

Ministry of Environment & Tourism
Directorate of Forestry

**INVENTORY OF THE DIRECTORATE OF FORESTRY
EUCALYPTUS PLANTATIONS IN KAVANGO REGION**

Namibia-Finland Forestry Programme
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1. INTRODUCTION

There are four eucalyptus plantations in the Kavango region, namely Musese Trial Woodlot, Kahemu Trial Woodlot, Kaisosi Trial Woodlot and Ndiyona Trial Woodlot. The total area of the plantations is 73.3ha. Three of the plantations are located near Rundu, while the fourth, Ndiyona is located 100 km east of Rundu on the road to Divundu. The inventory in the plantations were carried out in October and November 1998. The field work was carried out by DoF staff in Rundu DFO. The design of the inventory, the data analysis and reporting were done by NFI (National Forest Inventory) staff in Windhoek.

The aim of this inventory is to provide the Directorate of Forestry in the Ministry of Environment & Tourism with information on the plantations to facilitate the decision making on the further utilisation of the plantations.

2. THE PLANTATIONS

2.1 Musese Trial Woodlot

Musese Trial Woodlot is located in the floodplain of the Kavango river, about 2 km north of Rundu. This woodlot is the oldest trial plantation in Kavango region (C. Shikaputo, 1994). The first plantation was carried out in 1967. This plantation involved eight different Eucalyptus species. Seeds have been collected from this woodlot to be used in other trial plantations like Ndiyona Trial Woodlot. According to the management plan some thinning operations have been carried out in this woodlot. There are however no records on the time or the intensity of the thinnings. According to the mapping done in conjunction with this inventory the size of the woodlot is 3.6 ha.

2.2 Kahemu Trial Woodlot

Kahemu Trial Woodlot is located on the eastern side of Musese Trial Woodlot. This plantation was established in 1987 with seeds collected from the best trees in Musese Trial Woodlot. The species planted were *Eucalyptus camaldulensis* and *Eucalyptus saligna* and the spacing was 2.7 m x 2.7 m. No thinning has been carried out in this woodlot. According to the mapping done in conjunction with this inventory the woodlot is 24.0 ha.

2.3 Kaisosi Trial Woodlot

Kaisosi Trial Woodlot is located about 3 km east of Rundu. The plantation was established in 1979. Also this woodlot was established with seeds from Musese Trial Woodlot. The species planted was *Eucalyptus camaldulensis* and the spacing was 2.7 m x 2.7 m. There is no information in the management plan about thinning or other

silvicultural operations carried out in this woodlot. According to the mapping done in conjunction with this inventory the size of the woodlot is 35.7 ha.

2.4 Ndiyona Trial Woodlot

Ndiyona Trial Woodlot is located about 100 km east of Rundu on the road to Divundu. The first planting started here in 1975. A second planting was carried out in 1978. The seedlings for the second planting were from seeds collected from the Musese Trial woodlot. The species planted in 1978 were *Eucalyptus camaldulensis* and *Eucalyptus tereticornis* and the spacing was 2.7 x 2.7 m. According to the management plan a part of the woodlot has been thinned. There is however no records of which part of the woodlot was thinned, the intensity or the time of the thinning. According to the mapping done in conjunction with this inventory the size of the woodlot is 10.0 ha.

3. METHOD DESCRIPTION

3.1 The field work

The inventory method used was systematic sampling with circular sample plots. The size of the circular sample plots was 200 m² (r=7.97m). A total of 37 sample plots were distributed systematically over the plantations (Annex 2). Given the total area and the size and number of plots, the sampling intensity is 1%. The plots were located in the plantations with distance tape and compass.

The dbh was measured for all trees in each plot. In every 5th plot the height also was measured for all trees. The tree status (living or dead) was recorded for all trees.

The number of trees measured in each plantation was as follows:

Musese Trial Woodlot:	59 trees
Kehemu Trial Woodlot:	223 "
Kaisosi Trial Woodlot:	168 "
Ndiyona Trial Woodlot:	<u>85</u> "
TOTAL:	535 trees

3.2 Data analysis

A height curve was calculated for each plantation using regression analysis. The calculation was based on the heights measured during the field work. The volumes were calculated using the height curves and the volume formula for *Eucalyptus globulus* from "Forest Inventory and Management Planning in the fuelwood plantations of Ethiopia" (T. Pukkala, V. Pohjonen, 1989). There are no volume models in Namibia for the inventoried plantations species. It was assumed that the growing conditions and

characteristics of *Eucalyptus globulus* from Ethiopia resembles the Eucalyptus species in Namibia. Microsoft Excel was used for the calculations.

4. RESULTS

4.1 The whole area

Table 1. Statistics for the whole area.

Area, ha	73.3
Total volume m ³	3467.7
Volume per ha, m ³	47.3
Total trees	52770
Trees per ha	720
Average dbh, cm	10.3

The total area of the Eucalyptus plantations in Kavango region is 73.3 ha. The total volume in the plantations is 3467.7 m³, which gives an average of 47.3 m³/ha. The average volume per tree is 0.07 m³. As can be seen in figure 1, the volume distribution by diameter classes follows a normal distribution, i.e. the volumes are concentrated on the diameter classes in the middle of the diameter class distribution. In this case in the volume is 5.72 m³/ha. This means that the average volume is between 41.6 m³/ha and 53.0 m³/ha with 67% probability.

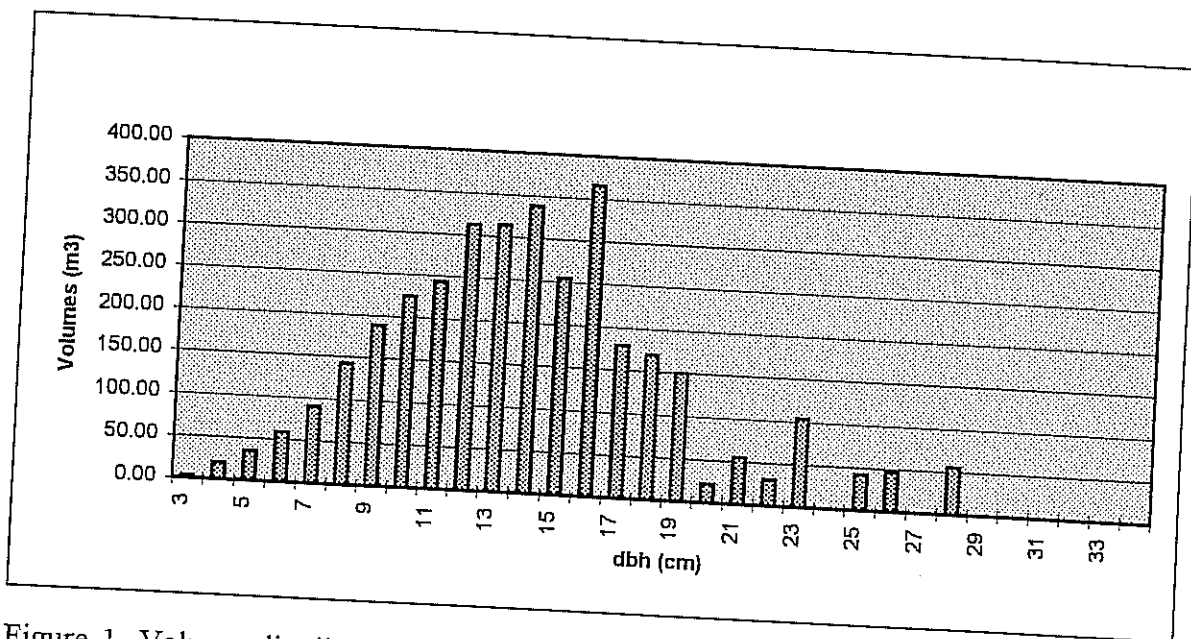


Figure 1. Volume distribution by dbh class for the eucalyptus plantations in Kavango region.

There is a total of 52770 trees in the plantations, which gives an average of 720 stems/ha. The average tree has a dbh of 10.3 cm and a height of 11.6 m. The trees in the plantations are generally small, 47% of the trees are below 10 cm dbh. Only 12% of the trees are above 15 cm dbh. The maximum diameter is 28 cm. Only trees with dbh ≥ 3 cm were measured in the inventory, hence the minimum diameter is 3 cm.

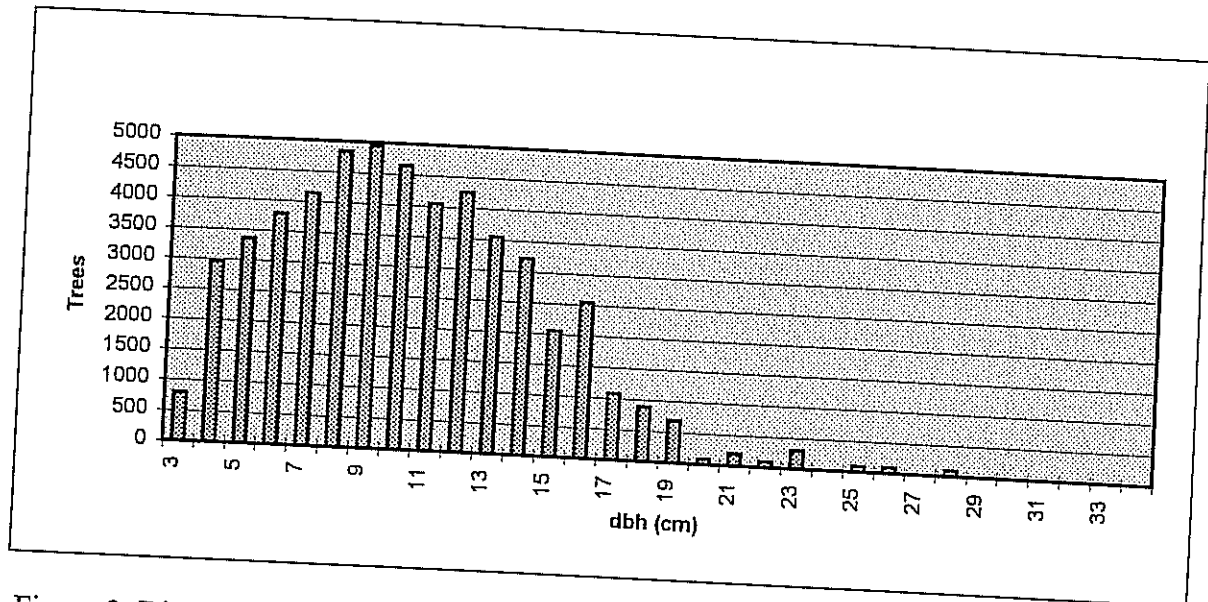


Figure 2. Diameter distribution of trees in the eucalyptus plantations in Kavango region..

4.2 Musese Trial Woodlot

Table 2. Statistics for Musese Trial Woodlot.

Area, ha	3.6
Total volume m ³	460.3
Volume per ha, m ³	127.9
Total trees	5310
Trees per ha	1475
Average dbh, cm	11.4

This woodlot is 3.6 ha. The total volume in the woodlot is 460.35 m³, which gives an average of 127.9 m³/ha. The average volume per tree is 0.087 m³. As can be seen from figure 3, most of the volume is concentrated in the dbh classes between 13 and 17 cm.

The standard error of the mean for the volume is 36.9 m³/ha. This means that the volume is between 91 m³/ha and 164.7 m³/ha with 67% probability.

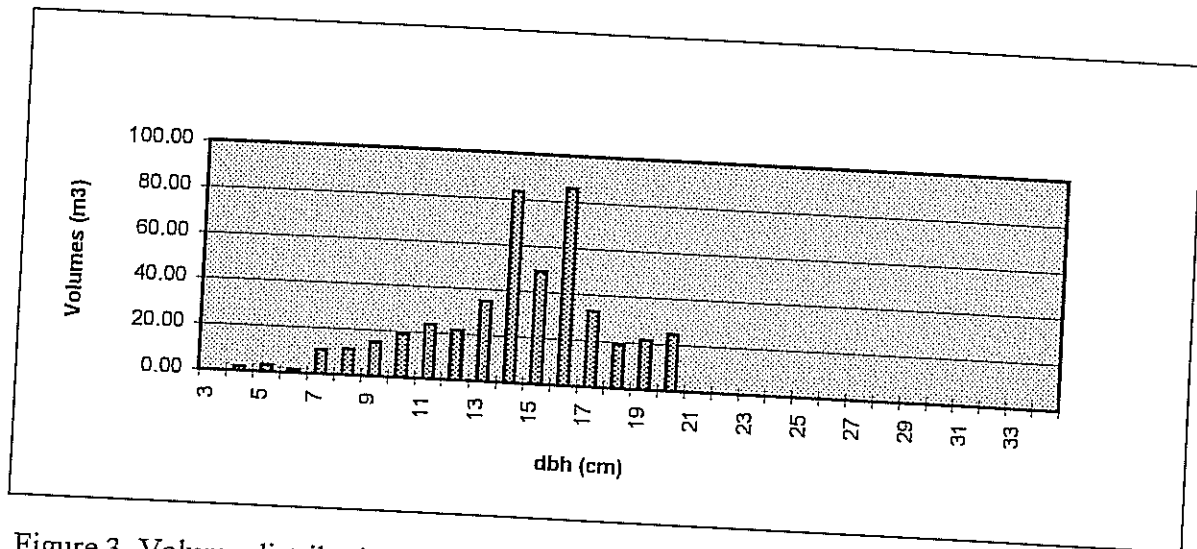


Figure 3. Volume distribution by dbh class in Musese Trial Woodlot.

The total number of trees in the woodlot is 5310, which gives an average of 1475 trees per ha. The average tree has a dbh of 11.4 cm and a height of 13.7 m. As can be seen from figure 4, most of the trees are in the dbh classes 7 to 16 cm. 50% of the trees are below dbh 13 cm and 19% of the trees are above dbh 15 cm. The maximum diameter is 20 cm. Only trees with dbh ≥ 3 cm were measured in the inventory, hence the minimum diameter is 3 cm.

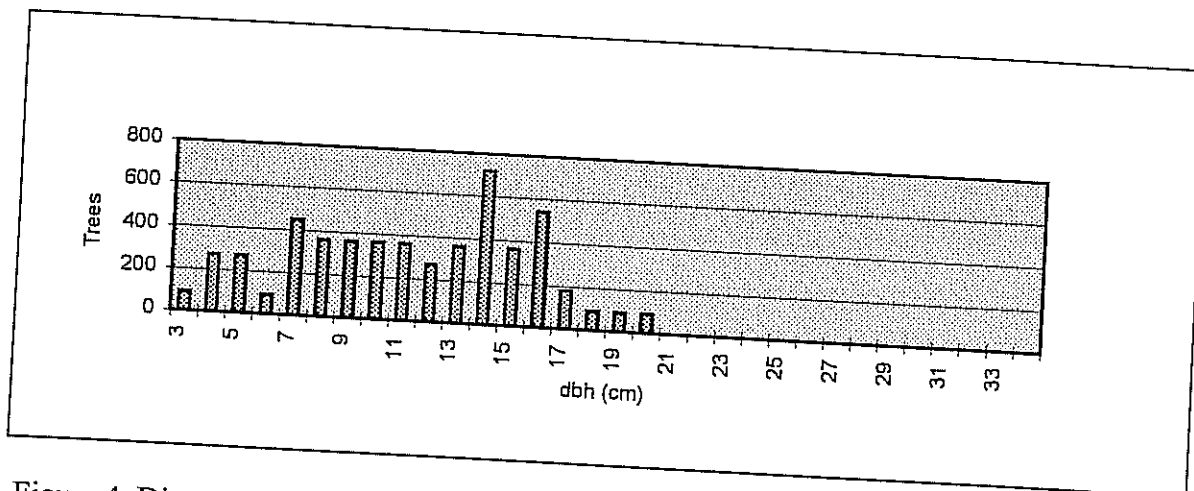


Figure 4. Diameter distribution of trees in Musese.

4.3 Kahemu Trial Woodlot

Table 3. Statistics for Kahemu Trial Woodlot.

Area, ha	24
Total volume m ³	1412.8
Volume per ha, m ³	58.9
Total trees	22300
Trees per ha	929
Average dbh, cm	10

The size of the woodlot is 24.0 ha. The total volume is 1412.8 m³. The average volume per ha is 58.9 m³/ha. The average volume per tree is 0.06 m³. As can be seen from figure 5, the volume follow a normal distribution with most of the volume concentrated in the middle of the diameter distribution.

The standard error of the mean for the volume is 19.2 m³/ha. This means that the volume is between 39.7 m³/ha and 78.1 m³/ha with 67% probability.

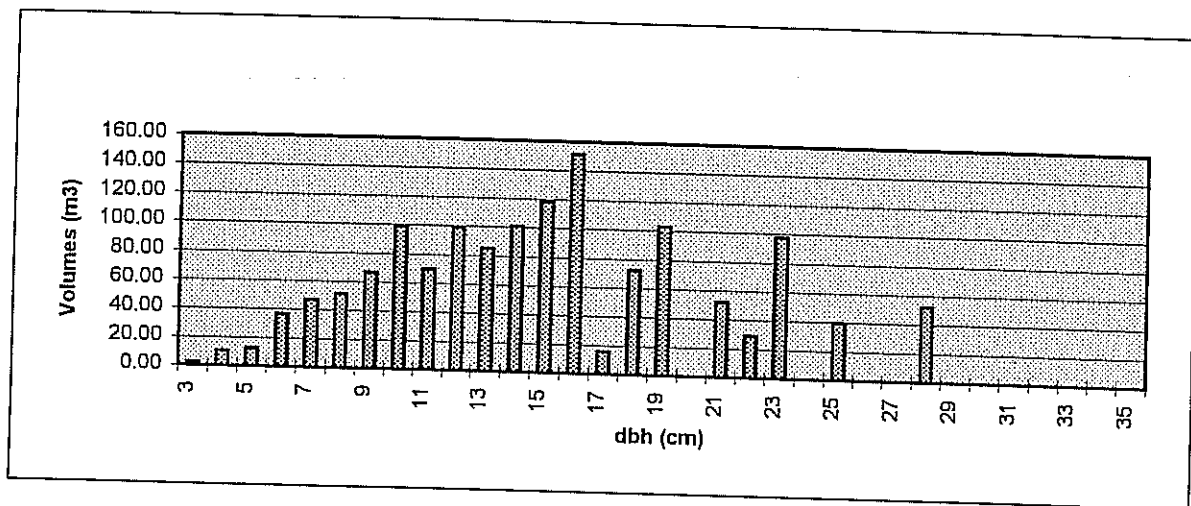


Figure 5. Volume distribution by dbh class in Kahemu Trial Woodlot.

The total number of trees in the woodlot is 22,300, which gives an average of 929 trees per ha. The average tree has a dbh of 10.0 cm and a height of 11.1 m. As can be seen from figure 6 there are very few trees with dbh bigger than 16 cm. 55% of the stems have a dbh below 10 cm. Only 13% of the trees have a dbh above 15 cm. The maximum dbh is 28 cm. Only trees with dbh \geq 3 cm were measured in the inventory, hence the minimum diameter is 3 cm.

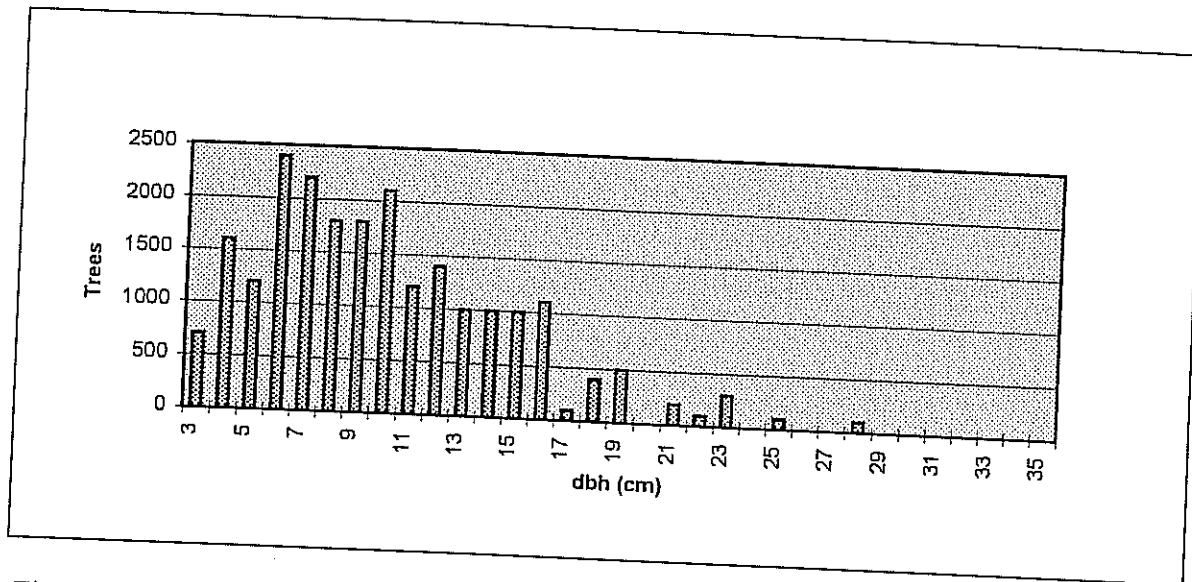


Figure 6. Diameter distribution of trees in Kahemu.

4.4 Kaisosi Trial Woodlot

Table 4. Statistics for Kaisosi Trial Woodlot.

Area, ha	35.7
Total volume m ³	826.5
Volume per ha, m ³	23.2
Total trees	16660
Trees per ha	466.7
Average dbh, cm	9.26

The size of the woodlot is 35.7 ha. The total volume in the woodlot is 826.5 m³, which gives an average of 23.15 m³/ha. Also in this woodlot the volume distribution quite well follows a normal distribution with the volumes concentrated in the middle of the diameter distribution, i.e. between the diameter classes 9 and 15 cm.

The standard error of the mean for the volume is 3.30 m³/ha. This means that the volume is between 19.85 m³/ha and 26.45 m³/ha with 67% probability.

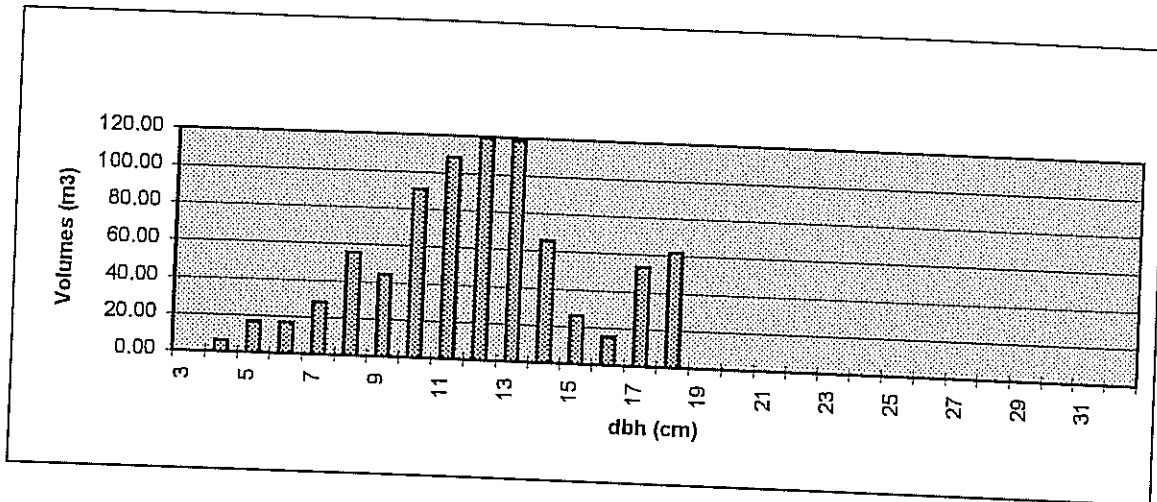


Figure 7. Volume distribution by dbh class in Kaisosi Trial Woodlot.

The total number of trees in the woodlot is 16600. This gives an average of 467 stems per ha. The average tree has a dbh of 9.26 cm and a height of 10.8 m. 52% of the stems are below 10 cm dbh, only 4% of the trees are above 15 cm dbh. The maximum diameter is 18 cm. Only trees with dbh ≥ 3 cm were measured in the inventory, hence the minimum diameter is 3 cm.

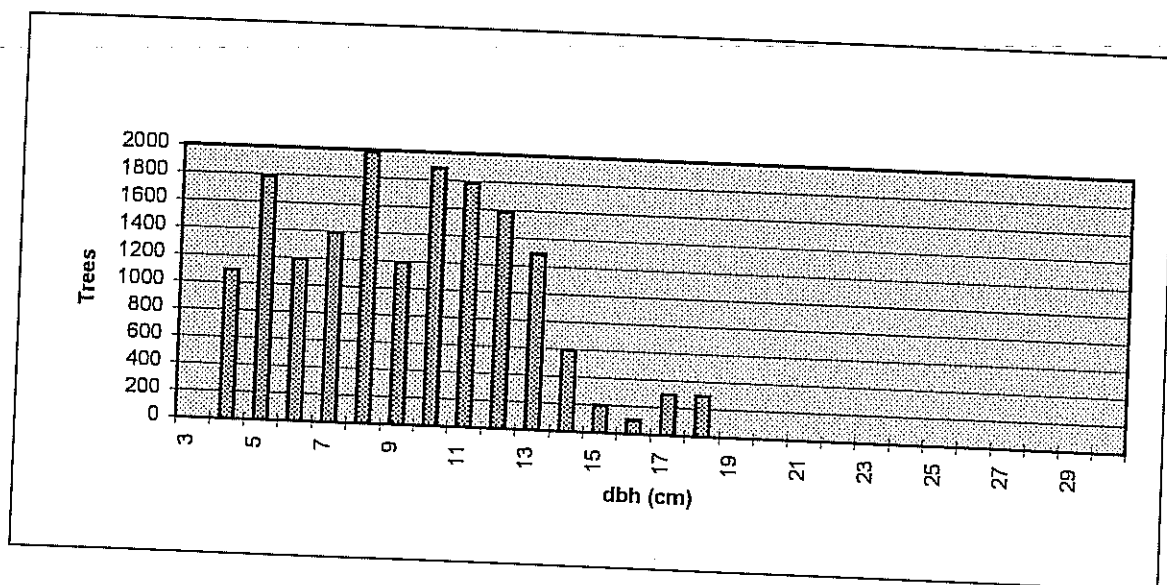


Figure 8. Diameter distribution of trees in Kaisosi.

4.5 Ndiyona Trial Woodlot

Table 5. Statistics for Ndiyona Trial Woodlot.

Area, ha	10
Total volume m ³	768.1
Volume per ha, m ³	76.8
Total trees	8500
Trees per ha	850
Average dbh, cm	12.2

The woodlot is 10 ha. The total volume is 768.1 m³, which gives an average of 76.81 m³/ha. Also in Ndiyona the volume distribution quite well follows a normal distribution with the volumes concentrated in the middle of the diameter distribution, i.e. between the diameter classes 12 and 17 cm.

The standard error of the mean for the volume is 19.2 m³/ha. This means that the volume is between 57.61 m³/ha and 96 m³/ha with 67% probability.

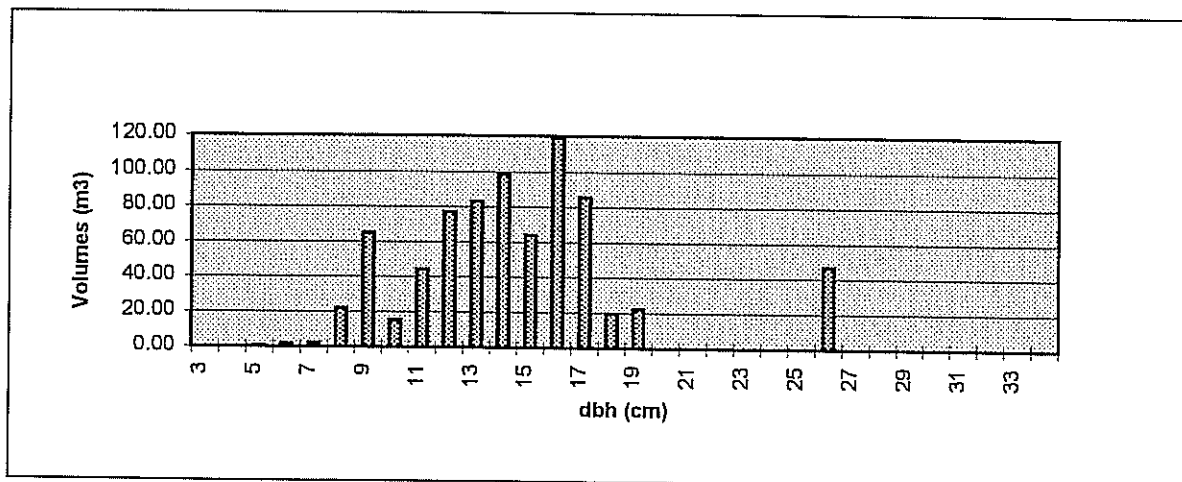


Figure 9. Volume distribution by dbh class in Ndiyona Trial Woodlot.

The total number of trees in the woodlot is 8500, which gives an average of 850 trees per ha. The average tree has a dbh of 12.2 cm and a height of 13.4 m. The maximum dbh is 26 cm. Only trees with dbh \geq 3 cm were measured in the inventory, hence the minimum diameter is 3 cm. 31% of the stems are below dbh 10 cm, and 19% of the stems are above dbh 15 cm.

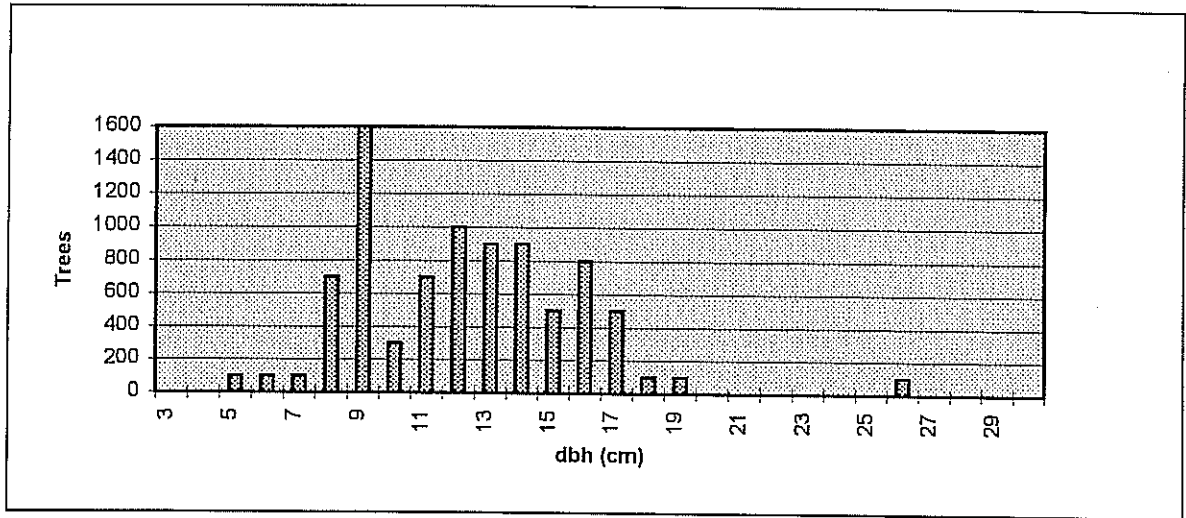


Figure 10. Diameter distribution of trees in Ndiyona.

5. DISCUSSION

The oldest plantation, Musese is more than 30 years old, while the youngest, Kahemu is 10 years old. There are differences in the volumes of the plantations, but not as much as one would expect given the age differences. Furthermore, the differences in volumes does not always follow the age, i.e. an older plantation is not always bigger in volume (m^3/ha) than a younger plantation.

Table 6. Statistics over the eucalyptus plantations in Okavango region.

	WHOLE AREA	MUSESE	KAISOSI	KAHEMU	NDIYONA
Area, ha	73.3	3.6	35.7	24	10
Age, years		32	20	12	24
Total volume m^3	3467.7	460.3	826.5	1412.8	768.1
Volume per ha, m^3	47.3	127.9	23.2	58.9	76.8
Total trees	52770	5310	16660	22300	8500
Trees per ha	720	1475	466.7	929	850
Average dbh, cm	10.3	11.4	9.26	10	12.2

The volumes in the plantations are low. Totally the stock in the plantations is 3467.7 m^3 , i.e. an average of $47.3 \text{ m}^3/\text{ha}$. The highest volume is in the oldest plantation, Musese, where the average volume is $127.9 \text{ m}^3/\text{ha}$. The volumes in the rest of the plantations range between $23.2 \text{ m}^3/\text{ha}$ and $76.8 \text{ m}^3/\text{ha}$. Kaisosi, a 20 year old plantation, has the lowest volumes, only $23.2 \text{ m}^3/\text{ha}$.

Considering that Eucalyptus is a fast growing species, these volumes are very low. The reasons for the slow growth might be both related to production factors such as soil fertility and water, and management of the plantations. Kehemu, Kaisosi and Musese Woodlots are growing in the river bank of Kavango River or close to the river. Hence, the availability of ground water to the trees should be the best in the region. Therefore, if water is the limiting factor for the growth of the trees in the present plantations, there are few options for plantation forestry without irrigation in the region. Since there is limited information available on the management of the plantations, it is difficult to determine the effect of the management on the volumes. Generally, thinning can not increase the total volume in a plantation, but concentrate the volume growth on fewer trees, hence getting bigger trees than without thinning operations.

There is still a considerable amount of stems in each plantation. The oldest plantation, Musese, has the most dense forest. Here there is still 1475 stems per ha standing. Most of the trees in the plantations are however small. 47% of the trees are below dbh 10 cm. There is a difference in the size of the trees between the plantations. Proportionally most small trees are in Kaisosi woodlot, where there is very few trees with dbh above 15 cm.

At the same time this woodlot is also the most open, i.e. having the fewest trees/ha. Ndiyona and Musese woodlots have proportionally more trees above dbh 15 cm.

Although there is some variations in the size distributions between the plantations, the general appearance of the plantations are rather similar with the exception of Kaisosi woodlot, the plantation in poorest shape. For example the average dbh in each plantation is rather similar, ranging from 10.0 cm to 12.2 cm.

There is generally a connection between the number of trees and the sizes of the trees. It is possible that the trees could have grown bigger if the plantations would have been thinned earlier. It is however questionable if the trees would react any more to such operations.

6. PROPOSAL FOR UTILISATION AND MANAGEMENT OF THE PLANTATIONS

The growth in the plantations have been very slow and will continue to be slow with the present stands. Hence there is no use to postpone the cutting of the trees in order to let them grow. Therefore the following is proposed:

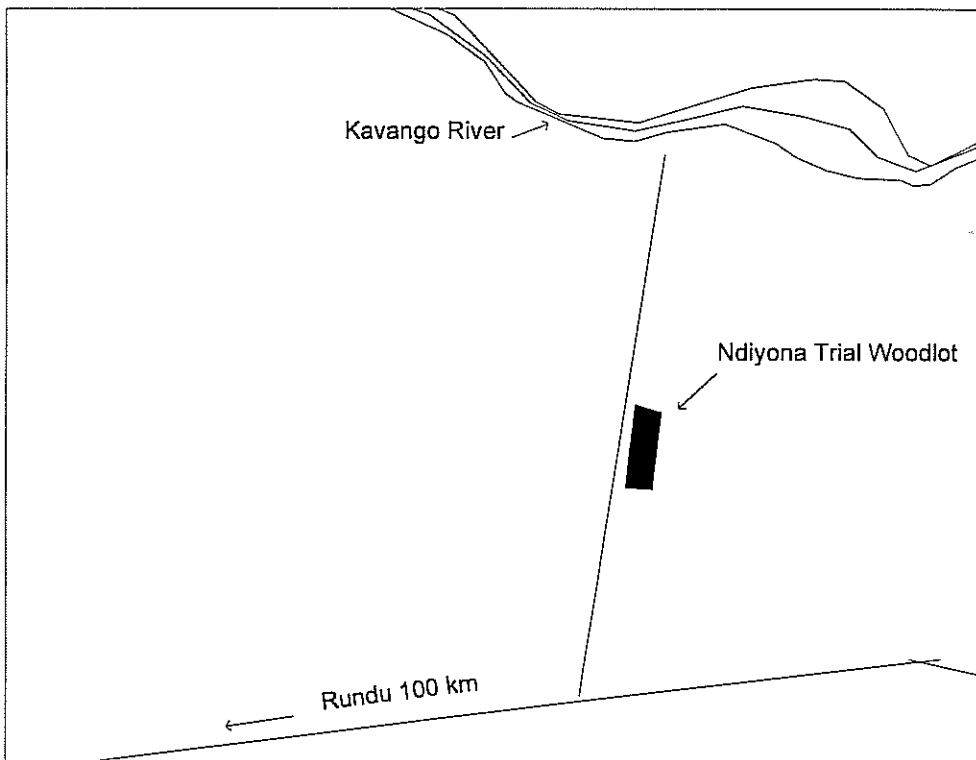
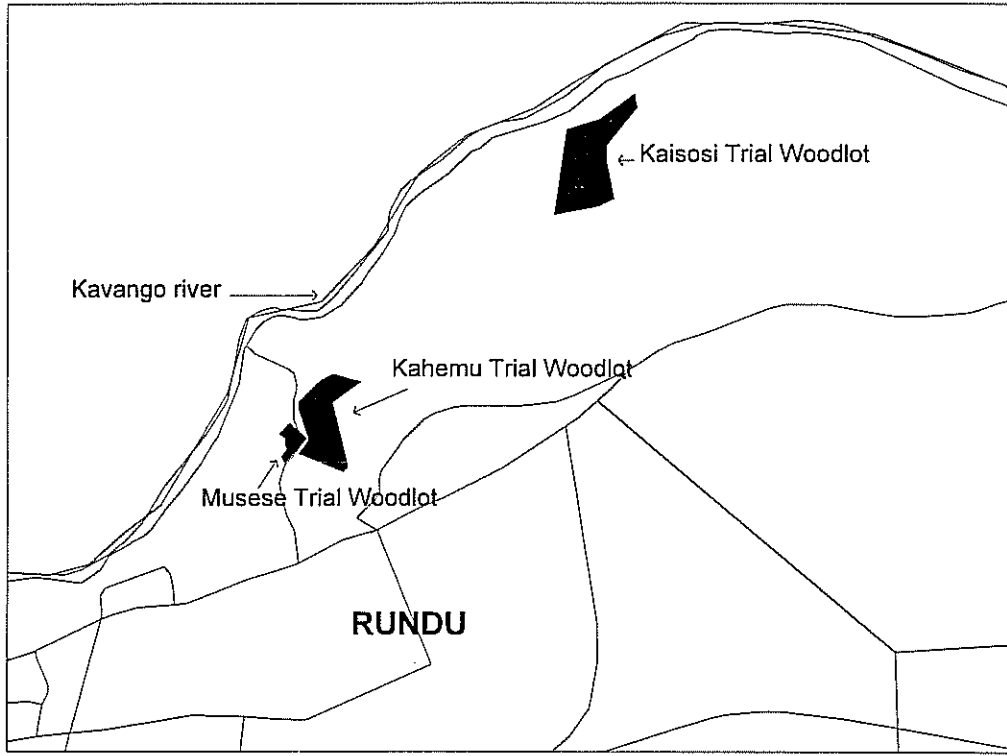
- Determine the economic value of the trees and set that as the stumpage price for the trees in order to give DoF optimal economic return for the plantations.
- Cut and sell the trees according to the stumpage price. Add the costs for harvesting if this is done by DoF personnel. If the harvesting is done by DoF the advantages would be the following: (1) Creation of additional employment opportunities for DoF, (2) better control of the harvesting.
- The results from this inventory together with the stumpage price give guidance on the size of the revenue that can be obtained from selling the plantations. When the selling of the plantations start, the volumes sold should however be determined by either a 100% enumeration of the trees in the area to cut or measurement of the poles after cutting at the road side.
- The next generation of eucalyptus in the plantation is coming from coppicing. To optimise the quality and growth of the coppiced trees: (1) Single out the best shoots from each stem, (2) carry out thinning operations in the future as the young stand grows.

7. REFERENCES

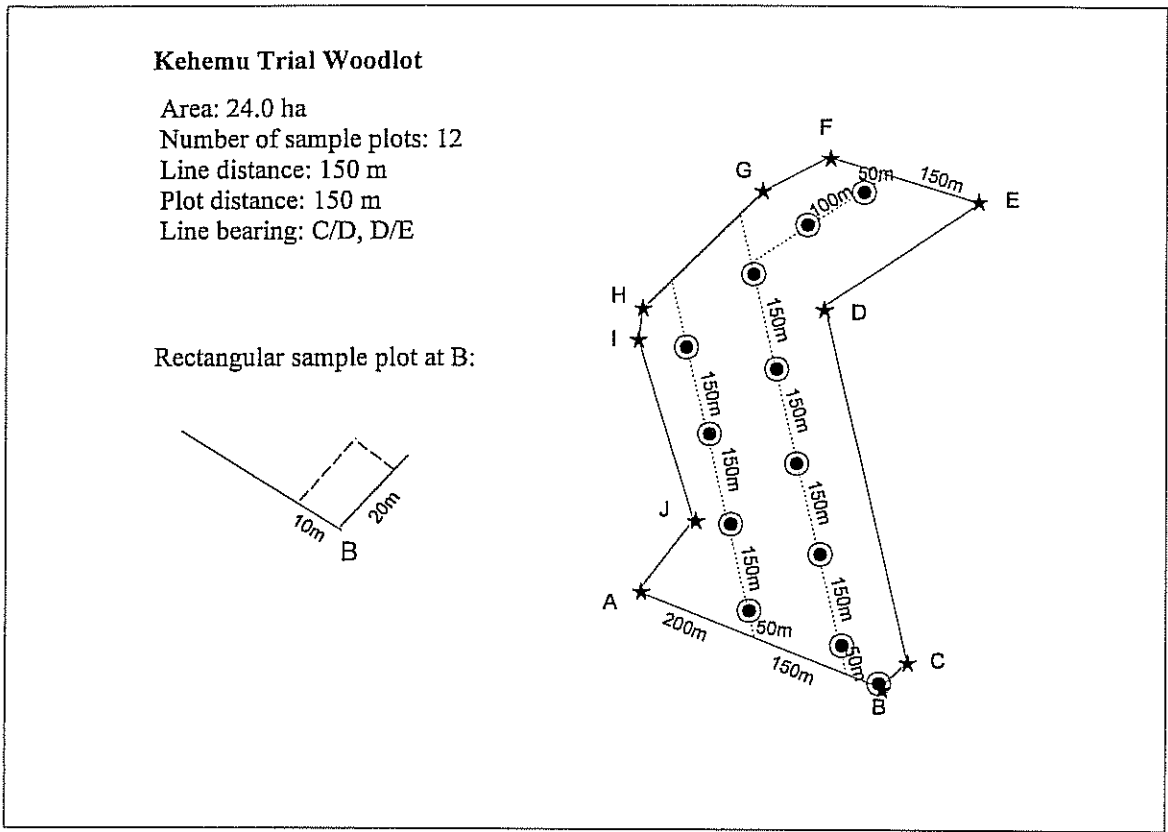
Pukkala T, & Pohjonen V. 1989. Forest Inventory and Management Planning in The Fuelwood Plantations of Ethiopia.

Shikaputo C. 1994. Management Plan for Eucalyptus Woodlots Grown in The Northern Region.

ANNEX 1. LOCATION OF THE MUSESE, KAHEMU, KAISOSI AND NDIYONA WOODLOTS



ANNEX 2 LOCATION OF THE SAMPLE PLOTS IN KEHEMU TRIAL WOODLOT.



ANNEX 3. TOTAL NUMBER OF TREES AND THE DIAMETER DISTRIBUTION

DIAMETER DISTRIBUTION FOR THE WHOLE AREA					
	KEHEMU	KAISOSI	MUSESE	NDIYONA	TOTAL
DBH (cm)	Total stems	Total stems	Total stems	Total stems	AREA
3	700	0	90	0	790
4	1600	1091	270	0	2961
5	1200	1785	270	100	3355
6	2400	1190	90	100	3780
7	2200	1388	450	100	4138
8	1800	1983	360	700	4843
9	1800	1190	360	1600	4950
10	2100	1884	360	300	4644
11	1200	1785	360	700	4045
12	1400	1587	270	1000	4257
13	1000	1289	360	900	3549
14	1000	595	720	900	3215
15	1000	198	360	500	2058
16	1100	99	540	800	2539
17	100	298	180	500	1078
18	400	298	90	100	888
19	500	0	90	100	690
20	0	0	90	0	90
21	200	0	0	0	200
22	100	0	0	0	100
23	300	0	0	0	300
24	0	0	0	0	0
25	100	0	0	0	100
26	0	0	0	100	100
27	0	0	0	0	0
28	100	0	0	0	100
29	0	0	0	0	0
30	0	0	0	0	0
31	0	0	0	0	0
32	0	0	0	0	0
33	0		0	0	0
34	0		0	0	0
TOTAL	22300	16660	5310	8500	52770

