MINISTRY OF ENVIRONMENT AND TOURISM
Directorate of Forestry

Inventory Report for Rehoboth Acacia Park

Namibia-Finland Forestry Programme

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Windhoek, April 2002

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EXECUTIVE SUMMARY

General description of the area

Rehoboth Acacia Park is situated about 7 km from Rehoboth to the east. Acacia tree species are dominant in the area from which the name Acacia Park is derived from. There are also some other tree species found in the area. Community members are currently farming with domestic livestock in Rehoboth Acacia Park. Rehoboth community requested the Directorate of Forestry to conduct a woody resource inventory to determine the volume and the number of stems in the area for management planning purposes after the area is declared as a Park.

The woody species

A total of 11 woody species were recorded in Rehoboth Acacia Park. 9 species were recorded as trees and 9 woody species were found in the shrub layer. 7 woody species were found both in the tree and the shrub layers. The most frequent tree species in the data were as follows: *Acacia erioloba, Acacia mellifera* and *Boscia foetida* trees (dbh $\geq$ 5cm) were found in more than half of the measured plots.

Stratification and vegetation types

Post stratification was carried out in the area. The main objective for this stratification was to identify and demarcate areas with generally higher volumes and lower volumes. Consequently the stratification resulted into seven strata.

The forest resource

Total area inventoried is 8732.3 ha. There is a total volume of 82835 m³ in the Rehoboth Acacia Park. The mean tree volume is 9.5 m³ per hectare and there are 27.8 stems per hectare.

The biggest trees are *Acacia erioloba, Boscia albitrunca, Acacia nilotica, Boscia foetida* and *Ziziphus mucronata. Acacia erioloba* is represented in most of the diameter classes from 5 to 155 cm. The bulk of the stems are in small sizes.

Dead trees were also analyzed. There is a total volume of 12721m³ of dead trees in Rehoboth Acacia Park. More than 95 % of the dead trees were *Acacia erioloba* trees. Most of the dead trees are in small diameter classes.

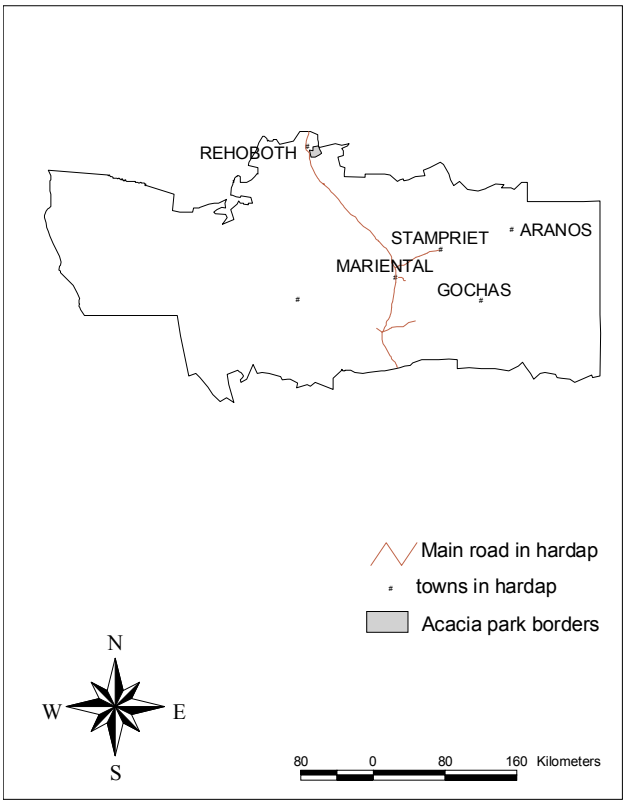
1. INTRODUCTION

This report presents the results from the wood resource inventory of Rehoboth Acacia Park. The inventory was carried out on the request by the Rehoboth community through the Forestry Office in Rehoboth. The main objective of the inventory is to determine the quantity and quality of the wood resources which are available in the area in order to facilitate the establishment of management strategies for the area after it is declared as a park.

2. GENERAL DESCRIPTION OF THE AREA

Rehoboth Acacia Park is situated approximately about 7 km east from Rehoboth town in Hardap Region (see Map 1 below). The name Acacia Park derives from the dominance of the Acacia species found in the area.

Map 1 : Location of Rehoboth Acacia Park in Hardap region.



3. INVENTORY DESIGN

3.1 Sampling method

The total area of Rehoboth Acacia Park is 10377 hectares including the river and the mountain. The area which was inventoried is 8732.3 ha.

Systematic plot sampling was used to estimate the quantity and quality of the woody resources in the Rehoboth Acacia Park. Stratification was done using ATV motor bikes and the GPS. Different vegetation types were tracked with the GPS. Consequently the stratification resulted into 7 strata as indicated in Table 3 and map 2 on page 10.

The total number of plots located in the area is 139. Coordinates for each plot were obtained by digitizing the strata and a grid of plots with Arc View GIS-software. GPS (Map datum: WGS84) and ATV motor bikes were used for locating the sample plots in the field.

The sample plots are not permanent measurement plots. They were not marked in the field with an aluminum pole as in the other areas and therefore cannot be relocated for re-measurements in the future. The co-ordinates are shown in appendix 1 page 25.

3.2 Field measurements

The data was collected in circular sample plots. The woody vegetation was classified into trees and shrubs. In this inventory trees are defined as woody plants with a dbh $\geq$ 5 cm. Shrubs are woody plants with a dbh < 5 cm. For tree measurements the size of the circular sample plot depends on the size of the tree (see figure 1 below). Diameter, location, species, crown class, quality, length and quality of possible saw log and regeneration were measured for all trees and shrubs in all sample plots.

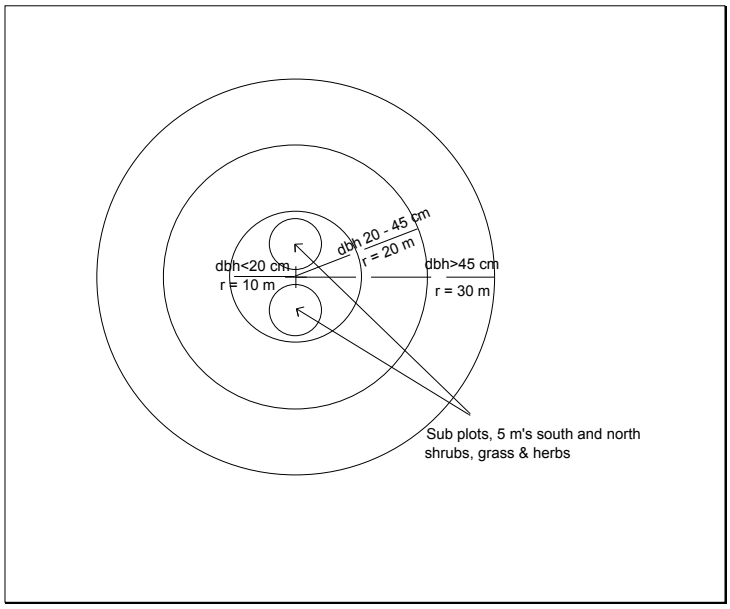


Figure 1: Sample plot structure.

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 details in the field instructions (Field Instructions for Western Bushman Land 1996) which can be obtained at Forestry Head Office, Windhoek. Shrubs and regeneration were measured on two sub plots on each plot (see figure 1.)

4. INVENTORY RESULTS

4.1 Measured data

The inventory field work in Rehoboth Acacia Park was carried out in October 2000. A total of 139 sample plots were measured. A total of 265 trees with a dbh ≥ 5 cm were measured in the plots (see Table 1, page 8), which is on average 1.9 trees per sample plot.

A total of 11 woody species were recorded in Rehoboth Acacia Park. 9 species were recorded as trees and 9 woody species were found in shrub layer. 7 woody species were found both in the tree and shrub layer. The most common tree species measured in the area were *Acacia erioloba, Acacia mellifera* and *Boscia foetida* which cover more than 90% of the measured trees. The table below indicates that more than half of the measured trees are *Acacia erioloba* trees. The frequency of different species in the data is indicated in the table below:

Species (Trees)	% of measured trees
Acacia erioloba	63.1
Acacia hebeclada (hebeclada)	2.7
Acacia mellifera	22.8
Acacia nilotica	1.9
Albizia anthelmintica	0.8
Boscia albitrunca	2.3
Boscia foetida	4.2
Dichrostachys cinerea (Setulosa)	0.4
Ziziphus mucronata	1.9
Total	100

Species (Shrubs)	% of measured shrubs
Acacia erioloba	9.5
Acacia hebeclada (hebeclada)	9.5
Acacia karroo	0.9
Acacia mellifera	16.4
Albizia anthelmintica	3.4
Boscia albitrunca	2.6
Boscia foetida	7.8
Rhigoszum brevispinosum	47.4
Ziziphus mucronata	2.6
Total	100

A total of 116 shrubs were measured (see appendix 3: total number of measured shrubs). The three most common shrub species (*Acacia erioloba, Acacia mellifera* and *Rhigozum brevispinosum*) represent 73.3 % of all total measured shrubs. Two of the three most common species in the tree layer were found among the three most common species in the shrub layer. These are *Acacia erioloba* and *Acacia mellifera.*

Table 1: Total number of measured trees

Species	Total No. of measured trees	% of measured trees
Acacia erioloba	166	63.1
Acacia hebeclada (hebeclada)	7	2.7
Acacia mellifera	60	22.8
Acacia nilotica	5	1.9
Albizia anthelmintica	2	0.8
Boscia albitrunca	6	2.3
Boscia foetida	11	4.2
Dichrostachys cinerea (setulosa)	1	0.4
Ziziphus mucronata	5	1.9
Total	263	100

4.2 Species diversity

There are several measures of species diversity such as Simpson's dominance and Shannon's species diversity indices that can be applied on the inventory data. Another simpler measure of the species diversity is the number of species found in the area and the number of clusters where each species was found for both trees and shrubs.

A total of 11 woody species were recorded in Rehoboth Acacia Park. 9 species were recorded as trees and 9 species were found in the shrub layer. 7 woody species were found both as trees in the tree layer and as shrubs in the shrub layer. This is a very small number of woody species recorded with in a relatively large area of 8732 ha. For example 26 woody species were found in M'kata Pilot Forest with the total area of 1054 ha, which is in western part of Tsumkwe district.

Acacia mellifera and *Acacia erioloba* species are found in the tree and shrub layer in most parts of the Rehoboth Acacia Park (see table below).

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 erioloba	11	54
Acacia hebeclada (hebeclada)	11	1
Acacia karroo	1	
Acacia mellifera	19	7
Acacia nilotica		1
Albizia anthelmintica	4	1
Boscia albitrunca	3	3
Boscia foetida	9	5
Dichrostachys cinerea (setulosa)		1
Rhigoszum brevispinosum	55	
Ziziphus mucronata	3	2

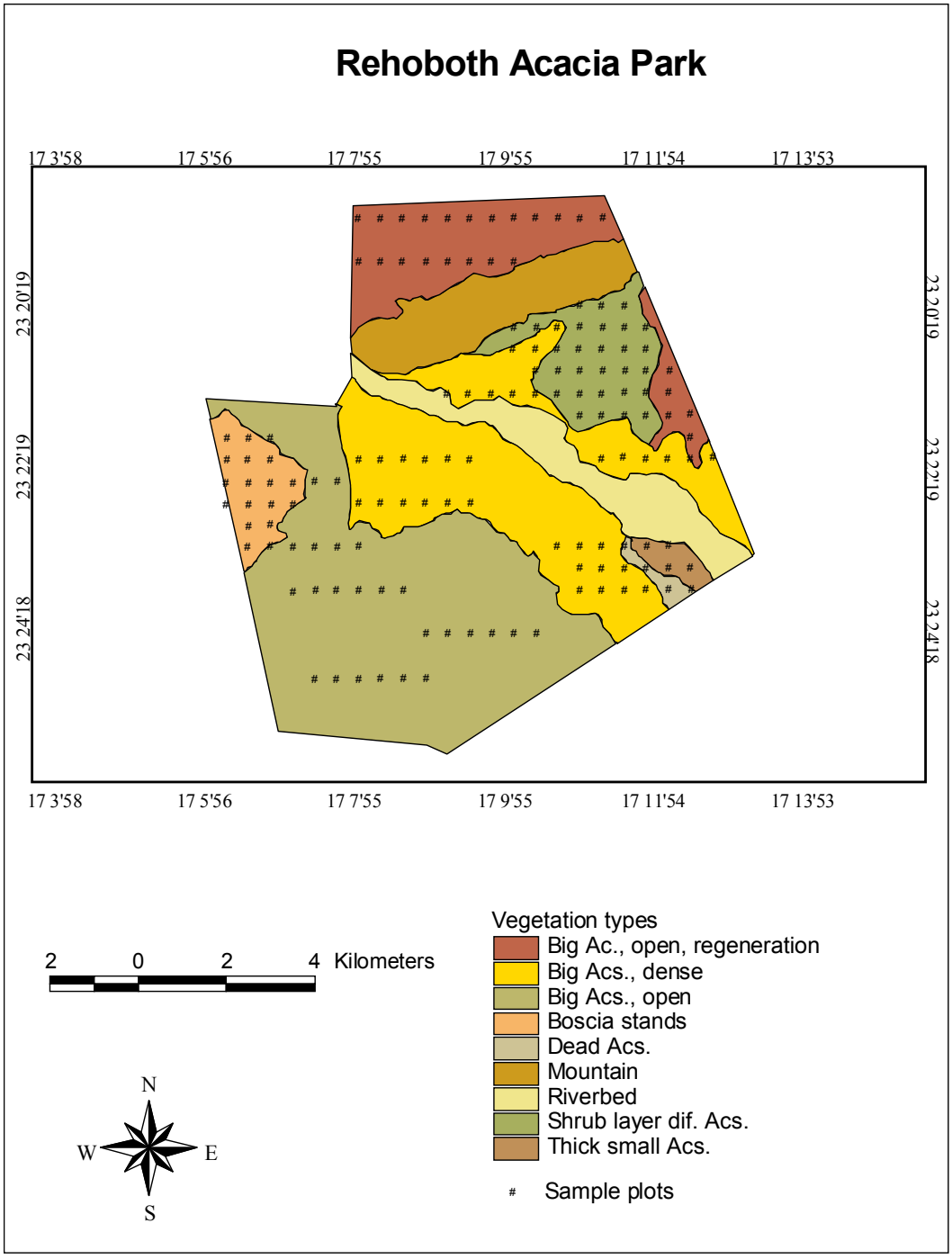
4.3 Stratification

Post stratification was carried out for the area. The main objective for this stratification was to identify areas with generally higher tree volumes and separate them from the river beds and mountains in the area. The stratification resulted into 7 strata (see map 1 below), namely Shrub layer Different Acacia (SDA), Big Acacia Open regeneration (BAO biggest stratum in the area), Big Acacia Dense (BAD, consist of highest tree volumes, also the second largest stratum in the area), Thick Small Acacia (TSA), Dead Acacia (DA), Boscia Stands (BS). The river and the mountain have also been indicated on the map.

Table 3: Area by stratum

Stratum	Area, in ha	% of total area
Mountain	848.1	8.2
Shrub layer Diff. Acs	769.4	7.4
Big Acs, Open, regeneration	1256.5	12.1
Big Acs, Dense	2478.9	23.9
Riverbed	796.6	7.7
Thick Small Acs,	117.6	1.1
Dead Acs,	68.9	0.7
Big Acs, Open	3619.1	34.9
Boscia Stands	421.9	4.1
Total	10377.0	100

Map 2: Strata for Rehoboth Acacia Park



4.4 Height of measured trees

Table 4 below shows the average, minimum and maximum height of the trees. The height of the woody vegetation is generally low. *Acacia erioloba* species is quite high with the average height of 10.6 m, compared to the other species found in the area.

Table 4: Average minimum and maximum height by species

Species	Average height (m)	Minimum height (m)	Maximum height (m)
Acacia erioloba	10.6	1.1	19.1
Acacia hebeclada (hebeclada)	3.2	3.1	3.3
Acacia mellifera	5.2	3.8	7
Acacia nilotica	6.7	4.5	11.1
Albizia anthelmintica	7.2	7.2	7.2
Boscia albitrunca	4.7	4.5	4.8
Boscia foetida	4.0	2.2	5.1
Dichrostachys cinerea (Setulosa)	3.5	3.5	3.5
Ziziphus mucronata	5.7	4.1	7.3

4.5 Tree volumes and number of stems

Volume functions:

Volume functions developed by Directorate of Forestry were used to estimate the volumes in Rehoboth Acacia Park. Volume functions are developed for the most common species only, but the functions are also applied for other species. For those who may wish to use the models, Appendix 5 and 6 shows which models were applied to each species.

All the woody stems with a dbh ≥ 5 cm are regarded as trees. 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. Volumes for dead stems are presented in Chapter 4.8 “Deadwood”. The number of trees and volumes for the whole area are as follows:

Total number of trees	243254
Mean stems per ha	27.8
Total tree volume (m^3)	82835.4
Mean tree volume per hectare (m^3/ha)	9.5
Total area, ha	8732.3
Total number of measured trees	263

The mean tree volume is 9.5 m^3/ha and the number of trees is 27.8 stems/ha in Rehoboth Acacia Park as shown in the table above. The mean number of trees and volumes are figures that can give a picture on how open or dense the forest is. Rehoboth Acacia Park can be classified as an open woodland according to the mean tree volume/ha.

Table 5 below shows the volumes and number of trees for all species for the main vegetation strata. It should be noted that only live trees are considered.

Table 5: Volume and number of trees per stratum

	Total No. of stems	Stems per ha	Total tree volume m³	Average tree volume m³/ha	% of Ave. tree vol./ha
Big Acs Dense (BAD)	64689	26	59682.9	24.1	44.1
Big Acs Open (BAO)	68666	19	15281.7	4.2	7.7
Big Acs, Open, Regeneration (BAOR)	98788	79	5512.2	4.4	8.0
Boscia Stands (BS)	7731	18	863.8	2	3.7
Thick small Acs (TSA)	936	8	25.5	0.2	0.4
Dead Acacia (DA)	1310	19	1350.3	19.6	35.8
Shrub layer Different, Acs (SDA)	1134	1	119	0.2	0.4
Total	243254	170	82835.4	54.7	100

There is a big variation in volumes. The highest average tree volume/ha was found in Big Acacia Dense (BAD). 44.1 % of the total tree volume/ha is from BAD stratum. Shrub layer Different Acacias (SDA) is with the lowest average volume per ha in the whole area.

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 m3/ha
Acacia erioloba	74584.8	8.5	74744.7	8.6
Acacia hebeclada (hebeclada)	14928.3	1.7	547.9	0.1
Acacia mellifera	114653.6	13.1	2387.5	0.3
Acacia nilotica	15600	1.8	1606.9	0.2
Albizia anthelmintica	3199.6	0.4	483.3	0.1
Boscia albitrunca	5707	0.7	810.4	0.1
Boscia foetida	7647.6	0.9	691.6	0.1
Dichrostachys cinerea (Setulosa)	1599.8	0.2	86.7	0
Ziziphus mucronata	5333.1	0.6	1476.5	0.2
Total	243253.8	28	82835.4	9.7

88.7 % of the total tree volume/ha is from *Acacia erioloba* trees. *Acacia mellifera* trees are many compared to the *Acacia erioloba* trees, but the average tree volume of *Acacia erioloba* is very much higher compared to the one of *Acacia mellifera* (3.1 %).

Table 7: Volume 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, m3/ha
Big Acacia Dense	*Acacia erioloba*	38565	16	58266.5	23.5
	Acacia hebeclada (hebeclada)	14928	6	547.9	0.2
	Acacia mellifera	10663	4	304.3	0.1
Big Acacia Open	*Acacia mellifera*	24000	7	777.1	0.2
	Acacia erioloba	19467	5	11235.5	3.1
Big Acacia Open and Regeneration	*Acacia mellifera*	79991	64	1306.1	1
	Acacia erioloba	13998	11	3636.1	2.9
Boscia Stands	*Boscia foetida*	7648	18	691.6	1.6
	Acacia erioloba	83	0	172.2	0.4
Dead Acacia	*Acacia erioloba*	1310	19	1350.3	19.6
Shrub layer Different Acacia	*Acacia erioloba*	227	0	58.5	0.1
Thick Small Acacia	*Acacia erioloba*	936	8	25.5	0.2

Table 7 shows the number of stems and volumes per stratum for the most common species in Rehoboth Acacia Park. More than 45 % of the total average tree volume of *Acacia erioloba*, *Acacia hebeclada and Acacia mellifera* are found in the Big Acacia Dense (BAD).

4.6 Diameter distribution

A desired diameter distribution from management point of view is one were the bulk of the stems are in the lower diameter classes, and the number of stems gradually decreased as the diameter gets bigger. With this kind of a diameter distribution, there is continuously going to be trees entering 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.

Apart from providing information on the diameter distribution, Table 8 also gives indications on which tree species have a potential to grow into big size trees in the area. *Acacia erioloba* is one of those species. Note that the diameter distribution presented in this chapter includes only live trees. The diameter distribution of dead trees is presented in chapter 4.8 “Deadwood”.

Table 8: Diameter distribution of stems by species (nr of stems)

Diameter class, cm

Species	5-15	15-25	25-35	35-45	45-55	55-65	65-75	75-85	85-95	95-105	115-125	135-145	Total	%
Acacia erioloba	16271	15158	10668	13498	8593	4705	2903	1246	770	61	474	237	74585	31
Acacia hebeclada (hebeclada)	14928												14928	6
Acacia mellifera	114654												114654	47
Acacia nilotica	9600	4800	1200										15600	6
Albizia anthelmintica		3200											3200	1
Boscia albitrunca	3307	1200	1200										5707	2
Boscia Foetida	5969	1679											7648	3
Dichrostachys cinerea (setulosa)	1600												1600	1
Ziziphus mucronata	1200	3600		533									5333	2
Total	167529	29636	13068	14031	8593	4705	2903	1246	770	61	474	237	243254	100
%	69	12	5	6	4	2	1	1	0	0	0	0	100	

There were 11 tree species found in the area. In the table above there are only 9 species. This is because only live trees are included in the table above, and the remaining 2 species were found dead. With the exception of the distribution of *Acacia erioloba* the diameter distributions in the Rehoboth Acacia Park are not well-balanced. As can be seen in the table 8 above, most of the stems of other species are in the small diameter classes. The biggest trees are *Acacia erioloba, Acacia nilotica, Boscia albitrunca, Boscia foetida* and *Ziziphus mucronata* - trees.

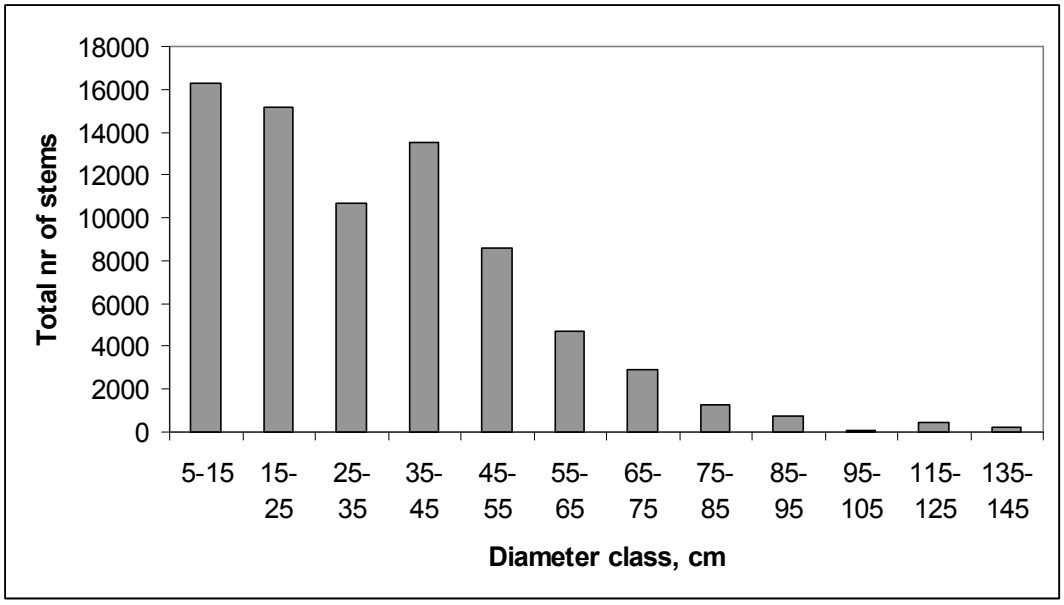


Figure 2: Diameter (cm) distribution (total number of stems) of *Acacia erioloba*

Table 9 and Figure 2 show that *Acacia erioloba* is represented in most of the diameter classes starting from 5 to 155 cm. The bulk of the stems are in small sizes and medium sizes. 56 % of the *Acacia erioloba* stems were found in diameter class between 5 – 35 cm. 25 % of A*cacia erioloba* stems have a diameter bigger than 45 cm.

To sum up:

- There is a well-balanced size class distribution of *Acacia erioloba* trees found in the Rehoboth Acacia Park. All size classes are represented which gives good opportunities for management for various objectives.
- Other species were mainly found in the small diameter classes.

Table 9: Total tree volume and number of stems by diameter classes for *Acacia erioloba*

Dbh class, cm	Total tree volume, m3	% of total *A. erioloba* volume	Total number of stems	% of total *A. erioloba*-stems
5-15	499	1	16271	22
15-25	2763	4	15158	20
25-35	5014	7	10668	14
35-45	12286	16	13498	18
45-55	13074	17	8593	12
55-65	11230	15	4705	6
65-75	9741	13	2903	4
75-85	5755	8	1246	2
85-95	5098	7	770	1
95-105	425	1	61	0
105-115	0	1	0	0
115-125	5114	7	474	1
125-135	0	0	0	0
135-145	3747	5	237	0
Total	74745	100	74585	100

90 % out of the total tree volume of the area is *Acacia erioloba* but only 31 % of out of the total number of the trees in the whole are *Acacia erioloba* -trees. The big share of the volume comes from big size *Acacia erioloba* trees.

4.7 Timber volume and qualities

The objectives of community based resource management are that:

1) The well being of the community is improved and
2) Utilization of the natural resource is sustainable.

The 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 utilization of different products. It is recognized that the woody resources can provide socio-economic benefits for a number of purposes, e.g. pole production, fruits, fodder for livestock or woodcarving. This chapter however focuses on the potential for sawn timber production for *Acacia erioloba* trees with dbh > 45 cm. There are also different types of species which could be utilized for this purpose, though it is thought that *Acacia erioloba* is more favorable because of its high volume and the suitable qualities for timber production which are found in the Rehoboth Acacia Park.

To be able to determine the potential for utilization of the woody resources for sawn timber production, the quantities of saw logs needs to be known. Timber volume or saw log volume means the volume of the part of the main trunk that has been regarded saw able. In the field, the dbh and length of the saw-able trunk were recorded. The saw log volume was estimated assuming that 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 recognized that some of the big trees have thick branches that to a certain extent can be utilized 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 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 2m 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 table below for *Acacia erioloba*. The table includes only trees with a dbh > 45 cm, i.e. trees that can be harvested. Note that the tables also include dead trees. The volumes in the table below are log volumes, not tree volumes.

Table 10 indicates that qualities of the stems are good enough to be sawn, combined with medium and poor quality. Some stems found are not saw-able which means that the stems are too much curving or defective.

There is a total of 918.9 m^3 of logs of *Acacia erioloba* in the area. Because only the main trunk of the tree is measured and analyzed excluding the branch wood which is sometimes utilized when suitable, it is possible that the volumes are underestimated. When sawn timber is produced, approximately 40 % of the saw log volume becomes sawn timber and the rest is residues. There fore, there is approximately 367.6 m^3 of sawn timber of *Acacia erioloba* in the Rehoboth Acacia

Park at the moment. This figure shows that there is a very small amount of sawn timber of *Acacia erioloba* in the Rehoboth Acacia Park. The utilization of timber volume is not encouraging at the moment.

Table 10: Distribution by status and quality of *Acacia erioloba* trees with a dbh > 45 cm

Status	Quality	Stems per ha	Total number of stems	Total log volume m³	Average log volume m³/ha
Live tree	No code	0.1	1068	77	0.01
Live tree	Good timber quality	0.7	5807	4922	0.56
Live tree	Medium quality	0.3	3048	2653	0.30
Live tree	Poor quality	0.3	2727	1709	0.20
Live tree	Not saw able	0.6	5272		
Standing dead tree	No code	0.1	718		
Dead, lying	No code	0.0	61		
Stump	No code	0.1	711		
Total		2.2	19412	9361.1	1.072

4.8 Deadwood

In the presentation of volumes and diameter distributions in the previous chapters only live trees were included. The information on deadwood was excluded. There is a considerable amount of dead trees in the Acacia Park. 20 % of the measured trees in the inventory were found to be dead.

Table 11 shows the deadwood volume in the Rehoboth Acacia Park. Note that the volume functions for live trees were used to calculate the deadwood volumes. These volume functions are assuming a certain amount of branch wood. 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 12721.0 m³ in Rehoboth Acacia Park, as seen on table 11 below. More than 96 % of the volumes are from *Acacia erioloba* species.

Table 11: Volume and number of stems of dead trees (totals and per ha)

Species	Total No. of stems	Stems per ha	Total tree volume	Average tree volume m3
Acacia erioloba	16399	1.9	12229.7	1.40
Acacia nilotica	1200	0.1	355.0	0.04
Boscia albitrunca	1600	0.2	136.3	0.02
Total	19199		12721.0	

20 % of the trees among the measured trees are dead. The majority of the dead trees (16 %-units) are *Acacia erioloba* –trees. *Acacia nilotica* and *Boscia albitrunca* represent each 2 %-unit of the dead trees.

According to Table 12 below, more than 85 % of the total number of dead trees including all diameter classes is *Acacia erioloba* trees. 96 % of all the dead trees are smaller than 45 cm (see figure 3).

Table 12: Diameter distribution of dead trees by species (nr of stems)

Species Name	5-15	15-25	25-35	35-45	45-55	55-65	65-75	75-85	85-95	95-105	105-115	Total	% of total
Acacia erioloba	4800	2133	4132	4555	0	61	0	61	61	535	61	16399	85
Acacia nilotica	0	1200	0	0	0	0	0	0	0	0	0	1200	6
Boscia albitrunca	1600	0	0	0	0	0	0	0	0	0	0	1600	8
Total	6400	3333	4132	4555	0	61	0	61	61	535	61	19198	100
% of total	33	17	22	24	0	0	0	0	0	3	0	100	

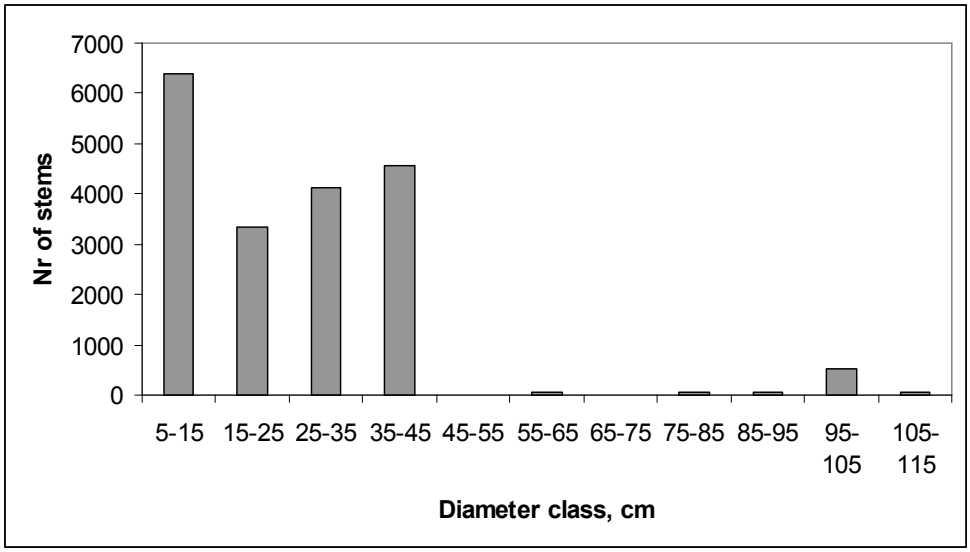


Figure 3: Total number of dead trees (all species) by diameter class

4.9 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 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 continuous harvesting for suitable sizes of poles and enough supply of non-wood products. Total amount of seedlings per hectare in the Rehoboth Acacia Park is 58. More than sixty percent of total seedlings per hectare are from *Acacia mellifera* trees. This indicates that *Acacia mellifera* trees are going to be more dominating in the tree layer in the future than at present.

Table 13: Number of tree seedlings per hectare by height classes (cm) and species

Species	0-25	26-50	51-100	101-150	151-200	201-250	251-300	300+	Total	% of total
Acacia erioloba	1	3	3	1	1			1	10	17.5
Acacia mellifera	1	4	16	8	3	4		1	36	62.5
Albizia anthelmintica		2	1		1		1		4	7.5
Boscia albitrunca			1	2	1				4	7.5
Ziziphus mucronata					1			2	3	5
Total	2	9	20	11	7	4	1	4	58	
% of total	3.8	15.0	35.0	18.8	12.5	7.5	1.3	6.3		100

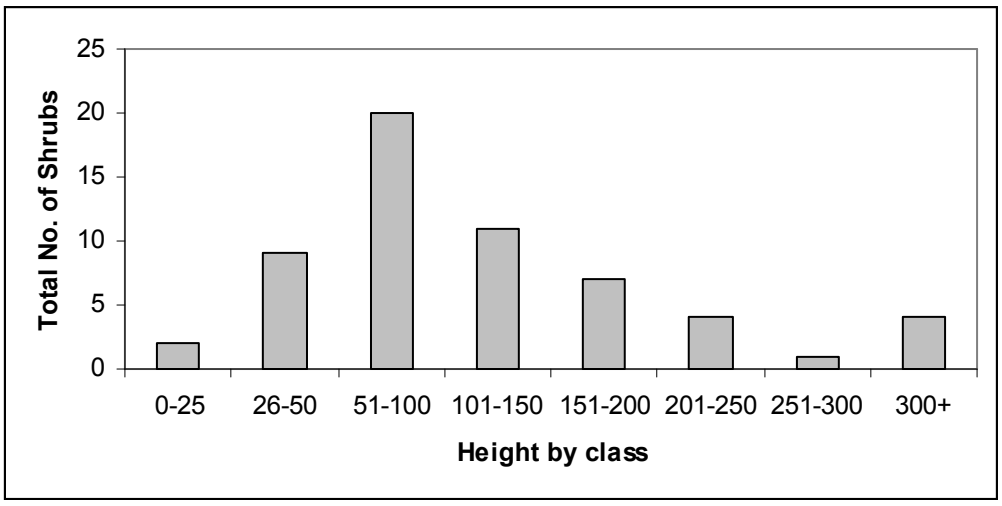


Figure 4: Number of tree seedlings per ha by height class (cm)

To sum up:

- 58 saplings per hectare were found in the area. More than 2/3 of the seedlings are from *Acacia erioloba* and *Acacia mellifera*. This two species are also dominant in tree layer. More than half of the seedlings are from *Acacia mellifera* alone.
- Almost 63 % of the saplings are from *Acacia mellifera*
- About 1/3 of the saplings are between 51-100 cm of height.

Table 14 shows the regeneration of woody species that do not generally grow into tree size, using the dbh ≤ 5 cm limit. Only two shrub species in the whole area don't grow into tree size as shown below.

Table 14: Number of shrub seedlings per hectare by height classes (cm) and species

Species	0-25	26-50	51-100	101-150	151-200	300+	Total	% of total
Acacia karroo						1	1	0.2
Rhigozum brevispinosum	22	68	204	68	1		362	99.8
Total	22	68	204	68	1	1	363	
% of total	6.2	18.7	56.2	18.7	0.2	0.2		100

To sum up:

- Almost all shrubs are from *Rhigozum brevispinosum* species.
- Most of the shrubs are in the range of 25 to 150 cm classes.

4.10 Sampling error and confidence limits

4.10.1 General

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

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 checking's were done to find out possible errors and inconsistencies in the data. The data processing and analysis, as well as the report were double checked.

Volume functions

The applied volume functions are probably the main source of errors. There were no trees felled in Rehoboth Acacia Park. Stem analysis were done only in Omusati, Caprivi and West Tsumkwe.

Sampling error estimator

The magnitude of sampling error, Table 15, was estimated with the formula of random sampling, using 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 overestimate the sampling error.

4.10.2 Sampling error and confidence limits

Table 15 shows the sampling error and confidence limits for tree volume for “all species” and for *Acacia erioloba*.

Table 15: 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	3.8	1.9	9.5	20	5.8	13.2	95
Acacia erioloba	3.8	1.9	8.5	20	4.8	12.2	95

The sampling error for the average volume per hectare of *Acacia erioloba* is 1.9 m³/ha (20 % of the average). This means that the average saw log timber volume of *Acacia erioloba* is between 4.8 and 12.2 m³/ ha with a probability of 95 %. There is a very little difference between the accuracy of the average volume of *Acacia erioloba* and the results of all species combined.

5. Conclusion

Volumes

There is a total volume of 82835 m³ of wood in the Rehoboth Acacia Park. The mean tree volume is 9.5 m³/ ha and there are 27.8 stems per ha. Dead trees were also analyzed. There is a total volume of 12720 m³ of dead trees in Rehoboth Acacia Park. More than 95 % of the dead trees were from *Acacia erioloba* species.

Total log volume of the main trunk of *Acacia erioloba* species is 919 m³ excluding the branch wood which might be used when suitable for sawn timber. Therefore, the volumes might be underestimated. Only 368 m³ of sawn timber out of the total log volume is available in the area for *Acacia erioloba* at the moment (only about 40 % of the total saw log volume become sawn timber and the rest is residues). There is a very small amount of sawn timber of *Acacia erioloba* available in the Rehoboth Acacia Park currently.

The woody species

A total of 11 woody species were recorded in Rehoboth Acacia Park. 9 species were recorded as trees and 9 woody species were found in shrub layer. 7 woody species were found both in tree and shrub layer. The most frequent species in the data were as follows: *Acacia erioloba, Acacia mellifera* and *Boscia foetida* trees (dbh $\geq$ 5 cm) were found in more than half of the measured plots.

Potential for economic utilization and environmental impacts now and in the future

The woody resource inventory indicates that Rehoboth Acacia Park has a very little volume of sawn timber at the moment. Woody resources currently available could provide number of other economic benefits to the community and environment in general. Some of the benefits are: animal fodder, controlled small scale wood carving, fire wood, carbon sequestration, and prevention of soil erosion.

Some management proposals

Proper management is crucial to utilize the woody resources sustainably.

The management of the woody resources in the Rehoboth Acacia Park should include at least the following:

- Management of the smaller trees for them to grow into mature trees. This could be done through issuing of permit only for the poles which are suitable for fencing, wood carving etc. with certain diameter ≥15 for fencing and wood carving.
- Fire management. This can be achieved by creating and maintaining fire breaks or cut lines.
- The inclusion of non-timber forest products which are utilized by the surrounding communities in the management planning. It should be noted that non- timber forest products were not considered in this inventory.

6. References

Angombe, S., Selanniemi, T. and Chakanga, M. (2001). Woody Resource Report of M'kata Pilot Forest area, April 2001. Directorate of Forestry. Namibia-Finland Forestry Programme.

Burke, Juola, Korhonen K. (1996). Field Instructions Western Bushmanland, National Forest Inventory Project, Directorate of Forestry.

Appendix 1: Cluster coordinates for Rehoboth Acacia Park

Cluster	Latitude	Longitude	Cluster	Latitude	Longitude	Cluster	Latitude	Longitude	Cluster	Latitude	Longitude
1	-23.320	17.130	**43**	-23.351	17.194	**85**	-23.374	17.120	**125**	-23.396	17.120
2	-23.320	17.135	**44**	-23.351	17.199	**86**	-23.374	17.125	**126**	-23.396	17.116
3	-23.320	17.140	**45**	-23.356	17.194	**88**	-23.378	17.106	**127**	-23.405	17.170
4	-23.320	17.145	**46**	-23.356	17.189	**89**	-23.378	17.111	**128**	-23.405	17.165
5	-23.320	17.150	**47**	-23.356	17.184	**90**	-23.378	17.115	**129**	-23.405	17.160
6	-23.320	17.155	**48**	-23.356	17.179	**91**	-23.378	17.130	**130**	-23.405	17.155
7	-23.320	17.160	**49**	-23.356	17.174	**92**	-23.378	17.135	**131**	-23.405	17.150
8	-23.320	17.165	**50**	-23.414	17.135	**93**	-23.378	17.140	**132**	-23.405	17.145
9	-23.320	17.169	**51**	-23.356	17.169	**94**	-23.378	17.145	**133**	-23.414	17.145
10	-23.320	17.174	**52**	-23.356	17.164	**95**	-23.378	17.150	**134**	-23.414	17.140
11	-23.320	17.179	**53**	-23.356	17.159	**96**	-23.378	17.155	**135**	-23.414	17.130
12	-23.320	17.184	**54**	-23.356	17.155	**97**	-23.387	17.106	**136**	-23.414	17.125
13	-23.329	17.130	**55**	-23.356	17.150	**98**	-23.387	17.111	**137**	-23.414	17.120
14	-23.329	17.135	**56**	-23.360	17.179	**99**	-23.387	17.116	**138**	-23.383	17.106
15	-23.329	17.140	**57**	-23.360	17.184	**100**	-23.387	17.120	**139**	-23.383	17.110
16	-23.329	17.145	**58**	-23.360	17.189	**101**	-23.387	17.125	**140**	-23.356	17.199
17	-23.329	17.155	**59**	-23.360	17.194	**102**	-23.387	17.130			
18	-23.329	17.155	**60**	-23.360	17.199	**103**	-23.387	17.179			
19	-23.329	17.160	**61**	-23.360	17.204	**104**	-23.387	17.179			
20	-23.329	17.164	**62**	-23.364	17.204	**105**	-23.387	17.184			
21	-23.338	17.179	**63**	-23.369	17.209	**106**	-23.387	17.189			
22	-23.338	17.184	**64**	-23.369	17.204	**107**	-23.387	17.194			
23	-23.338	17.189	**65**	-23.369	17.199	**108**	-23.387	17.199			
24	-23.342	17.164	**66**	-23.369	17.194	**109**	-23.391	17.179			
25	-23.342	17.170	**67**	-23.369	17.189	**110**	-23.392	17.184			
26	-23.342	17.174	**68**	-23.369	17.184	**111**	-23.392	17.189			
27	-23.342	17.179	**69**	-23.369	17.155	**112**	-23.392	17.194			
28	-23.342	17.184	**70**	-23.369	17.150	**113**	-23.391	17.199			
29	-23.342	17.189	**71**	-23.369	17.145	**114**	-23.391	17.204			
30	-23.342	17.194	**72**	-23.369	17.140	**115**	-23.396	17.204			
31	-23.347	17.194	**73**	-23.369	17.135	**116**	-23.396	17.199			
32	-23.347	17.189	**74**	-23.369	17.135	**117**	-23.396	17.194			
33	-23.347	17.184	**75**	-23.369	17.110	**118**	-23.396	17.189			
34	-23.347	17.179	**76**	-23.369	17.111	**119**	-23.396	17.184			
35	-23.347	17.174	**77**	-23.369	17.101	**120**	-23.396	17.179			
36	-23.347	17.169	**78**	-23.365	17.111	**121**	-23.396	17.140			
37	-23.347	17.164	**79**	-23.365	17.106	**122**	-23.396	17.135			
38	-23.351	17.169	**80**	-23.365	17.101	**123**	-23.396	17.130			
39	-23.351	17.174	**81**	-23.374	17.101	**124**	-23.396	17.125			
40	-23.351	17.179	**82**	-23.374	17.106						
41	-23.351	17.184	**83**	-23.374	17.111						
42	-23.351	17.189	**84**	-23.374	17.115						

Appendix 2: Status of measured trees

Species	Dead, lying	Live trees	Standing dead trees	Stumps	Total	% of total measured trees
Acacia erioloba	13	134	15	4	166	63.1
Acacia hebeclada (hebeclada)		7			7	2.7
Acacia mellifera		60			60	22.8
Acacia nilotica	1	4			5	1.9
Albizia anthelmintica		2			2	0.8
Boscia albitrunca		5	1		6	2.3
Boscia foetida		11			11	4.2
Dichrostachys cinerea (Setulosa)		1			1	0.4
Ziziphus mucronata		5			5	1.9
Total	**14**	**229**	**16**	**4**	**263**	
% of measured trees	**5.3**	**87.1**	**6.1**	**1.5**		**100**

Appendix 3: Total number of measured shrubs

Species	No. of measured shrubs	% of measured shrubs
Acacia erioloba	11	9.5
Acacia hebeclada (hebeclada)	11	9.5
Acacia karroo	1	0.9
Acacia mellifera	19	16.4
Albizia anthelmintica	4	3.4
Boscia albitrunca	3	2.6
Boscia foetida	9	7.8
Rhigoszum brevispinosum	55	47.4
Ziziphus mucronata	3	2.6
Total	116	100

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	85-95	95-105	105-115
Acacia erioloba	0.04	0.24	0.51	0.82	1.49	1.34	1.49	0.77	0.9	0.63	0.43
Acacia hebeclada (hebeclada)	0.07	0.03									
Acacia mellifera	0.4	0.07									
Acacia nilotica		0.11		0.08							
Albizia anthelmintica		0.06									
Boscia albitrunca		0.04	0.05								
Boscia foetida	0.04	0.06	0								
Dichrostachys cinerea (Setulosa)		0.01									
Ziziphus mucronata		0.03	0.07	0.06							
Total	0.55	0.64	0.64	0.97	1.49	1.34	1.49	0.77	0.9	0.63	0.43

Appendix 5: Volume functions for Rehoboth Acacia Park

Acacias and Dichrostachys cineria:

$V = (a_0 + a_1 * d + a_2 * d^2) * d^2$ 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_0, a_1 & a_2 = parameters (see table below)

Boscia albitrunca, Boscia foetida and Albizia anthelmintica:

$V = e^{(a_0 + a_1 * d + a_2 * d^2)}$

Where v = tree volume in dm^3
d = tree diameter (dbh) in cm
a_0, 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 Alban	2.81959700	0.14324800	-0.00010783
3 Bosal	2.81959700	0.14324800	-0.00010783
4 Bosfo	2.81959700	0.14324800	-0.00010783
5 Diccy	0.21795109	0.01407904	-0.00090000
6 Rhibr	0.21795109	0.01407904	-0.00090000
7 Zizmu	0.21795109	0.01407904	-0.00090000

Example: For *Boscia albitrunca* tree with diameter DBH = 47 cm.

$V = e^{(a_0 + a_1 * d + a_2 * d^2 * d^3)}$

$= e^{(2.81959700) + (0.14324800) * (47) + (-0.00090000) * (47)^3}$ $= (2.71828)^{(2.819597 + 6.7327 – 1.9881)}$

$= (2.71828)^{(7.5641)}$

$= 1927.72\ dm^3$

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

Appendix 6: List of trees and shrubs of Rehoboth Acacia Park

Number = index for the model applied to calculate volume according to Appendix 5, on page 27.

Code	Species	Index to volume model
Acaer	*Acacia erioloba*	1
Acahe	*Acacia hebeclada*	1
Acame	*Acacia mellifera*	1
Acani	*Acacia nilotica*	1
Acaka	*Acacia karroo*	1
Alban	*Albizia anthelmintica*	1
Bosal	*Boscia albitrunca*	3
Bosfo	*Boscia foetida*	3
Diccy	*Dichrostachys cineria*	5
Rhibr	*Rhigszum brevispinosum*	6
Zizmu	*Ziziphus mucronata*	7

Appendix 7: Acknowledgements

The successful completion of the Forest Inventory Exercise in Rehoboth Acacia Park was a result of the co-operation efforts of the Steering Committee and many other individuals with in the Directorate of Forestry. The key personnel directly involved in the forest inventory consisted of Directorate of Forestry and Government of Finland staff.

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Government of Finland

Risto Laamanen	Technical adviser for Forest Inventory and Management Planning (NFFP Phase II)
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Thanks also to Rehoboth Forestry Office for their assistance.