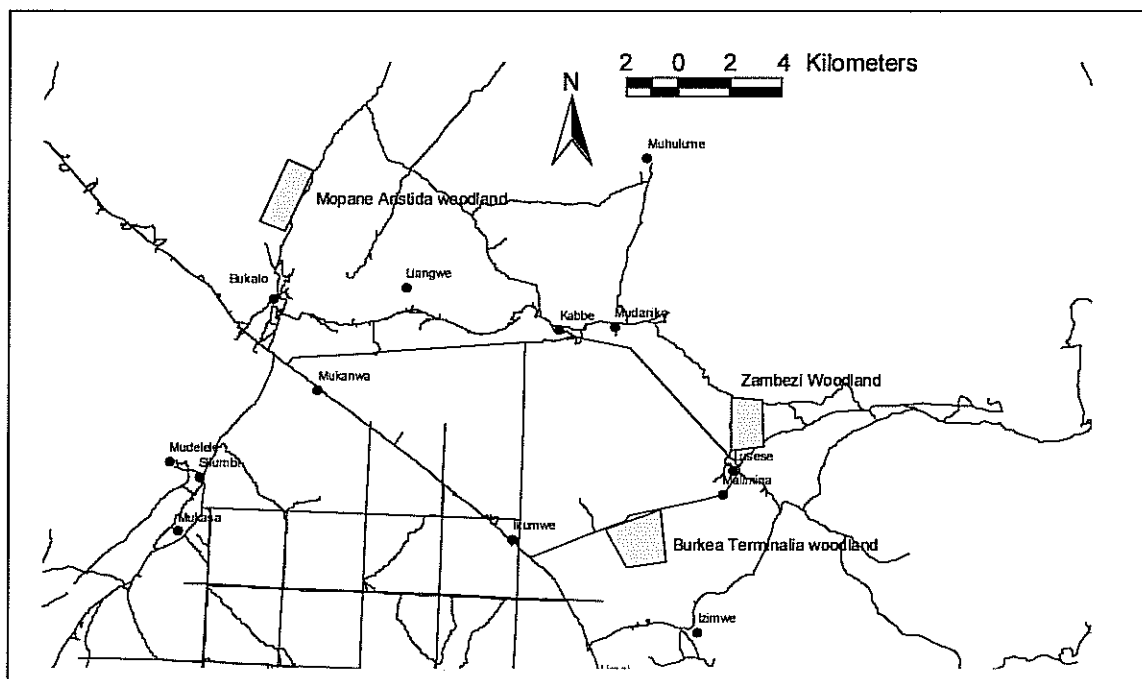


MINISTRY OF ENVIRONMENT AND TOURISM Directorate of Forestry



WOODY RESOURCES OF BUKALO PILOT FOREST AREAS – an inventory report



Namibia-Finland Forestry Programme Phase II

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Windhoek, November 2001

List of contents:

Summary

1. Introduction	1
2. General information of the inventory areas	1
3. Inventory design	2
3.1. Sampling	2
3.2. Field measurements	3
3.3. Volume functions	4
4. Inventory results	5
4.1. Results for Mopane Aristida Woodland	5
4.1.1. Site and stand data	5
4.1.2. Species diversity	5
4.1.3. Number of stems by species	6
4.1.4. Diameter distribution	8
4.1.5. Stem volumes by species	10
4.1.6. Regeneration and shrubs	12
4.2. Results for Zambezi woodland inventory area	13
4.2.1. Site and stand data	13
4.2.2. Species diversity	13
4.2.3. Number of stems by species	14
4.2.4. Diameter distribution	16
4.2.5. Stem volumes by species	18
4.2.6. Regeneration and shrubs	19
4.3. Results for Burkea terminalia woodland inventory area	19
4.3.1. Site and stand data	19
4.3.2. Species diversity	19
4.3.3. Number of stems by species	20
4.3.4. Diameter distribution	22
4.3.5. Stem volumes by species	24
4.3.6. Regeneration and shrubs	26
5. Reliability of the results	26
5.1. Sources of error	26
5.2. Sampling error and confidence limits	26

List of Annexes:

- Annex 1. Vegetation map
- Annex 2. Volume functions
- Annex 3. Result tables for Mopane Aristida woodland inventory area
- Annex 4. Result tables for Zambezi woodland inventory area
- Annex 5. Result tables for Burkea Terminalia woodland inventory area
- Annex 6. Coordinates of the sampling plots
- Annex 7. Acknowledgments
- Annex 8. List of inventory reports by the Directorate of Forestry.

List of maps:

- Map 1. Location of inventory areas (Bukalo pilot forest areas). 2

List of tables:

- Table 1. Inventory areas and number of sampling units. 3
- Table 2. Mopane Aristida inventory area: species diversity by the number of plots where each species was found. 6
- Table 3. Mopane Aristida woodland inventory area: Number of stems (dbh 45 and more) with good, medium or poor sawlog quality and the total volume of logs. 11
- Table 4: Zambezi woodland inventory area: species diversity by the number of plots where each species was found. 14
- Table 5. Burkea Terminalia woodland inventory area: Species diversity by the number of clusters where each species was found. 20
- Table 6: Sampling error and confidence limits for mean tree volume. 27

List of figures:

- Figure 1. Sample plot design. 4
- Figure 2. Mopane Aristida woodland: dominant live tree species, number of trees per hectare. 7
- Figure 3. Mopane Aristida woodland inventory area: most frequent dead tree species, stems per ha. 8
- Figure 4. Mopane Aristida woodland inventory area: diameter distribution of the 5 most dominant tree species (% of stems of total by species). 9
- Figure 5. Mopane Aristida woodland: diameter distribution of the 3 most frequent species among dead trees. 10
- Figure 6. Mopane aristida woodland inventory area: total volume of live trees by species (m³). 11
- Figure 7. Mopane Aristida inventory area: total volume of dead trees (m³). 12
- Figure 8. Zambezi woodland inventory area: live tree species, number of trees per hectare. 15

Figure 9. Zambezi woodland inventory area: most frequent dead tree species, stems per ha.	16
Figure 10. Zambezi woodland inventory area: diameter distribution of the 5 most frequent tree species.	17
Figure 11. Zambezi woodland inventory area: diameter distribution of dead trees, all species together.	17
Figure 12. Zambezi woodland inventory area: volume of live trees by species (in total, m3).	18
Figure 13. Burkea Terminalia woodland: live tree species, number of trees per hectare.	21
Figure 14. Burkea Terminalia woodland inventory area: most frequent dead tree species, trees per hectare.	22
Figure 15. Burkea Terminalia woodland inventory area: diameter distribution of the 5 most frequent species.	23
Figure 16. Burkea Terminalia woodland inventory area: diameter distribution of dead trees, all species together.	24
Figure 17. Burkea Terminalia woodland inventory area: total volume (m3) by species.	24
Figure 18. Burkea Terminalia woodland inventory area: volume of 5 most frequent dead wood tree species (total, m3).	25

1. INTRODUCTION

The Directorate of Forestry (DoF) under the Ministry of Environment and Tourism in Namibia has a mission to carry out forest resource assessments in Namibia. In this task it has been supported since 1995 by the Government of Finland. Initially the aim of the support was to build the capacity of the Directorate to carry out regional forest inventories - that is inventories of very large areas (National Forest Inventory component, NFI). During the years, an increasing number of local level inventories have also been carried out to fulfill specific requests by projects and forest managers. The support from the Government of Finland today – Namibia-Finland Forestry Programme Phase II – aims now more at strengthening the capacity of DoF to serve the needs for local level forest management planning.

A request from DED was received by DoF in July 2001 to help assessing the woody resources of three separate areas in Caprivi region near Bukalo and Lushese. These three areas are pilot forest areas for community forest management development activities by DED. The inventory was given a high priority in the work plan and it was implemented in early August. Preliminary results were made available for DED in the end of August. A simple non-stratified systematic sampling was applied. The field work was carried out using the methodology of the earlier NFI. The results for all three areas (Burkea-terminalia woodland, Mopane woodland and Zambezi woodland) are presented in this report. The three areas as a whole are referred later as the Bukalo pilot forest areas.

For those readers who may be interested to know what other forest areas the DoF has inventoried, a list of inventory reports has been attached as an annex at the end of this report. These reports are available at the Directorate of Forestry in Windhoek.

2. GENERAL INFORMATION OF THE INVENTORY AREAS

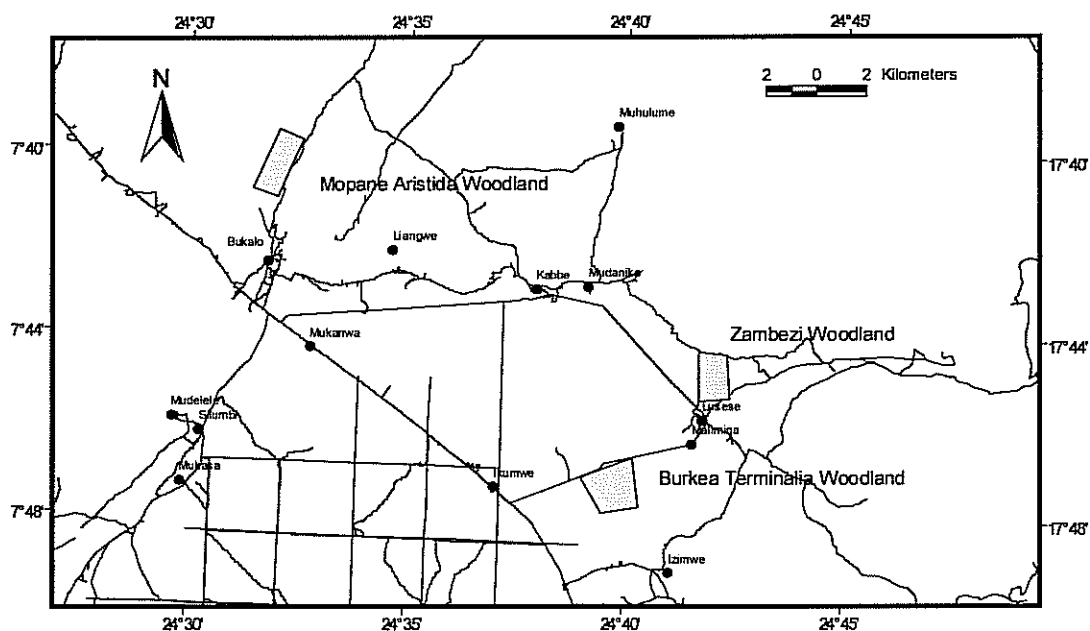
Bukalo pilot forest areas are located in the western parts of Caprivi Region (see Map 1.). The areas have been named according to the main vegetation class of each specific area in the vegetation maps of Namibia (see Annex 1). According to the vegetation map, the first area, Mopane Aristida woodland, has a small strip of Bukalo-Liambezi grassland too. The second area, Zambezi woodland, belongs partly to Zambezi transition grassland. In addition, according to the map, a small part of it belongs to class Chobe grassland-hummock mosaic. The third area, Burkea Terminalia woodland, has a small piece of Chobe grassland-hummock mosaic too.

The Zambezi woodland inventory area and the Burkea Terminalia woodland inventory area both belong to Salambala Conservancy. The Mopane Aristida inventory area is outside the Conservancy.

3. INVENTORY DESIGN

3.1. Sampling

The inventory areas were defined by using the coordinates given by the DED. Black and white aerial photographs (from the Department of Land Survey) and a Landsat TM satellite image were visually analysed before the inventory in order to see if there are any possibilities for stratification. Stratification in many cases can improve the efficiency of the field work and results with higher accuracy can be produced for sub-areas of interest. In the case of Bukalo pilot forests, the areas were found to be uniform to the extent that no stratification was seen useful. Therefore, a uniform systematic layout of sample units was applied on all areas. One sample unit consists of three concentric plots (see below 3.2. Field measurements).



Map 1. Location of inventory areas (Bukalo pilot forest areas).

The design of the sampling and sampling intensity were chosen in order to carry out a simple and straightforward inventory and aiming at an accuracy of about 10 % in the main characteristics of the trees (e.g. volume/ha) on each area.

Shrubs and regeneration were measured in two sub-plots (radius 3.99 m) located on each sampling plot (see Figure 1).

A different radius of sample plot was applied for small trees, medium size trees and big trees. For small trees ($5\text{cm} < \text{dbh} \leq 20\text{cm}$) the radius is 10 m, for medium size trees ($20\text{cm} < \text{dbh} \leq 45\text{cm}$) the radius is 20 m and for big trees ($\text{dbh} > 45\text{cm}$) 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. In addition, tree height, diameter of canopy, crown height and damages were recorded for each tree.

One sampling unit consists of one plot which again consists of three concentric circles. In the following text, a sample plot is understood to be the same as a sample unit. The woody vegetation is classified into trees and shrubs. In this inventory trees are defined as woody plants with $\text{dbh} \geq 5\text{ cm}$ and saplings/shrubs are woody plants with $\text{dbh} < 5\text{ cm}$.

The data collection in the field was carried out using the methodology of several previous inventories. This methodology is described in details in the Manual for woody resource inventories by the Directorate of Forestry.

3.2. Field measurements

The plot coordinates were determined at the office in advance for the field work. Inventory field work was carried out by 2 teams. The teams moved in the field using ATVs and they located the plot sites with the help of the predefined coordinates and GPS-receivers.

The sampling intensity for Mopane *Artisida* woodland and Burkea *Terminalia* woodland was about 4.5 % for big trees, about 2 % for medium size trees and about 0.5 % for small trees. In Zambezi woodland, a higher intensity was applied (about 2 times higher) because more variation in the vegetation could be seen on the air-photo. Also, this intensity was used for gathering experience how intensity affects accuracy.

Table 1. Inventory areas and number of sampling units.

Inventory Area	Area, Hectares	Number of sampling units
1. Mopane <i>Artisida</i> w.	271.2	44
2. Zambezi woodland	226.2	78
3. Burkea <i>Terminalia</i> w.	337.4	57

The size of each area and the number of sampling units are listed in the Table 1. below.

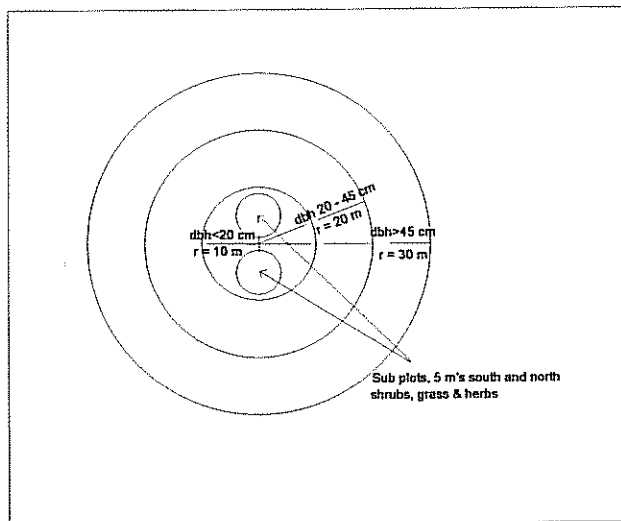


Figure 1. Sample plot design.

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, human influence and grazing.

3.3. Volume functions

Volumes for the trees in this inventory were calculated using the volume functions derived by the DoF. A data set of 252 trees of the most common species from West Tsumkwe, Caprivi, Oshikoto and Omusati Regions were used when these functions were made.

Only the most common tree species have their own volume functions. For a tree species without a function of its own, a function of a species that has a similar shape of the stem, has been applied. The functions used in these calculations can be found in the Annex 2.

4. INVENTORY RESULTS

In the following, results for all three areas will be presented separately. The results are presented as graphs whenever it has been possible. Tables with full numeric data on the inventory results can be found in the Annexes 2, 3 and 4. The data itself is available at the Directorate of Forestry in dbf-files.

4.1. Results for Mopane Aristida woodland inventory area

4.1.1. Site and stand data

In the inventory, a stand data form was filled in on each plot. This data describes some features of the stand and site in general surrounding the plot.

The Mopane Aristida woodland inventory area was classified as a plain by its geomorphology. On all plots, the soil texture was classified as sand.

On 75 % of the plots, moderate signs of grazing were found (vegetation being still vital) and on 15 % of the plots, no signs of grazing were seen. Plots with intensive grazing were not found.

84 % of the plots were found without damages on the trees. On one plot (out of 44) a damage caused by wild mammals (elephant) was detected. Damage caused by cattle was recorded on three plots. In all cases the damage was considered to be mild not really affecting the trees. On one plot some timber sized trees had been removed by man. These results indicate that the area has been protected from cuttings or there are no species of interest for the community.

4.1.2. Species diversity

Species diversity on the area can be described by presenting the number of species found in the area and the number of plots where each species was detected. This data is presented here in Table 2.

A total of 33 woody species were found in the Mopane Aristida forest. 19 species were recorded in the tree layer and 14 species in the regeneration/shrub layer. 12 species were found both in the tree layer and the regeneration/shrub layer. The area is relatively rich in species as we are talking about an area of 271 hectares only. As a comparison, in the regional inventory of Caprivi, a total of 57 species were found. So, about 58 % of all woody species of Caprivi region can be found in this inventory area (Mopane Aristida).

Species	No. of plots, dbh<5 cm	No. of plots, dbh>5 cm
<i>Acacia ataxacantha</i>	2	
<i>Acacia erioloba</i>	6	1
<i>Acacia fleckii</i>	1	
<i>Acacia nebrownii</i>		1
<i>Acacia nilotica</i>	1	2
<i>Albizia harveyi</i>	2	
<i>Baikiaea plurijuga</i>	1	1
<i>Baphia massaiensis</i>	4	
<i>Bauhinia petersiana</i>	6	
<i>Boscia albitrunca</i>	1	
<i>Burkea africana</i>	8	19
<i>Colophospermum mopane</i>	15	18
<i>Combretum apiculatum (apiculatum)</i>	1	
<i>Combretum collinum</i>	5	6
<i>Combretum engleri</i>	1	
<i>Combretum imberbe</i>	1	8
<i>Combretum zeyheri</i>	3	1
<i>Diospyros mespiliformis</i>	1	3
<i>Flueggea virosa</i>		2
<i>Grewia retinervis</i>	9	
<i>Guibourtia coleosperma</i>		1
<i>Lonchocarpus capassa</i>		1
<i>Lonchocarpus nelsii</i>		1
<i>Ochna pulchra</i>	6	
<i>Parinari curatellifolia</i>		1
<i>Peltophorum africanum</i>	1	2
<i>Piliostigma thonningii</i>	1	2
<i>Rhigoszum brevispinosum</i>	1	
<i>Strychnos pungens</i>		1
<i>Terminalia sericea</i>	22	33
<i>Vangueria infausta</i>	1	
<i>Ximenia Americana var americana</i>	3	
<i>Ximenia caffra var microphylla</i>	1	

Table 2. Mopane Aristida inventory area: species diversity by the number of plots where each species was found.

4.1.3. Number of stems by species

Live trees

A total of 19 tree species were found in the area. Including all species, altogether 176 stems per hectare and a total of 47753 stems have been estimated to grow on this area. The six most frequent species are: *Terminalia sericea* (94 stems/ha, 25 390 stems in total), *Colophospermum mopane* (46 stems/ha, 12 606 stems in total), *Combretum collinum* (14 stems/ha, 3802 stems in total), *Burkea africana* (8 stems/ha, 2215 stems in total), *Combretum imberbe* (5 stems/ha, 1410 stems in total) and *Combretum zeyheri* (4 stems/ha, 1028 stems in total) (see figure 2).

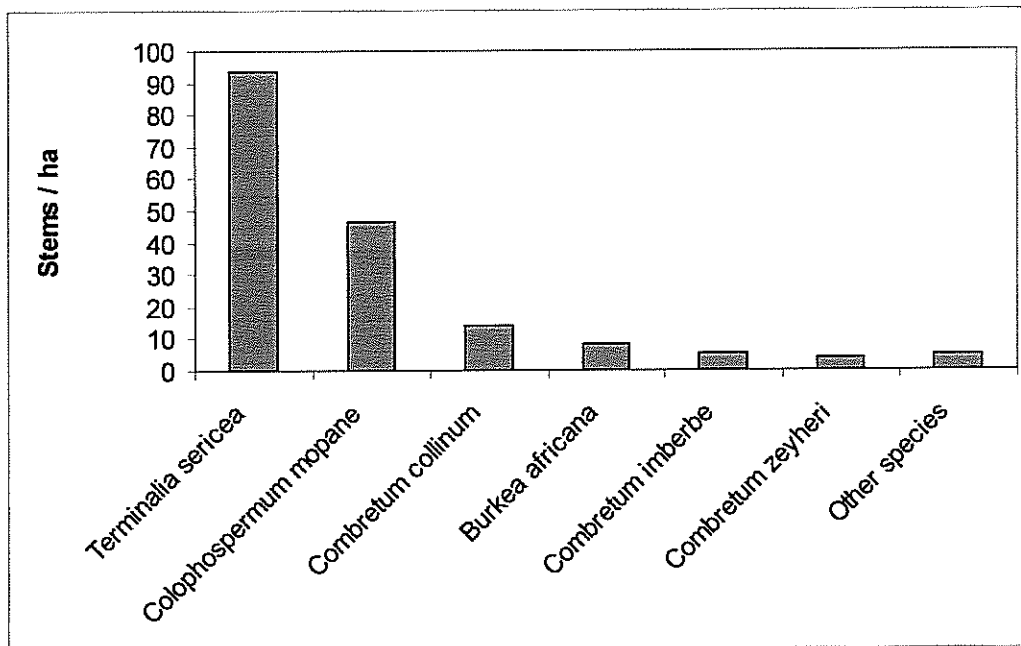


Figure 2. Mopane Aristida woodland: dominant live tree species, number of trees per hectare.

In addition to the 6 most frequent species listed above, 13 other species were found. However, they were not very frequent and represent only 5 stems per hectare in total. Only 1 to 4 individual trees of each of these other species were detected in the sample of the whole area. See full list of species in Annex 3 (table 4).

Dead trees

A total of 10 species could be found among the dead trees. Including all species, 17 dead trees per hectare and a total of 4590 dead trees were estimated to be in the area. The four most frequent species were *Burkea africana* (5 stems/ha), *Terminalia sericea* (5 stems/ha), *Colophospermum mopane* (3 stems/ha) and *Peltophorum africanum* (1.5 stems/ha) (see Figure 3). The other 6 species represent a total of 1.5 stems per hectare. See full list of dead wood species in Annex 3 (table 6).

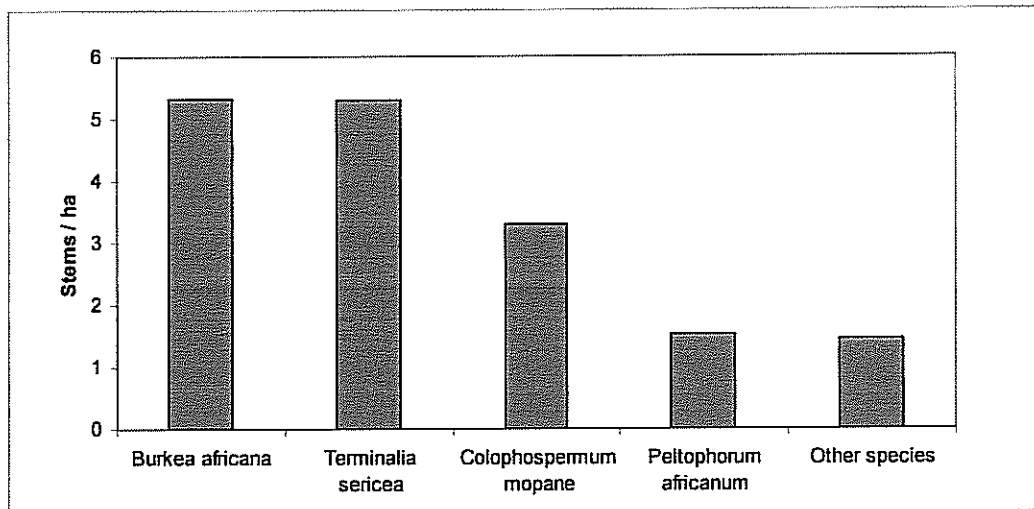


Figure 3. Mopane *Aristida* woodland inventory area: most frequent dead tree species, stems per ha.

4.1.4. Diameter distribution

Live trees

The diameter distribution (as % of trees in diameter class by species) for the 5 most dominant live tree species has been illustrated in Figure 4. It can be clearly seen, that *Terminalia*, *Colophospermum* and both *Combretum* have most of the stems in the smallest diameter class (5-15 cm) and much fewer trees in the bigger classes. The timber size trees – that is trees with dbh more than 45 cm are relatively few among these species. Only 1 % (212 trees) of *Terminalia* trees have a dbh more 45 cm, and respectively 7 % (531 trees) of *Colophospermum* and 2 % (23 trees) of *Combretum imberbe* have a dbh more than 45 cm. There are no *Combretum collinum* trees of this size at all.

Burkea africana is showing a more even diameter distribution than the species discussed above. From the Figure 4 it is easy to see that diameter classes 5-15 cm, 25-35 cm and 35-45 cm all have a share of about 30 % of the stems. The number of big *Burkea* trees (dbh more than 45 cm) is about 211 (10 % of all *Burkeas*).

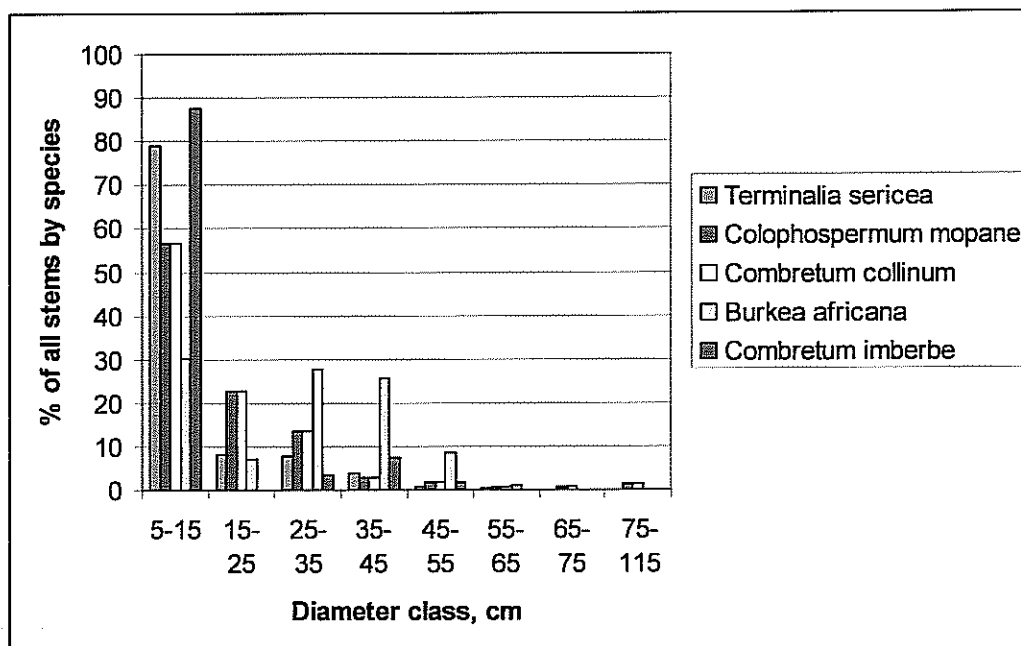


Figure 4. Mopane Aristida woodland inventory area: diameter distribution of the 5 most dominant tree species (% of stems of total by species).

All stems of *Combretum zeyheri* were found in the diameter class 5 – 15 cm. The other species do not show a proper diameter distribution either, as only 1-4 individual trees were found in the whole sample. A complete diameter distribution for all species in numbers is given in the Annex 3 (table 5).

Dead trees

The diameter distribution of the 3 most frequent species among dead trees is shown on the figure 5 below. Dead *Colophospermum* trees were found mainly in the smaller diameter classes (5-15 cm, 15-25 cm). Dead *Terminalia* are also more frequent in the smaller diameter classes. On the other hand *Burkea* is showing a different shape of distribution with more trees in the medium size diameter classes.

The other species found among dead trees do not show a proper diameter distribution as they could only be found in one or two diameter classes. A complete diameter distribution for dead trees by species in numbers can be found in Annex 3 (table 8).

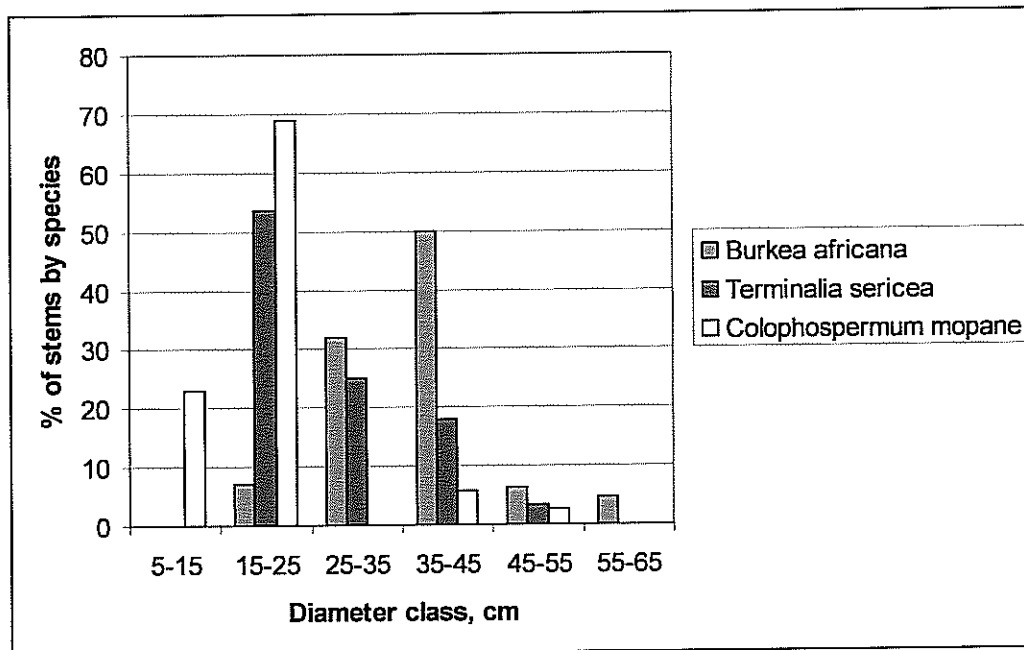


Figure 5. Mopane Aristida woodland: diameter distribution of the 3 most frequent species among dead trees.

4.1.5. Stem volumes by species

Live trees

The total volume of all live trees in Mopane Aristida inventory area is 9198 m³ (33.9 m³/ha). The volume of *Terminalia sericea* is 3141 m³ (11.5 m³/ha) and the volume of *Colophospermum mopane* is 2788 m³ (10.3 m³/ha). The volume of *Burkea africana* is 1898 m³ (7 m³/ha). There are also some trees of *Baikiea plurijuga* (a total of 299 m³ with 1 m³/ha) and some trees of *Combretum imberbe* (a total of 294 m³ with 1 m³/ha). All other species have a volume of less than 1 m³/ha each (see Figure 6 and Annex 3, table 4 for full list of species and volumes).

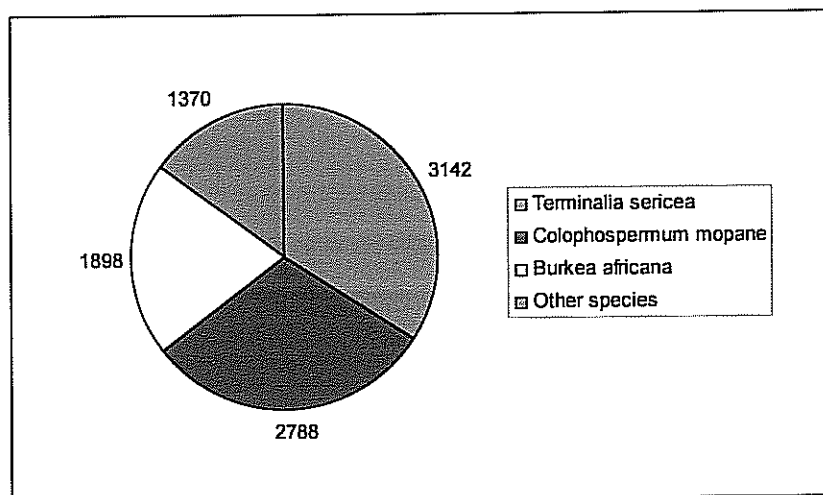


Figure 6. Mopane aristida woodland inventory area: total volume of live trees by species (m³).

Timber volume of live trees

In this inventory, the big trees – that is trees with dbh 45 cm or more were classified according to the quality of the sawlog part of the stem. The height of the sawlog was measured and the volume of that part was calculated. The volumes expressed here do not directly reveal the final output as sawlogs. This volume only includes the stem and not the volume of the big branches. The number of stems having good, medium or poor quality timber and the total volume of potential sawlogs are presented in the following table. Good quality means that there is at least a 2 m long straight stem without damages. Medium quality means that the stem is slightly curving or having other damages but is still having at least 2 meters of saw-able log. Poor quality means that it is only possible to find a 1.2-2 meters long sawlog in the stem.

Table 3. Mopane Aristida woodland inventory area: Number of stems (dbh 45 and more) with good, medium or poor sawlog quality and the total volume of logs.

Species	Quality	Total nr of stems	Total log vol, m ³
Colophosp. mopane	Good	114	139
“	Medium	23	16
“	Poor	137	134
Terminalia sericea	Good	23	28
“	Medium	23	8
“	Poor	97	42
Burkea africana	Good	97	513
“	Medium	69	29

Dead trees

The volume of all dead trees is about 11 m³/ha which accounts for a total of 2980 m³. These are relatively high figures compared to the volume of live trees (33.9 m³/ha and 9198 m³ in total). *Burkea africana* is the species with the biggest dead wood volume, that is 1903 m³ and 7 m³/ha on the area. *Terminalia sericea* has a total of 561 m³ and 2 m³/ha of dead wood. All other species have less than 0.5 m³/ha of dead wood (see Figure 7. and Annex 3, table 6).

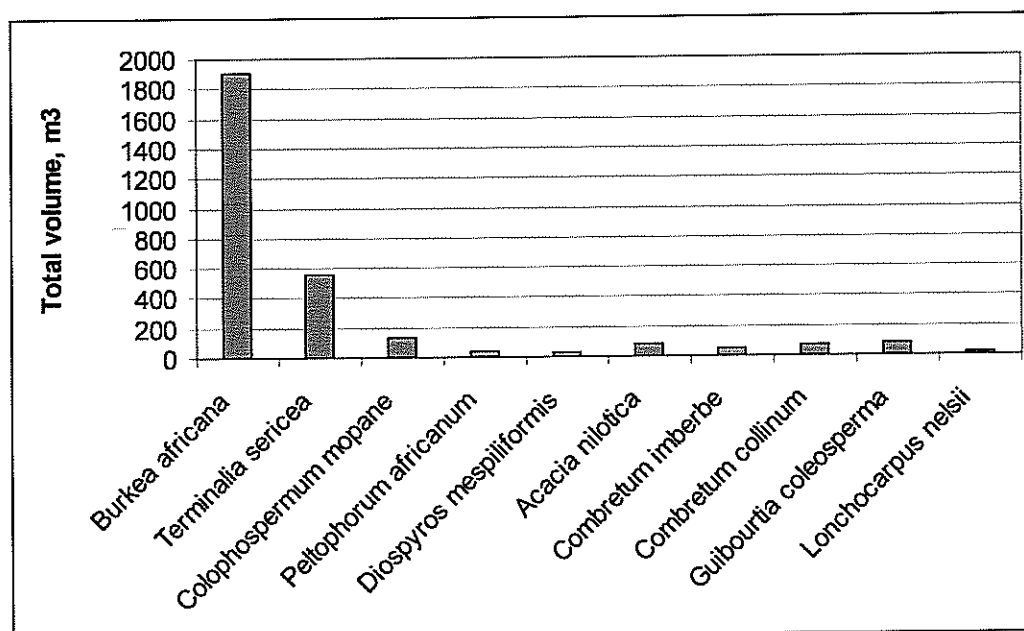


Figure 7. Mopane Aristida inventory area: total volume of dead trees (m³).

4.1.6. Regeneration and shrubs

Regeneration

In the inventory, trees with dbh less than 5 cm were enumerated as regeneration of trees (saplings). A total of 1479 saplings per hectare were found in the area. The most frequent sapling is *Colophospermum* with 1067 saplings per hectare and the second most frequent is *Terminalia* with 260 saplings per hectare. Full list of the number of saplings by species and by height classes can be found in Annex 3 (table 8). These figures indicate that there is a good number of regeneration coming up to secure the future of the forest too.

The species with the most saplings compared to the number of trees of the same species is *Acacia erioloba*. This species has 8 saplings growing for every 100 tree stems. Even though *Colophospermum* has the biggest absolute number of saplings, it has only 4 saplings for every 100 tree stems. The lowest figure is by *Combretum imberbe*, which has only 0.35 saplings growing for every 100 tree stems. The regeneration of this species as well as the regeneration of *Baikiaea* and *Acacia nilotica* is very poor.

Shrubs

In addition to enumerating the regeneration, shrub species were counted too. A total of 15 different species were identified with a total of 498 shrubs per hectare. The most frequent species is *Bauhinia petersiana* with 255 shrubs per hectare. *Grewia retinervis* has 64 individuals per hectare and *Rhigoszum brevispinosum* has 31 individuals per hectare. The full list of shrubs enumerated by height classes can be found in Annex 3 (table 9).

4.2. Results for Zambezi woodland inventory area

4.2.1. Site and stand data

By its geomorphology, the Zambezi woodland inventory area was mainly classified as plain (78 % of the plots). 22 % of the plots were classified as flood plain. On 75 % of the plots, the soil texture was classified as sand and on 25 % it was classified as sandy loam.

On 24 % of the plots, no signs of grazing were observed. On 20 % of the plots, moderate signs of grazing were seen (vegetation still vital). However, on 56 % of the plots signs of intensive grazing were visible (vitality of vegetation clearly threatened).

42 % of the plot stands were found with no damages. 34 % had moderate damages (decreasing the vitality of the trees) caused by domestic cattle and 20 % of the plots had serious damages (most of the trees damaged) caused by elephants. 4 % of the plots had mild damages caused by man.

Human influence on the trees is visible: on 43 % of the plots, signs of cuttings of small size trees were recorded (on two plots big trees have been removed too).

4.2.2. Species diversity

Species diversity on the area is described by the number of species found in the area and the number of plots where each species was detected. This data is presented below in Table 4.

A total of 33 woody species were found in the Zambezi woodland inventory area. This is the same number as in Mopane *Aristida* area, however, only 23 species were the same. In Zambezi woodland, 24 species were found in the tree layer and 22 species in the regeneration/shrub layer. 12 species were found in both layers.

Species	No. of plots, dbh>5 cm	No. of plots, dbh<5 cm
<i>Acacia erioloba</i>		1
<i>Acacia mellifera</i>	1	
<i>Acacia nebrownii</i>	5	
<i>Acacia nilotica</i>	6	8
<i>Albizia harveyi</i>	1	
<i>Boscia albitrunca</i>	1	
<i>Burkea africana</i>	3	4
<i>Colophospermum mopane</i>	18	16
<i>Combretum apiculatum (apiculatum)</i>	1	3
<i>Commiphora angolensis</i>		2
<i>Combretum engleri</i>	4	4
<i>Combretum imberbe</i>	15	9
<i>Dichrostachys cinerea (africana)</i>		1
<i>Diospyros mespiliformis</i>	17	8
<i>Ficus sycomorus</i>	2	
<i>Flueggea virosa</i>	2	
<i>Grewia bicolor</i>		3
<i>Grewia flava</i>		3
<i>Grewia retinervis</i>		3
<i>Hyphaene petersiana</i>	1	12
<i>Kigelia africana</i>	2	
<i>Lonchocarpus capassa</i>	5	1
<i>Lonchocarpus nelsii</i>	6	2
<i>Oehna pulchra</i>	1	
<i>Parinari curatellifolia</i>	1	
<i>Peltoporum africanum</i>	2	
<i>Piliostigma thonningii</i>	3	2
<i>Sclerocarya birrea</i>	3	
<i>Strychnos pungens</i>		1
<i>Terminalia prunioides</i>	1	
<i>Terminalia sericea</i>	9	7
<i>Ximения americana var americana</i>		10
<i>Ziziphus mucronata</i>		1

Table 4: Zambezi woodland inventory area: species diversity by the number of plots where each species was found.

4.2.3. Number of stems by species

Live trees

A total of 14 tree species were found in the Zambezi woodland inventory area. Including all species, altogether 40 stems per hectare and a total of 8977 stems have been estimated to grow on this area. The most frequent species is *Colophospermum mopane* with 12 stems per hectare (a total of 2786 stems). *Acacia nilotica* with 6.5 stems per hectare (1487 stems in total) and *Terminalia sericea* with 5.5 stems per hectare (1233 stems in total) are the two other most frequent species.

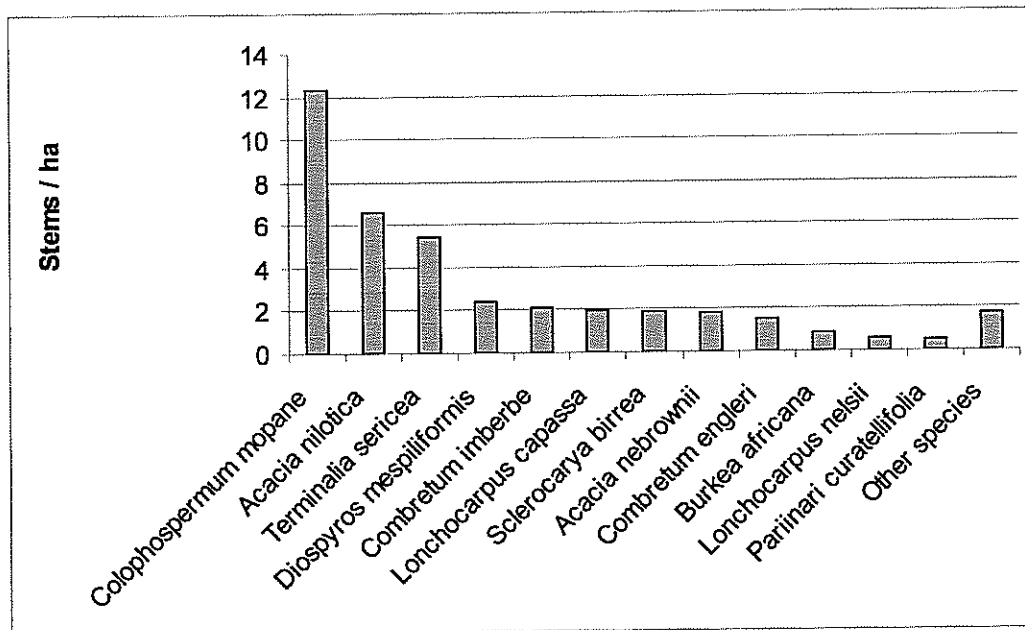


Figure 8. Zambezi woodland inventory area: live tree species, number of trees per hectare.

In addition to the 3 most frequent species listed above, there are 6 species which have 1 or 2 stems per hectare (see figure 8). The group of other species in the Figure consists of 12 species which all have less than 0.5 stems per hectare. A full list of species and their number of stems can be found in Annex 4 (table 4).

Dead trees

A total of 8 tree species were found among the dead trees. The number of dead trees all species included – 2.7 trees per hectare and a total of 618 trees on the whole area is very low. *Combretum imberbe* and *Colophospermum mopane* are the most frequent dead trees to be found, however, both with less than 1 stem per hectare (see Figure 9).

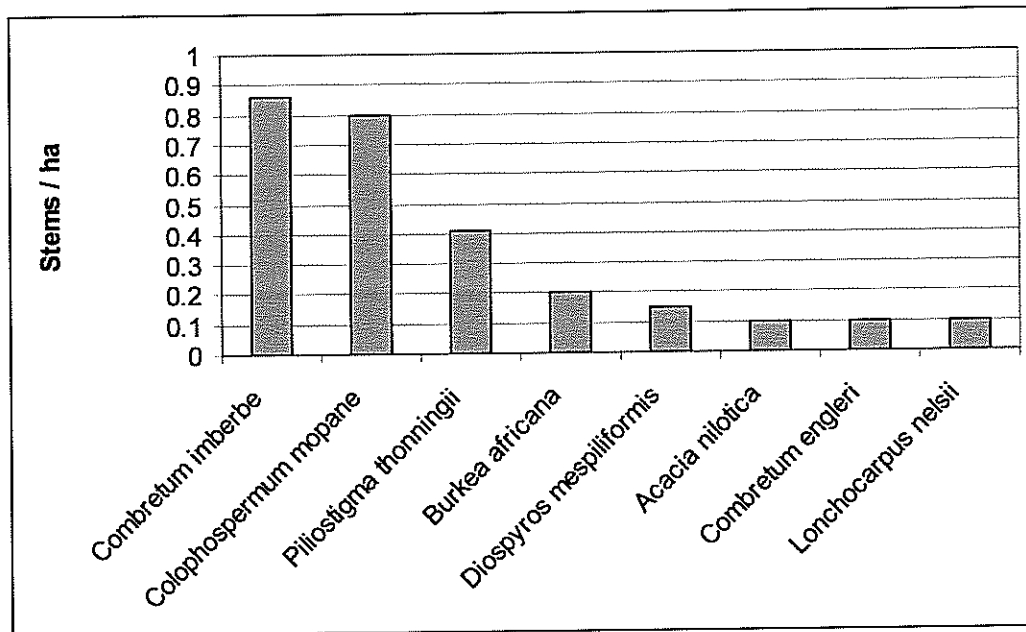


Figure 9. Zambezi woodland inventory area: most frequent dead tree species, stems per ha.

4.2.4. Diameter distribution

Live trees

The diameter distribution (as % of trees in diameter class by species) for the 5 most frequent live tree species has been illustrated in Figure 10.

Colophospermum mopane, *Acacia nilotica* and *Terminalia sericea* have a very big share of their number in the smallest diameter class (5-15 cm). *Diospyros mespiliformis* and *Combretum imberbe* are much more evenly distributed over the diameter range. Almost all big trees (over 45 cm at dbh) are *Diospyros* trees.

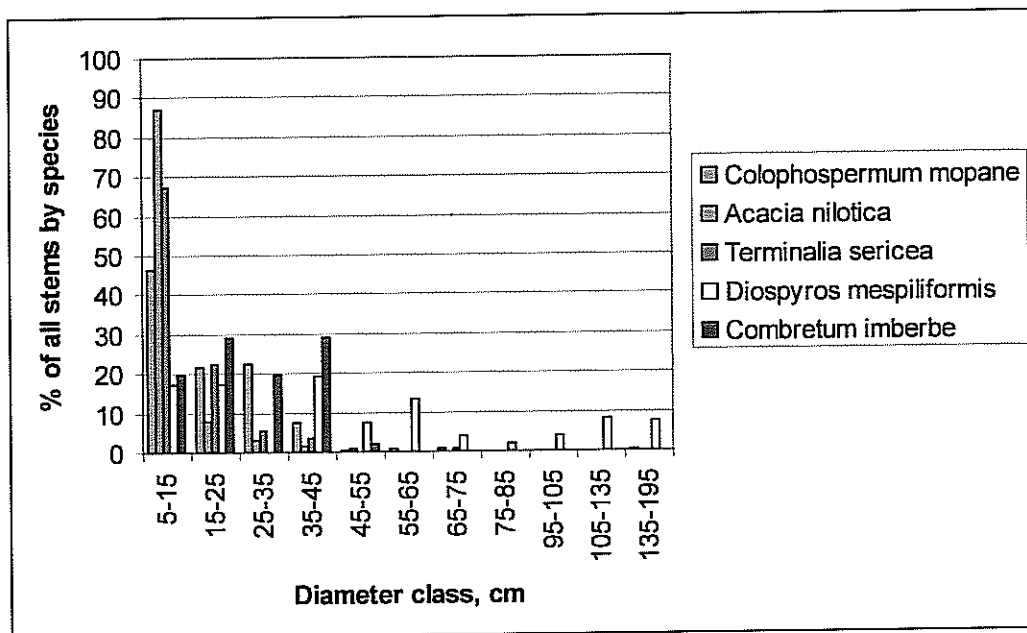


Figure 10. Zambezi woodland inventory area: diameter distribution of the 5 most frequent tree species.

For other species a complete diameter distribution for all species in numbers is given in the Annex 4 (table 5).

Dead trees

The number of dead trees in diameter classes (percent of all trees, 618 trees in total, 2.7 trees/ha) is illustrated here in Figure 11. Most of the trees were found in the medium size classes (15-25 cm and 25-35 cm). The diameter distribution on dead trees by species can be found in Annex 4 (Table 7).

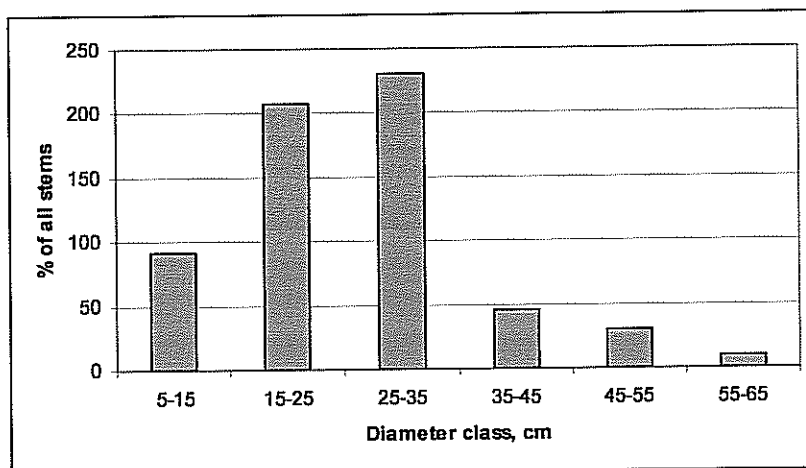


Figure 11. Zambezi woodland inventory area: diameter distribution of dead trees, all species together.

4.2.5. Stem volumes by species

Live trees

The total volume of all live trees in Zambezi woodland inventory area is 5089 m³ (22.5 m³/ha). The proportions of the 6 species with the highest volumes have been illustrated in Figure 12. *Diospyros mespiliformis* has got the highest volume – 2222 m³ in total (9.8 m³/ha). *Colophospermum mopane* has 817 m³ (3.6 m³/ha) in total. All other species have relatively low volumes. See full list of volumes by species in Annex 4 (table 4).

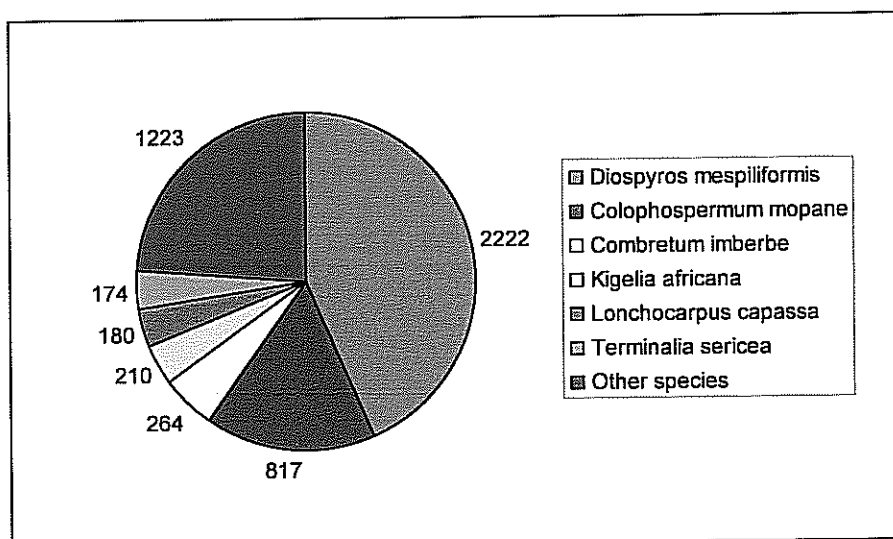


Figure 12. Zambezi woodland inventory area: volume of live trees by species (in total, m³).

Timber volume of live trees

Only two tree species have dimensions big enough to be considered as timber size. *Colophospermum mopane* has about a total of 44 trees with good, medium or poor timber quality. The log volume of these trees is about 30 m³. *Diospyros mespiliformis* has about a total of 113 trees (total volume 240 m³) with good, medium or poor timber quality. However, it is not known whether this species can be used as timber.

Dead trees

There is only a total 340 m³ (1.5 m³/ha) of dead wood in the Zambezi woodland inventory area. Almost half of this volume is *Combretum imberbe* dead wood (149 m³). See full list of species and their dead wood volumes in Annex 4 (table 6).

4.2.6. Regeneration and shrubs

Regeneration

A total of 583 tree saplings per hectare were found in the Zambezi woodland inventory area. The regeneration of Mopane is very good as most of the saplings are *Colophospermum mopane* saplings (486 saplings per hectare). There are some 42 *Terminalia* saplings per hectare as well as 19 *Combretum engleri* and 19 *Burkea africana* saplings per hectare too. In addition, there are 5 other species with a smaller number of saplings (see full list of saplings in height classes in Annex 4, table 8.) Some species - such as *Combretum imberbe*, *Diospyros mespiliformis* and *Piliostigma thonningii* - have trees but do not have any saplings at all.

Shrubs

Four shrub species were recorded in the Zambezi woodland sample: *Grewia retinervis* (17 shrubs per hectare), *Grewia bicolor* (13 shrubs per hectare), *Combretum apiculatum* (9 shrubs per hectare) and *Grewia flava* (9 shrubs per hectare).

4.3. Results for *Burkea terminalia* woodland inventory area

4.3.1. Site and stand data

By its geomorphology, *Burkea Terminalia* woodland inventory area was classified as plain (all plots). On 91 % of the plots, the soil texture was classified as sand and on 9 % it was classified as sandy loam.

On 14 % of the plots, no signs of grazing were observed. On 60 % of the plots, moderate signs of grazing were seen (vegetation still vital) and on 26 % of the plots signs of intensive grazing were visible (vitality of vegetation clearly threatened).

95 % of the plots were found with damages caused by elephants. 28 % of these plots had mild severity, 30 % with moderate severity and 37 % with serious severity (most of the trees damaged seriously).

On 51 % of the plots, no signs of human influence could be seen. On 37 % of the plots, signs of fallow farming (not in use currently) were recorded. On 7 % of the plots some pole size trees had been removed.

4.3.2. Species diversity

A total of 33 woody species were found in the *Burkea Terminalia* inventory area. Again, this is the same number as in the other areas. 22 species were detected in the tree layer and 29 in the regeneration/shrub layer. 18 species were found in both layers (See Table 5 for list of species.)

Species	Number of clusters, dbh>5cm	Number of clusters, dbh<5cm
<i>Acacia ataxacantha</i>		2
<i>Acacia erioloba</i>	11	5
<i>Acacia nebrownii</i>	1	2
<i>Baikiaea plurijuga</i>	5	3
<i>Baphia massaiensis</i>		5
<i>Bauhia petersiana</i>		8
<i>Burkea africana</i>	43	17
<i>Colophospermum mopane</i>	3	4
<i>Combretum apiculatum (apiculatum)</i>	5	5
<i>Combretum collinum</i>	17	19
<i>Combretum engleri</i>	2	2
<i>Combretum hereroense</i>	1	
<i>Combretum imberbe</i>	5	5
<i>Combretum psidioides (psidioides)</i>		3
<i>Combretum zeyheri</i>	10	14
<i>Dichrostachys cinerea (Setulosa)</i>		1
<i>Diospyros mespiliformis</i>	2	1
<i>Erythrophleum africanum</i>	4	8
<i>Grewia bicolor</i>		2
<i>Grewia retinervis</i>		14
<i>Guibourtia coleosperma</i>	3	3
<i>Hyphaene petersiana</i>		1
<i>Lonchocarpus capassa</i>	3	
<i>Lonchocarpus nelsii</i>	4	2
<i>Ochna pulchra</i>	5	21
<i>Peltophorum africanum</i>	4	4
<i>Ptilostigma thonningii</i>	2	1
<i>Pterocarpus angolensis</i>	1	
<i>Rhus tenuinervis</i>		1
<i>Terminalia sericea</i>	43	41
<i>Ximenia Americana var americana</i>		1
<i>Ximenia caffra var microphylla</i>		1
<i>Ziziphus mucronata</i>	1	

Table 5. *Burkea Terminalia* woodland inventory area: Species diversity by the number of clusters where each species was found.

4.3.3. Number of stems by species

Live trees

A total of 22 tree species were found in the *Burkea Terminalia* woodland inventory area. Including all species, altogether 137 stems per hectare and a total of 46092 stems (on an area of 337.4 hectares) have been estimated to grow on this area. The far most frequent species is *Terminalia sericea* with 60 stems per hectare (a total of 20176 stems). *Burkea africana* is the second most frequent with 14 stems per hectare (4600 stems in total) and

Combretum collinum the third with 12 stems per hectare (4166 stems in total) (see Figure 13).

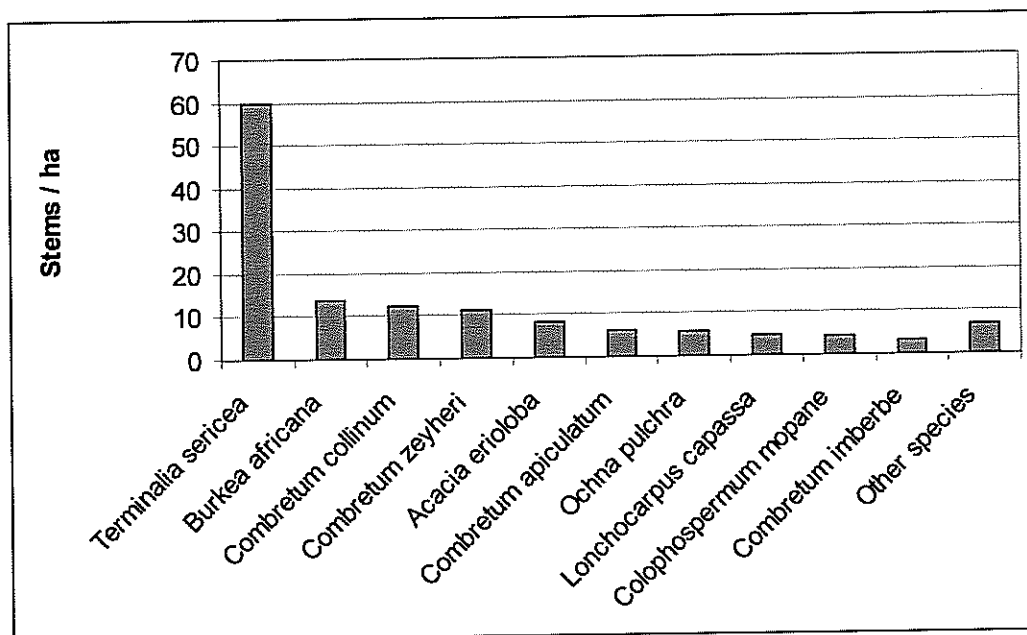


Figure 13. *Burkea Terminalia* woodland: live tree species, number of trees per hectare.

Combretum zeyheri has 11 stems per hectare (3789 stems in total). The other species have less than 10 stems per hectare (see full list of species in Annex 5, table 4).

Dead trees

A total of 15 tree species were found among the dead trees. Including all species there are about 27 dead trees per hectare which totals in about 9200 dead trees in the whole area. The most frequent species among dead trees is *Terminalia sericea* (10 trees per hectare, 3438 trees in total) and the second most frequent is *Burkea africana* (8 trees per hectare, 2627 trees in total). The other trees are much less frequent: *Colophospermum mopane* has 2.5 dead trees per hectare (869 trees in total) and *Combretum collinum* has 1.6 dead trees per hectare (9539 in total). Full list of dead tree species can be found in Annex 5 (table 6).

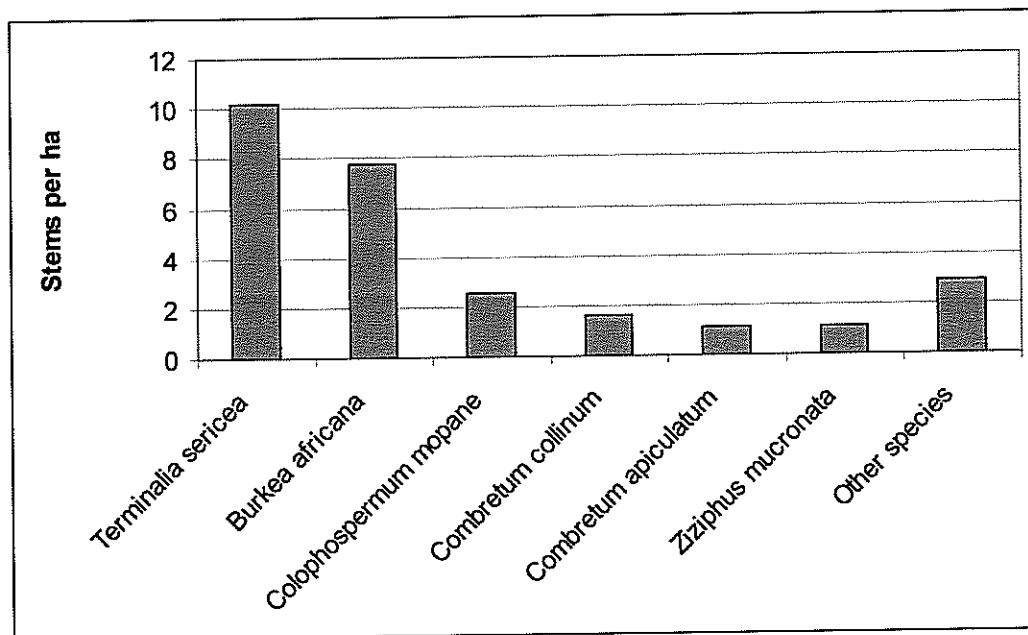


Figure 14. *Burkea Terminalia* woodland inventory area: most frequent dead tree species, trees per hectare.

4.3.4. Diameter distribution

Live trees

The diameter distribution (as % of trees in diameter class by species) for the 5 most dominant live tree species has been illustrated in Figure 15.

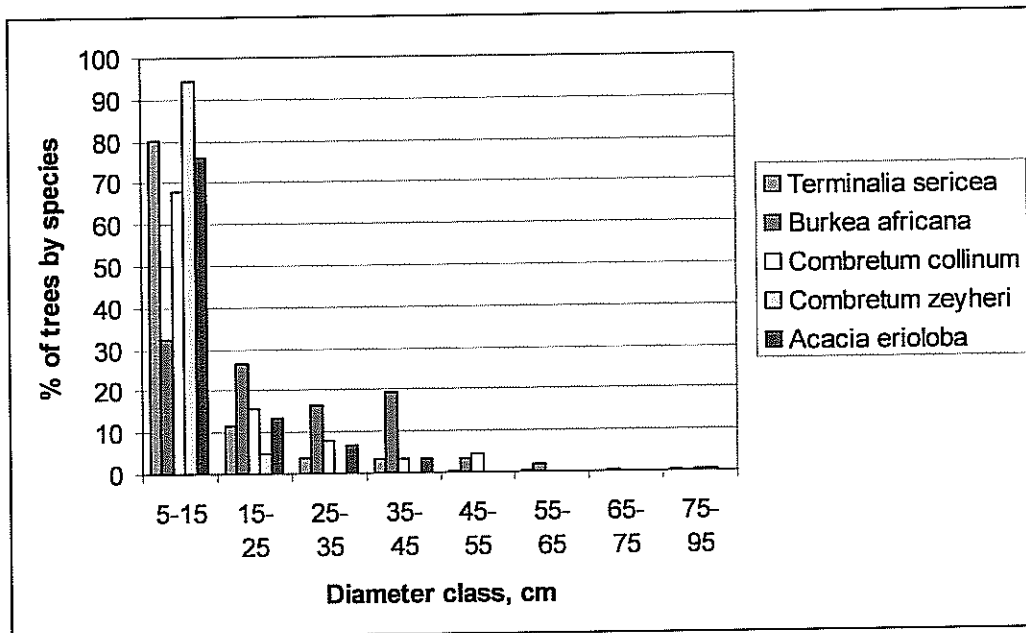


Figure 15. Burkea Terminalia woodland inventory area: diameter distribution of the 5 most frequent species.

Terminalia sericea, Combretum collinum, Combretum zeyheri and Acacia erioloba all have a very big proportion of their number in the smallest diameter class (5-15 cm). On the other hand, Burkea africana is showing a fairly even distribution over the diameter classes. Burkea as well as Terminalia and Combretum collinum have some, however not many, big trees too. See full list of trees in diameter classes in Annex 5 (table 5).

Dead trees

The number of dead trees in diameter classes in percent of all trees (9200 trees in total) is illustrated below in Figure 16. Most of the trees were found in the small and medium size diameter classes (from 5 cm to 35 cm). Some 15 % of the stems belong to the bigger classes. The diameter distribution on dead trees by species can be found in Annex 5 (Table 7).

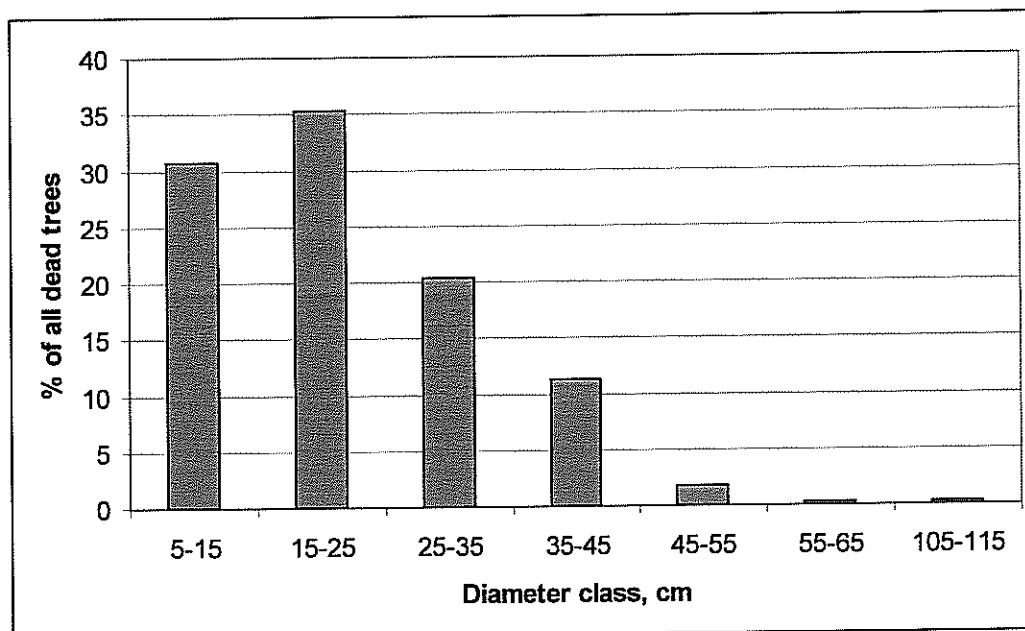


Figure 16. Burkea Terminalia woodland inventory area: diameter distribution of dead trees, all species together.

4.3.5. Stem volumes by species

Live trees

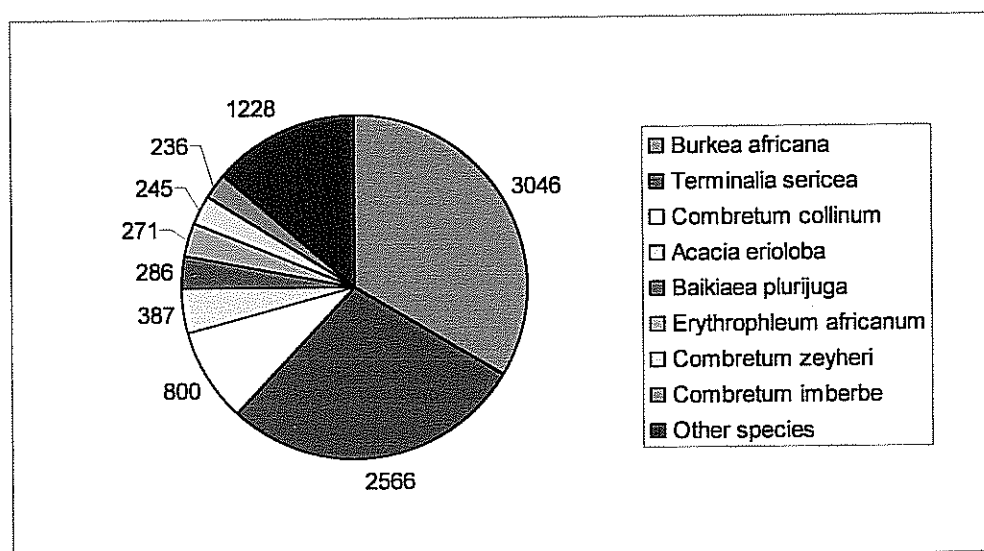


Figure 17. Burkea Terminalia woodland inventory area: total volume (m³) by species.

The volume of all live trees in the Burkea Terminalia inventory area is about 27 m³/ha, that is a total of 9080 m³ on the whole area. The three species with the biggest volumes

are: *Burkea africana* 3045 m³ (9 m³/ha), *Terminalia sericea* 2566 m³ (7.6 m³/ha) and *Combretum collinum* 800 m³ (2.4 m³/ha) (see figure 17 below). Full list of species and their respective volumes can be found in Annex 5 (table 4).

Timber volume of live trees

Part of the big trees (with dbh more than 45 cm) were classified to have potential as producing sawlogs. There are about 230 *Terminalia sericea* trees which were classified having either good, medium or poor quality sawlogs. The sawlog volume of these trees is about 36 m³ (30 m³ of good and medium quality). There are about 60 trees of *Burkea africana* having a volume of 30 m³ classified as good sawlog (no medium or poor quality trees were detected).

Dead trees

The total volume of dead trees in the *Burkea Terminalia* woodland inventory area is about 3745 m³ (11 m³/ha). More than half of this volume – 1957 m³ (5.8 m³/ha) – is *Burkea africana* dead wood. *Terminalia sericea* has a dead wood volume of 728 m³ (2.2 m³/ha). There is also dead wood from *Baikiaea plurijuga* (267 m³), *Combretum collinum* (227 m³) and *Colophospermum mopane* (200 m³). In addition to these, there are smaller amounts of dead wood from 10 other species (see full list of species and dead wood volumes in Annex 5, table 6).

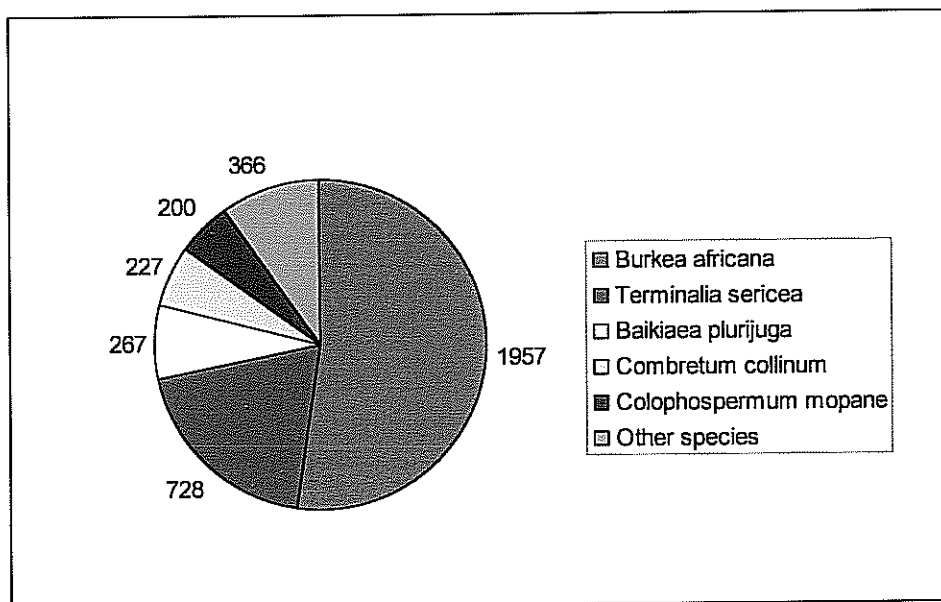


Figure 18. *Burkea Terminalia* woodland inventory area: volume of 5 most frequent dead wood tree species (total, m³).

4.3.6. Regeneration and shrubs

Regeneration

There are about 809 tree saplings per hectare in the Burkea Terminalia inventory area. 30 % of them are Terminalia sericea saplings, 14 % Ochna pulcra saplings and 13 % Combretum collinum saplings. Both Colophospermum mopane and Combretum zeyheri have about 10 % of these saplings. In addition to these, there are 12 other species with saplings (see full list of saplings by species and height classes in Annex 5, Table 8). There are four tree species for which no saplings at all were found in the sample. These are Lonchocarpus capassa, Combretum imberbe, Combretum hereroense and Pterocarpus angolensis.

Shrubs

Eleven shrub species were recorded in the Burkea Terminalia woodland sample with a total of 179 shrubs per hectare. The most frequent ones are: Grewia retinervis (56 shrubs per hectare), Bauhia petersiana (46 shrubs per hectare), Combretum psidioides (28 shrubs per hectare) and Baphia massainis (19 shrubs per hectare). See full list of shrubs by species and height classes in Annex 5 (table 9).

5. Reliability of the results

5.1. Sources of error

There are a few possible sources of error in each forest inventory. Measurement errors in the field can be avoided by training the field teams properly. The Bukalo pilot forest areas were inventoried by a very experienced NFI field staff and the field measurement errors can be expected to be very few. Errors in the data entry were eliminated by several cross checkings.

The volume estimates in this report contain an error caused by the volume functions used in the calculations. The volume functions used were general functions designed for nationwide use. There are not volume functions for all species available. Most likely the volume estimates in this report are to some extent underestimates as the stem forms are better in Caprivi than in other areas.

In every sampling, a sampling error is included. The magnitude of this error can be estimated and confidence limits can be given to the mean values obtained from the sample.

5.2. Sampling error and confidence limits

The estimates for the standard errors of mean volumes were calculated using the formula applicable for random sampling. The sampling in Bukalo 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. In the following tables, the sampling errors and confidence limits with 95 % confidence have been listed for each area. First, an estimate of sampling error for the volume of all species is given. Secondly, an estimate of sampling error for the 2 most dominant species have been given.

Table 6: Sampling error and confidence limits for mean tree volume.

Mopane Aristida inventory area (271.2 hectares with 44 plots):

Species	Sampling variance	Standard error, m ³ /ha	Average volume, m ³ /ha	Sampling error, %	Lower confidence limit, m ³ /ha	Upper confidence limit, m ³ /ha
All species	11.58	3.40	34.96	9.74	28.29	41.63
Terminaria sericea	2.53	1.59	11.58	13.74	8.46	14.70
Colophospermum mopane	8.57	2.93	10.28	28.47	4.54	16.02

Zambezi woodland inventory area (226.2 hectares with 78 plots):

Species	Sampling variance	Standard error, m ³ /ha	Average volume	Sampling error, %	Lower confidence limit, m ³ /ha	Upper confidence limit, m ³ /ha
All species	12.98	3.60	22.77	15.82	15.71	29.83
Diospyros mespiliformis	7.94	2.81	9.82	28.62	4.31	15.32
Colophospermum mopane	1.27	1.13	3.61	31.20	1.40	5.83

Burkea Terminalia inventory area (337.4 hectares with 57 plots):

Species	Sampling variance	Standard error, m ³ /ha	Average volume, m ³ /ha	Sampling error, %	Lower confidence limit, m ³ /ha	Upper confidence limit, m ³ /ha
All species	7.00	2.65	28.33	9.34	23.14	33.52
Burkea africana	2.05	1.43	9.03	15.85	6.22	11.83
Terminaria sericea	1.87	1.37	7.61	17.98	4.93	10.29

Confidence limits here mean that with 95 % probability the true mean value is between the lower confidence limit and the upper confidence limit.

From the tables above it can be seen that the objective of an accuracy of about 10 % in the mean volume was achieved in the Mopane Aristida and Burkea Terminalia inventory areas. However, in the Zambezi woodland area the objective was not achieved, even though a double sampling intensity was applied.

It can also be seen from the tables that the sampling error is much higher when individual species are analysed. Actually, results for a certain species only should be used with caution due to the high sampling error.

Annex 2 (page 1): Volume functions for Bukalo Pilot Forest inventory

For *Pterocarpus angolensis* use:

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

where v = tree volume in dm^3

d = tree diameter (dbh) in cm

a_0, a_1 & a_2 = parameters (see table below)

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:

$$v = (a_0 + a_1 * d + a_2 * d^2) * d^2 \text{ or } v = a_0 * d^2 + a_1 * d^3 + a_2 * d^4$$

where v = tree volume in dm^3

d = tree diameter (dbh) in cm

a_0, a_1 & a_2 = parameters (see table below)

Parameters:

Species	a_0	a_1	a_2
1 ACACIAS	0.21795109	0.01407904	-0.00010783
2 BA IPL	0.2501141	0.0227406	-0.000198461
3 BURAF	0.0976836	0.034642	-0.000334653
4 COLMO	0.12798339	0.01580639	-0.00014894
5 COMAN	0.18057025	0.01974331	-0.00010431
6 COMCO	0.1932033	0.0199121	-0.000108192
7 LONNE	0.2830256	0.0207832	-0.000278607
8 PTEAN	2.7760988	0.1426456	-0.000868738
9 TERSE	0.3221886	0.0079926	-0.000034270

Example 1: For a *Baikiaea plurijuga* tree with diameter (DBH) = 26.5 cm.

$$\begin{aligned} v &= a_0 * d^2 + a_1 * d^3 + a_2 * d^4 \\ &= (0.2501141)*(26.5)^2 + (0.0227406)*(26.5)^3 + (-0.000198461)*(26.5)^4 \\ &= 175.64 + 423.25 - 97.87 \\ &= 501 \text{ dm}^3 \end{aligned}$$

Example 2: For a *Pterocarpus angolensis* tree with diameter (DBH) = 47 cm.

$$\begin{aligned} v &= e^{(a_0 + a_1 * d + a_2 * d^2)} \\ &= e^{((2.7760988) + (0.1426456)*(47) + (-0.000868738)*(47)^2)} \\ &= (2.71828)^{(2.7760988 + 6.704343 - 1.91904)} \\ &= (2.71828)^0 \\ &= 1923 \text{ dm}^3 \end{aligned}$$

Note: $1000 \text{ dm}^3 = 1 \text{ m}^3$

Annex 2 (page 2): List of tree species and the volume models used.

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 on previous page)

Code	Species	Index to volume model
ACAER	Acacia erioloba	1
ACANE	Acacia newbournii	1
ACANI	Acacia nilotica	1
ALBHA	Albizia harveyi	1
BAIPL	Baikiaea plurijuga	2
BOSAL	Boscia albitrunca	8
BURAF	Burkea africana	3
COMAA	Combretum apiculatum (apiculatum)	9
COMCO	Combretum collinum	6
COMEN	Combretum engleri	6
COMHE	Combretum hereroense	6
COMIM	Combretum imberbe	6
COMZE	Combretum zeyheri	6
COLMO	Colophospermum mopane	4
DIOME	Diospyros mespiliformis	2
ERYAF	Erythrophleum africanum	3
FICSY	Ficus sycomorus	8
FLUVI	Flueggea virosa	6
GUICO	Guibourtia coleosperma	8
HYPPE	Hyphaene petersiana	8
KIGAF	Kigelia africana	8
LONCA	Lonchocarpus capassa	7
LONNE	Lonchocarpus nelsii	7
OCHPU	Ochna pulchra	8
PELAF	Peltoporum africanum	8
PILTH	Piliostigma thonningii	8
PTEAN	Pterocarpus angolensis	8
SCLBI	Screlocarya birrea	8
STRPU	Strychnos pungens	9
TERSE	Terminalia sericea	9
TERPR	Terminalia prunioides	9
ZIZMU	Ziziphus mucronata	8

Annex 3. Result tables for Mopane Aristida inventory area.

Annex 3.

Table 1: Total number of measured trees

Species	Number of measured trees	% of measured trees
<i>Terminalia sericea</i>	202	41.82
<i>Colophospermum mopane</i>	141	29.19
<i>Burkea africana</i>	72	14.91
<i>Combretum collinum</i>	21	4.35
<i>Combretum imberbe</i>	11	2.28
<i>Combretum zeyheri</i>	5	1.04
<i>Acacia nilotica</i>	4	0.83
<i>Baikiaea plurijuga</i>	4	0.83
<i>Peltophorum africanum</i>	4	0.83
<i>Diospyros mespiliformis</i>	3	0.62
<i>Flueggea virosa</i>	3	0.62
<i>Lonchocarpus nelsii</i>	3	0.62
<i>Parinari curatellifolia</i>	2	0.41
<i>Piliostigma thonningii</i>	2	0.41
<i>Strychnos pungens</i>	2	0.41
<i>Acacia erioloba</i>	1	0.21
<i>Acacia nebrownii</i>	1	0.21
<i>Guibourtia coleosperma</i>	1	0.21
<i>Lonchocarpus capassa</i>	1	0.21
Total	483	100

Table 3: Average, minimum and maximum height by species

Species	Average height (m)	Minimum height (m)	Maximum height (m)
<i>Guibourtia coleosperma</i>	16.6	16.6	16.6
<i>Parinari curatellifolia</i>	15.4	15.4	15.4
<i>Baikiaea plurijuga</i>	14.5	14.0	15.4
<i>Flueggea virosa</i>	14.23	8.30	19.60
<i>Lonchocarpus nelsii</i>	14.2	11.9	16.4
<i>Acacia nebrownii</i>	12.6	12.6	12.6
<i>Piliostigma thonningii</i>	12.4	10.5	14.2
<i>Diospyros mespiliformis</i>	12.3	6.7	17.8
<i>Lonchocarpus capassa</i>	12.2	12.2	12.2
<i>Burkea africana</i>	11.7	1.3	21.6
<i>Colophospermum mopane</i>	10.6	1.2	17.8
<i>Acacia erioloba</i>	10.5	10.5	10.5
<i>Acacia nilotica</i>	10.5	8.2	13.7
<i>Peltophorum africanum</i>	10.1	6.6	16.4
<i>Terminalia sericea</i>	8.7	1.3	17.5
<i>Combretum imberbe</i>	7.8	4.4	12.2
<i>Combretum collinum</i>	5.8	2.8	13.5
<i>Strychnos pungens</i>	4.0	4.0	4.0
<i>Combretum zeyheri</i>	3.9	3.3	4.4

Table 4: Volume and number of stems by species totally and per ha

Annex 3.

Species	Total number of stems	Stems per ha	Total tree volume (m3)	Average tree volume, m3/ha
<i>Terminalia sericea</i>	25390	93.62	3141.66	11.58
<i>Colophospermum mopane</i>	12606	46.48	2788.34	10.28
<i>Combretum collinum</i>	3802	14.02	173.39	0.64
<i>Burkea africana</i>	2215	8.17	1898.14	7.00
<i>Combretum imberbe</i>	1410	5.20	293.71	1.08
<i>Combretum zeyheri</i>	1028	3.79	35.83	0.13
<i>Peltophorum africanum</i>	257	0.95	84.21	0.31
<i>Acacia erioloba</i>	206	0.76	24.89	0.09
<i>Baikiaea plurijuga</i>	177	0.65	298.85	1.10
<i>Diospyros mespiliformis</i>	103	0.38	73.27	0.27
<i>Parinari curatellifolia</i>	103	0.38	67.85	0.25
<i>Piliostigma thonningii</i>	103	0.38	58.71	0.22
<i>Strychnos pungens</i>	103	0.38	41.91	0.15
<i>Acacia nilotica</i>	74	0.27	78.36	0.29
<i>Lonchocarpus nelsii</i>	74	0.27	78.22	0.29
<i>Acacia nebrownii</i>	51	0.19	11.12	0.04
<i>Lonchocarpus capassa</i>	51	0.19	49.78	0.18
Total	47753	176.08	9198.24	33.92

Table 5: Diameter distribution stems by species

Species	Diameter classes								Total	% of total
	5-15	15-25	25-35	35-45	45-55	55-65	65-75	75-115		
<i>Terminalia sericea</i>	20091	2107	2004	976	143	69			25390	53.17
<i>Colophospermum mopane</i>	7142	2878	1696	360	211	91	69	160	12606	26.40
<i>Combretum collinum</i>	3700		51	51					3802	7.96
<i>Burkea africana</i>	668	154	617	565	188	23			2215	4.64
<i>Combretum imberbe</i>	1233		51	103	23				1410	2.95
<i>Combretum zeyheri</i>	1028								1028	2.15
<i>Peltophorum africanum</i>	206			51					257	0.54
<i>Acacia erioloba</i>		206							206	0.43
<i>Baikiaea plurijuga</i>				103	74				177	0.37
<i>Diospyros mespiliformis</i>			103						103	0.22
<i>Parinari curatellifolia</i>			51	51					103	0.22
<i>Piliostigma thonningii</i>			103						103	0.22
<i>Strychnos pungens</i>			103						103	0.22
<i>Acacia nilotica</i>				51	23				74	0.16
<i>Lonchocarpus nelsii</i>				51	23				74	0.16
<i>Acacia nebrownii</i>		51							51	0.11
<i>Lonchocarpus capassa</i>			51						51	0.11
Total	34068	5395	4830	2364	685	183	69	160	47753	
% of total	71.34	11.30	10.11	4.95	1.43	0.38	0.14	0.33		100

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

Annex 3.

Species	Total number of stems	Stems per ha	Total tree volume (m ³)	Average tree volume, m ³ /ha
Burkea africana	1444	5.33	1902.95	7.02
Terminalia sericea	1439	5.31	561.12	2.07
Colophospermum mopane	896	3.31	133.42	0.49
Peltophorum africanum	411	1.52	36.54	0.13
Diospyros mespiliformis	206	0.76	30.34	0.11
Acacia nilotica	74	0.27	80.75	0.30
Combretum imberbe	51	0.19	51.27	0.19
Combretum collinum	23	0.08	77.20	0.28
Guibourtia coleosperma	23	0.08	83.36	0.31
Lonchocarpus nelsii	23	0.08	23.27	0.09
Total	4590	16.93	2980.22	10.99

Table 7: Diameter distribution of dead trees by species

Species	5-15	15-25	25-35	35-45	45-55	55-65	Total	% of total
Burkea africana		103	462	719	91	69	1444	31.5
Terminalia sericea		771	360	257	51		1439	31.3
Colophospermum mopane	206	617		51	23		896	19.5
Peltophorum africanum	411						411	8.96
Diospyros mespiliformis		206					206	4.48
Acacia nilotica				51	23		74	1.62
Combretum imberbe				51			51	1.12
Combretum collinum						23	23	0.5
Guibourtia coleosperma						23	23	0.5
Lonchocarpus nelsii				23			23	0.5
Total	617	1696	822	1153	188	114	4590	
% of total	13	36.9	17.9	25.1	4.1	2.49		100

Table 8: Number of tree seedlings per ha by height classes

Species	0-25	26-50	51-100	101-150	151-200	201-250	251-300	300+	Total	% of total
<i>Colophospermum mopane</i>	100	664	171	33	57	31	5	5	1067	72.1
<i>Terminalia sericea</i>		36	57	36	40	24	67		260	17.6
<i>Combretum collinum</i>			48	10	2	2	2		64	4.35
<i>Burkea africana</i>	2	14	10	7			2		36	2.42
<i>Acacia erioloba</i>			2	7	7				17	1.13
<i>Peltophorum africanum</i>			2	2		5			10	0.64
<i>Combretum zeyheri</i>				2			2	2	7	0.48
<i>Diospyros mespiliformis</i>			5	2					7	0.48
<i>Baikiaea plurijuga</i>			5						5	0.32
<i>Combretum imberbe</i>					2	2			5	0.32
<i>Acacia nilotica</i>						2			2	0.16
Total	102	714	300	100	110	67	79	7	1479	
% of total	6.9	48.3	20.3	6.76	7.4	4.5	5.31	0.48		100

Table 9: Number of shrub seedlings per ha by height classes

Species	0-25	26-50	51-100	101-150	151-200	201-250	251-300	300+	Total	% of total
<i>Bauhinia petersiana</i>	19	67	55	69	43	2			255	51.2
<i>Grewia retinervis</i>		19	19	5	12			10	64	12.9
<i>Rhigoszum brevispinosum</i>		31							31	6.2
<i>Baphia massaiensis</i>		7	10	2	0	5			24	4.8
<i>Ochna pulchra</i>		7	5	2	7		2		24	4.8
<i>Acacia ataxacantha</i>	5	14	2						21	4.3
<i>Albizia harveyi</i>		7	2	2	7				19	3.8
<i>Combretum engleri</i>				7	7				14	2.9
<i>Ximenia americana var americana</i>					10	5			14	2.9
<i>Boscia albitrunca</i>	2	10							12	2.4
<i>Combretum apiculatum (apiculatum)</i>					5			5	10	1.9
<i>Acacia fleckii</i>			2						2	0.5
<i>Piliostigma thonningii</i>				2					2	0.5
<i>Vangueria infausta</i>				2					2	0.5
<i>Ximenia caffra var microphylla</i>								2	2	0.5
Total	26	162	95	93	90	12	2	17	498	
% of total	5.3	32.5	19.1	18.7	18.2	2.4	0.5	3.3		100

Annex 4. Result tables for Zambezi woodland inventory area.

Annex 4.

Table 3: Total number of measured trees

Species	Total number of measured trees	% of measured trees
Colophospermum mopane	90	31.7
Diospyros mespiliformis	36	12.7
Combretum imberbe	26	9.2
Acacia nilotica	21	7.4
Terminalia sericea	19	6.7
Combretum engleri	12	4.2
Lonchocarpus capassa	11	3.9
Acacia nebrownii	10	3.5
Lonchocarpus nelsii	9	3.2
Sclerocarya birrea	7	2.5
Parinari curatellifolia	6	2.1
Piliostigma thonningii	6	2.1
Burkea africana	5	1.8
Flueggea virosa	4	1.4
Albizia harveyi	2	0.7
Boscia albitrunca	2	0.7
Ficus sycomorus	2	0.7
Kigelia africana	2	0.7
Ochna pulchra	2	0.7
Peltophorum africanum	2	0.7
Acacia mellifera	1	0.4
Combretum apiculatum (apiculatum)	1	0.4
Hyphaene petersiana	1	0.4
Terminalia prunioides	1	0.4
Total	284	100.0

Table 2: Average, minimum and maximum height by species

Species	Average height (m)	Minimum height (m)	Maximum height (m)
Acacia mellifera	19.0	19.0	19.0
Ficus sycomorus	18.7	15.0	22.4
Kigelia africana	17.8	14.0	21.5
Terminalia prunioides	16.8	16.8	16.8
Diospyros mespiliformis	15.3	1.5	22.7
Acacia nebrownii	13.8	10.0	17.8
Lonchocarpus nelsii	12.5	6.2	21.0
Parinari curatellifolia	12.3	12.3	12.3
Parinari curatellifolia	12.3	12.3	12.3
Peltophorum africanum	11.9	10.4	13.3
Ochna pulchra	11.2	8.8	13.5
Piliostigma thonningii	10.6	8.2	13.7
Albizia harveyi	10.0	7.0	13.0
Colophospermum mopane	9.8	1.3	21.4
Lonchocarpus capassa	9.8	6.2	13.2
Burkea africana	9.6	6.3	13.4
Terminalia sericea	9.4	2.9	14.4
Sclerocarya birrea	9.3	6.5	20.9
Combretum imberbe	9.3	3.2	14.8
Acacia nilotica	8.8	4.3	22.7
Combretum engleri	8.4	3.2	13.8
Flueggea virosa	8.3	7.3	9.8
Boscia albitrunca	6.8	6.8	6.8
Combretum apiculatum (apiculatum)	5.5	5.5	5.5
Hyphaene petersiana	4.5	4.5	4.5

Annex 4.

Table 4: Volume and number of stems by species totally and per ha

Species	Total number of stems	Stems per ha	Total tree volume (m ³)	Average tree volume, m ³ /ha
<i>Colophospermum mopane</i>	2786.46	12.32	817.48	3.61
<i>Acacia nilotica</i>	1486.80	6.57	121.74	0.54
<i>Terminalia sericea</i>	1233.02	5.45	173.92	0.77
<i>Diospyros mespiliformis</i>	535.76	2.37	2221.58	9.82
<i>Combretum imberbe</i>	471.67	2.09	263.61	1.17
<i>Lonchocarpus capassa</i>	448.60	1.98	180.11	0.80
<i>Sclerocarya birrea</i>	425.53	1.88	98.39	0.44
<i>Acacia nebrownii</i>	412.71	1.83	151.45	0.67
<i>Combretum engleri</i>	340.94	1.51	158.29	0.70
<i>Burkea africana</i>	194.82	0.86	41.79	0.18
<i>Lonchocarpus nelsii</i>	133.30	0.59	166.58	0.74
<i>Pariinari curatellifolia</i>	115.35	0.51	71.01	0.31
<i>Flueggea virosa</i>	79.47	0.35	76.58	0.34
<i>Boscia albitrunca</i>	46.14	0.20	22.73	0.10
<i>Piliostigma thonningii</i>	46.14	0.20	53.43	0.24
<i>Albizia harveyi</i>	33.32	0.15	29.93	0.13
<i>Ficus sycomorus</i>	33.32	0.15	114.96	0.51
<i>Ochna pulchra</i>	33.32	0.15	26.23	0.12
<i>Peltophorum africanum</i>	33.32	0.15	31.56	0.14
<i>Combretum apiculatum (apiculatum)</i>	23.07	0.10	13.11	0.06
<i>Hyphaene petersiana</i>	23.07	0.10	6.49	0.03
<i>Kigelia africana</i>	20.51	0.09	209.65	0.93
<i>Acacia mellifera</i>	10.25	0.05	21.30	0.09
<i>Terminalia prunioides</i>	10.25	0.05	17.17	0.08
Total	8977.18	39.70	5089.09	22.50

Annex 4.

Table 5: Diameter distribution stems by species

Species	5-15	15-25	25-35	35-45	45-55	55-65	65-75	75-85	95-105	105-135	135-195	Total
<i>Colophospermum mopane</i>	1292	600	623	208	10	21	23				10	2786
<i>Acacia nilotica</i>	1292	115	46	23	10							1487
<i>Terminalia sericea</i>	831	277	69	46			10					1233
<i>Diospyros mespiliformis</i>	92	92		103	41	72	21	10	21	44	41	536
<i>Combretum imberbe</i>	92	138	92	138	10							472
<i>Lonchocarpus capassa</i>	185	138	69	46	10							449
<i>Sclerocarya birrea</i>	277	115	23				10					426
<i>Acacia nebrownii</i>		254	138		10	10						413
<i>Combretum engleri</i>	185	46	46	44	10	10						341
<i>Burkea africana</i>	92	92			10							195
<i>Lonchocarpus nelsii</i>			23	69	21	21						133
<i>Parinari curatellifolia</i>			115									115
<i>Flueggea virosa</i>		46		23		10						79
<i>Boscia albitrunca</i>		23	23									46
<i>Piliostigma thonningii</i>			23	23								46
<i>Albizia harveyi</i>			23			10						33
<i>Ficus sycomorus</i>		23								10		33
<i>Ochna pulchra</i>			23		10							33
<i>Peltoporum africanum</i>			23		10							33
<i>Combretum apiculatum (apiculatum)</i>			23									23
<i>Hyphaene petersiana</i>		23										23
<i>Kigelia africana</i>							11				10	21
<i>Acacia mellifera</i>						10						10
<i>Terminalia prunioides</i>					10							10
Total	4337	1984	1384	723	164	164	64	21	21	54	62	8977

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

Species	Total number of stems	Stems per ha	Total tree volume	Average volume m ³ /ha
<i>Combretum imberbe</i>	195	0.86	149.86	0.66
<i>Colophospermum mopane</i>	182	0.80	49.02	0.22
<i>Piliostigma thonningii</i>	92	0.41	19.70	0.09
<i>Burkea africana</i>	46	0.20	26.42	0.12
<i>Diospyros mespiliformis</i>	33	0.15	36.70	0.16
<i>Acacia nilotica</i>	23	0.10	6.70	0.03
<i>Combretum engleri</i>	23	0.10	35.38	0.16
<i>Lonchocarpus nelsii</i>	23	0.10	16.29	0.07
Total	618	2.73	340.07	1.50

Annex 4.

Table 7: Diameter distribution of dead trees by species

Species	5-15	15-25	25-35	35-45	45-55	55-65	Total
<i>Acacia nilotica</i>		23.07					23.07
<i>Burkea africana</i>			46.14				46.14
<i>Colophospermum mopane</i>	92.28	23.07	46.14		20.51		182.00
<i>Combretum engleri</i>				23.07			23.07
<i>Combretum imberbe</i>		69.21	92.28	23.07		10.25	194.82
<i>Diospyros mespiliformis</i>			23.07		10.25		33.32
<i>Lonchocarpus nelsii</i>			23.07				23.07
<i>Piliostigma thonningii</i>		92.28					92.28
Total	92.28	207.64	230.71	46.14	30.76	10.25	525.50

Table 8: Number of tree seedlings per ha by height classes

Species	0-25	26-50	51-100	101-150	151-200	201-250	251-300	300+	Total	% of total
<i>Colophospermum mopane</i>	19	190	127	58	49	6	9	28	486	67.4
<i>Diospyros mespiliformis</i>	3	14	8	8	12				44	6.0
<i>Terminalia sericea</i>		6	5	13	9	1		8	42	5.9
<i>Hyphaene petersiana</i>	3	4	10	8	5	1		1	32	4.4
<i>Acacia nilotica</i>		8	8	1	10	1	1		29	4.1
<i>Combretum engleri</i>	3		4	3	10				19	2.7
<i>Burkea africana</i>	3	1	4	5	1	4		1	19	2.7
<i>Combretum imberbe</i>		1	3		4	1		8	17	2.3
<i>Piliostigma thonningii</i>				3	6	5		1	15	2.1
<i>Combretum apiculatum (apiculatum)</i>		3	3	4					9	1.2
<i>Lonchocarpus nelsii</i>			3	1	1				5	0.7
<i>Lonchocarpus capassa</i>			3						3	0.4
Total	29	227	176	103	108	21	10	47	721	
% of total	4.1	31.5	24.4	14.2	14.9	2.8	1.4	6.6		100

Table 9: Number of shrub seedlings per ha by height classes

Species	26-50	51-100	101-150	151-200	201-250	300+	Total	% of total
<i>Ximenia americana var americana</i>	1	10	5	1	1	1	21	29.09
<i>Grewia retinervis</i>	4	3	10				17	23.64
<i>Grewia bicolor</i>		1	3	5		4	13	18.18
<i>Grewia flava</i>			4	3	1		8	10.91
<i>Dichrostachys cinerea (Africana)</i>		4	3				6	9.09
<i>Commiphora angolensis</i>		1	1				3	3.64
<i>Acacia erioloba</i>			1				1	1.82
<i>Strychnos pungens'</i>			1				1	1.82
<i>Ziziphus mucronata</i>		1					1	1.82
Total	5	21	28	9	3	5	71	
% of total	7.27	29.09	40.00	12.73	3.64	7.27		100

Annex 4. Result tables for Burkea Terminalia inventory area.

Annex 5.

Table 1: Total number of measured trees

Species	Number of measured trees	% of measured trees
Terminalia sericea	183	35.81
Burkea africana	121	23.68
Combretum collinum	44	8.61
Acacia erioloba	28	5.48
Combretum zeyheri	23	4.50
Colophospermum mopane	18	3.52
Combretum apiculatum (apiculatum)	16	3.13
Ochna pulchra	12	2.35
Combretum imberbe	10	1.96
Lonchocarpus capassa	10	1.96
Baikiaea plurijuga	9	1.76
Peltophorum africanum	9	1.76
Erythrophleum africanum	6	1.17
Lonchocarpus nelsii	4	0.78
Piliostigma thonningii	4	0.78
Combretum engleri	3	0.59
Guibourtia coleosperma	3	0.59
Diospyros mespiliformis	2	0.39
Pterocarpus angolensis	2	0.39
Ziziphus mucronata	2	0.39
Acacia nebrownii	1	0.20
Combretum hereroense	1	0.20
Total	511	100

Table 3: Average, minimum and maximum height by species

Species	Average height (m)	Minimum height (m)	Maximum height (m)
Pterocarpus angolensis	17.90	16.8	19
Acacia nebrownii	14.10	14.1	14.1
Diospyros mespiliformis	13.45	7.9	19
Baikiaea plurijuga	12.16	6.3	18.5
Burkea africana	11.36	1.3	21.3
Erythrophleum africanum	10.20	1.7	16.3
Piliostigma thonningii	9.45	6.8	12.1
Peltophorum africanum	9.42	7	12
Acacia erioloba	9.36	4.1	13.2
Combretum collinum	8.97	4.2	17
Terminalia sericea	8.11	1.5	19
Combretum imberbe	7.86	5	11.9
Lonchocarpus nelsii	7.83	2.4	14.8
Colophospermum mopane	7.71	2.8	16.6
Lonchocarpus capassa	7.47	3.9	21.3
Combretum apiculatum (apiculatum)	7.28	4	11.9
Combretum engleri	7.07	4.2	9.9
Guibourtia coleosperma	6.63	1.7	16.2
Combretum hereroense	6.30	6.3	6.3
Ochna pulchra	5.78	3.4	11.6
Combretum zeyheri	4.58	3.1	9.1
Ziziphus mucronata	2.10	2.1	2.1

Table 4: Volume and number of stems by species totally and per ha

Annex 5.

Species	Total number of stems	Stems per ha	Total tree volume (m ³)	Average tree volume, m ³ /ha
<i>Terminalia sericea</i>	20176	59.80	2566.42	7.61
<i>Burkea africana</i>	4637	13.74	3045.64	9.03
<i>Combretum collinum</i>	4166	12.35	1277.78	3.79
<i>Combretum zeyheri</i>	3789	11.23	245.06	0.73
<i>Acacia erioloba</i>	2779	8.24	387.43	1.15
<i>Combretum apiculatum (apiculatum)</i>	2073	6.14	150.56	0.45
<i>Ochna pulchra</i>	1931	5.72	121.92	0.36
<i>Lonchocarpus capassa</i>	1575	4.67	136.94	0.41
<i>Colophospermum mopane</i>	1507	4.47	149.41	0.44
<i>Combretum imberbe</i>	1130	3.35	236.36	0.70
<i>Piliostigma thonningii</i>	586	1.74	105.21	0.31
<i>Peltophorum africanum</i>	471	1.40	195.68	0.58
<i>Erythrophleum africanum</i>	398	1.18	271.19	0.80
<i>Combretum engleri</i>	236	0.70	37.46	0.11
<i>Lonchocarpus nelsii</i>	236	0.70	31.47	0.09
<i>Combretum hereroense</i>	188	0.56	14.36	0.04
<i>Baikiaea plurijuga</i>	84	0.25	285.98	0.85
<i>Diospyros mespiliformis</i>	68	0.20	76.66	0.23
<i>Acacia nebrownii</i>	21	0.06	38.20	0.11
<i>Guibourtia coleosperma</i>	21	0.06	90.30	0.27
<i>Pterocarpus angolensis</i>	21	0.06	94.48	0.28
Total	46092	136.62	9558.51	28.33

Table 5: Diameter distribution stems by species

Species	5-15	15-25	25-35	35-45	45-55	55-65	65-75	75-95	Total	% of total
<i>Terminalia sericea</i>	16203	2355	727	659	105	42	21	63	20176	43.77
<i>Burkea africana</i>	1507	1225	754	895	152	84	21		4637	10.06
<i>Combretum collinum</i>	2826	659	330	141	188			21	4166	9.04
<i>Combretum zeyheri</i>	3580	188						21	3789	8.22
<i>Acacia erioloba</i>	2120	377	188	94					2779	6.03
<i>Combretum apiculatum (apiculatum)</i>	1696	283	94						2073	4.50
<i>Ochna pulchra</i>	1884		47						1931	4.19
<i>Lonchocarpus capassa</i>	1319	236			21				1575	3.42
<i>Colophospermum mopane</i>	1130	188	94	94					1507	3.27
<i>Combretum imberbe</i>	565	283	283						1130	2.45
<i>Piliostigma thonningii</i>	188	377			21				586	1.27
<i>Peltophorum africanum</i>		330	94	47					471	1.02
<i>Erythrophleum africanum</i>	188	94		94		21			398	0.86
<i>Combretum engleri</i>		236							236	0.51
<i>Lonchocarpus nelsii</i>	188		47						236	0.51
<i>Combretum hereroense</i>	188								188	0.41
<i>Baikiaea plurijuga</i>					42	21		21	84	0.18
<i>Diospyros mespiliformis</i>			47		21				68	0.15
<i>Acacia nebrownii</i>					21				21	0.05
<i>Guibourtia coleosperma</i>						21			21	0.05
<i>Pterocarpus angolensis</i>							21		21	0.05
Total	33584	6830	2706	2025	570	188	63	126	46092	
% of total	72.86	14.82	5.87	4.39	1.24	0.41	0.14	0.27		100

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

Annex 5.

Species	Total number of stems	Stems per ha	Total tree volume (m ³)	Average tree volume, m ³ /ha
<i>Terminalia sericea</i>	3438	10.19	727.50	2.16
<i>Burkea africana</i>	2627	7.79	1956.81	5.80
<i>Colophospermum mopane</i>	869	2.58	200.45	0.59
<i>Combretum collinum</i>	539	1.60	227.13	0.67
<i>Combretum apiculatum (apiculatum)</i>	377	1.12	18.01	0.05
<i>Ziziphus mucronata</i>	377	1.12	14.00	0.04
<i>Combretum zeyheri</i>	236	0.70	38.67	0.11
<i>Combretum engleri</i>	188	0.56	31.09	0.09
<i>Baikiaea plurijuga</i>	157	0.47	267.42	0.79
<i>Lonchocarpus nelsii</i>	94	0.28	37.46	0.11
<i>Peltophorum africanum</i>	94	0.28	88.56	0.26
<i>Acacia erioloba</i>	68	0.20	51.83	0.15
<i>Combretum imberbe</i>	47	0.14	29.64	0.09
<i>Ochna pulchra</i>	47	0.14	10.54	0.03
<i>Pterocarpus angolensis</i>	47	0.14	45.77	0.14
Total	9206	27.29	3744.89	11.10

Table 7: Diameter distribution of dead trees by species

Species	5-15	15-25	25-35	35-45	45-55	55-65	105-115	Total	% of total
<i>Terminalia sericea</i>	1319	1413	471	236				3438	37.35
<i>Burkea africana</i>	377	565	1036	565	63	21		2627	28.54
<i>Colophospermum mopane</i>	188	612	47				21	869	9.44
<i>Combretum collinum</i>	188	141	141	47	21			539	5.86
<i>Combretum apiculatum (apiculatum)</i>	377							377	4.09
<i>Ziziphus mucronata</i>	377							377	4.09
<i>Combretum zeyheri</i>		236						236	2.56
<i>Combretum engleri</i>		188						188	2.05
<i>Baikiaea plurijuga</i>				94	63			157	1.71
<i>Lonchocarpus nelsii</i>		47	47					94	1.02
<i>Peltophorum africanum</i>			47	47				94	1.02
<i>Acacia erioloba</i>			47		21			68	0.74
<i>Combretum imberbe</i>			47					47	0.51
<i>Ochna pulchra</i>		47						47	0.51
<i>Pterocarpus angolensis</i>				47				47	0.51
Total	2826	3250	1884	1036	167	21	21	9206	
% of total	30.70	35.30	20.47	11.26	1.82	0.23	0.23		100

Table 8: Number of tree seedlings per ha by height classes

Annex 5.

Species	0-25	26-50	51-100	101-150	151-200	201-250	251-300	300+	Total	% of total
<i>Terminalia sericea</i>	7	11	44	42	63	44	26	5	242	29.9
<i>Ochna pulchra</i>		9	40	23	21	16		2	111	13.7
<i>Combretum collinum</i>		11	19	26	19	9	14	5	104	12.8
<i>Colophospermum mopane</i>	14	30	25	16	7				91	11.3
<i>Combretum zeyheri</i>		4	19	19	23	9	7		81	10.0
<i>Burkea africana</i>	5	14	11	9	18		2		58	7.2
<i>Acacia erioloba</i>	7	5	5	5	2				25	3.0
<i>Erythrophleum africanum</i>		2	12	2	7	2			25	3.0
<i>Combretum apiculatum (apiculatum)</i>	2	2	12			4		4	23	2.8
<i>Lonchocarpus nelsii</i>			5			4			9	1.1
<i>Guibourtia coleosperma</i>		5	4						9	1.1
<i>Peltophorum africanum</i>			4		2	2			7	0.9
<i>Ptilostigma thonningii</i>			0		7				7	0.9
<i>Diospyros mespiliformis</i>			5						5	0.7
<i>Baikiaea plurijuga</i>		2	2		2				5	0.7
<i>Combretum engleri</i>					4	2			5	0.7
<i>Acacia nebrownii</i>				2				2	4	0.4
Total	35	93	207	144	174	89	49	18	809	
% of total	4.3	11.5	25.6	17.8	21.5	11.1	6.1	2.2		100

Table 9: Number of shrub seedlings per ha by height classes

Species	0-25	26-50	51-100	101-150	151-200	201-250	300+	Total	% of total
<i>Grewia retinervis</i>			16	25	12	4		56	31.37
<i>Bauhinia petersiana</i>		14	12	7	9	4		46	25.49
<i>Combretum psidioides (psidioides)</i>	2		9	12	5			28	15.69
<i>Baphia massaiensis</i>		7	4	9				19	10.78
<i>Grewia bicolor</i>		5	2		5			12	6.86
<i>Acacia ataxacantha</i>							5	5	2.94
<i>Dichrostachys cinerea (Setulosa)</i>		2		4				5	2.94
<i>Hyphaene petersiana</i>			2					2	0.98
<i>Rhus tenuinervis</i>					2			2	0.98
<i>Ximenia americana var americana</i>				2				2	0.98
<i>Ximenia caffra var microphylla</i>			2					2	0.98
Total	2	28	46	58	33	7	5	179	
% of total	0.98	15.69	25.49	32.35	18.63	3.92	2.94		100