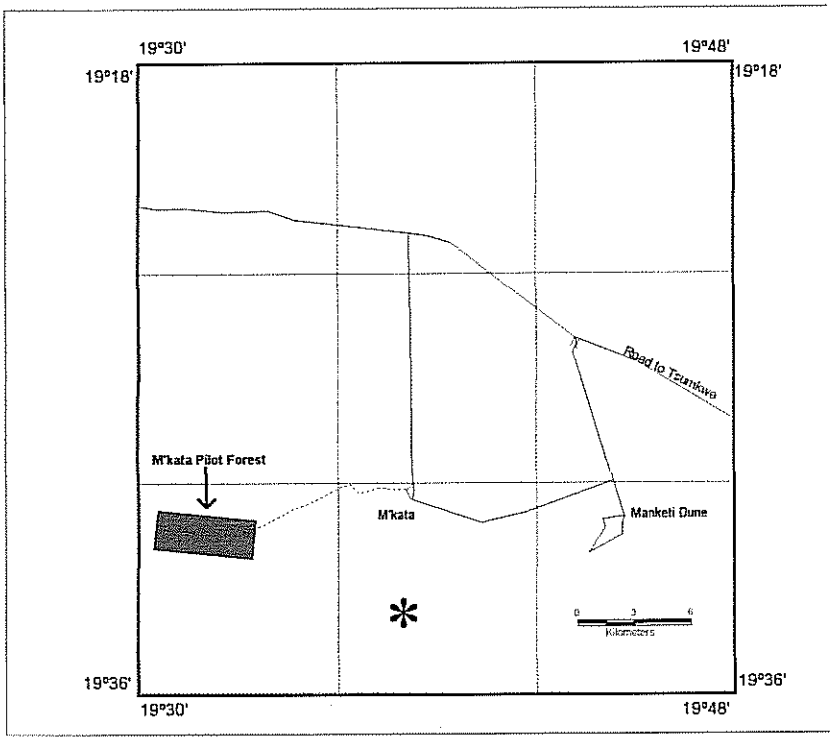
Ministry of Environment and Tourism
Directorate of Forestry

Wood Resources Report of M'kata Pilot Forest area



Namibia Finland Forestry Programme
National Forest Inventory Sub-component

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EXECUTIVE SUMMARY

General description of the area
M'kata pilot forest is situated in the western parts of Tsumkwe district in Otjozondjupa region, this area is part of the Kalahari Highland.

The woody species
A total of 26 woody species were recorded in M'kata pilot Forest. 13 were recorded as trees and 23 woody species were found in shrub layer. 10 woody species were found both as trees in the tree layer and as shrubs in the shrub layer. This is a relatively large number of woody species recorded within a 1054 ha area.

The most common species found in the tree layer were *Burkea africana, Combretum collinum, Pterocarpus angolensis* and *Terminalia sericea.* The most common species in the shrub layer were *Baphia massaiensis, Bauhinia petersiana, Grewia retinervis* and *Combretum engleri.*

Stratification and vegetation types
Post stratification was carried out in the area. The main objective for this stratification was to identify areas with uniquely high volumes of *Pterocarpus angolensis* and the areas with generally higher tree volumes. The measured data in the inventory and the aerial photographs were used to stratify the area.

The first step was to delinate the areas with high volumes of *Pterocarpus angolensis.* Then the rest of the pilot forest was divided into areas with generally higher volume and with very low volumes. Consequentry the stratification resulted into 4 strata, namely Pterocarpus woodland, Mixed woodland (higher volume), Mixed woodland (low volume) and Shrubland.

Almost 1/5 of the pilot forest consists of area with specifically high *Pterocarpus angolensis* volume ("Pterocarpus woodland"). The biggest area in the Pilot Forest is covered by the stratum "Mixed Woodland, higher volume". More than half of the area ("Pterocarpus woodland" and "Mixed Woodland", higher volume), consist of woodland with relatively high tree volumes. Shrubland covers almost a third of the Pilot Forest.

The forest resource
There is total volume of 15399 m^3 of live trees in the Pilot Forest. The mean tree volume and mean number of trees are 14.62 m^3 and 90.7 stems per ha respectively. 80% of the total volume is from areas belongs to the strata "Pterocarpus woodland" and "Mixed woodland, high volume".

Dead trees were also analysed. There is a total volume of 1386 m^3 of dead trees in M'kata Pilot Forest. Whereby more than 80% of the total volumes are from *Burkea africana* and *Pterocarpus angolensis* trees. Most of the dead trees are in smaller diameter classes. Dead trees with bigger diameter were from *Burkea africana* and *Pterocarpus angolensis* trees.

The tree species in M'kata Pilot Forest shows a well-balanced diameter distribution, i.e. the bulk of the stems for most species were found in the small diameter classes.

Regeneration
There is on average 3350 shrubs and tree saplings per hectare in the shrub layer. 73% of these shrubs are saplings i.e. also found in the tree layer. Hence the regeneration of tree species is good in the area. The tree species dominating the tree layer and shrub layer differs. In some areas both

layers are dominated by the same species, 2/3 of the seedlings are from *Acacia erioloba* and *Terminalia sericea.* The species mentioned above, are not the species dominating the tree layer.

Seedlings of *Pterocarpus angolensis* and *Burkea africana* were very few. This will have consequences for sustainable utilisation of these species in future. Something has to be done to enhance the regeneration of those scarce species.

Potential for economic utilization at present and in the future

It is recognized that the woody resource can provide economic benefits from a number of other products than sawn timber, e.g. pole production, veld products, fruits or woodcarving. The information on veld products were collected but were not analysed, therefore not included in the report. The data on veld products will be available at later stage. The inventory was focussing on the potential for sawn timber production and veld products, but does not try to estimate the woody resource utilization for other purposes.

The limit for timber harvesting is 45 cm dbh i.e. trees with dbh >45 cm. There is a total of 506.7m^3 saw-log volume of *Pterocarpus angolensis* in the Pilot Forest. Volumes include only the main trunk. Of this tree volume, 161m^3 is sawable log volume. There is in fact a bigger log volume of *Pterocarpus angolensis* than of *Burkea africana* in the Pilot Forest. The figures in Table 11 exclude branchwood and deadwood, and the log volumes are only for trees with dbh>45 cm.

So, there is a potential for utilisation on a limited small-scale basis of *Pterocarpus angolensis* for construction, capentry and furniture making at the moment.

Some management proposals

There is a potential for limited small-scale utilization of *Pterocarpus angolensis.* Proper management is crucial for this utilization to be sustainable. This also goes for any other species that would be utilized in the M'kata Pilot Forest.

The management of the woody resources in the Pilot Forest should include at least the following:

- Management of the mature trees through of calculation of Annual Allowable Cut to ensure a sustainable utilization.
- Management of the smaller trees for them to grow into mature trees.
- Management of the regeneration in form of both the management of existing seedlings and the management to enhance regeneration.
- Fire management.
- The inclusion of Non Timber Forest Products, such as veld products etc, into the planning.

1. INTRODUCTION

The information on Namibian forest resources has been limited on all levels (local, regional and national). Therefore, in 1995 the Directorate of Forestry in co-operation with FINNIDA started a National Forest Inventory (NFI), the main aim was to produce region level information on the woody vegetation in the communal lands of northern Namibia. In April 1997 the Directorate of Forestry began a comprehensive implementation of the Namibia Forestry Strategic Plan of 1996 by launching the Namibia-Finland Forestry Programme and the NFI was incorporated as a sub-component into this programme. The main objectives of the NFI are: (1) To produce regional level forest resource data on northern Namibia for strategic planning; (2) To produce more detailed forest resource data for strategic or operational management planning on sub region areas, and (3) To build a Namibian capacity to carry out the inventories.

The utilization of information from different levels of inventories is different. The region level inventories provide information on the forest resource for the entire region for region level planning. The sampling intensity is low, therefore information on very small units cannot be derived, and the results cannot be used for operational management. To get detailed information for operational management, local level inventories have to be carried out. Basically the information substance is similar for both region level and local level inventories. The sampling intensity in the local level inventories is high compared to the region level inventories, and the information is site specific to small units in the area inventoried.

The decision to prioritise the region level inventories in the Directorate of Forestry was decided at the initiation of the NFI in 1995. The logical sequence in developing forestry in the region is to first carry out a region inventory to determine the resource information for different uses in the region. If potentiality is determined, e.g. timber utilization, then the next step is to identify small areas for forest development and to carry out local level inventories in those local level areas identified.

This report presents the results from the inventory of M'kata Pilot Forest. The pilot forest is a case study for DED (German Development Service). The woody resource inventory was carried out on the request of the DED. The data collected and the information presented in this report reflects the information need stated by the DED personnel, at the time of the inventory design and fieldwork. However, information on veld products were also collected in the inventory. But the data was not analysed and therefore is not included in this report. The spot maps in the Appendices provide site-specific information on vegetation types and volumes. It is possible to produce more site-specific information for certain areas within the Pilot Forest by analysing only clusters measured in that smaller area. Data for each sample plot is available at the Directorate of Forestry Headquarter in Windhoek.

Below is the list of resource reports produced within the NFI. The reports are all available at the Directorate of Forestry.

The previous reports are:

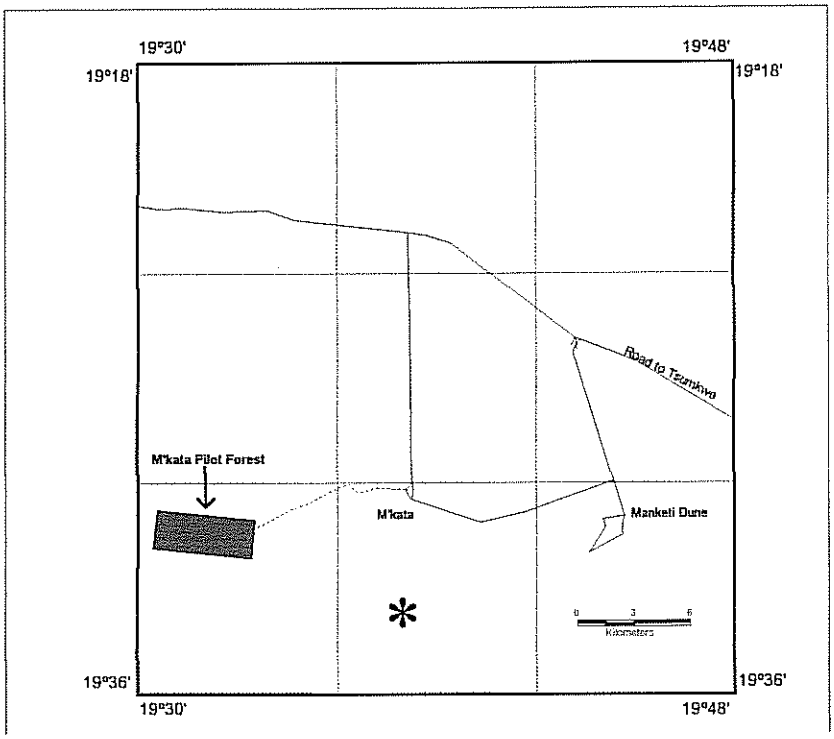
- Forest Inventory Report of Caprivi Region
- Inventory Report on the Woody Resources in the Omusati Region
- Inventory Report on the Woody Resources in the Oshana Region
- Woody Resources of Western Tsumkwe
- Woody Resources of East and South Tsumkwe, Otjinene and Okakarara Districts
- Forest Inventory Report on Uukwaludhi Community Forest
- Forest Inventory Report on Ongandjera Community Forest

- Forest Inventory Report on Caprivi State Forestry
- Inventory of the Directorate of Forestry Eucalyptus Plantations in Kavango Region
- Forest Inventory Report on Nkurenkuru Concession Area
- Inventory Report on the Woody Resources in the Okongo Community Forest

2. GENERAL DESCRIPTION OF THE AREA

M'kata pilot forest is situated in the western parts of Tsumkwe district in Otjozondjupa region, this area is part of the Kalahari Highland.

According to the Directory of Forestry vegetation maps, the area is classified as both forest and savanna type vegetation. *Burkea africana* is the dominant species in the area followed by *Pterocarpus angolensis*. Common species in the lower tree layer and in the shrub layer are different *Combretum* species, *Terminalia sericea, Lonchocarpus nelsii, Boscia albitrunca, Ochna pulchra, Acacia* species and *Grewia* species. The soil is always sandy, but the soil colour may differ due to the mineral content.



Map 1. Location of the M'kata Pilot Forest

The M'kata pilot forest is a part of the project "Community Forestry in North-Eastern Namibia". The project is a co-operation between the Directorate of Forestry (DoF), the German Development Service (DED) and the German Bank of Development (KfW). The project started in October 1999.

The first 30 months of the project is a pilot and study phase. During this phase a sound operational basis for an extension and development programme on a larger scale is to be prepared. Therefore, the area in M'kata is called "pilot forest". Except in M'kata the project is also operating in Caprivi region. The aim of the project is to "assist in the preservation and

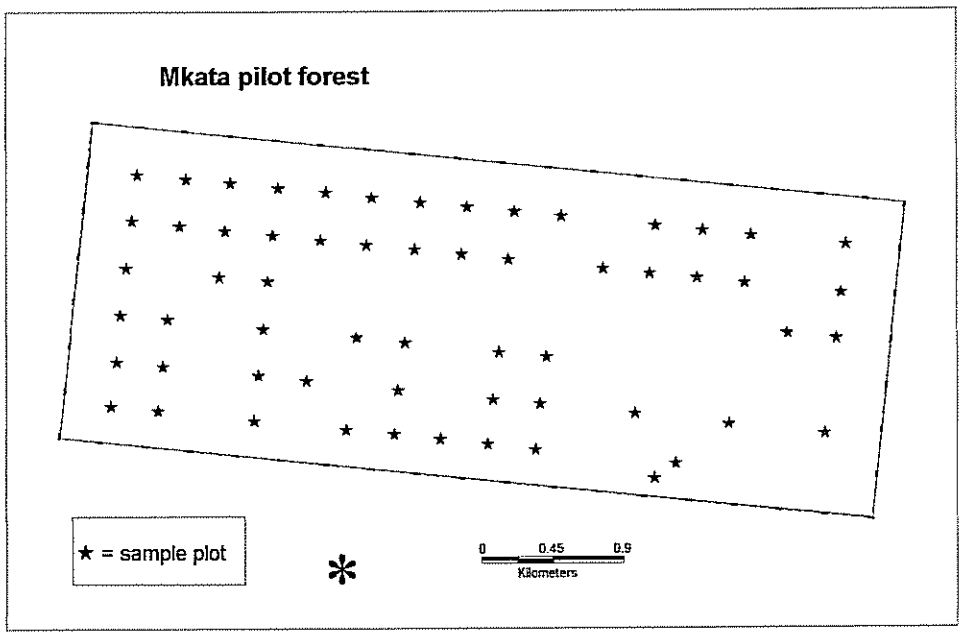
sustainable use of the natural resources in the communal lands of northeastern Namibia by the local communities, so that the forest can contribute to improved livelihoods of the people".

3. INVENTORY DESIGN

3.1 Sampling method

M'kata Pilot Forest is located on the eastern part of Otjozondjupa region. The total area is 1054 ha. Stratified systematic plot sampling was used to estimate the quantity and quality of the woody resources in the M'kata Pilot Forest. Arial photos and inventory results were used to stratify the area. Consequentry the stratification has resulted into 4 strata. The sampling intensity was higher in strata with more *Pterocarpus angolensis* and with more denser tree cover.

The total number of clusters located in the area was 30. Each cluster consists of 2 sample plots. Each plot has its own coordinates. Therefore, a total of 60-sample plots were located in the area. Map 2 below shows the location of saple plots in the area.



Map 2: Location of plots in M'kata pilot Forest.

The plots plotted on the Vegetation Maps were digitised using MapInfo software to obtain co-ordinates for each plot. The co-ordinates and GPS were used for locating the plots in the field. The map datum WG84 was used to locate the plots.

The sample plots are not permanent measurement plots. They have co-ordinates but not marked in the field with an aluminium pole as in other areas and therefore cannot be re-located for remeasurements in future, because it is very difficult to re-locate for example the original centre of the plot with only co-ordinates. The co-ordinates are shown in appendix 1 for those who want to locate plots in the field.

3.2 Field measurements

The data is collected in circular sample plots. The woody vegetation is classified into trees and shrubs. In this inventory trees are defined as woody plants with dbh≥5 cm and shrubs are woody plants with dbh<5 cm.

For tree measurements the size of the circular sample plot depends on the size of the tree (see Figure 1). For small trees (5cm≤dbh≤20cm) the radius is 10 m, for medium size trees (20cm<dbh≤45cm) the radius is 20 m and for big trees (dbh>45 cm) the radius is 30 m.
Diameter, location, species, crown class, quality, length and quality of possible saw log were measured for all trees in all sample plots. The trees in the first plot of each cluster are called sample trees. For them also height, diameter of canopy, crown height, damages and phenology were recorded.

Shrubs, regeneration, coverage of grasses and herbs were measured in two sub-plots (radius 3.99m) located only in the first plot of each cluster (see Figure 1).

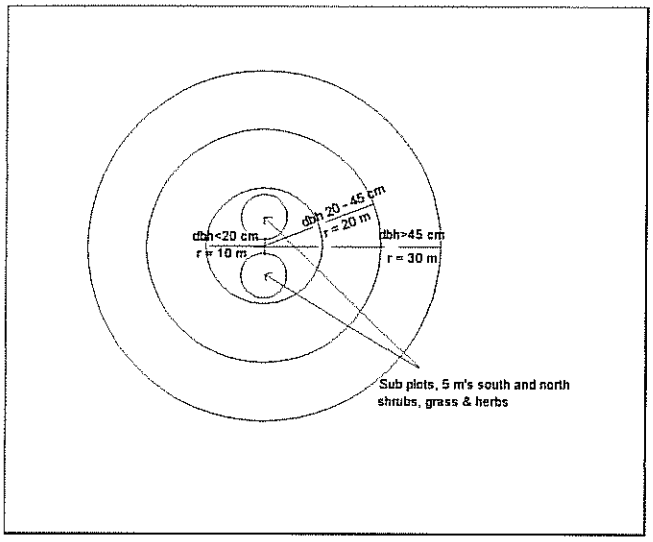


Figure 1: Plot Design

Information describing the environment surrounding the sample plot ("the stand") was also recorded. This description includes e.g. the soil, the land type, damage to the woody vegetation and human influence. All the measurements are described in more detail in the field instructions (Field Instructions Western Bushman land 1996).

3.3 Stem analysis and volume functions

So far stem analysis for the development of volume functions has been carried out in West Tsunkwe, Caprivi and Omusati region. A total of 181 trees of the most common species have been felled and measured for this purpose. These volume functions were used also in the analysis of the data for M'kata pilot forest.

Volume functions have been developed only for the most common species. For the other species the volume functions were applied to estimate the volumes of those species. For other users who may wish to use the models, Appendix 6 (p.37) shows which models that were applied to the species where no functions were developed.

4. INVENTORY RESULTS

4.1 Measured data

The inventory fieldwork in M'kata Pilot Forest was carried out in September 2000. A total of 60 sample plots (30 clusters) were measured.

A total of 295 trees with dbh≥ 5 cm were measured in the plots (see Table 1 p.11), which is on average 4.9 trees per sample plot. The average trees per sample plot are higher than in all other areas inventoried in Otjozondjupa and Omahake region. This is a large number of trees per sample plot taking into consideration that some of the areas are open. Out of the 295 trees, 113 (38%) were sample trees, i.e. trees where additional variables were measured (see Chapter 3.2 "Field measurement" p.8).

A total of 26 woody species were recorded in M'kata Pilot Forest. 13 were recorded as trees and 23 woody species were found in the shrub layer. The most frequent species in the data were as follows:

Species (trees)	% of measured trees
Burkea Africana	43.4
Combretum collinum	22.4
Pterocarpus angolensus	13.9
Terminalia sericea	9.2
Total	88.9

Species (shrubs)	% of measured shrubs
Terminalia Sericea	18
Combretum collinum	16.5
Baphia massaiansis	15.8
Burkea africana	7.9
Total	57.9

The most common tree species measured in the area was *Burkea africana*. The table above indicates that almost 1/2 of the measured trees are from that species. Almost 90% of the measured trees are from four species. West Tsumkwe, an area of about 600000 ha situated west of M'kata Pilot Forest, was inventoried in 1997. 75% of the measured trees in that area comprise of the same four species mentioned above. This indicates that there is more varying species composition in West Tsumkwe area.

A total of 139 shrubs were measured (see Appendix 3 "Total number of measured shrubs, p.34). The 4 most common species represent 60% of the total measured shrubs. Only three of the 4 most common species in the tree layer were found among the 4 most common shrub species. Of the 4 most common species in the shrub layer, one (*Baphia massaiensis*) is a typical shrub species, i.e. it does not grow into tree size.

Table 1: Total number of measured trees and sample trees

Species	Total No. of measured trees	% of measured trees	Total No. of sample trees	% of sample trees
Burkea africana	128	43.4	52	46.0
Combretum collinum	66	22.4	22	19.5
Pterocarpus angolensis	41	13.9	18	15.9
Terminalia sericea	27	9.2	6	5.3
Lonchocarpus nelsii	10	3.4	4	3.5
Ochna pulchra	6	2.0	4	3.5
Boscia foetida	4	1.4	0	0.0
Boscia albitrunca	3	1.0	2	1.8
Combretum psidioides (psidioides)	3	1.0	0	0.0
Combretum zeyheri	3	1.0	2	1.8
Acacia erioloba	2	0.7	2	1.8
Acacia Tortilis (spirocarpa)	1	0.3	0	0.0
Dichrostachys cinerea (Setulosa)	1	0.3	1	0.9
Total	295	100	113	100

4.2 Species diversity

There are several measures of species diversity such as Simpson's dominance and Shannon's species diversity indeces that can be applied on the inventory data. Another simpler measure of species diversity is the number of species found in the area and the number of clusters where each species was found. Table 5 shows the number of clusters where each species was found for both trees (dbh≥5 cm) and shrubs (dbh<5 cm).

Table 2: Species diversity by the number of clusters where each species was found

Species	No. of clusters, dbh<5 cm	No. of clusters, dbh>5 cm
Acacia ataxacantha	2	
Acacia crioloba	1	2
Acacia fleckii	1	
Acacia mellifera	1	
Acacia Tortilis (spirocarpa)		1
Baissea wulfhorstii	1	
Baphia massaiensis	22	
Bauhia petersiana	6	
Boscia albitrunca		2
Boscia foetida		1
Burkea africana	11	25
Combretum collinum	23	21
Combretum engleri	1	
Combretum psidioides (psidioides)	1	2
Combretum zeyheri	8	2
Commiphora angolensis	3	
Dichrostachys cinerea (Setulosa)	8	1
Grewia bicolor	1	
Grewia flava	1	
Grewia retinervis	4	
Lonchocarpus nelsii	9	8
Ochna pulchra	7	3
Ozoroa schinzii	1	
Pterocarpus angolensis	1	20
Terminalia prunioides	1	
Terminalia sericea	25	9

A total of 26 woody species were recorded in M'kata pilot Forest. 13 were recorded as trees and 23 woody species were found in the shrub layer. 10 woody species were found both as trees in the tree layer and as shrubs in the shrub layer. This is a relatively large number of woody species recorded within a 1054 ha area. In West Tsumkwe an area of about 600000 ha, 29 woody species were found. Hence almost the same number of species was recorded in M'kata, although the area is much smaller.

Pterocarpus angolensis, Burkea africana and *Combretum collinum* trees (dbh≥5cm) were found in 2/3 of the measured clusters. *Baphia massiansis, Burkea africana, Combretum collinum* and *Terminalia sericea* shrubs were found in most of the clusters.

This is a clear indication that these species are found in the tree and shrub layer in most of the pilot forest. *Pterocarpus angolensis* regeneration was found only in one cluster. Therefore there is very little *Pterocarpus angolensis* regeneration in the area. Although the number of woody species found in the area is relatively high, few species are very common. More than half of the species found in the area are extremely rare.

4.3 Stratification

Post stratification was carried out for the area. The main objective for this stratification was to identify areas with specifically high volumes of *Pterocarpus angolensis* and the areas with generally higher tree volumes. The measured data in the inventory and aerial photographs were used to stratify the area.

The first step was to delinate the areas with specifically high volumes of *Pterocarpus angolensis*. Then the rest of the pilot forest was divided into areas with generally higher volume, low volume and with very low volumes. Consequently the stratification resulted into 4 strata, namely Pterocarpus woodland, Mixed woodland (higher volume), Mixed woodland (low volume) and Shrubland (see table 3). Appendix nn shows the location of each stratum in the pilot forest.

Almost 1/5 of the pilot forest consists of area with specifically high *Pterocarpus angolensis* volume ("Pterocarpus woodland"). Volumes are further described in chapter 4.4, 4.5 and 4.6. The biggest area in the Pilot Forest is covered by the strata "Mixed Woodland, higher volume". More than half of the area ("Pterocarpus woodland" and "Mixed Woodland", higher volume), consist of woodland with relatively high tree volumes. Shrubland covers almost a third of the pilot forest. Note that the total tree volume in "Pterocarpus woodland" stratum is higher than in the "Mixed Woodland, with more volume" stratum.

Table 3: Area by stratum

Stratum	Area, in ha	% of total area
Shrubland	297	28.2
Mixed Woodland, low volume	198.8	18.9
Mixed Woodland, higher volume	376.3	35.7
Pterocarpus Woodland	181.1	17.2
Total	1053.2	100

Table 4 below shows the average, minimum and maximum height of the woodland by species. The height of the woody vegetation is generally low. The average height of *Burkea africana* and *Pterocarpus angolensis* is close to 10 m, while the average height of *Combretum collinum* and *Terminalia sericea* is lower. Since the four species are common in the area, this indicates two-storey woodland, where the upper storey consists of *Pterocarpus angolensis* and *Burkea africana* and the lower storey consist of *Combretum collinum* and *Terminalia sericea*.

Table 4: Average minimum and maximum height by species

Species	Average height (m)	Minimun height (m)	Maximum height (m)
Acacia erioloba	6.8	6.8	6.8
Boscia albitrunca	8.5	8.5	8.5
Burkea africana	8.6	2.8	14.9
Combretum collinum	5.8	2.5	13.6
Dichrostachys cinerea (Setulosa)	4.1	4.1	4.1
Lonchocarpus nelsii	6.2	4.5	7.7
Ochna pulchra	5.0	4.6	5.6
Pterocarpus angolensis	10.6	4.4	16.4
Terminalia sericea	3.7	2.5	4.7

4.4 Tree volumes and number of stems

Volume functions: An important activity within the NFI region inventories is to develop volume functions for the most common tree species in each region. This is done by stem-analysis on a representative number of stems, for the most common species in each region. Stem analysis has so far been carried out in Otjozondjupa, Caprivi and Omusati regions. Volume functions developed within the NFI region inventories were used to estimate the volumes in M'kata Pilot Forest.

Volume functions are developed for the most common species only, but the functions are also applied on other species without own volume functions. For those who may wish to use the models, Appendix 6 "List of tree/shrub species for M'kata Pilot Forest" (p.37) shows which models were applied to the species without volume functions to estimate the volume.

All the woody stems with a dbh≥5 cm are regarded as trees. Unless specified otherwise, **Tree volume** means the volume of the entire tree comprising of the main tree trunk and branch wood. Note that the volumes and number of stems presented in this chapter include only live trees. Tree volumes and number of stems are presented in three formats in this chapter: 1) for the whole area, 2) per strata (Table 5) and 3) per species (Table 6). Deadwood volumes and stems are presented in Chapter 4.7 "Deadwood". The number of trees and volumes for the whole area are as follows:

Total number of trees	95 512
Mean number of trees per hectare	91
Total tree volume (m^3)	15399
Mean volume per hectare (m^3/ha)	15
Total area, ha	1053

The mean tree volume and the mean number of trees in M'kata Pilot Forest are 14.62 m^3/ha and 90.69 stems/ha respectively as shown in the table above. The mean number of trees and volumes are figures that can give a picture on how dense the forest is.
The number of stems per hectare for M'kata Pilot Forest is more or less the same as those found in neighbouring areas such as Western Tsumkwe and East & South Tsumkwe, Otjinene and Okakarara districts. Therefore the density of the trees in those three areas is basically the same, but the volume differs.

Table 5 below shows the volumes and number of trees for all species for the main vegetation types.

Table 5: Volumes and number of trees stratum

	Woodland with more volume	Pterocarpus woodland	Woodland with less volume	Shrubland
Total No. of stems	47541	23806	12643	11522
Stems per ha	126.3	131.5	63.6	38.8
Total tree volume	6095.8	6465.16	1971.7	866.6
Average tree volume	16.2	35.7	9.9	2.9

There is a big variation in volumes. The highest tree volume was found in Pterocarpus woodland (PW). The volumes in the "Mixed woodland, high volume" (WHV) are also relatively high. "PW and WHV" stratums cover half of M'kata Pilot Forest. 80% of the total volume is in those two strata. Although the number of stems per ha is more or less the same in the "PW" and "WHV", the volume is twice as high in "PW's". This indicates that the sizes of the trees are rather big in "PW's".

Table 6 below shows the number of stems and tree volumes by species for the whole M'kata Pilot Forest. Table 7 (p.16) breaks down the information for the four most common tree species into stems and volumes for different stratum in the area. Only living trees are included in the tables. More information on volume distribution can be found in Appendix 4 (p.35) "Diameter distribution of volumes by species".

The most common species (*Burkea africana, Combretum collinum, Terminalia sericea* and *Pterocarpus angolensis)*, accounts for 90% of the total number of stems in the Pilot Forest. *Burkea africana* is the most common species. There are more trees of *Terminalia sericea* and *Combretum collinum* in the pilot forest than *Pterocarpus angolensis* trees. The volume of *Pterocarpus angolensis* is however higher than *Terminalia sericea* and *Combretum collinum*. This is due to the fact that, *Pterocarpus angolensis* trees are bigger than both *Terminalia sericea* and *Combretum collinum*.

Table 6: Volume and number of stems by species totally and per hectare

Species	Total No. of stems	Stems per ha	Total tree volume	Average tree volume, m^3/ha
Burkea africana	42084.07	39.96	7229.90	6.86
Combretum collinum	24096.20	22.88	1996.25	1.90
Terminalia sericea	12356.92	11.73	761.59	0.72
Pterocarpus angolensis	7787.73	7.39	4052.08	3.85
Lonchocarpus nelsii	3213.98	3.05	460.19	0.44
Ochna pulchra	2376.53	2.26	466.09	0.44
Boscia foetida	1808.00	1.72	79.19	0.08
Combretum psidioides (psidioides)	1036.56	0.98	95.02	0.09
Boscia albitrunca	343.34	0.33	126.85	0.12
Acacia erioloba	295.43	0.28	98.29	0.09
Acacia Tortilis (spirocarpa)	113.00	0.11	33.79	0.03
Total	95511.77	90.69	15399.24	14.62

Table 7 shows the number of stems and volumes per vegetation type for the four most common species. More than 40% of the average tree volumes in each stratum are from *Burkea africana*. The bulk of *Pterocarpus angolensis* volumes were found in "Pterocarpus Woodland". The average volume for *Pterocarpus angolensis* and *Burkea africana* in "Pterocarpus Woodland" are basically the same, although the number of stems of *Burkea africana* are almost four times as much as *Pterocarpus angolensis*. This is because most of *Pterocarpus angolensis* trees are bigger than *Burkea africana*. All the common species were found in all the strata; with *Burkea africana* dominating all the strata.

Table 7: Volumes and number of stems for the dominant species by stratum

Stratum	Dominant species	Total No. of Stems	Stems per ha	Total tree volume	Average tree volume, m^3/ha
Woodland with more volume	Burkea africana	18363.7	48.8	3447.24	9.16
	Combretum collinum	14281.5	38.0	870.06	2.31
	Terminalia sericea	6449.7	17.1	209.11	0.56
	Pterocarpus angolensis	2687.4	7.1	911.11	2.42
Pterocarpus woodland	Burkea africana	11822.7	65.3	2523.23	13.93
	Combretum collinum	6712.0	37.1	888.29	4.90
	Pterocarpus angolensis	3122.5	17.2	2459.27	13.58
	Terminalia sericea	1614.6	8.9	296.71	1.64
Woodland with less volume	Burkea africana	5989.0	30.1	923.82	4.65
	Combretum collinum	1921.0	9.7	194.41	0.98
	Boscia foetida	1808.0	9.1	79.19	0.40
	Pterocarpus angolensis	1682.4	8.5	543.48	2.73
	Terminalia sericea	452.0	2.3	4.84	0.02
Shrubland	Burkea africana	5908.6	19.9	335.61	1.13
	Terminalia sericea	3840.6	12.9	250.94	0.84
	Combretum collinum	1181.7	4.0	43.49	0.15
	Pterocarpus angolensis	295.4	1.0	138.23	0.47

To sum up:

- The number opf stems per ha for M'kata pilot Forest is more or less the same as those found in neightbouring areas.
- There is big variation in volumes of different stratums.
- 90% of the total numbers of stems in the Pilot Forest are from the common species (*Burkea africana, Combretum collinum, Terminalia sericea* and *Pterocarpus angolensis).*

4.5 Diameter distribution

A desired diameter distribution from management point of view is one where the bulk of the stems are in the lower diameter classes, and the number of stems gradually decreasing as the diameter gets bigger. With this kind of distribution there is continuously going to be trees entering into mature stage and a continuous harvesting of timber and poles will be possible. If the actual diameter distribution deviates from the desired one, it is bound to affect short or long term management decisions.

Table 8 below shows the distribution of stems into diameter classes for the different species. Apart from providing information on the diameter distribution, Table 8 also gives indications on which tree species that have a potential to grow into big size trees in the area. Table 9 (p.18) shows in more detail the diameter distribution of stems and volumes for *Burkea africana* and *Pterocarpus angolensis* in the M'kata Pilot Forest. Note that the diameter distribution presented in this chapter includes only live trees. The diameter distribution of dead trees is presented in chapter 4.7 "Deadwood" (p.22).

Table 8: Diameter distribution of stems by species

	Diameter class, in cm								
Species	5-15	15-25	25-35	35-45	45-55	55-65	65-85	Total	% of total
Burkea africana	28350	9895	2565	1169	53		51	42084	44.2
Combretum collinum	19339	4415	115	120	53	53		24043	25.2
Terminalia sericea	11888	120	295				53	12357	13.0
Pterocarpus angolensis	3247	1729	1489	588	472	212	51	7576	8.0
Lonchocarpus nelsii	2303	567	343					3214	3.4
Ochna pulchra	2323						53	2377	2.5
Boscia foetida	1808							1808	1.9
Combretum psidioides (psidioides)	461	576						1037	1.1
Boscia albitrunca		228	115					343	0.4
Acacia crioloba			295					295	0.3
Acacia Tortilis (spirocarpa)		113						113	0.1
Total	69720	17643	5219	1878	579	265	209	95247	100.0

There were 13 tree species found in the area. In the table above there is only 11 species. This is because only live trees are included in the table above, and the remaining 2 species were found dead. The tree species in the M'kata Pilot Forest show a well-balanced diameter distribution, i.e. the bulk of the stems for most species are found in the small diameter classes. The biggest trees are *Burkea africana, Terminalia sericea, Pterocarpus angolensis* and *Ochna pulchra.* Most of the big trees are *Pterocarpus angolensis.*

Table 9 below shows that *Pterocarpus angolensis* is represented in all diameter classes. The bulk of the stems are in small sizes.

90% of *Burkea africana* stems were found in diameter class between (5-25 cm). So, most of *Burkea africana* trees are small. Almost 2/3 of the stems are in the range of 5-25 cm diameter class. More than 80% of the total volumes of *Pterocarpus angolensis* were found in a diameter class between 25-65 cm. *Pterocarpus angolensis* trees are generally bigger than *Burkea africana* trees. The table further shows that, less than 1% of *Burkea africana* and 10% of *Pterocarpus angolensis* stems have a diameter bigger than 45 cm.

Table 9: Total tree volume and number of stems by diameter classes for *Burkkea africana* and *Pterocarpus angolensis*

	Burkea africana			Pterocarpus angolensis		
Dbh class, cm	Total tree volume, m3	Total number of stems	% of total stems	Total tree volume, m3	Total number of stems	% of total stems
5-15	1723.3	28350	67.4	190.7	3247	41.7
15-25	1995.1	9895	23.5	245.0	1729	22.2
25-35	1721.0	2565	6.1	749.0	1489	19.1
35-45	1457.0	1169	2.8	802.0	588	7.6
45-55	103.6	53	0.1	1042.4	472	6.1
55-65				783.1	211	2.7
65-75	229.9	51	0.1	240.0	51	0.7
Total	7229.9	42084	100.0	4052.1	7788	100.0

To sum up:

- There is a well-balanced distribution among the tree species found in the Pilot Forest. Therefore with proper management, there will be mature trees to be utilised also in the future.
- The bulk of *Pterocarpus angolensis* trees were also found in smaller diameter classes. There were no *Baikiaea plurijuga* trees found in the area
- With proper management there will be a potential for harvesting of timber in the future.

4.6 Timber volumes and qualities

The objectives of community based resource management are that, 1) the well being of the communities is improved and 2) the utilisation of the natural resource is sustainable. The woody resource supplies a number of products ranging from timber and poles to various non-timber products. Therefore, the well being of the local communities can be improved by the utilisation of different products. One of the income generating activities for the communities by managing the M'kata Pilot Forest might be the processing of standing trees into logs and sawn timber. It is recognised that the woody resource can provide socio-economic benefits for a number of other purposes than sawn timber, e.g. pole production, fruits or woodcarving. This chapter however focuses on the potential for sawn timber production and does not try to estimate wood utilisation for other purposes. Data on veld products was colleted in the inventory. But the data is not yet analysed, and therefore not included in this report.

To be able to determine the tree potential for utilisation of the woody resources for sawn timber production, the quantities of saw logs needs to be known. Since mainly *Pterocarpus angolensis* and *Burkea africana* are utilised for this purpose, this chapter focuses on these species. However, it is important to note that there are also other species that can be utilised by the timber industry.

Timber volume or saw log volume means the volume of the part of the main trunk that has been regarded sawable. In the field, the dbh and length of the sawable trunk were recorded. The saw log volume was estimated assuming the log has a cylindrical form. The log lengths presented in the tables exclude deformed bases. To get the volume of sawn timber, the volume of residues has to be subtracted from the saw log volume.

It is recognised that, some of the big trees have thick branches that to a certain extent can be utilised as saw logs. But for simplicity in the classification in the field, it was decided not to include any branch wood into the timber volumes.

The quality classification used in the inventory is as follows:

Good quality	There is at least a 2m long straight stem without damages.
Medium quality	The stem is slightly curving or sweeping or having other damages but still having at least a 2 m saw-able log.
Poor quality	It is possible to find only 1.2 - 2 m long log meeting the minimum timber quality requirement.
Not saw-able	The log is not saw-able and will probably never develop saw-able quality.

The timber volumes and qualities are presented in Tables 10 and 11 for *Burkea africana* and *Pterocarpus angolensis*. The tables include only trees with dbh>45 cm, i.e. trees that can be harvested. Note that the tables also include dead trees. The volumes in Tables 10 and 11 are log volumes, not tree volumes. Hence the volumes are smaller than in Table 9, which shows the tree volumes.

Table 10 shows that all *Burkea africana* with dbh > 45cm are alive and the qualities are good enough to be sawn. However all the trees are of medium quality timber, i.e stems are not very straight or have some damages, but still having at least a 2m sawable pole.

There is a total of 74.7 m^3 of logs of *Burkea africana* in the area. *Burkea africana* trees are frequently hollow inside. This cannot be judged from outside, therefore from this point of view the volume is probably overestimated. On the other hand, the volumes include only the main trunk. Experience from DED assessment of deadwood has shown that a considerable amount of branchwood can also be utilised. If that is the case, then the branches of live trees can also be utilised, so the volume is underestimsted, since the volume include only the main trunk.

If the log volume in table 10 below is compared to the total log volume of *Burkea africana* in table 9 (p.18), only 1% of the tree volume is sawable log volume. When sawn timber is produced, approximately 40% of the sawlog volume becomes sawn timber the rest is residues. Therefore, there is approximatery 29.9 m^3 of sawn timber of *Burkea africana* in the Pilot Forest at the moment, which is on average 0.028 m^3/ha. This figure shows that, there is very little sawn timber of *Burkea africana* in the Pilot Forest. The utilization of timber volume is not encouraging at the moment. However, note that this figure excludes branchwood and deadwood. The log volumes are only for trees with dbh>45 cm.

Table 10: Distribution by status and quality of *Burkea africana* trees with dbh>45 cm

Status	Quality	Stems per ha	Total number of stems	Total log volume m^3	Average log volume, m^3/ha
Live tree	Medium quality	0.05	51	53	0.05
Live tree	Expected medium quality	0.05	53	21.7	0.021
Total		0.10	104	74.7	0.071

Table 11 shows timber volumes and quality of *Pterocarpus angolensis*. Bear in mind that the table shows only log volumes for harvestable trees, i.e. trees with dbh>45 cm.

The table shows that almost 90% of the harvestable stems (dbh > 45 cm) can be utilised by the timber industry. 2/3 of harvestable stems have a good or medium quality, i.e, stems having atleast a 2m sawable pole. 10% of the harvestable *Pterocarpus angolensis* trees (dbh > 45 cm) are dead.

There is a total of 506.7m^3 saw-log volume of *Pterocarpus angolensis* in the Pilot Forest. Volumes include only the main trunk. There is in fact a bigger log volume of *Pterocarpus angolensis* than of *Burkea africana* in the Pilot Forest. The figures in table 11 excludes branchwood and deadwood, and the log volumes are only for trees with dbh>45 cm.

Comparing log volumes in Table 11, with tree volumes in Table 9 shows that 10% of *Pterocarpus angolensis* tree volume is sawable log volume, i.e, volume that can be utilised by the timber industry. Therefore, the part of the tree volume that can be utilised by the timber industry (i.e. sawlog volume) is six times that for *Burkea africana*. When sawn timber is produced, approximately 40% of the sawlog volume becomes sawn timber the rest is residues. Therefore there is approximatery 161.5 m^3 of sawn timber of *Pterocarpus angolensis* in the Pilot Forest, which is on average 0.15 m^3/ha.

Table 11: Distribution by status and quality of *Pterocarpus angolensis* trees with dbh>45 cm

Status	Quality	Stems per ha	Total number of stems	Total log volume m^3	Average log volume, m^3/ha
Live tree	No code	0.05	53.38	27.14	0.03
Live tree	Good timber quality	0.35	365.14	258.56	0.25
Live tree	Medium quality	0.15	160.13	81.48	0.08
Live tree	Poor quality	0.10	104.56	52.54	0.05
Live tree	Not sawable	0.05	51.19	0.00	0.00
Standing dead tree	Good timber quality	0.05	53.38	63.68	0.06
Standing dead tree	Not sawable	0.05	51.19	23.33	0.02
Total		0.80	838.96	506.74	0.48

To sum up:

- Even though *Burkea africana* is the most common species in the area, the saw-log volume of *Pterocarpus angolensus* is almost six times the saw-log volume for *Burkea Africana* for trees with dbh> 45 cm.

4.7 Deadwood

In the presentation on volumes and diameter distributions in the previous chapters only living trees were included. The information on deadwood was excluded. "Dead wood" refers to trees that are dead. There is a considerable amount of dead trees in the Pilot Forest. In fact, 9% of the measured trees in the inventory were found to be dead trees. 1/3 of the dead trees found in the inventory were from the four species *Burkea africana, Combretum collinum, Pterocarpus angolensis* and *Terminalia sericea,* see Appendix 2 "Status of measured trees" (p.34).

The table below shows the proportion of the measured trees that were dead among the most common species in the M'kata Pilot Forest. The proportion shows that there is very few dead trees found in the area. A study focusing only on dead trees was carried out by DED pelsonnel in Kanoflei forestry station. The report will be released at the later stage.

Species	% of dead trees among the measured trees
Burkea africana	7 %
Combretum collinum	8 %
Pterocarpus angolensis	10 %
Terminalia sericea	11 %

Table 12 shows the deadwood volume in the M'kata Pilot Forest. Note that the volume functions for living trees were used to calculate the deadwood volumes. These volume functions are assuming a certain amount of branchwood. Therefore the deadwood volumes might be overestimated, because most of dead trees have no branches like live trees.

There is a total deadwood volume of 1386 m^3 in M'kata pilot forest, see Table 12 (p.23). More than 80% of the volumes are from *Burkea africana* and *Pterocarpus angolensis* trees. Table 13 (p.23) shows that the dead trees are in small diameter class. 87% of the dead trees have a dbh smaller than 15 cm. Dead trees with bigger diameter are either from *Burkea africana* and *Pterocarpus angolensis*, especially *Pterocarpus angolensis*. Less than 2% of the dead trees have a dbh > 45 cm.

The German Development Service (DED) is, as a part of their development co-operation programme "Community Forestry in Namibia" doing research on the utilization of deadwood for carpentry. The species included in this research at the moment are *Baikiaea plurijuga, Burkea africana, Pterocarpus angolensis, Guibourtia coleosperma* and *Combretum imberbe.* The results so far in the research are encouraging. Carpenters in Namibia already utilize deadwood from *Guibourtia coleosperma.*

If deadwood were found to be suitable as raw material for carpentry, this would give the wood a financial value. Considering the big volumes of deadwood in the Pilot Forest, the utilization of deadwood for carpentry would become an option for income generation by the communities in the area. Since the Pilot Forest is in the care of DED and the community, further co-operation will benefit the community financially.

Table 12: Volume and number of stems of dead trees (totals and per hectare)

Species	Total No. of stems	Stems per ha	Total tree volume	Average tree volume m^3/ha
Combretum collinum	2374	2.25	78.41	0.07
Burkea africana	1736	1.65	532.60	0.51
Combretum zeyheri	1413	1.34	84.57	0.08
Terminalia sericea	1382	1.31	29.35	0.03
Dichrostachys cinerea (Setulosa)	1182	1.12	25.17	0.02
Acacia erioloba	452	0.43	8.81	0.01
Pterocarpus angolensis	333	0.32	627.15	0.60
Total	8871	8.42	1386.05	1.32

Table 13: Diameter distribution of dead trees by species

Species	5-15	15-25	25-35	35-45	55-65	65-75	Total	% of total
Combretum collinum	2374						2374	26.8
Burkea africana	932.4	228.2	575.9				1736	19.6
Combretum zeyheri	1413						1413	15.9
Terminalia sericea	1382						1382	15.6
Dichrostachys cinerea (Setulosa)	1182						1182	13.3
Acacia erioloba	452						452	5.1
Pterocarpus angolensis			113	115.2	51.19	53.38	333	3.8
Total	7734	228	689	115	51	53	8871	
% of total	43.6	1.3	3.9	0.6	0.3	0.3		100.0

To sum up:

- Most of the dead trees were mostly from *Burkea africana* and *Pterocarpus angolensis.*
- Most of the dead trees were mostly found in smaller diameter class, e.g, dbh <15 cm.
- Dead trees with bigger dbh were either from *Burkea africana* or *Pterocarpus angolensis.*

4.8 Regeneration of the trees and the shrub layer

Regeneration plays a critical role in the renewal and perpetuation of forest/woodland ecosystems. Good regeneration of trees means that there is continuously going to be sufficient number of saplings growing into tree sizes, which in turn means later on trees entering into mature stage. For the utilization of the wooded areas this means that; (1) a continuous harvesting of timber or poles will be possible, (2) the supply of non-wood forest products (e.g. fruits, fodder etc.) will not decrease as the old trees are dying. If the regeneration is weak, it is going to affect the desired diameter distribution mentioned in Chapter 4.5 (p. 17) and hence also affects short or long-term decisions.

Table 14 below shows the regeneration in terms of number of seedlings by height classes and species. Note that this table includes only woody species that are known to grow into tree size in the area.

The table shows that there are a considerable number of seedlings in the area. Most of the saplings are in the range of 26-50 cm. 2/3 of the seedlings are from *Acacia erioloba* and *Terminalia sericea.* The species mentioned above, are not the species dominating the tree layer.

Seedlings of *Pterocarpus angolensis* and *Burkea africana* were very few. This will have consequences for sustainable utilisation of these species in future. Something has to be done to enhance the regeneration of those scarce species.

Table 14: Number of tree seedlings per hectare by height classes and species

Species	0-25	26-50	51-100	101-150	151-200	201-250	251-300	300+	Total	% of total
Acacia erioloba		940							940	38.5
Terminalia sericea		20	160	270	190	63	3	3	710	29.1
Combretum collinum		47	87	57	47	10	3	3	253	10.4
Dichrostachys cinerea (Setulosa)	93	23	37	40					193	7.9
Burkea africana	3	30	63	13	20				130	5.3
Lonchocarpus nelsii	13	17	37	30	3				100	4.1
Combretum zeyheri	3	13	30	3	7	7			63	2.6
Ochna pulchra	17	10	3	3		3			37	1.5
Combretum psidioides (psidioides)			7						7	0.3
Pterocarpus angolensis			3			3			7	0.3
Total	130	1100	427	417	267	87	7	7	2440	
% of total	2.7	22.5	8.7	8.5	5.5	1.8	0.1	0.1		100.0

Table 15 shows the regeneration of woody species that do not generally grow into tree size, using the dbh≥5 cm limit.

Table 15: Number of shrub seedlings per hectare by height classes and species

Species	0-25	26-50	51-100	101-150	151-200	201-250	251-300	Total	% of total
Baphia massaiensis	7	37	173	220	127	20	7	590	64.8
Bauhia petersiana		3	27	57				87	9.5
Grewia retinervis		3	20		27	20		70	7.7
Combretum engleri		67	0					67	7.3
Acacia ataxacantha		0	10	7	10			27	2.9
Commiphora angolensis		3	10	7				20	2.2
Baissea wulfhorstii		17	0					17	1.8
Terminalia prunioides			3	3		3		10	1.1
Acacia mellifera				7				7	0.7
Ozoroa schinzii			7					7	0.7
Acacia fleckii					3			3	0.4
Grewia bicolor				3				3	0.4
Grewia flava				3				3	0.4
Total	7	130	250	307	167	43	7	910	
% of total	0.4	7.1	13.7	16.8	9.2	2.4	0.4		100.0

To sum up:

- There is a considerable amount of saplings.
- Almost 40% of the seedlings are from *Acacia erioloba*.
- There is very few saplings from *Pterocarpus angolensis*
- Something has to be done to enhance the regeneration of *Pterocarpus angolensis*.

4.14 Sampling error and confidence limits

4.14.1 General

Source of error
In sampling based forest inventories the following error sources are always present: sampling error, measurement error including coding error, errors in data processing and errors in models used for e.g. volume estimation.

Training
In this work, specific attention was paid to guarantee good quality field data. Field personnel were continuously trained on-the-job in forest measurements and species identification. The field team attended a course on species identification at the National Botanical Research Institute during 1998. Field instructions were reviewed both in the office and in the field. Data processing programs were carefully designed and double checked. Several cross checkings were done to find out possible errors and inconsistencies in the data. The data processing and analysis, and reports were double checked.

Volume functions
The applied volume functions are propably the main source of errors. There were no trees felled in M'kata Pilot Forest. Instead we used the existing volume functions to estimate the volumes. Stem analysis were done only for Caprivi, Omusati and West Tsumkwe.

Sampling error estimator
The magnitude of sampling error, Table 16, was estimated with the formula of stratified random sampling, using clusters but not sample plots, as sampling units. The applied sampling method was systematic, not random, but the formula is more or less valid. However, the formula may over estimate the sampling error.

4.14.2 Sampling error and confidence limits for tree volume

Table 16 (p.27) shows the sampling error and confidence limits for tree volume for 'all species', *Burkea africana, Pterocarpus angolensis, Combretum collinum* and *Terminalia sericea.* For the estimate of average tree volume per hectare of "all species" the sampling error was 1.17 m^3/ha, that is, 7.97% of the average. Therefore, the true average tree volume for all species is between 12.34 and 16.91 m^3/ha with the probability of 95%.

The sampling error for the average tree volume per hectare of *Burkea africana, Pterocarpus angolensis, Combretum collinum* and *Terminaria sericea* were as follows: 0.19 m^3/ha (16.82% of the average), 0.72 m^3/ha (18.62% of the average), 0.38 m^3/ha (20.01% of the average) and 0.31 m^3/ha (42.63% of the average) respectively. Hence, the average trees volume of *Burkea africana, Pterocarpus angolensis, Combretum collinum* and *Terminalia sericea* were between 0.74 and 1.48; 2.44 and 5.25, 1.15 and 2.64 and 0.12 and 1.33 m^3/ha with the probability of 95%, respectively.

Table 16: Sampling error and confidence limits for tree volume for the whole area

Species	Sampling variance	Standard error, m3/ha	Average volume, m3/ha	Sampling error, %	Lower confidence limit, m3/ha	Upper confidence limit, m3/ha	Confidence level, %
All species	1.36	1.17	14.62	7.97	12.34	16.91	95
B. africana	0.03	0.19	1.11	16.82	0.74	1.48	95
P. angolensis	0.51	0.72	3.85	18.62	2.44	5.25	95
C. collinum	0.14	0.38	1.90	20.01	1.15	2.64	95
T. sericea	0.10	0.31	0.72	42.63	0.12	1.33	95

5. Conclusion

M'kata Pilot Forest is situated in the western parts of Tsumkwe district in Otjozondjupa region. The area is a part of the Kalahari Highland.

The M'kata Pilot Forest is a part of the project "Community Forestry in North-Eastern Namibia". The project is a co-operation between the Directorate of Forestry (DoF), the German Development Service (DED) and the German Bank of Development (KfW). The project started in October 1999. The data collected and the information presented in this report reflects the information need stated by the project representative in Kanovlei at the time of inventory design and fieldwork.

The woody species
A total of 26 woody species were recorded in M'kata pilot Forest. 13 were recorded as trees and 23 woody species were found in shrub layer. 10 woody species were found both as trees in the tree layer and as shrubs in the shrub layer. This is a relatively large number of woody species recorded within a 1054 ha area. Althought the number of species recorded in the area is high few species are very common. More than half of the species found in the area are extremely rare.

Stratification
Post stratification was carried out for the area. The main objective for this stratification was to identify areas with specifically high volumes of *Pterocarpus angolensis* and the areas with generally higher tree volumes. The measured data in the inventory and the aerial photographs were used to stratify the area.

Almost 1/5 of the pilot forest consists of area an with specifically high *Pterocarpus angolensis* volume ("Pterocarpus woodland"). The biggest area in the Pilot Forest is covered by the strata "Mixed Woodland, higher volume". More than half of the area ("Pterocarpus woodland" and "Mixed Woodland", higher volume), consist of woodland with relatively high tree volumes. Shrubland covers almost a third of the pilot forest.

Forest resource
The total tree volume in the Pilot Forest is 15399 m^3. The mean tree volume and the mean number of trees in M'kata Pilot Forest are 14.62 m^3/ha and 90.69 stems/ha respectively.

There is a big variation in volumes. The highest tree volume was found in Pterocarpus woodland (PW). The volumes in the "Mixed woodland, high volume" (WHV) are also relatively high. "PW and WHV" strata cover half of M'kata Pilot Forest. And 80% of the total volume is in those two strata. Although the number of stems per ha is more or less the same in the "PW" and "WHV", the volume is twice as high in "PW's". Note that these figure include only live trees.

There is a total volume of 1386 m^3 of deadwood in M'kata Pilot Forest. More than 80% of the volumes are from *Burkea africana* and *Pterocarpus angolensis* trees. Most of dead trees are in small diameter classes. 87% of the dead trees have a dbh smaller than 15 cm. Dead trees

with bigger diameter are either from *Burkea africana* and *Pterocarpus angolensis*, especially *Pterocarpus angolensis*. Less than 2% of the dead trees have a dbh > 45 cm.

Regeneration
Regeneration plays a critical role in the renewal and perpetuation of forest/woodland ecosystems. Good regeneration of trees means that there is continuously going to be sufficient number of saplings growing into tree sizes, which in turn means later on trees entering into mature stage.

There is on average 3350, shrubs and tree saplings per hectare in the shrub layer. 73% of these shrubs were found also in the tree layer. Hence the regeneration of tree species is good in the area. The woody species dominating the tree layer and shrub layer differs. In some areas both layers are dominated by the same species. 2/3 of the seedlings are from *Acacia erioloba* and *Terminalia sericea.* The species mentioned above, are not the species dominating the tree layer.

Seedlings of *Pterocarpus angolensis* and *Burkea africana* were very few. This will affect negatively sustainable utilisation of these species in future. Something has to be done to enhance the regeneration of those scarce species.

Pontential for economic utilisation now and in the future
It is recognized that the woody resource can provide economic benefits from a number of other products than sawn timber, e.g. pole production, veld products, fruits or woodcarving. The information on veld products were collected but were not analysed, therefore it is not included in the report. The data on veld products will be available at the later stage. The inventory was focussing on the potential for sawn timber production and veld products, but does not try to estimate the woody resource utilization for other purposes.

The limit for timber harvesting is 45 cm dbh. There is a total of 506.7m^3 saw-log volume of *Pterocarpus angolensis* in the Pilot Forest. Volumes include only the main trunk. There is in fact a bigger log volume of *Pterocarpus angolensis* than of *Burkea africana* in the Pilot Forest. The figures in Tables 10 and 11 exclude branchwood and deadwood, and the log volumes are only for trees with dbh>45 cm.

When sawn timber is produced, approximately 40% of the sawlog volume becomes sawn timber the rest is residues. Therefore there is approximatery 161.5 m^3 of sawn timber of *Pterocarpus angolensis* in the Pilot Forest, which is on average 0.15 m^3/ha.

The total saw-log volume is very small. If we assume that one cubic meter consists of aproximately three big trees of size >45 cm, then we must have approximately a total of 500 big trees to have 161.5 m^3. This does not mean that if we have those cubic meters, then we can harvest all. So we are talking about approximately 400 trees to be cut and others to produce seeds to enhance regeneration. So, there is a potential for utilisation on a very limited small-scale of *Pterocarpus angolensis* for construction, carpentry and furniture making at the moment.

The diameter distribution of *Pterocarpus angolensis* trees is well balanced with the bulk of the stems in small diameter classes. With proper management these small trees are going to grow into mature trees. The growth of species is not yet assessed, to determine how long those small trees will take to grow into mature trees.

The present regeneration is the future mature trees. The regeneration of *Pterocarpus angolensis* was very few. So something has to be done to enhance the regeneration of that species.

Some management proposals

There is a potential for limited small-scale utilization of *Pterocarpus angolensis*. Proper management is crucial for this utilization to be sustainable. This goes also for any other species that is going to be utilized in the M'kata pilot Forest.

The management of the woody resources in the Pilot Forest should include at least the following:

- Management of the mature trees through of calculation of Annual Allowable Cut to ensure a sustainable utilization.
- Management of the smaller trees for them to grow into mature trees.
- Management of the regeneration in form of both the management of existing seedlings and the management to enhance regeneration.
- Fire management.
- The inclusion of Non Timber Forest Products, such as veld products etc, into the planning.

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Appendix 1: Cluster coordinates for M'kata Pilot Forest

Note: Coordinates are in decimal degrees.

Cluster	Latitude	Longitude
1	-19.5095	19.5072
2	-19.5227	19.5068
3	-19.5245	19.5083
4	-19.5251	19.5252
5	-19.5256	19.5304
6	-19.5272	19.5301
7	-19.5288	19.5300
8	-19.5220	19.5530
9	-19.5259	19.5064
10	-19.5275	19.5062
11	-19.5205	19.5275
12	-19.5221	19.5273
13	-19.5250	19.5509
14	-19.5096	19.5090
15	-19.5299	19.5223
16	-19.5203	19.5258
17	-19.5209	19.5326
18	-19.5214	19.5378
19	-19.5212	19.5087
20	-19.5216	19.5221
21	-19.5219	19.5056
22	-19.5229	19.5359
23	-19.5233	19.5393
24	-19.5230	19.5202
25	-19.5264	19.5216
26	-19.5283	19.5248
27	-19.5248	19.5218
28	-19.5227	19.5342
29	-19.5281	19.5387
30	-19.5295	19.5368

Appendix 2: Status of measured trees

Species	Dead, lying	Live tree	Standing dead tree	Total	% of total measured trees
Acacia erioloba		1	1	2	0.7
Acacia Tortilis (spirocarpa)		1		1	0.3
Boscia albitrunca		3		3	1.0
Boscia foetida		4		4	1.4
Burkea africana	2	119	7	126	43.3
Combretum collinum	1	61	4	65	22.3
Combretum psidioides (psidioides)		3		3	1.0
Combretum zeyheri			3	3	1.0
Dichrostachys cinerea (Setulosa)			1	1	0.3
Lonchocarpus nelsii		10		10	3.4
Ochna pulchra		6		6	2.1
Pterocarpus angolensis	1	37	3	40	13.7
Terminalia sericea		24	3	27	9.3
Total	4	269	22	291	
% of total measured trees	1.4	92.4	7.6		100.0

Appendix 3: Total number of measured shrubs

Species	No. of measured shrubs	% of measured shrubs
Terminalia sericea	25	18.0
Combretum collinum	23	16.5
Baphia massaiensis	22	15.8
Burkea africana	11	7.9
Lonchocarpus nelsii	9	6.5
Combretum zeyheri	8	5.8
Dichrostachys cinerea (Setulosa)	8	5.8
Ochna pulchra	7	5.0
Bauhia petersiana	6	4.3
Grewia retinervis	4	2.9
Commiphora angolensis	3	2.2
Acacia ataxacantha	2	1.4
Acacia erioloba	1	0.7
Acacia fleckii	1	0.7
Acacia mellifera	1	0.7
Baissea wulfhorstii	1	0.7
Combretum engleri	1	0.7
Combretum psidioides (psidioides)	1	0.7
Grewia bicolor	1	0.7
Grewia flava	1	0.7
Ozoroa schinzii	1	0.7
Pterocarpus angolensis	1	0.7
Terminalia prunioides	1	0.7
Total	139	100.0

Appendix 4: Volume distribution by diameter class and species (m^3/ha)

Species	5-15	15-25	25-35	35-45	45-55	55-65	65-75	75-85	Total

Acacia erioloba			98.29						98.29
Acacia Tortilis (spirocarpa)		33.79							33.79
Boscia albitrunca		70.42	56.43						126.85
Boscia foetida	79.19								79.19
Burkea africana	1723.28	1995.12	1720.98	1456.99	103.65		229.88		7229.90
Combretum collinum	654.54	796.88	97.36	151.42	121.03	175.03			1996.25
Combretum psidioides (psidioides)	6.36	88.66							95.02
Lonchocarpus nelsii	152.67	132.51	175.01						460.19
Ochna pulchra	204.12						261.97		466.09
Pterocarpus angolensis	190.68	244.98	748.97	802.01	1042.39	783.11	239.95		4052.08
Terminalia sericea	383.53	27.03	127.57					223.46	761.59
Total	3394.38	3389.38	3024.60	2410.41	1267.06	958.14	731.80	223.46	15399.24

Appendix 5: Volume functions for M'kata Pilot Forest

For *Pterocarpus angolensis* use:
$v = e^{\wedge} (a_0 + a_1 * d + a_2 * d^2)$,
where v = tree volume in dm^3
d = tree diameter (dbh) in cm
a_o, a_1 & a_2 = parameters (see table below)

Note: 1. ^ means "to the power of"
2. e = 2.71828
For *Terminalia sericea, Acacias, Lonchocarpus nelsii, Combretum collinum, Colophospermum mopane, Burkea africana, Baikiaea plurijuga* and *Commiphora angolensis* use:
$v = (a_0 + a_1 * d + a_2 * d^2) * d^2$ or $v = a_0 * d^2 + a_1 * d^3 + a_2 * d^4$
where v = tree volume in dm^3
d = tree diameter (dbh) in cm
a_o, a_1 & a_2 = parameters (see table below)

Parameters:

Species	a_0	a_1	a_2
1 ACACIAS	0.21795109	0.01407904	-0.00010783
2 BAIPL	0.260011	0.02368	-0.00021
3 BURAF	0.151269	0.030485	-0.00029
4 COLMO	0.12798339	0.01580639	-0.00014894
5 COMAN	0.18057025	0.01974331	-0.00010431
6 COMCO	0.18057025	0.01974331	-0.00010431
7 LONNE	0.46735748	0.00342083	0.00008758
8 PTEAN	2.81959700	0.14324800	-0.00090000
9 TERSE	0.21795109	0.01407904	-0.00010783

Example 1: For a *Baikiaea plurijuga* tree with diameter (DBH) = 26.5 cm.
$v = a_0 * d^2 + a_1 * d^3 + a_2 * d^4$
$= (0.260011)*(26.5)^2+(0.02368)*(26.5)^3+(-0.00021)*(26.5)^4$
$= 182.59272+440.67592-103.56256$
$= 519.7\ dm^3$

Example 2: For a *Pterocarpus angolensis* tree with diameter (DBH) = 47 cm.
$v = e^{\wedge} (a_0 + a_1 * d + a_2 * d^2 + a_3 * d^3)$
$= e^{\wedge} (2.81959700)+(0.14324800)*(47)+(-0.00090000)*(47)^2$
$= (2.71828)^{\wedge}(2.819597+6.7327-1.9881)$
$= (2.71828)^{\wedge}(7.5641)$
$= 1927.72\ dm^3$

Note: $1000\ dm^3 = 1\ m^3$

Appendix 6: List of tree/shrub species for M'kata Pilot Forest

Number = index for the model applied to calculate volume: 1= ACACIAS (v model=TERSE) 2=BAIPL 3=BURAF 4=COLMO 5=COMAN (v model=COMCO) 6=COMCO 7=LONNE 8=PTEAN 9=TERSE (Refer to models in Appendix 5, on page 36 above)

Code	Species	Index to volume model
ACAAT	Acacia ataxacantha	1
ACAER	Acacia erioloba	1
ACAFL	Acacia fleckii	1
ACAPO	Acacia polyacantha	9
ACASC	Acacia schweinfurthii	1
ANCBA	Ancylanthos baniesii	9
BAIPL	Baikiaea plurijuga	2
BAIWU	Baissea wulfhorstii	9
BAPMA	Baphia massaiensis	9
BAUPE	Bauhia petersiana	9
BOSAL	Boscia albitrunca	8
BURAF	Burkea africana	3
COMAA	Combretum apiculatum (apiculatum)	9
COMAF	Commiphora africana	5
COMAN	Commiphora angolensis	5
COMCO	Combretum collinum	6
COMEL	Combretum elaeagnoides	6
COMEN	Combretum engleri	6
COMPS	Combretum psidioides (psidioides)	6
COMZE	Combretum zeyheri	6
CROGG	Croton gratissimus	9
DIAEN	Dialium engleranum	9
DICCA	Dichrostachys cinerea (Africana)	9
DICCS	Dichrostachys cinerea (Setulosa)	9
DICCY	Dichapetalum cymosum	9
DIPCO	Diplorhynchus condylocarpon	9
DOMRO	Dombeya rotandifolia	9
ERYAF	Erythrophleum africanum	3
GREAV	Grewia avellana	9
GREBI	Grewia bicolor	9
GREFL	Grewia flava	9
GRERE	Grewia retinervis	9
GUICO	Guibourtia coleosperma	8
LONNE	Lonchocarpus nelsii	7
MARAC	Markhamia acuminata	3
MUNSE	Mundulea sericea	9
OCHPU	Ochna pulchra	8
OZOIN	Ozoroa insignis	9
OZOLO	Ozoroa longipes	9
OZOPA	Ozoroa paniculosa	9
OZOSC	Ozoroa schinzii	9
PAVZE	Pavetta zeyheri	9
PELAF	Peltophorum africanum	8
PSEMA	Pseudolachnostylis maprouneifolia	9
PTEAN	Pterocarpus angolensis	8
RHIBR	Rhigoszum brevispinosum	9
RHUTE	Rhus tenuinervis	9
SCHRA	Schinziophyton rautanenii	3
SECLO	Securidaca longepedunculata	8
STEAR	Steganotaenia araliacea	8
STRCO	Strychnos cocculoides	9
STRPU	Strychnos pungens	9
TERSE	Terminalia sericea	9
VANIN	Vangueria infausta	8
XXXXX	Unknown2	8

Appendix 7: Acknowledgements

The successful completion of the Forest Inventory Exercise in M'kata Pilot Forest was a result of the co-operative efforts of the Steering Committee and many other individuals within the Directorate of Forestry and other institutions. The key personnel directly involved in the forest inventory consisted of Directorate of Forestry and Government of Finland staff.

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