trees grown in Namibia's nurseries, especially not enough for afforestation.
- There is very little public awareness on which tree species are indigenous and most suitable for the different regions of Namibia.
- There are no production trials with indigenous tree species of different provenances. This would allow selecting high-quality mother trees from which seeds can be collected or cuttings taken.
- Value addition for indigenous timber and NTFPs is too limited.

5.3 OPPORTUNITIES

- The recently established BIS provides a unique opportunity to create an updated forest map for Namibia.
- Considering that the main driver of deforestation is the conversion to agricultural land, one of the best ways to slow down deforestation is to intensify agricultural production on existing agricultural land.
- The ongoing revision of the Forest Act and Regulations provides an opportunity to add more specifications, especially for the forest management plan.
- The Forest Act provides for the establishment of regional forest reserves, which could be considered for areas where ecological or wildlife corridors are needed.

- Deliberate efforts to overcome technical and management skills shortages in the DoF and community forests must be made, preferably with short, applied, and targeted courses.
- There are tremendous opportunities for forest and woodland research in Namibia as there is a general lack of the information needed for SFM. For example, more research on assisted tree regeneration is urgently needed. The analysis of decades of data collected in fire trials by the DoF would provide urgently needed fact-based advice on fire management. Collaboration between institutions and people should be encouraged, potentially culminating in an independent, non-governmental research institute, possibly in cooperation with the agroforestry and INP sectors.
- The establishment of at least 12 new PSPs for Namibia's woodlands as part of the SECO project will provide more information for SFM, especially on tree mortality and regeneration.
- Assisted tree regeneration in Namibia's forests offers a less expensive and potentially more successful option than planting indigenous trees.
- Cultivating indigenous fruit and timber tree species would improve food security and economic independence of local communities, thereby reducing the pressure on natural forest and woodland resource stocks.
- Active coppice management shows a lot of promise, especially in the mopane woodlands.
- The continuously evolving carbon credit market may offer other means of income for CFs by increasing fire intervals.

5.4 THREATS

- The state forests are not legally protected until they are proclaimed.
- Increase in global demand for African hardwood (This could become an opportunity if timber prices and value addition in Namibia were to increase.).
- With northern Namibia projected to become warmer and drier, fire frequency is expected to increase.
- Deforestation for agriculture continues in northern Namibia, even in CFs, threatening especially the riverine forests along perennial rivers.

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TREE NAMES

Scientific name	Common names
Acacia erioloba	camelthorn, muhoto
Adansonia digitata	baobab
Baikiaea plurijuga	Zambezi teak, mukusi, mukusu
Baphia massaiensis	sand camwood
Bauhinia petersiana	white bauhinia
Berchemia discolor	bird plum
Burkea africana	red syringa, wild seringa, musheshe, mukarati
Colophospermum mopane	mopane
Combretum apiculatum	kudu-bush, red bushwillow
Combretum collinum	variable Combretum, mububu
Combretum imberbe	leadwood
Combretum zeyheri	large-fruited bushwillow
Commiphora africana	hairy corkwood
Commiphora angolensis	sand corkwood
Dialium englerianum	Kalahari podberry
Diospyros chamaethamnus	dwarf jackal-berry
Grewia spp.	raisin bush
Guibourtia coleosperma	false mopane, ushivi, rosewood, musivi, muzauli, mchici, musibi
Ochna pulchra	peeling plane, lekkerbreek
Philenoptera nelsii	Kalahari apple-leaf
Pterocarpus angolensis	kiaat, mukwa, mulumbe, mukwa
Schinziophyton rautanenii	mangetti, mugongo
Sclerocarya birrea	marula
Spirostachys africana	tamboti
Strychnos cocculoides	monkey orange, maguni, uguni
Strychnos punges	spine-leaved monkey-orange
Terminalia sericea	silver cluster-leaf, muhonono, mugoro
Ximenia americana	blue sourplum




Sustainable Forest Management (SFM) aims to balance the various uses of forests while ensuring their ecological functioning and the provision of benefits and functions in the future. It supports multifunctional forests, which require a sound forest policy, committed stakeholders and forest managers and users with ecological knowledge and technical skills. This book gives an overview of the progress made in SFM since Namibia's Independence, the obstacles encountered and the challenges ahead. The application of SFM is currently limited in Namibia for a variety of reasons. One of the main problems is that the existence of forests in Namibia is not well recognised by laymen, policymakers, and ecologists. There are no forests in Namibia according to local classifications, only savanna. No updated forest map according to FAO classifications has been made for Namibia since Independence, nor has a national forestry inventory. The Namibian Directorate of Forestry is small and has limited resources, especially considering the vast areas of forested land to manage and the increasing pressure on forests for subsistence agriculture and tropical hardwoods. Community Forests provide opportunities for SFM, however, they need a lot of assistance to draft management plans and monitor annual allowable harvest guidelines. There is no silviculture applied in Namibia; forest management in protected forests is restricted to the bare extraction of resources with a trend of overharvesting. Opportunities are hence manifold to improve SFM in Namibia.

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