MINISTRY OF ENVIRONMENT AND TOURISM
Directorate of Forestry

MASHARE FOREST INVENTORY REPORT

Namibia-Finland Forestry Programme

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TABLE OF CONTENTS

List of figures

List of maps

List of appendices

List of tables

EXECUTIVE SUMMARY

General description of the area

Mashare forest is situated in Kavango Region south of Rundu. The Mashare community requested the Directorate of Forestry to conduct a forest inventory to determine the volume and the number of stems in the area for harvesting purposes.

The forest resources

The inventory concentrated on 5 tree species only, *Baikiaea plurijuga*, *Burkea africana*, *Pterocarpus angolensis*, *Guibourtia coleosperma* and *Schinziophton rautanenii*.

The size of the Mashare forest area inventoried is 186,000 hectares. There are 14,685,000 trees with a total volume of 4,205,000 m^3 of live trees in the Mashare forest. The mean tree volume is 22.6 m^3/ha and the mean number of trees for the whole area is 78.8 stems/ha. Dead trees were also analysed. There is a total volume of 342,000 m^3 of dead trees in Mashare forest.

Majority of trees are in the diameter class 5-25 cm. Only 7 % of the trees are bigger than 45 cm at breast height, that is over the harvesting limit. *Burkea africana* is the most frequent tree with 78 % of all stems found in the inventory. Only one individual of *Schinziophyton rautanenii* was found.

Burkea africana shows a well-balanced distribution, i.e. the bulk of the stems for most species were found in the small diameter classes. The diameter distribution of the other species is different from *Burkea*, there are not so much small size trees.

Regeneration

There is an average of 448 tree saplings per hectare in the area. Only *Burkea africana* is commonly found as saplings (360 per ha). *Baikiaea plurijuga* and *Guibourtia coleosperma* saplings are found to some extent (52 and 29 per ha), while regeneration of *Pterocarpus angolensis* is very scarce (7 per ha).

Harvesting potential

No harvesting of *Pterocarpus angolensis* and *Baikiaea plurijuga* is proposed because of poor regeneration and small number of mature trees. In the case of *Burkea africana* harvesting of 47,000 stems with a total log volume of 25,000 m3 is estimated as the allowable sustainable cut. Also, harvesting of some pole size *Burkea*-trees is possible. In the case of *Guibourtia coleosperma*, harvesting of 12,770 large trees is possible.

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, supported by the Government of Finland, 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 DoF began a comprehensive implementation of the Namibia forestry strategic plan of 1996 by launching the Namibia-Finland Forestry Programme and the National Forest Inventory was incorporated as a sub-component into this programme.

The main objectives of the National Forest Inventory in NFFP Phase I were to provide regional level forest resource data on northern Namibia for strategic planning, to provide more detailed forest resource data for strategic or operational management planning on sub region areas, and to build a Namibian capacity to carry out the inventories.

The Directorate of Forestry was given first a higher priority to region level inventories in order to have basic knowledge of the forest resources in each region. After the region level inventories, the work will proceed to more detailed local level inventories. The support from the government of Finland today – through Namibia-Finland Forestry Programme phase II (2001-2005) – aims now more at strengthening the capacity of directorate to serve the needs specifically for local level forest management planning.

The utilization of information from different levels of inventories is different. The region level inventories provide information on the forest resource from 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 inventories.

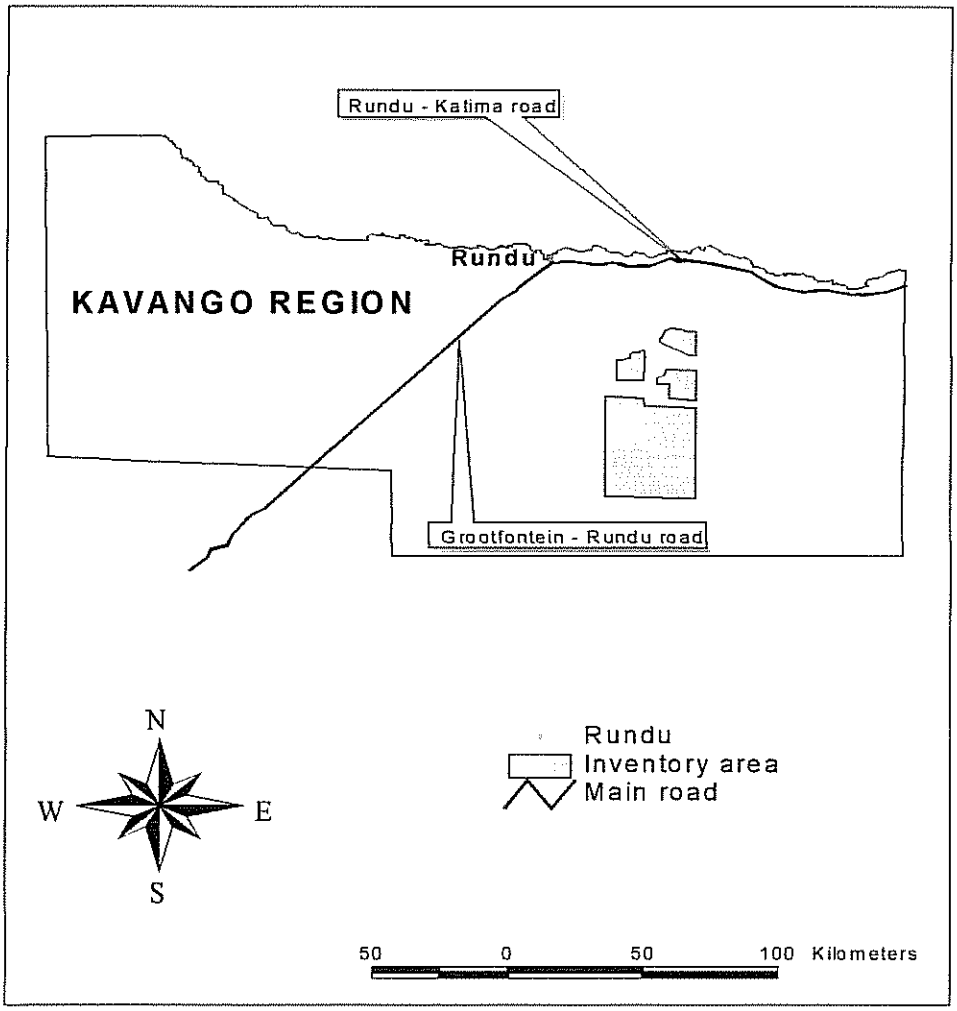
This report presents the results from the timber inventory of Mashare forest. The inventory was carried out on the request of the local community. An additional data collection for the design of the woody resource monitoring system was implemented too. The objective of the woody resource monitoring system was to collect field samples of woody vegetation cover to be used with Landsat TM satellite data. This report presents only the results for the timber inventory covering data of 5 species only.

For those readers who may be interested to know what other forest areas the Directorate of Forestry has inventoried, a list of inventory reports has been attached (Appendix 5 page 23) at the end of this report. These reports are available at the Directorate of Forestry in Windhoek.

2. DESCRIPTION OF THE AREA

The Mashare forest is located in the Southern part of Rundu district in Kavango region (See Map 1). According to the vegetation maps, the area is classified as forest. The size of the inventory area is 186,286 ha. The tree species covered in the inventory are *Baikiaea plurijuga, Burkea africana, Pterocarpus angolensis, Guibourtia coleosperma and Schinziophyton rautanenii.*

Map 1: Location of Mashare forest



3. INVENTORY DESIGN

3.1 Sampling method

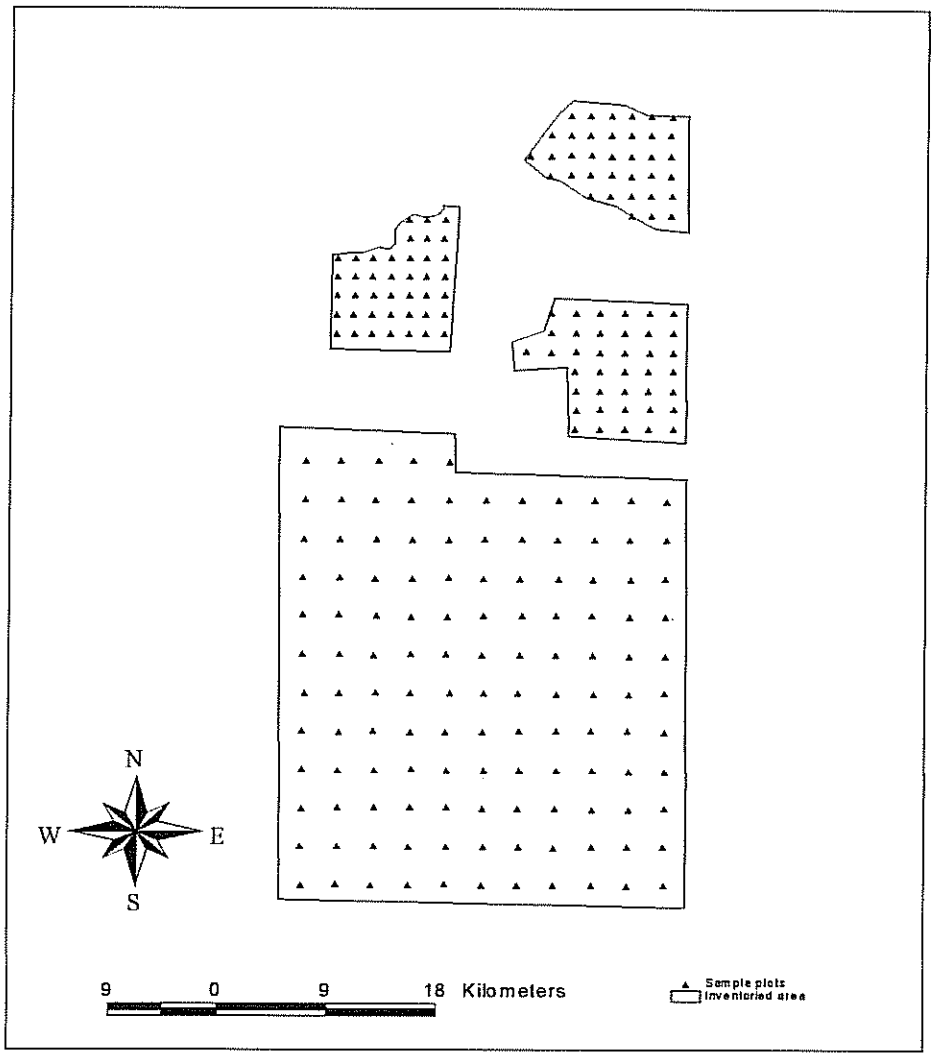
A systematic sampling design was applied. The total number of plots located in the area was 221. Each plot has its own coordinates. Map 2 shows the location of plots in the area.

With the help of a preliminary field survey in the area and a Landsat TM satellite image, the area was divided into 4 separate blocks. Based on visual interpretation, trees of the 5 species of interest were expected to be found in these blocks. A portion of the southern block was left out because only acacia species was found there.

A different sampling intensity was applied on the smaller blocks than for the bigger area. This was done to have enough plots on all blocks. Then, if needed, reasonably reliable results could be given to each block too. However, in this report the results are given for all blocks together.

A grid of plots was laid on the vegetation maps and then digitized using ArcView to obtain coordinates for each plot. Coordinates and a GPS were used for locating the plots in the field. The plots were not marked as permanent plots.

Map 2: Location of plots in the inventory area



3.2 Field measurements

The data was 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 ≥ 5cm, and shrubs are woody plants with dbh < 5cm.

A different radius of sample plot was applied for small trees, medium size trees and big trees. For small trees (5 cm ≤ dbh < 20 cm) the radius is 10 m, for medium size trees (20 ≤ dbh < 45 cm the radius is 20 m and for big trees dbh ≥ 45 cm the radius is 30 m.

Dbh, location, species, crown class quality, length and quality of possible saw log were measured for all trees in all sample plots. In addition, tree height, diameter of canopy and the crown height were also recorded for each tree. In this inventory, damages to trees were not recorded. Regeneration of all species was measured in two sub-plots (radius 3.99 m) located in each plot (See Figure 1).

Information describing the environment surrounding the sample plot ("the stand") was also recorded. This description includes e.g the soil, the land types, damages to the woody vegetation and human influence. All the measurements are described in more detail in the field instructions (Manual for woody resource inventory, 2001).

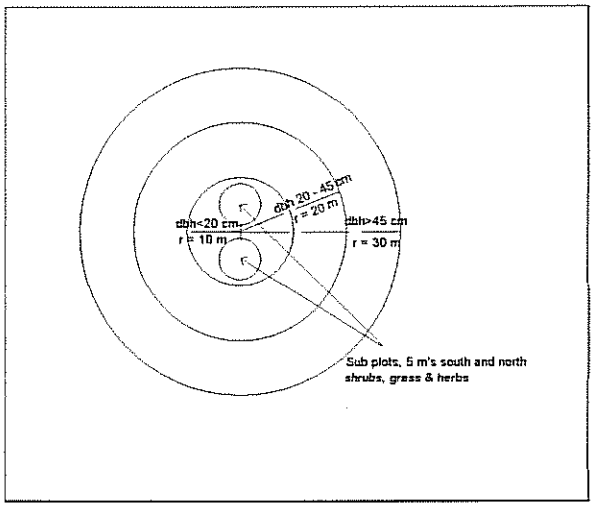


Figure 1: Plot design

3.3 Volume functions

The volume functions used in the inventory have been developed by DoF. The data used for the modelling has been collected from four areas: Tsumkwe, Caprivi, Omusati and Oshikoto regions. The volume functions for *Burkea africana, Pterocarpus angolensis, Baikiaea plurijuga, Guibourtia coleosperma and Schinziophyton rautanenii* can be found in Appendix 2.

4. INVENTORY RESULTS

4.1 Measured data

The inventory fieldwork in Mashare forest was carried out from October to December 2001. A total of 221 sample plots were measured in the inventory.

A total of 992 trees with dbh ≥ 5cm were measured in the plots (See Table 1) which is on average 4.5 trees per sample plot.

The tree species measured in the whole area were *Burkea africana, Baikiaea plurijuga Pterocarpus angolensis, Schinziophyton rautanenii* and *Guibourtia coleosperma.* Table 1 indicates that 65 % of measured trees are *Burkea africana* -trees.

Table 1: Total number of measured trees

Species	Total No. of measured trees	% of measured trees
Baikiaea plurijuga	159	16.0
Burkea africana	642	64.7
Guibourtia coleosperma	131	13.2
Pterocarpus angolensis	59	6.0
Schinziophyton rautanenii	1	0.1
Total	992	100

4.2 Height of measured trees

Table 2 below shows the average and maximum height of the trees. The height of the woody vegetation is generally low. Only *Burkea africana* and *Guibourtia coleosperma* trees could be found with heights above 20 meters.

Table 2: Average, minimum and maximum height by species

Species	Average height (m)	Maximum height (m)
Baikiaea plurijuga	8.9	16.3
Burkea africana	9.9	20.8
Guibourtia coleosperma	10.2	24.3
Pterocarpus angolensis	10.8	17.9
Schinziophyton rautanenii	6.2	6.2

4.3 Tree volumes and number of stems

All the woody stems with a dbh ≥ 5 cm are regarded as trees. The number of stems and tree volumes by species for the whole Mashare inventory area are shown in Table 3 below.

The number of trees is 78.8 stems/ha and the mean volume is 22.6 m^3/ha as shown in the Table 3 below. The total number of stems is 14,685,000 and the total volume of the trees is 4,205,000 m^3. *Burkea africana* has got the highest share: 78 % of the stems and 72 % of the volume. Only very few *Schinziophyton* trees can be found in the area.

Table 3: Volume and number of stems by species, total and per hectare

Species	Total No. of stems (1000's)	Stems per ha	Total tree volume (1000 m^3)	Mean volume (m^3/ha)
Baikiaea plurijuga	988	5.3	278	1.5
Burkea africana	11382	61.1	3030	16.3
Guibourtia coleosperma	1564	8.4	637	3.4
Pterocarpus angolensis	747	4.0	258	1.4
Schinziophyton rautanenii	3	0.0	2	0.0
Total	14685	78.8	4205	22.6

4.4 Distribution of stems and volume

Number of stems in diameter classes

A desired diameter distribution from management point of view is one where the majority of the stems is in the lower diameter classes, and the number of stems is gradually decreasing as the diameter gets bigger. With this kind of distribution there are 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. The diameter distribution presented in this chapter includes only live trees. Figure 2 below shows the diameter distribution of trees for different diameter classes in Mashare inventory area. The full list of species with total number of trees in diameter classes is shown in Appendix 1 (Table 4).

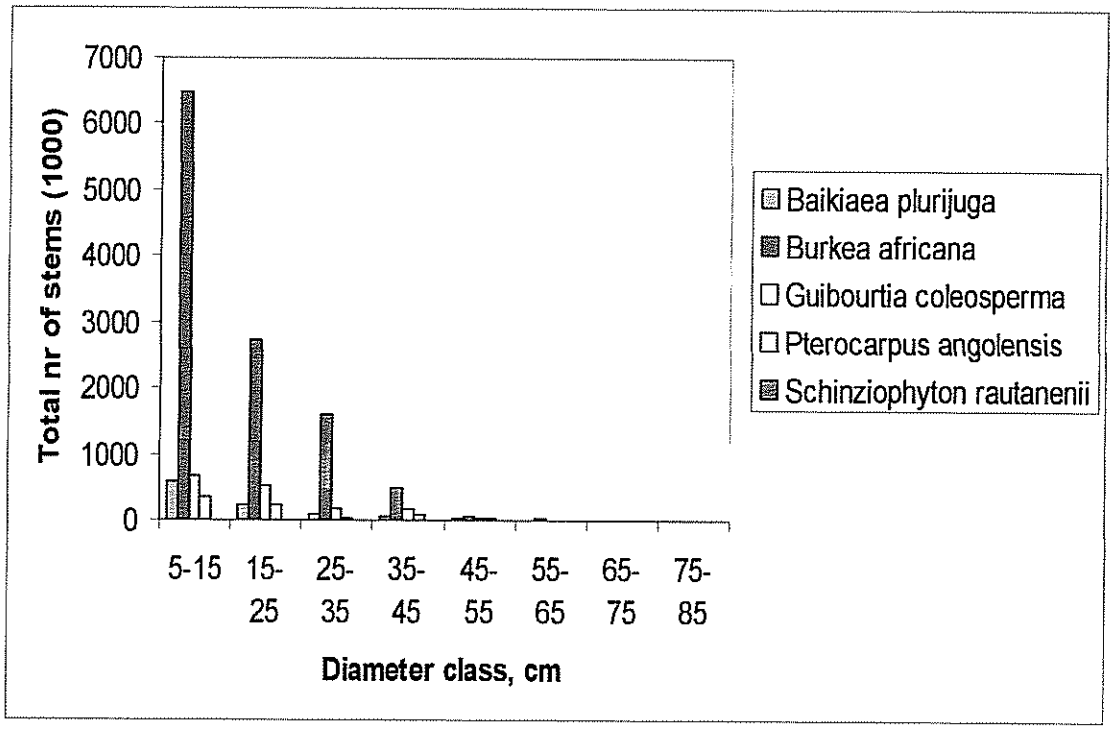


Figure 2: Diameter distribution of stems by species

Majority of the stems were found in small diameter classes. 80 % of the stems were found between 5-25 cm. *Burkea africana* dominates in all diameter classes. Four out five trees in the small diameter classes (5-25 cm) are *Burkea africana* –trees. However, among the large size trees (> 45 cm at breast height) the share of *Burkea*-trees goes down

to 40 %. The second most frequent species is *Guibourtia coleosperma* with 11 % of the total number of stems and 32 % of the large size (dbh > 45 cm) trees.

Table 4 in Appendix 1 also shows which species have a potential to grow into big trees. Species that were found in the biggest diameter class were *Burkea africana* and *Guibourtia coleosperma*. Only 7 % of all stems have a diameter bigger than 45 cm which is the current harvesting limit.

Volume in diameter classes

Majority of the volume – that is 52 % - is in the diameter classes between 15 cm and 35 cm. The share of *Burkea africana* of the total volume is 72 %. The total volume of all trees in the big diameter classes (dbh more than 45 cm) is 633,000 m^3. Of this volume, the share of *Burkea* is 41 %, the share of *Guibourtia coleosperma* is 36 %, the share of *Pterocarpus angolensis* is 14 % and the share of *Baikiaea plurijuga* is 9 %.

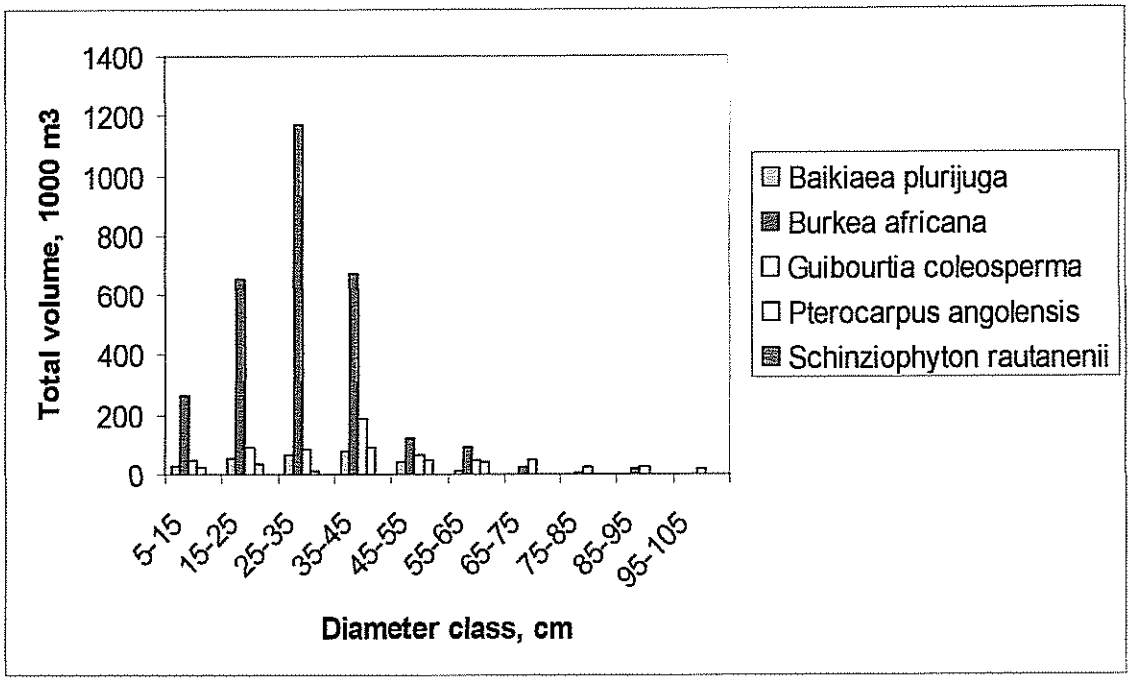


Figure 3: Distribution of total volume in diameter classes

4.5 Deadwood

Table 6 shows the number of dead trees and the deadwood volume by species in the Mashare Forest. A volume function for living trees was used to calculate the deadwood volumes. This function includes branch volume too, so for dead trees the function gives

an overestimate. There are 1,278,000 dead trees in the area with a total deadwood volume of 342,000 m^3. 78 % of the dead stems are *Burkea africana* -trees. Figure 4 below and Appendix 1 (Table 7) show that the majority of the dead trees are in small diameter classes. Dead trees with larger diameters are *Burkea africana* and *Baikiaea plurijuga* – trees, however only very few have a dbh over 45 cm.

Table 6: Volume and number of stems of dead trees (total and per ha)

Species	Total No. of stems (1000)	Stems per ha	Total tree volume (1000 m^3)	Mean volume, m^3/ha
Baikiaea plurijuga	156	0.8	33	0.2
Burkea africana	992	5.3	283	1.5
Guibourtia coleosperma	89	0.5	24	0.1
Pterocarpus angolensis	41	0.2	2	0.0
Total	1278	6.9	342	1.8

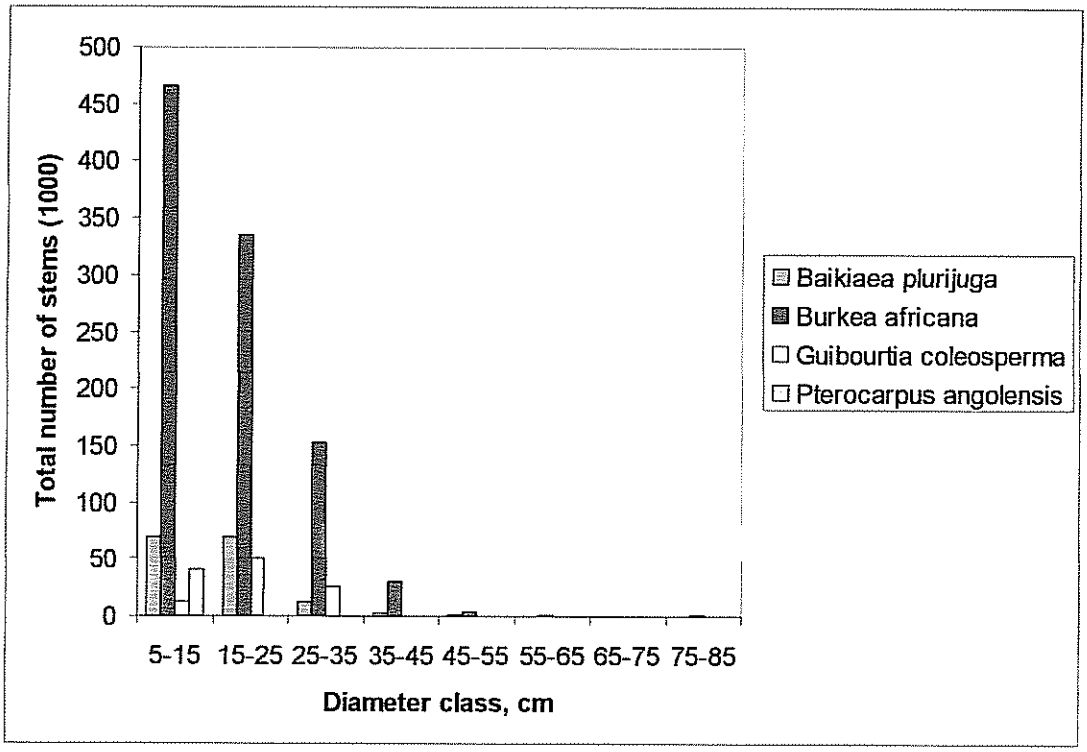


Figure 4: Total number of dead trees by species and diameter class

4.6 Timber volumes and qualities

Timber volume or saw log volume means the volume of the part of the main trunk that has been regarded as saw-able. In the field, the dbh and length of the saw-able trunk were recorded. The saw log volumes were estimated assuming the log has a cylindrical form. Table 8 shows timber volumes and qualities of *Burkea africana*, *Pterocarpus angolensis*, *Guibourtia coleosperma* and *Baikiaea plurijuga*. It should be kept in mind that the tables show only log volumes for trees mature for harvesting, i.e. trees with a dbh more than 45 cm. Most of the harvestable stems are of good or medium quality, i.e. stems having at least 2 m of saw-able stem. Some stems were found not saw-able because they were too curvy. Dead trees were not considered saw-able either.

The quality classification used in the inventory is as follows:

Good quality	There is at least a 2 m 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 a 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

There is a total volume of 49,000 m^3 of saw logs of *Burkea africana*, 5,900 m^3 of *Baikiaea plurijuga*, 23,400 m^3 of *Pterocarpus angolensis* and 13,700 m^3 of *Guibourtia coleosperma* in the inventory area. Volumes include only the main trunk and only the part of the stem that has been classified as a saw log.

Table 8: Status and qualities of *Burkea africana, Baikiaea plurijuga, Pterocarpus angolensis* and *Guibourtia coleosperma* saw-able stems

Burkea africana

Status	Quality	Stems per ha	Total No. of stems	Total log volume, m^3	Average log volume, m^3/ha
Alive tree	Good quality	0.19	36273	29886	0.16
	Medium quality	0.15	28502	13275	0.07
	Poor quality	0.09	17492	6542	0.04
	Not saw-able	0.02	4534	0	0.00
Standing dead tree		0.04	7127	0	0.00
Total		0.50	93928	49703	0.27

Baikiaea plurijuga

Status	Quality	Stems per ha	Total No. of stems	Total log volume, m^3	Average log volume, m^3/ha
Alive tree	Medium quality	0.04	7779	3325	0.02
	Poor quality	0.02	3889	1307	0.01
	Expected good quality	0.01	1296	1295	0.01
	Not sawable	0.06	11661	0	0.00
Standing dead tree		0.01	1296	0	0.00
Total		0.14	25922	5927	0.03

Pterocarpus angolensis

Status	Quality	Stems per ha	Total No. of stems	Total log volume, m^3	Average log volume, m^3/ha
Alive tree	Good quality	0.11	20730	19392	0.10
	Medium quality	0.02	4534	2551	0.01
	Poor quality	0.02	4534	1421	0.01
	Not sawable	0.02	4534	0	0.00
Total		0.18	34332	23364	0.13

Guibourtia coleosperma

Status	Quality	Stems per ha	Total No. of stems	Total log volume, m^3	Average log volume, m^3/ha
Alive trees	No code	0.03	5831	0	0.00
	Good quality	0.05	9068	2762	0.01
	Medium quality	0.11	20730	7573	0.04
	Poor quality	0.05	9068	3411	0.02
	Not sawable	0.08	14899	0	0.00
Total		0.32	59596	13746	0.07

4.7 Regeneration

Regeneration plays a critical role in the renewal and perpetuation of forest and woodland ecosystems. Good regeneration of trees means that there is continuously going to be a sufficient number of saplings growing into tree sizes, which in turn means that there will be enough mature trees in the future, resulting in a possibility for harvesting for suitable sizes of poles and enough supply of non-wood products.

Table 9 below shows the regeneration in terms of number of saplings per hectare by height classes and species. The table shows that there are about 450 saplings per hectare in the area. About 80 % of the saplings are *Burkea africana* -saplings. This indicates that *Burkea africana* trees are perhaps going to be even more dominating in the tree layer in the future than at present. No saplings of *Schinziophyton rautanenii* were found. Note that only five species were assessed in the regeneration plots.

Especially the regeneration of *Pterocarpus angolensis* is very poor (only 7 saplings/ha). *Baikiaea plurijuga* and *Guibourtia coleosperma* have only a little better number of saplings (52 and 29 saplings/ha). These findings must be taken into account when the management of Mashare forest is being planned.

Table 9: Number of tree saplings per hectare by height classes (cm) and species

	0-25	26-50	51-100	101-150	151-200	201-250	251-300	300+	Total/ha	% of total
Baikiaea plurijuga	4	19	19	4	4	0	0	0	52	12
Burkea africana	31	69	108	71	54	15	10	2	360	80
Guibourtia coleosperma	1	0	5	11	10	0	0	0	29	6
Pterocarpus angolensis	0	2	0	0	4	0	0	0	7	2
Total	36	90	133	86	72	16	11	2	448	100
% of total	8	20	30	19	16	4	3	1		

4.8 Sampling error and confidence limits

Sources 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

The Mashare Forest was inventoried by experienced NFI field staff and the field measurement errors can be expected to be very few. Field instructions were reviewed both in the office and in the field. In this work, specific attention was paid to guarantee good quality field data. Data processing programs have been 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, as well as reports were double checked.

Volume functions

The applied volume functions are probably the main source of errors. This error however does not affect the figures related to number of stems.

Sampling error and confidence limits for tree volume

The estimates for the standard errors of mean volumes were calculated using the formula applicable for random sampling. The sampling in Mashare was done with systematic sampling. Generally, the formula for random sampling gives an overestimate of the sampling error for systematic sampling. Therefore, it is safe to use these estimates.

For the estimate of average tree volume per hectare of all species the standard error of the mean volume is 1.32 m^3/ha which is 5.8 % of mean volume 22.6 m^3/ha. Therefore, the true mean tree volume of all species is between 19.96 m^3/ha and 25.24 m^3/ha with a probability of 95 %.

5. HARVESTING POSSIBILITIES

In this chapter, the harvesting possibilities in Mashare inventory area are discussed. In planning of any sustainable harvesting activities, the first thing to consider is the regeneration of trees. According to the inventory, the regeneration of *Pterocarpus angolensis* is very poor (7 saplings/ha). The regeneration of *Baikiaea plurijuga* (52 saplings/ha) and *Guibourtia coleosperma* (29 saplings/ha) is weak as well. As it is unknown at what level the regeneration should be to maintain the current structure of the forest with respect to these species, and because the number of mature trees is fairly low, it is proposed that no harvesting of trees below 65 cm dbh is done at all. This also means, that no harvesting of *Pterocarpus* and *Baikiaea* at all should be done as there are no trees above dbh 65 cm in the area.

In the case of *Guibourtia coleosperma*, harvesting of large size trees (dbh > 65 cm) may be done and an allowable cut is given below. In the case of *Burkea africana*, sustainable harvesting in other mature diameter classes is possible too. Also, it may be possible to cut some poles by thinning.

The following calculation of the harvesting potential of mature trees is based on a silvicultural system in which selective cutting of mature trees is applied. A stock of vital seed trees are kept to ensure the regeneration capacity. This method has been applied in the yield estimation of Mkata pilot forest by DED and in the allowable cut calculations of Otjituuo forest by the DoF. In this system, trees with a dbh more than 65 cm are considered to be in a state where their vitality and seeding capacity is already degrading rapidly. Therefore, these trees can all be harvested. In the diameter class 55-65 cm, it is proposed that 2/3 of the stems can be harvested and 1/3 left for seeding. In the class 45-55 cm, the respective harvesting rate is 50 % during a period in which trees from the class 35-45 cm can grow to the class 45-55 cm. This period is calculated using an annual increment rate of the diameter. There is no information on increment of trees in the inventory area. A study in Oshikoto by the DoF showed a mean diameter increment of 0.28 cm for *Burkea africana*. In this report, the lowest observed value of this study (0.19 cm) was used.

Allowable cut of *Burkea africana*

Following the principles explained above, the harvesting potential of *Burkea* is given in the table below.

Diameter class	Total number of stems having saw log quality	Allowable cut in total, nr of trees	Annual cut (for 10 years), nr of trees	Annual log volume to cut, m3
45-55	45389	20425	388	184
55-65	25531	15395	1540	807
65-	11347	11347	1135	1519
Total	82267	47167	3062	2510

This allowable cut of mature trees is covering an area of 186,000 hectares. In the harvesting of the 47,000 stems given above, it must be kept in mind that the trees must be cut evenly over the whole area. Assuming that the trees are evenly distributed over the area, only one tree in each 4 hectares can be harvested. In reality, there are of course differences in the densities of the stands in the area and the harvesting intensity can vary accordingly.

In the case of *Burkea africana*, thinning of pole size trees is possible too as there are a lot trees in the smaller diameter classes. Using the diameter increment and having an objective to maintain the structure of the diameter distribution, a calculation of the thinning possibilities can be made. This calculation gives the following results:

Diameter class	Nr of stems/ha standing	Nr of stems/ha after 10 years	Nr of stems to be thinned/ha	Total nr to be thinned in area
5-15	35	40	5	93,0120
15-25	15	17	2	399,740
25-35	9	9	0	48,840
35-45	3	4	1	237,160
Total	61	70	9	1,615,860

According to this calculation, a total of 1,600,000 poles (9 poles per hectare) can be sustainably removed from the area during a ten years period.

Allowable cut of *Guibourtia coleosperma*

As already discussed earlier, due to poor regeneration of *Guibourtia*, only the overmature (dbh > 65 cm) trees may be harvested. In the inventory area of Mashare, there are currently 12,770 stems with a dbh more than 65 cm and with a saw log quality.

No allowable cut is presented here for *Baikiea plurijuga* and *Pterocarpus angolensis*. The number of mature trees of these species is not very high and the regeneration is not very good. Therefore, harvesting of these species is not recommended.

6. INVENTORY COSTS

In this chapter the costs of the inventory of Mashare community forest are presented. This can in the future be used for planning of new inventories. In all inventory designs, the cost-effectiveness of the work should be kept in mind. Here only a rough estimate of the costs incurred in Mashare inventory will be given. The inventory in Mashare forest was carried out from October to December 2001. From October to November there were 7 NFI team members participating in the field work and in December there were 6 team members.

Altogether 2 field trips of 21 days in the field (700 km one way) were made using 3 cars. In the field, 4 ATVs were used for moving from one plot to another. The costs for fuel are real, but the cost for vehicle maintenance is an estimate which has been derived from annual maintenance costs. This calculation only includes immediate costs of the inventory. It does not include fixed costs and overhead costs like office facilities, computers, etc. The total cost of Mashare inventory was about N$ 141, 000 which is N$ 0.76 per hectare. The biggest cost items are the manpower in the field and the maintenance of the cars and ATVs.

These inventory costs include also the costs of the field measurements done for the development of the woody resource monitoring system. However, about 80 % of the total costs were caused by the timber inventory.

Table 10: Inventory costs

Cost item	Units	Cost/unit, N$	Total cost, N$
Inventory planning	1 week	1,000	1,000
Inventory equipment			10,000
1. Field work trip	21 days for 7 people	7,500	52,500
2. Field work trip	21 days for 6 people	6,000	36,000
Fuel	1,500 litres	4.00	6,000
Vehicle maintenance			25,000
Data input	2 weeks	1,000	2,000
Data analysis	2 weeks	1,000	2,000
Report writing	6 weeks	1,000	6,000
Report printing			500
Total			**141,000**

Appendix 1: Diameter distribution of live stems by species, of total volume and of dead stems by species

Table 4: Diameter distribution of stems by species (1000)

	Diameter class in cm											
Species	5-15	15-25	25-35	35-45	45-55	55-65	65-75	75-85	85-95	95-105	Total	% of total
Baikiaea plurijuga	583	227	92	61	21	4					988	7
Burkea africana	6483	2740	1587	485	48	27	6	1	5		11382	78
Guibourtia coleosperma	659	515	160	160	34	13	9	5	5	5	1564	11
Pterocarpus angolensis	362	242	29	80	21	14					747	5
Schinziophyton rautanenii			3								3	0
Total	8087	3724	1871	787	124	58	15	6	9	5	14685	100
% of total	55	25	13	5	1	0	0	0	0	0	100	

Table 5: Distribution of total volume (1000 m^3) by species and diameter class

	Diameter class in cm											
SpeciesName	5-15	15-25	25-35	35-45	45-55	55-65	65-75	75-85	85-95	95-105	Total	% of total
Baikiaea plurijuga	28	52	64	77	44	12					278	7
Burkea africana	267	658	1172	675	118	89	26	6	19		3030	72
Guibourtia coleosperma	47	89	84	186	68	46	46	25	23	21	637	15
Pterocarpus angolensis	24	38	15	93	47	42					258	6
Schinziophyton rautanenii			2								2	0
Total	366	838	1337	1031	278	188	72	31	43	21	4205	100
% of total	9	20	32	25	7	4	2	1	1	0	100	

Table 7: Diameter distribution of dead stems by species (1000)

	Diameter class in cm									
SpeciesName	5-15	15-25	25-35	35-45	45-55	55-65	65-75	75-85	Total	% of total
Baikiaea plurijuga	70	70	12	3	1	0	0	0	156	12
Burkea africana	466	335	153	31	5	1	0	1	992	78
Guibourtia coleosperma	12	51	26	0	0	0	0	0	89	7
Pterocarpus angolensis	41	0	0	0	0	0	0	0	41	3
Total	589	456	191	34	6	1	0	1	1278	100
% of total	46	36	15	3	0	0	0	0	100	

Appendix 2: Volume functions for Mashare 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 3: Volume models used for different tree species.

Index refers to the volume model in Appendix 2

Code	Species	Index to volume model
BAIPL	*Baikiaea plurijuga*	2
BURAF	*Burkea africana*	3
PTEAN	*Pterocarpus angolensis*	8
SCHRA	*Schinziophyton rautanenii*	3
GUICO	*Guibourtia coleosperma*	8