CAPRUI STATE FOREST

EXECUTIVE SUMMARY

1. INTRODUCTION

The Caprivi State Forest is found in the east of Caprivi Region which forms a 400 km long narrow strip, starting at Bagani, in Northeastern Namibia. East Caprivi covers a land area of about 1.2 million Ha and has a total population of about 66,622 people (1996 Census). The area belongs to

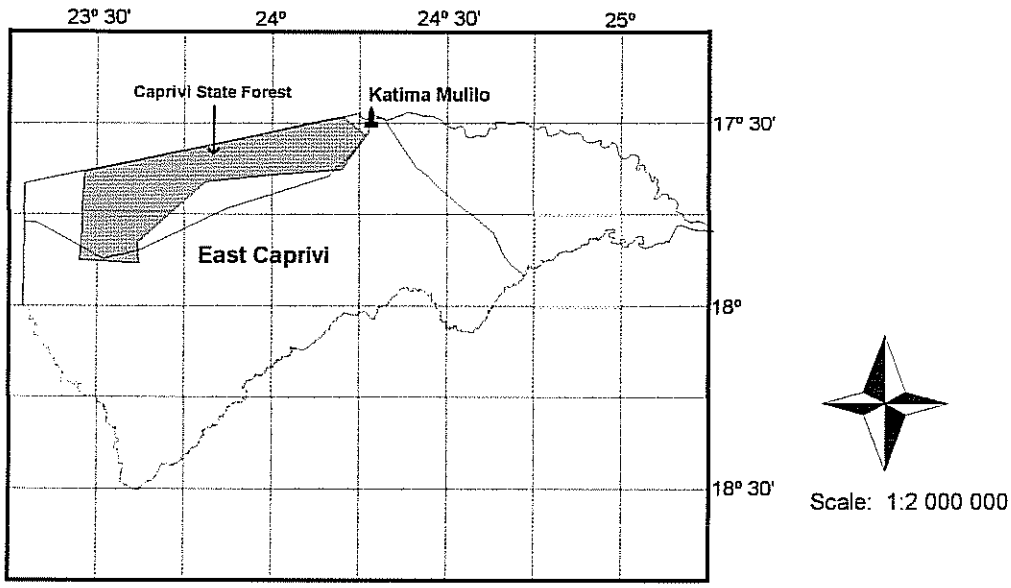
the Tree Savanna and Woodland vegetation zone in the classification of Giess (National Atlas of South West Africa) covering 20% of Namibia's land area. The soil is derived from Kalahari sand.

East Caprivi is divided into three physiographic regions based on elevation, soils and duration of floods: (1) an elevated upland region in the northwest. This area is dominated mainly by *Baikiaea plurijuga*. There is also scattered *Pterocarpus angolensis*. (2) Lowland southern and southeastern region. This area is mainly characterised by *Colophospermum mopane. Baikiaea plurijuga* is not found in this area. (3) Marsh and swamp region in the flooding eastern and southern parts of east Caprivi. *Phoenix reclinata* and *Piliostigma thonningii* occur in this area.

Woodlands dominated by *Pterocarpus angolensis* and *Baikiaea plurijuga* are from economic point of view most important for forestry. The Upland *Baikiaea plurijuga* region of east Caprivi forms part of the *Baikiaea* woodlands found also in south-west Zambia, north-west Botswana and north-west Zimbabwe. This is a unique forest ecosystem found only in this part of Africa. It is partly because of the economic importance of *Baikiaea plurijuga* dominated woodlands that the Directorate of Forestry, in 1994, took the initiative to set aside and proclaim part of the Upland *Baikiaea plurijuga* region in Caprivi as Caprivi State Forest (See Map 1).

Map 1: Caprivi State Forest in Caprivi Region

In 1995 the Directorate of Forestry in cooperation with FINNIDA started a National Forest Inventory Project aimed at producing forest data and information on the woody vegetation in



Northern Namibia. And, in April 1997 the Directorate began a comprehensive implementation of the Namibia Forestry Strategic Plan of 1996 by launching the new Namibia-Finland Forestry Programme. The overall programme objective is to ensure an increased role of forestry in the socio-economic development of Namibia through continuous implementation and development of sustainable forest management practices. The National Forest Inventory Project was incorporated, as a sub-component, into the Namibia-Finland Forestry Programme.

The main objectives of the National Forest Inventory sub-component are: (1) To produce forest resource data on northern Namibia for strategic planning; and (2) To produce forest resource data for operational management planning on selected forest areas.

A forest inventory covering the whole Caprivi Region was carried out between June and November 1997. A more detailed forest inventory of Caprivi State Forest was carried out between September and November 1998. These inventories covered all tree species. The presentation of results from the Caprivi State Forest inventory in this report is one of the several possibilities in which the data can be analysed to provide different overviews of the status of the forest resources in Caprivi State Forest.

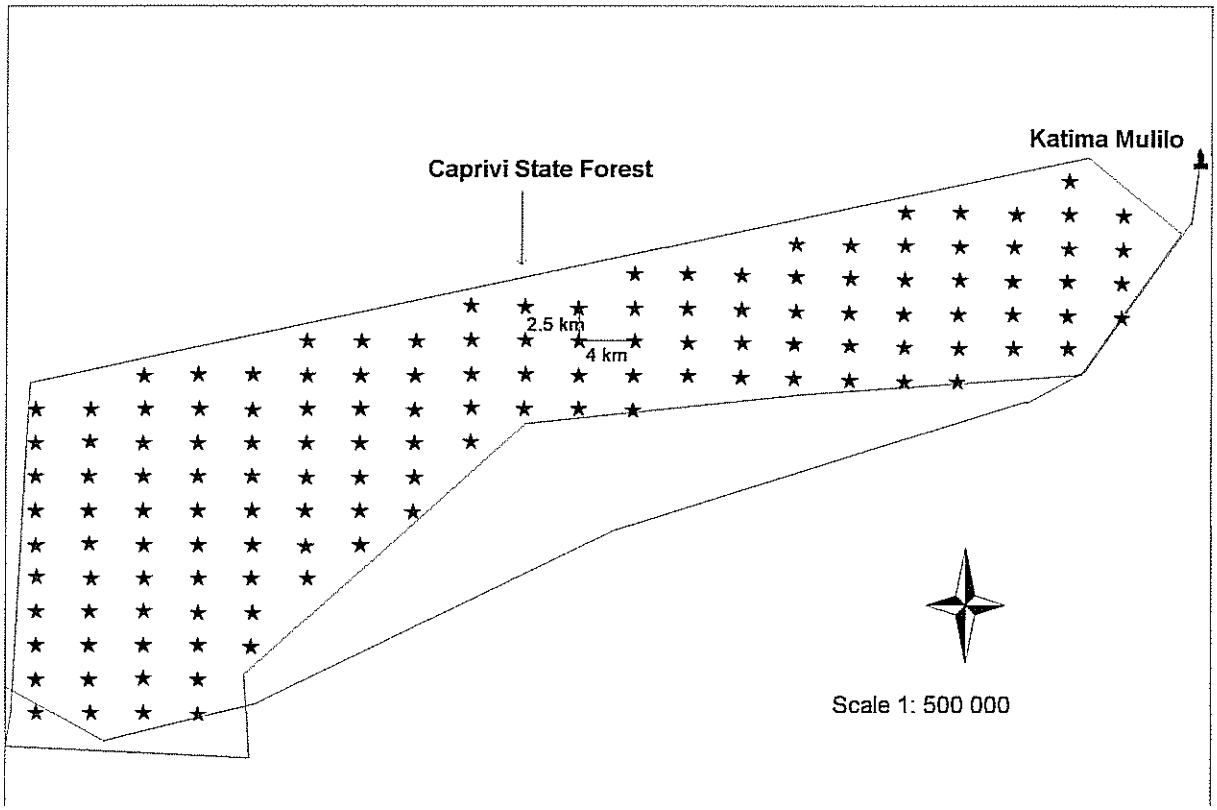
The Caprivi State Forest database created from the collected field data provides possibilities for further studies on the Caprivi State Forest *Baikiaea* woodland ecosystems. Information on the species composition on different sites as well as on the species diversity may be obtained by further analysis of the data. The database can be accessed at the Directorate of Forestry, Ministry of Environment and Tourism.

This report is related to a series of inventories carried out in various other parts of Namibia. The previous reports are "Woody Resources of Western Tsumkwe", "Woody Resources of East and South Tsumkwe, Otjinene and Okakarara Districts", "Forest Inventory Report of Ongadjera Community Forest" , "Forest Inventory Report of Caprivi Region" and "Forest Inventory Report on Uukwaludhi Community Forest" available at the Directorate of Forestry.

2. INVENTORY DESIGN

2.1 Sampling method

Caprivi State Forest is located on six Namibian Series 1:50 000 scale topographic map sheets: 1723 CB, 1723CD, 1723 DA, 1723 DB, 1723 DC and 1724 DC. The area is about 146,100 Ha. Stratified systematic plot sampling was used to estimate the quantity and quality of the forest resources in Caprivi State Forest. Vegetation Maps at the Directorate of Forestry, corresponding in scale to the topographic maps, were used to lay a systematic grid of clusters on the Caprivi State Forest (See Figure 1). The distance between the clusters was 4 km in the east-west



direction and 2.5 km in the north-south direction.

Figure 1: Systematic grid of clusters in Caprivi State Forest

The total number of clusters was 135. Each cluster consisted of 2 sample plots at a distance of 100 m apart in the north-south direction. Hence, a total of 270 sample plots were located on the six map sheets covering Caprivi State Forest. The clusters plotted on the Vegetation Maps were digitized using MapInfo to obtain coordinates for each cluster. The coordinates and GPS were used for locating the clusters in the field.

The map coordinates, reference ellipsoid and compass declination used when locating the cluster coordinates were:

- Datum: Schwarzeck
- Ellipsoid: Modified Bessel 1841
- Compass declination: 13.3° west of true north

All sample plots in each cluster are regarded as permanent measurement plots. They have coordinates and are marked in the field with an aluminium stake and can be re-located for re-measurements in future. The coordinates are shown in Appendix 1 (p. 42) for other users who may wish to locate the plots in the field. The coordinates are the locations of the first plot (the plot most to the south) in the cluster. To locate the second plot a compass and measurement tape are used.

2.2 Field measurements

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

For tree measurements the size of the circular sample plot depends on the size of the tree (see Figure 2). For small trees (DBH 5 - 20 cm) the radius is 10 m, for medium size trees (DBH 20 - 45 cm) the radius is 20 m and for big trees (DBH>45 cm) the radius is 30 m.

Diameter, location, species, crown class, quality, length and quality of possible saw log were measured for all trees in all sample plots. The trees in the first plot of each cluster are called sample trees. For them also height, diameter of canopy, crown height, damages and phenology were recorded.

Shrubs, regeneration, coverage of grasses and herbs were measured in two sub-plots (radius 3.99m) located only in the first plot of each cluster (see Figure 2).

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

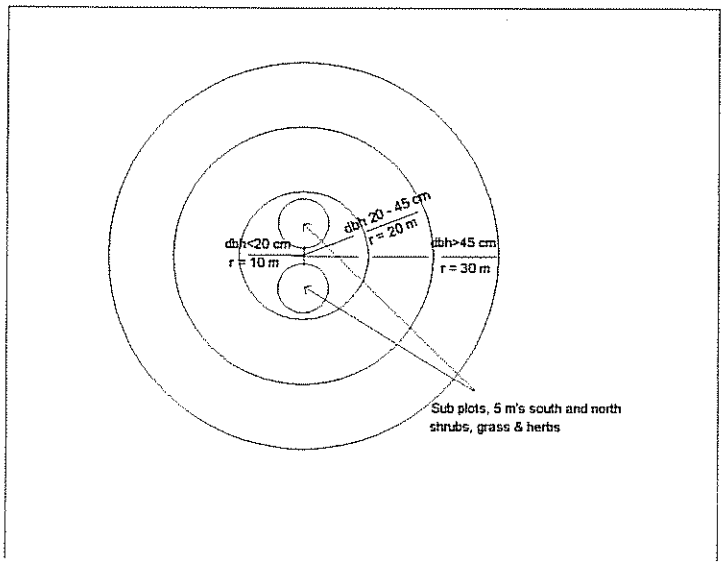


Figure 2: Plot Design

3. INVENTORY RESULTS

3.1 Measured data

A total of 246 sample plots (123 clusters) were measured in the inventory. UXO's (unexploded ordinates) were found in the eastern part of the State Forest and the inventory was stopped for safety reasons. Hence 24 of the originally planned 270 sample plots were not measured. This means that each measured sample plot represents an area of 594 ha.

A total of 1378 trees with diameter ≥ 5 cm were measured on the plots. Out of the 1,378 trees, 676 were sample trees i.e trees where additional variables were measured (see chapter 2.2).

Twenty seven (27)species were enumerated and the most frequent trees in the data were as follows:

Species (trees)	**%**
Baikiaea plurijuga	55.3
Combretum collinum	10.5
Terminalia sericea	4.9
Burkea africana	4.8
Lonchocarpus nelsii	4.4
Pterocarpus angolensis	4.3
TOTAL:	84.2 %

Baikiaea plurijuga is by far the most common species in the Caprivi State Forest. More than half of the trees measured are from that species. Six (6) species account for 84 % of all the trees measured, hence although there are 27 tree species in the area, the species commonly found are rather few. Table 1 (p. 6) shows the total number of measured trees per species. Table 2 (p. 7) shows the status of the measured trees.

A total of 584 shrubs (DBH < 5 cm) of 45 different species were measured on the sub-plots. The most frequent shrubs in the sub-plots were:

Species (shrubs)	**%**
Baphia massaiensis	18.2
Combretum collinum	11.5
Terminalia sericea	11.5
Baikiaea plurijuga	7.4
Bauhinia petersiana	7.2
Lonchocarpus nelsii	5.3
TOTAL:	61.1 %

There are clearly more species in the shrub layer compared to the tree layer. No species in the shrub layer is as dominant as *Baikiaea plurijuga* in the tree layer. Of the six most common shrub species, four also occur as trees. Only *Baphia massaiensis* and *Bauhinia petersiana* are typical shrub species, i.e. they do not grow into tree size. More information on the measured shrubs can be found in Appendix 2 (p. 44).

Table 1. Total number of measured trees and sample trees by species

Species	Total No. of measured trees	% of measured trees	Total No. of sample trees	% of sample trees
Baikiaea plurijuga	762	55.3	366	54.1
Combretum collinum	145	10.5	81	12.0
Terminalia sericea	68	4.9	27	4.0
Burkea africana	66	4.8	33	4.9
Lonchocarpus nelsii	60	4.4	37	5.5
Pterocarpus angolensis	59	4.3	28	4.1
Guibourtia coleosperma	45	3.3	22	3.3
Schinziophyton rautanenii	39	2.8	14	2.1
Boscia albitrunca	23	1.7	8	1.2
Combretum zeyheri	16	1.2	4	0.6
Erythrophleum africanum	14	1.0	11	1.6
Dichrostachys cinerea (Africana)	12	0.9	7	1.0
Unknown1	11	0.8	11	1.6
Acacia erioloba	10	0.7	2	0.3
Combretum psidioides (dinteri)	8	0.6	6	0.9
Lonchocarpus capassa	7	0.5		
Combretum mossambicense	5	0.4	5	0.7
Sclerocarya birrea	5	0.4	4	0.6
Combretum engleri	4	0.3	4	0.6
Combretum psidioides (psidioides)	4	0.3		
Commiphora angolensis	4	0.3	2	0.3
Croton gratissimus	4	0.3	1	0.1
Acacia nigrescens	2	0.1		
Ochna pulchra	2	0.1	1	0.1
Acacia fleckii	1	0.1		
Acacia tortilis (heterecantha)	1	0.1	1	0.1
Terminalia prunioides	1	0.1	1	0.1
Total	1378	100.0	676	100.0

Table 2 shows that 8.6 % of the 1378 measured trees in the Caprivi State Forest were standing dead trees. A large portion (76%) of the dead trees were either *Baikiaea plurijuga*, *Pterocarpus angolensis* or *Burkea africana*. Half of the dead trees are Baikiaea plurijuga trees.

Table 2: Status of measured trees

Species	Missing status code	Live tree	Standing dead tree, without any holes and/or cavities	Dead, lying	Stump	Standing dead tree, with holes and/or cavities	Total	% of total measured trees
Acacia erioloba		8			1	1	10	0.73
Acacia fleckii		1					1	0.07
Acacia nigrescens		2					2	0.15
Acacia tortilis (heterecantha)		1					1	0.07
Baikiaea plurijuga	2	663	45	3	35	14	762	55.30
Boscia albitrunca		22			1		23	1.67
Burkea africana		43	17		4	2	66	4.79
Combretum collinum		134	5	1	4	1	145	10.52
Combretum engleri		4					4	0.29

Combretum mossambicense		5					5	0.36
Combretum psidioides (dinteri)		5	3				8	0.58
Combretum psidioides (psidioides)	2	2					4	0.29
Combretum zeyheri	1	14	1				16	1.16
Commiphora angolensis		3	1				4	0.29
Croton gratissimus		4					4	0.29
Dichrostachys cinerea (Africana)		8	4				12	0.87
Erythrophleum africanum		12	2				14	1.02
Guibourtia coleosperma		39	5		1		45	3.27
Lonchocarpus capassa		7					7	0.51
Lonchocarpus nelsii		60					60	4.35
Ochna pulchra		2					2	0.15
Pterocarpus angolensis		43	12		3	1	59	4.28
Schinziophyton rautanenii		39					39	2.83
Sclerocarya birrea		5					5	0.36
Terminalia prunioides		1					1	0.07
Terminalia sericea		62	3		1	2	68	4.93
Unknown1		11					11	0.80
Total measured trees	5	1200	98	4	50	21	1378	
% of total measured trees	**0.4**	**87.1**	**7.1**	**0.3**	**3.6**	**1.5**		**100.00**

3.2 Structure of the woody vegetation

3.2.1 The classification used

Edwards Vegetational Structural Types (Edwards 1983) is used for describing the structure of the woody vegetation (Appendix 3, p. 45). This classification is based on the crown cover of the tree, shrub and grass layer and the height of the tree and shrub layer. The classification distinguishes 6 main classes; forest, woodland, thicket, bushland, shrubland and grassland. Each main class is further divided into sub-classes, e.g short closed woodland, tall closed woodland, short open woodland and short closed woodland. The main classes in the classification of the vegetation structure by Edwards can briefly be described as follows:

- Forest - Dense tree layer. Not much shrubs.
- Woodland - The woody vegetation is in the tree layer. The shrub layer is sparse. Closed woodland is according to the FAO classification regarded as forest. Hence the criteria for what is to be called forest is much more rigorous in the Edwards classification than in the FAO classification. Open and sparse woodland implies very little woody vegetation.
- Thicket - The woody vegetation is in two layers, i.e in both the tree layer and the shrub layer. As the name indicates, these areas are thick. Also "short thicket" would be classified as forest in the FAO classification.
- Bushland - The woody vegetation is in the shrub layer. But there is still trees scattered in the area.
- Shrubland - The woody vegetation is in the shrub layer. Virtually no trees in the area. Open and sparse shrubland implies very little woody vegetation.
- Grassland and herbsland - Virtually no woody vegetation.

In the vegetation maps produced by the Directorate of Forestry a slightly different classification is used. Here there are 3 main classes; forest, savanna and grassland. Since also here crown coverage and height are used as classification criteria, this classification is compatible with the

Edwards classification.

The classification in vegetation units in "The environmental profile and atlas of Caprivi (produced by Directorate of Environmental Affairs) is based on Edwards Vegetational Structural Types.

3.2.2 The structure of the woody vegetation in the State Forest

The structure of the woody vegetation in the State Forest is presented in tables 3 and 4 (p. 9). The most common vegetation type is woodland, which is covering 65 % of the area. This implies that there is a tree layer in a considerable part of the State Forest. More than half of the woodland area is classified as closed woodland, meaning that the tree layer is rather dense. According to the FAO classification the closed woodland is regarded as forest. Half of the closed woodland is classified as tall, i.e. the height of the trees are 11 - 20 m.

One fifth of the area is classified as thicket, which implies rather dense woody vegetation in two layers. Also this area would be classified as forest in the FAO classification. Hence, using the FAO classification a total of 80771 Ha (closed woodland and thicket) would be classified as forest in the Caprivi State Forest. This is 55% of the total State Forest.

Dense shrub layer with few trees (bushland & closed shrubland) is found on 13 % of the area. On one third of the area there is very little woody vegetation (open shrubland, open and sparse woodland).

To sum up:

- There are no areas dense enough to be classified as forest using the Edwards classification. However, on more than half of the area (80771Ha) there is a tree layer dense enough to be classified as forest if the FAO criteria were used.
- The areas with a dense shrub layer are few.
- There is very little woody vegetation on one third (46324 Ha) of the Caprivi State Forest.

Map 2 (p. *39*) shows the vegetation types of each cluster in the State Forest.

Table 3: Area by Vegetation Structural Types

Vegetation structure type	Area, in Ha	% of total area
Tall Closed Woodland	33259	22.8
Short Closed Woodland	15441	10.6
Low Closed Woodland	2376	1.6
Tall Open Woodland	15441	10.6
Short Open Woodland	22568	15.4
Low Open Woodland	1188	0.8
Low Sparse Woodland	4751	3.3
Short Thicket	29695	20.3
Short Bushland	15441	10.6
Low Closed Shrubland	3563	2.4
Tall Open Shrubland	1188	0.8
Low Open Shrubland	1188	0.8
Total	146100	100.0

Table 4: Summary of vegetation structure type

Vegetation structure type	Area, in Ha	% of total area
Woodland	95024	65.0
Thicket	29695	20.3
Bushland	15441	10.6
Shrubland	5939	4.1
Total	146100	100.0

Table 5: Average and maximum height by species

Species	Average height in meters	Maximum height in meters
Acacia erioloba	8.8	8.9
Acacia tortilis (heterecantha)	11.3	11.3
Baikiaea plurijuga	10.7	24.8
Boscia albitrunca	5.4	10.8
Burkea africana	9.7	18.3
Combretum collinum	6.0	13.4
Combretum engleri	1.0	4.1
Combretum mossambicense	2.1	5.4
Combretum psidioides (dinteri)	7.7	9.6
Combretum zeyheri	9.0	12.3
Commiphora angolensis	4.2	4.7
Croton gratissimus	7.5	7.5
Dichrostachys cinerea (Africana)	3.3	5.1
Erythrophleum africanum	9.9	22.0
Guibourtia coleosperma	11.9	17.6
Lonchocarpus nelsii	6.7	17.3
Ochna pulchra	5.1	5.1
Pterocarpus angolensis	12.6	20.4
Schinziophyton rautanenii	8.6	17.5
Sclerocarya birrea	2.0	7.4
Terminalia prunioides	8.4	8.4
Terminalia sericea	4.8	10.0
Unknown1	4.4	14.3

Table 5 shows the average and maximum height of tree species in the area. The height of the tree layer is one criteria for the Edward's vegetation type classification, hence this table is of interest.

Four species, namely *Acacia tortilis, Baikiaea plurijuga, Guibourtia coloesperma* and *Pterocarpus angolensis* have an average height of more than 10 m. The highest tree species on average is *Pterocarpus angolensis*, 12.6 m. The highest tree in the State Forest is a *Baikiaea plurijuga,*

which is 24.8 m high. This tree is however more than double the average height of the *Baikiaea plurijuga* in the forest.

3.3 Species diversity

There are several measures of species diversity such as Simpson's dominance and Shannon's species diversity index that can be applied on the inventory data. Another simpler measure of species diversity is the number of clusters where each species was found. Table 6 shows the number of clusters where each species was found for both trees (DBH≥5 cm) and shrubs (DBH <5 cm). A total of 27 different tree species were recorded on the tree field form and 45 shrub species on the regeneration and shrub field form. This is considerably less than in the inventory of Caprivi region, where a total of 57 species were recorded both as trees and shrubs.

Table 6: Species diversity indicated by the number of clusters where each species was found

Species	No. of clusters, Dbh < 5 cm	No. of clusters, Dbh > 5 cm
Acacia ataxacantha	12	
Acacia erioloba	3	5
Acacia fleckii	12	1
Acacia nigrescens	2	1
Acacia Tortilis (spirocarpa)	1	
Acacia Tortilis (heterecantha)		1
Baikiaea plurijuga	43	101
Baphia massaiensis	106	
Bauhinia petersiana	42	
Boscia albitrunca	13	15
Burkea africana	10	24
Colophospermum mopane	1	
Combretum collinum	67	67
Combretum elaeagnoides	1	
Combretum engleri	7	1
Combretum mossambicense		1
Combretum psidioides (dinteri)	5	3
Combretum psidioides (psidioides)	1	2
Combretum zeyheri	28	8
Commiphora africana	6	
Commiphora angolensis	8	2
Croton gratissimus	14	3

Species	No. of clusters, Dbh < 5 cm	No. of clusters, Dbh > 5 cm
Erythrophleum africanum	3	8
Euclea divinorum	1	
Grewia bicolor	1	
Grewia flava	1	
Grewia retinervis	16	
Grewia villosa	3	
Guibourtia coleosperma	1	23
Lonchocarpus capassa		1
Lonchocarpus nelsii	31	32
Markhamia acuminata	7	
Mundulea sericea	1	
Ochna pulchra	6	2
Ozoroa longipes	2	
Ozoroa paniculosa	8	
Pterocarpus angolensis	11	28
Rhigozum brevispinosum	16	
Rhus marlothii	1	
Schinziophyton rautanenii	6	11
Sclerocarya birrea		1
Strychnos pungens	2	
Terminalia prunioides		1
Terminalia sericea	67	25

Dichrostachys cinerea (Africana)	6	1
Dichrostachys cinerea (Setulosa)	3	
Elephantorrhiza elephantina	2	

Unknown1	2	2
Vangueria infausta	3	
Ximenia americana	2	

Baikiaea plurijuga trees, the most common tree species in the State Forest, was found on 101 clusters, i.e., almost in every cluster, while *Baikiaea plurijuga* shrub/regeneration was found on 43 clusters. Comparatively, *Pterocarpus angolensis* trees were found on 28 clusters while *Pterocarpus angolensis* shrub/regeneration was found on 11 clusters. Hence, there is more *Baikiaea plurijuga* regeneration compared to *Pterocarpus angolensis* and clearly this area is dominated by *Baikiaea plurijuga*. This means in fact, that *Baikiaea plurijuga* can be found all over the State Forest, while *Pterocarpus angolensis* trees can be found on only 22% of the area.

Other important tree species were found on the following number of clusters: *Combretum collinum*, 67; *Lonchocarpus nelsii*, 32;*Terminalia sericea*, 25; *Guibourtia coleosperma*, 25; *Burkea africana*, 24 and *Acacia erioloba*, 5. Shrubs/regeneration for the same species were found on the following number of clusters: *Combretum collinum*, 67; *Lonchocarpus nelsii, 31*; *Terminalia sericea*, 67; *Guibourtia coleosperma*, 1; *Burkea africana*, 10; and *Acacia erioloba*, 3.
The above figures imply that *Combretum collinum* and *Terminalia sericea* are spread over half of the area, while the other important species are found on smaller areas of the State Forest. *Acacia* species are sparse in the State Forest. The regeneration of economically valuable species like *Guibourtia coleosperma* and *Burkea africana* is rather poor. Map 3 (p. 40) shows the number of species found in each cluster in the State Forest. Note that this map is showing only the number of species occurring as trees (Dbh > 5 cm) in the cluster.

Common shrub species are *Baphia massaiensis* and *Bauhinia petersiana.* The former is the most common woody species and can be found virtually all over the State Forest.

Tree species, like *Terminalia prunioides*, *Lonchocarpus capassa and Acacia nigrescens*, were found only on 1 cluster each. Although the number of woody species found in the state forest is rather comprehensive the number of species that are frequently occurring is rather few.

3.4 Dominant species and species composition in the tree layer

The dominant species is derived from the crown coverage of each species in the measured sample plots. Table 7 shows the dominant species in Caprivi State Forest. The table confirms the information presented in chapter 3.1 "Measured data" (p. 5) and in Table 6 (p.11) on the species diversity. The species most commonly found in the State Forest are logically also the species dominating the tree layer. In 64.2% of the State Forest *Baikiaea plurijuga* is the dominant species. The six species covering 84.2% of the measured trees are the ones that are found dominant on 88.7% of the area.

Table 7: Area (Ha) and %, of dominant species

Species	Area, in Ha	% of total area
Baikiaea plurijuga	93837	64.2
Combretum collinum	9502	6.5
Burkea africana	8315	5.7
Lonchocarpus nelsii	5939	4.1
Pterocarpus angolensis	5939	4.1
Terminalia sericea	5939	4.1
Guibourtia coleosperma	4751	3.3
Schinziophyton rautanenii	3563	2.4
Erythrophleum africanum	2376	1.6
Acacia erioloba	1188	0.8
Boscia albitrunca	1188	0.8
Combretum mossambicense	1188	0.8
Dichrostachys cinerea (Africana)	1188	0.8
Lonchocarpus capassa	1188	0.8
Total	**146100**	**100.0**

Table 8 shows how the species dominance for the six most common species varies in the main vegetation types in the State Forest. The table shows that *Baikiaea plurijuga* is equally dominant in all vegetation types. *Burkea africana* and *Pterocarpus angolensis* on the other hand, do not occur as dominant species in areas with a significant shrub layer. *Terminalia sericea* is dominant in areas where the tree layer is open.

Table 8: Area (Ha) and % of dominant species in different vegetation types for the six most

common species

	Woodland				Thicket		Bushland	
	Closed		Open					
Species	Area	%	Area	%	Area	%	Area	%
Baikiaea plurijuga	35634	65.2	26132	64.7	22568	76.0	9502	61.5
Combretum collinum	3563	6.5	3563	8.8	2376	8.0		
Burkea africana	2376	4.3	3563	8.8				
Lonchocarpus nelsii	1188	2.2	1188	2.9	2376	8.0		
Pterocarpus angolensis	3563	6.5	2376	5.9				
Terminalia sericea			1188	2.9			2376	15.4

Table 9 shows in how dense crown cover each species is occurring as dominant. The figures inside the table are percentages of the area of the respective dominat species in each crown cover class. Since Table 9 is showing crown cover of trees it is basically showing the same information as Table 8. The difference is that in Table 8 the focus is on the vegetation types and in Table 9 the focus is on the percentage crown cover.

Table 9: Distribution of crown cover of dominant species by crown cover classes

	Crown cover class, in %					
Dominant Species	**0-10**	**10-20**	**20-40**	**40-70**	**>70**	**Total, %**
Acacia erioloba			100			100
Baikiaea plurijuga	41.8	31.6	21.6	5.0		100
Boscia albitrunca	100.0					100
Burkea africana	71.4	14.3	14.3			100
Combretum collinum	37.5	37.5	12.5	12.5		100
Combretum mossambicense		100				100
Dichrostachys cinerea (Africana)				100		100
Erythrophleum africanum	50.0					100
Guibourtia coleosperma	50	25	25			100
Lonchocarpus capassa	100.0					100
Lonchocarpus nelsii	40	60				100
Pterocarpus angolensis	40	60				100
Schinziophyton rautanenii		66.7	33.3			100
Terminalia sericea	100					100

More than half of the areas where *Baikiaea* is dominant are closed woodlands or thickets (tree crown cover > 10%). In fact, two thirds of the areas with a crown cover bigger than 10 % are dominated by *Baikiaea plurijuga*. More than half of the areas where *Combretum collinum* is dominant are closed woodlands or thickets. This species is the one most commonly found in the State Forest after *Baikiaea*. The two most commonly found species in the State Forest, *Baikiaea plurijuga* and *Combretum collinum*, are dominant in more than 80% of the closed woodlands and thickets. This means that, in areas with the most dense tree cover in the State Forest the trees found are most likely either *Baikiaea plurijuga* or *Combretum collinum*.

The areas where *Pterocarpus angolensis* is dominant are rather open. *Terminalia sericea*, one of the commonly found species in the State Forest is dominant only in open areas.

Tables 10, 11 and 12, 13 (p. 15 and 16) show the species composition in the main vegetation types based on which species that typically occur with a certain dominant species. Two species are noted, i.e., even if there might be more than 2 species in the cluster measured, only the second species following the dominant species in crown coverage is noted. The tables show the % occurrence of the second species with a certain dominant species. Hence, e.g. in Table 10: in 33 % of the area where *Baikiaea plurijuga* is the dominant species it is associated with *Combretum collinum* and the vegetation type could be called *Baikiaea combretum* woodland. In 23 % of the area where *Baikiaea plurijuga* is the dominant species there are no other species, which means that *Baikiaea plurijuga* occurs in pure stands.

The tables show only the six most common species; *Baikiaea plurijuga*, *Combretum collinum*, *Terminalia sericea*, *Burkea africana, Lonchocarpus nelsii* and *Pterocarpus angolensis.*

Table 10: Species composition in closed woodlands

	Second dominant species									
Dominant species	**Baikiaea plurijuga**	**Burkea africana**	**Combretum collinum**	**Guibourtia coleosperma**	**Lonchocarpus nelsii**	**No Second dominant**	**Pterocarpus angolensis**	**Schinziophyton rautanenii**	**Terminalia sericea**	**Total area of dominant species in %**
Baikiaea plurijuga		10	33	3	3	23	3	7	17	100
Burkea africana	100									100
Combretum collinum	33						67			100
Lonchocarpus nelsii			100							100
Pterocarpus angolensis	33	33		33						100

Table 10 shows the species composition in closed woodlands. *Baikea plurijuga* is mostly either associated with *Combretum collinum* or *Terminalia sericea* or occurring as pure stands. Since *Baikea plurijuga* is the dominant species in most of this vegetation type (see Table 8, p. 13), this species composition is the one most commonly found in the closed woodlands.

Table 11: Species composition in open woodlands

	Second dominant species												
Dominant species	**Acacia erioloba**	**Baikiaea plurijuga**	**Boscia albitrunca**	**Burkea africana**	**C. collinum**	**Combretum psidioides (dinteri)**	**E. africanum**	**Guibourtia coleosperma**	**L. nelsii**	**No second dominant**	**P. angolensis**	**T. sericea**	**Total area of dominant species, in %**
Baikiaea plurijuga	5		9	9	27	5	5	5	5	9	18	5	100
Burkea africana		67			33								100
Combretum collinum		33								33		33	100
Lonchocarpus nelsii										100			100
Pterocarpus angolensis		50		50									100
Terminalia sericea					100								100

Table 11 shows the species composition in open woodlands. *Baikea plurijuga* is the dominant species also in most of the open woodlands (see Table 8, p. 13). Hence, since Table 11 shows that *Baikea plurijuga* is associated with a number of different species, there is a rather mixed species composition in this woodland type.

Table 12: Species composition in thicket

	Second dominant species												
Dominant species	**B. plurijuga**	**Boscia albitrunca**	**Combretum collinum**	**Commiphora angolensis**	**Croton gratissimus**	**Guibourtia coleosperma**	**L. nelsii**	**No second dominant**	**P. angolensis**	**S. rautanenii**	**T. sericea**	**Unknown1**	**Total area of dominant species, in %**
Baikiaea plurijuga		11	11	5		5	11	16	11	11	11	11	100
Combretum collinum	50						50						100
Lonchocarpus nelsii	50				50								100

Table 12 shows the species composition in thickets. *Baikiaea plurijuga* is the dominant species also in most of the thickets (see Table 8, p. 13). Furthermore *Baikiaea plurijuga* is commonly associated both with *Combretum collinum* and *Lonchocarpus nelsii* when these species occur as dominant. Hence, *Baikea plurijuga* is present in most of the thicket stands but, as table 12 shows, associated with a number of different species. Therefore there is a rather mixed species composition also in this woodland type.

Table 13: Species composition in bushland

	Second dominant species							
Dominat species	**Acacia erioloba**	**Burkea africana**	**Combretum collinum**	**Combretum psidioides (dinteri)**	**Croton gratissimus**	**L. nelsii**	**No second dominant species**	**Total area of dominant species, in %**
Baikiaea plurijuga		13	38	13	13	13	13	100
Terminalia sericea	50						50	100

Table 13 shows the species composition in bushland. Two species are dominant in most of the bushland stands, namely *Baikea plurijuga* and *Terminalia sericea*. *Baikea plurijuga* is associated with a number of different species, but *Combretum collinum* is the most common associate. *Terminalia sericea* is either associated with *Acacia erioloba* or occuring in pure stands.

The following can be concluded on the species composition in the Caprivi State Forest:

- At least one of the six most common species in the State Forest are likely to be found in each stand of the forest. Especially *Baikiaea plurijuga* is occuring in most stands regardless of vegetation type.
- *Baikiaea plurijuga* occurs with a number of different species, where a composition of *Baikiaea/Combretum collinum* and *Baikiaea/Terminalia sericea* seems to be rather common.
- Otherwise there are no clear patterns on the species compositions in the Caprivi State Forest.

3.5 Tree volumes and number of stems

Volume functions: Volume functions from Caprivi Region inventory for *Burkea africana*, *Combretum collinum*, *Lonchocarpus nelsii*, *Pterocarpus angolensis*, *Baikiaea plurijuga*, *Colophospermum mopane* and *Terminalia sericea* were used to calculate tree volume in Caprivi State Forest. The volume functions are in Appendix 4 (p. 46). For other species without a volume function one of these functions was applied to estimate the volume of such species. For other users who may wish to use the models, Appendix 5 (p. 47) shows which models were applied to the species without volume functions.

Unless specified otherwise, ***Tree volume*** means the volume of the entire tree comprising of the main tree trunk and branch wood. The total number of trees, the average number of trees per hectare and, the average total tree volume per hectare for the whole Caprivi State Forest are as follows:

Total number of trees	10 316 600
Trees per hectare	70.6
Mean volume, m^3/Ha	33.3

The mean volume in the Caprivi State Forest is clearly higher than 21.4 m^3/ha in the Caprivi Region at large, but the number of trees per hectare, 86.6, is bigger in the Caprivi Region than in the State Forest. This implies that the trees sizes are bigger in the Caprivi State Forest.

For the average tree volume of all species the standard error was 2.19 m^3/Ha or 6.6% of the average tree volume per hectare. Therefore, the true average tree volume per hectare is between 28 and 37 m^3/ha with the probability of 95%. Other sampling errors are presented in Table 32 (p. 32).

Table 14 shows how the volumes and number of trees are distributed over the main vegetation types. The bulk of the tree volumes are in the closed woodlands and the thicket. Also the mean volumes per hectare are clearly higher in these vegetation types than in the other vegetation types. Although the number of stems per hectare is rather similar, the mean volume in both closed woodland and thicket is double the mean volume in the Caprivi region. This means that the trees in these vegetation types are considerably bigger than in the Caprivi region at large.

Table 14. Volumes and number of trees in the main vegetation types

	Vegetation type			
	Closed woodland	Open woodland	Thicket	Bushland
Total No. of stems, 1000s	4091.2	1945.6	2667.6	1194.7
Stems per Ha	80	50	90	77
Total tree volume, 1000s m3	2082.8	961.6	1449.3	315.8
Average tree volume, m3/ha	40.8	24.5	48.8	20.5

Table 15 shows the number of stems and tree volumes by species for the whole Caprivi State Forest. Table 16 (p. 19) brakes down the information for the six most common tree species into stems and volumes for the main vegetation types in the State Forest. This is for trees with DBH ≥ 5 cm. And, only living trees are included in the table. More information on volume distribution can be found in Appendix 6b (p. 53).

Table 15: Total number of stems, stems/Ha, total tree volume, and average volume by species and for the whole area

Species	Total No. of stems, 1000s	Stems per Ha	Total tree volume, 1000s m3	Average tree volume, m3/ha
Baikiaea plurijuga	3811.4	26.1	3262.6	22.3
Combretum collinum	1731.3	11.9	254.9	1.7
Terminalia sericea	1095.9	7.5	93.1	0.6
Lonchocarpus nelsii	862.3	5.9	122.3	0.8
Burkea africana	481.5	3.3	121.0	0.8
Schinziophyton rautanenii	397.5	2.7	199.3	1.4
Pterocarpus angolensis	233.2	1.6	234.9	1.6
Combretum zeyheri	219.5	1.5	18.6	0.1
Boscia albitrunca	198.0	1.4	48.0	0.3
Dichrostachys cinerea (Africana)	151.2	1.0	10.7	0.1
Unknown1	137.1	0.9	29.4	0.2
Lonchocarpus capassa	132.3	0.9	5.7	0.0
Guibourtia coleosperma	125.0	0.9	297.1	2.0
Erythrophleum africanum	122.4	0.8	45.9	0.3
Combretum mossambicense	94.5	0.6	3.3	0.0
Sclerocarya birrea	94.5	0.6	9.6	0.1
Combretum engleri	75.6	0.5	2.0	0.0
Croton gratissimus	75.6	0.5	2.9	0.0
Acacia erioloba	58.3	0.4	39.0	0.3
Commiphora angolensis	56.7	0.4	2.5	0.0
Combretum psidioides (dinteri)	52.0	0.4	16.1	0.1
Acacia nigrescens	37.8	0.3	2.2	0.0
Ochna pulchra	37.8	0.3	4.1	0.0
Acacia fleckii	18.9	0.1	0.7	0.0
Combretum psidioides (psidioides)	6.8	0.0	33.7	0.2
Acacia tortilis (heterecantha)	4.7	0.0	1.0	0.0
Terminalia prunioides	4.7	0.0	1.9	0.0
Total	**10316.6**	**70.6**	**4862.6**	**33.3**

The most common species is *Baikiaea plurijuga*, on average 26.1 stems per Ha, followed by *Combretum collinum* 11.9 stems per Ha, *Terminalia sericea* 7.5 stems per Ha, *Lonchocarpus nelsii* 5.9 stems per Ha, *Burkea africana* 3.3 stems per Ha. *P. angolensis* has 1.6 stems per Ha.

B. plurijuga has the highest mean and total tree volume 22.3 m^3/Ha and 3,262,600 m^3 followed by *G. coleosperma* 2 m^3/Ha and 297,100 m^3; *C. collinum* 1.7 m^3/Ha and 254,900 m^3; and *Pterocarpus angolensis* 1.6 m^3/Ha with total tree volume of 234,900 m^3. Even though there is less than one *G. Coleosperma* trees per hectare, the volume is high because the trees are very large.

Table 16. Volumes and number of stems for the dominant species in main woodland types

Main vegetation type	Species	Total No. of stems, 1000s	Stems per Ha	Total tree volume, 1000s m3	Average tree volume, m3/ha
Closed woodland	Baikiaea plurijuga	1163.68	22.8	1355.93	26.5
	Burkea africana	89.80	1.8	53.01	1.0
	Combretum collinum	968.86	19.0	121.15	2.4
	Lonchocarpus nelsii	309.30	6.1	55.09	1.1
	Pterocarpus angolensis	165.41	3.2	130.26	2.6
	Terminalia sericea	436.90	8.6	34.03	0.7
Open woodland	Baikiaea plurijuga	991.44	25.3	640.57	16.3
	Burkea africana	98.72	2.5	40.71	1.0
	Combretum collinum	349.21	8.9	63.71	1.6
	Lonchocarpus nelsii	42.53	1.1	10.84	0.3
	Pterocarpus angolensis	50.41	1.3	55.11	1.4
	Terminalia sericea	245.76	6.3	11.89	0.3
Thicket	Baikiaea plurijuga	1160.00	39.1	1048.85	35.3
	Burkea africana	9.45	0.3	9.38	0.3
	Combretum collinum	271.49	9.1	54.10	1.8
	Lonchocarpus nelsii	330.83	11.1	45.54	1.5
	Pterocarpus angolensis	10.50	0.4	39.52	1.3
	Terminalia sericea	259.94	8.8	30.28	1.0
Bushland	Baikiaea plurijuga	487.32	31.6	197.61	12.8
	Burkea africana	37.81	2.4	3.16	0.2
	Combretum collinum	85.07	5.5	14.13	0.9
	Lonchocarpus nelsii	151.24	9.8	5.87	0.4
	Pterocarpus angolensis	6.83	0.4	9.98	0.6
	Terminalia sericea	94.52	6.1	5.57	0.4

Table 16 shows the number of stems and volumes per vegetation type for the six most common species. *Baikiaea plurijuga* dominates in all vegetation types. The average tree volumes (m3/ha) of the other species are very small. The highest tree volumes, both average and total for *Pterocarpus angolensis* can be found in the closed woodlands.

Comparing this table with Table 14 (p. 17) gives the following information:

- The total volume of six tree species make up more than 80% of the total tree volume in all vegetation types.
- More than 2/3 of the mean volumes per hectare in all vegetation types comes from *Baikiaea plurijuga*.

The tree volume distribution in the State Forest is further visualised in map 4 (p. 41).

3.6 Diameter distribution

Table 17 shows the distribution of stems into diameter classes for the different species. Table 18 (p.21) shows in more detail the diameter distribution of stems and volumes for 3 species, namely *Baikiaea plurijuga, Burkea africana* and *Pterocarpus angolensis* in the Caprivi State Forest. More information on the size distribution can be found in Appendix 6a (p. 52).

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

Table 17: Diameter distribution of stems by species

	Diameter class, in cm										
Species	**5-10**	**10-20**	**20-05**	**30-40**	**40-60**	**60-80**	**80-100**	**100-120**	**130-150**	**Total**	**% of total**
Baikiaea plurijuga	699	1007	544	706	685	135	25	11		3811	36.94
Combretum collinum	945	539	165	61	16	2	2			1731	16.78
Terminalia sericea	699	378	9	5		2	2			1096	10.62
Lonchocarpus nelsii	284	473	90	9	7					862	8.36
Burkea africana	170	189	71	28	23					482	4.67
Schinziophyton rautanenii	151	189	24		6	8	15	2	2	398	3.85
Pterocarpus angolensis	57	57		43	71	6				233	2.26
Combretum zeyheri	151	57	5	5	2					220	2.13
Boscia albitrunca	57	76	43	19	4					198	1.92
Dichrostachys cinerea (Africana)	76	76								151	1.47
Unknown1		118	14		5					137	1.33
Lonchocarpus capassa	76	57								132	1.28
Guibourtia coleosperma		19	5	19	49	21	8	2	2	125	1.21
Erythrophleum africanum	19	38	47	16		2				122	1.19
Sclerocarya birrea	19	76								95	0.92
Combretum mossambicense	57	38								95	0.92
Combretum engleri	76									76	0.73
Croton gratissimus	76									76	0.73
Acacia erioloba	19	19	5	9		4		2		58	0.56
Commiphora angolensis	38	19								57	0.55
Combretum psidioides (dinteri)		38	5	5	5					52	0.50
Acacia nigrescens	38									38	0.37
Ochna pulchra	19	19								38	0.37
Acacia fleckii	19									19	0.18
Combretum psidioides			5					2		7	0.07

(psidioides)											
Acacia tortilis (heterecantha)			5							5	0.05
Terminalia prunioides			5							5	0.05
Total	**3743**	**3478**	**1040**	**925**	**873**	**181**	**53**	**19**	**5**	**10317**	
% of total	**36.28**	**33.72**	**10.08**	**8.97**	**8.46**	**1.76**	**0.51**	**0.18**	**0.04**		**100.0**

Except providing information on the diameter distribution, Table 17 also gives indications on which tree species that have a potential to grow into big size trees in the area.

The table shows that the bulk of the stems for *Combretun collinum*, *Terminalia sericea* and *Lonchocarpus nelsii* are in the smaller diameter classes. Hence, from a management point of view their diameter distribution is good. The table further shows that these species can also grow into bigger size trees. The diameter distribution of *Baikiaea plurijuga, Burkea africana* and *Pterocarpus angolensis* is discussed in connection with Table 18 (p 21).

The biggest trees are *Schinziophyton rautanenii* and *Guibourtia coloesperma*. The former have also a good number of trees in the smaller diameter classes. The situation for *Guibourtia coloesperma* raises concern. There are very few trees in the smaller diameter classes, hence the diameter distribution for this species is skewed. From a management point of view this is not good. Furniture from *Guibourtia coloesperma* is in high demand, hence this species is economically valuable.

Table 18: Total tree volume and number of stems by diameter classes for *Baikiaea plurijuga*, *Burkea africana* and Pterocarpus angolensis

Baikiaea plurijuga				Burkea africana			Pterocarpus angolensis		
Dbh class, cm	**Total tree volume, 1000 m3**	**Total No. of stems, 1000s**	**% of total stems**	**Total tree volume, 1000 m3**	**Total No. of stems, 1000s**	**% of total stems**	**Total tree volume, 1000 m3**	**Total No. of stems, 1000s**	**% of total stems**
5-10	16.4	699	18.4	3.9	170	35.3	2.8	56.7	24.3
10 -20	111.9	1007	26.4	13.9	189	39.3	6.0	56.7	24.3
20 - 30	273.5	544	14.3	32.0	71	14.7			
30 - 40	703.0	706	18.5	27.5	28	5.9	41.9	42.5	18.2
40 - 50	805.8	465	12.2	31.4	19	3.9	75.2	43.1	18.5
50 - 60	602.1	221	5.8	12.2	4	0.9	81.5	27.8	11.9
60 - 70	341.7	92	2.4				16.8	4.2	1.8
70 - 80	200.6	43	1.1				10.7	2.1	0.9
80 - 90	125.9	23	0.6						
90 - 100	11.9	2	0.1						
100-110	40.9	6	0.2						
110-120	28.8	4	0.1						
Total	**3262.6**	**3811**	**100.0**	**121.0**	**482**	**100.0**	**234.9**	**233.2**	**100.0**

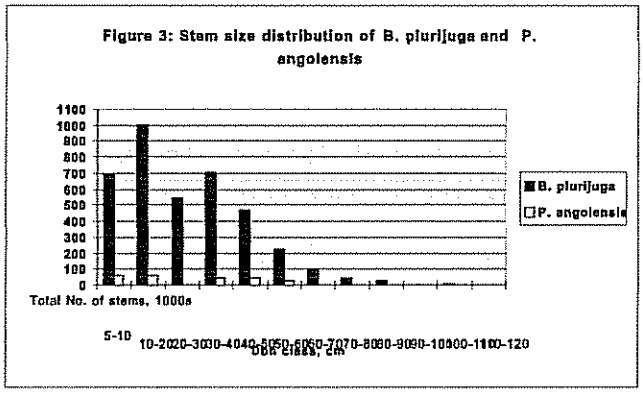
Table 18 shows that *Baikiaea plurijuga* is represented in all diameter classes from 5 -10 to 110-120 cm. The bulk of the stems are in the smaller Dbh classes, hence the diameter distribution is rather good from a management point of view. It is important to manage these small sized trees since they will eventually grow into timber size trees. If properly managed, the *Baikiaea plurijuga* in Caprivi State Forest will be of considerable economic value in the future.

On the other hand, very big trees are rather few. There is a total of 2,157,700 m3 of *Baikiaea*

plurijuga in the DBH classes above 40 cm. This is on average 14.7 m3/ha over the whole State Forest. Note that this is tree volume, not log volume. This means that although small, there is a potential income from *Baikiaea* timber cutting on a short perspective.

The diameter distribution for *Pterocarpus angolensis* is skewed to the right. The number of stems in the lower classes (5 - 20 cm) are too few. There is a total of 184,200 m3 of *Pterocarpus angolensis* in the DBH classes above 40 cm. This is on average 1.26 m3/ha over the whole State Forest. Note that this is tree volume, not log volume. All in all there are few trees. This has the following implications:

- The potential income from timber cutting of *Pterocarpus* on a short term perspective are rather limited if viewed from a per hectare basis.
- After the trees at present in the middle Dbh classes (Dbh 30 - 40 cm) have become mature there is going to be very few *Pterocarpus angolensis* trees possible to cut in the Caprivi State Forest, because of the very low recruitment of trees from the 5-20 cm Dbh classes.
- The scarcity of *Pterocarpus angolensis* trees means that both on a short and long term perspective the economic importance of *Pterocarpus angolensis* in the Caprivi State Forest is going to be limited. From sustainable management point of view it is urgent to undertake activities to ensure the regeneration of *Pterocarpus angolensis* in the State Forest.



Burkea africana is found in the classes from 5-11 to 50-60 cm. The bulk of the stems are found in the smaller DBH sizes. Hence, the distribution is good for the long term development of the species. There is a total of 43,600 m^3 of *Burkea africana* in the DBH classes above 40 cm. Hence, the potential income from timber cutting of *Burkea* on a short term perspective are rather limited if viewed from a per hectare basis.

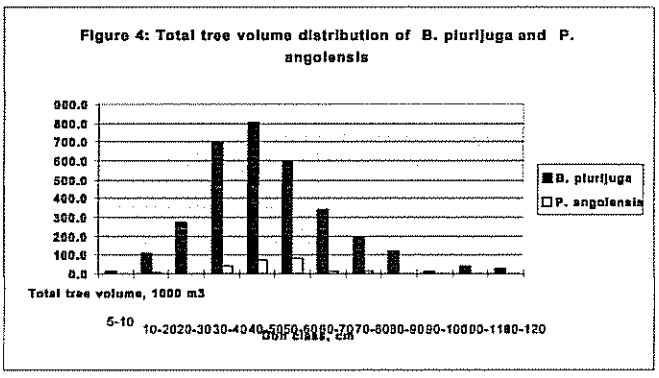


Figure 3: Stem size distribution of *Baikiaea plurijuga* and *Pterocarpus angolensis*

Figure 4: Volume distribution of *Baikiaea plurijuga* and *Pterocarpus angolensis*

Figure 4 shows the distribution of total tree volume by DBH classes. The volume of *B. Plurijuga* is more or less normally distributed while that of *P. Angolensis* is not.

3.7 Timber volumes and quality classification

For commercial forestry it is of interest to have a general idea of the quantities of saw log or merchantable volume of the commercial saw-timber tree species mainly *Baikiaea plurijuga* and *Pterocarpus angolensis*. These two species produce good quality industrial timber and are therefore important to the country's economy and the forestry sector in particular. Although only *Baikiaea plurijuga* and *Pterocarpus angolensis* are analysed here, there are also other species that can be utilised by the timber industry (e.g. *Burkea africana* and *Guibourtia coleosperma).*

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

The quality classification used in the inventory is the following:

Good quality : There is at least 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 2 m saw able log.
Poor quality: It is possible to find only 1.2 - 2 m long log meeting the minimum timber quality requirement
Not sawable: The log is not sawable and will probably never develop sawable quality.

The timber volumes and qualities are presented in tables 19 and 20 for *Baikiaea plurijuga* and *Pterocarpus angolensis* trees with Dbh>45 cm regardless of tree trunk length. On the other hand, tables 20 and 21 show the distribution of stems by DBH and log lengths classes. The timber volumes are further visualised in maps 4b and 4c (p. 41).

Table 19: Distribution by status and quality of *Baikiaea plurijuga* trees with DBH>45 cm

Baikiaea plurijuga					
Status	**Quality**	**Stems per Ha**	**Total No. of stems, 1000s**	**Total log volume, 1000 m3**	**Average log volume, m3/ha**

Live tree	No code	0.07	10.50	12.00	0.08
Live tree	Good quality	1.30	189.57	195.28	1.34
Live tree	Medium quality	0.68	98.72	87.61	0.60
Live tree	Poor quality	1.19	173.29	73.72	0.50
Live tree	Not sawable	0.49	71.94	21.17	0.14
Standing dead tree, without any holes and/or cavities	No code	0.07	10.50		
Standing dead tree, without any holes and/or cavities	Poor quality	0.03	4.20	1.77	0.01
Standing dead tree, without any holes and/or cavities	Not sawable	0.12	16.80	0.88	0.01
Dead, lying	Poor quality	0.01	2.10		
Stump	No code	0.06	8.40		
Stump	Poor quality	0.01	2.10	0.65	0.004
Stump	Not sawable	0.07	10.50		
Standing dead tree, with holes and/or cavities	No code	0.03	4.20		
Standing dead tree, with holes and/or cavities	No code	0.01	2.10		
	Total	**4.14**	**604.95**	**393.07**	**2.69**

The saw log volume of *Baikiaea plurijuga* is 393 070 m^3 (2.69 m^3/ha) for the whole Caprivi State Forest including all quality classes. There is 282 890 m^3 (1.94 m^3/ha) of good and medium quality logs in the forest.

Table 20: Distribution by status and quality of *Pterocarpus angolensis* trees with DBH>45 cm

Pterocarpus angolensis					
Status	**Quality**	**Stems per Ha**	**Total No. of stems, 1000s**	**Total log volume, 1000 m3**	**Average log volume, m3/ha**
Live tree	Good quality	0.12	16.80	19.64	0.13
Live tree	Medium quality	0.07	10.50	8.22	0.06
Live tree	Poor quality	0.09	12.60	9.53	0.07
Live tree	Not sawable	0.06	8.93	2.87	0.02
Standing dead tree, without any holes and/or cavities	Poor quality	0.03	4.20	1.71	0.01
Standing dead tree, without any holes and/or cavities	Not sawable	0.01	2.10		
Standing dead tree with holes and/or cavities	Not sawable	0.01	2.10	2.33	0.02
Total		**0.39**	**57.24**	**44.31**	**0.30**

The average saw log volume of *Pterocarpus angolensis* trees is 0.3 m^3/ha, totalling about 44 310 m^3 for the whole Caprivi State Forest including all quality classes. There is 27 860 m^3 (0.19 m^3/ha) of good and medium quality logs in the forest. The proportion of medium and good quality logs is quite similar for both *Pterocarpus angolensis* and *Baikiaea plurijuga*.

Tables 21 and 22 show the distribution of live sawable *B. Plurijuga* and *P. Angolensis* trees by diameter and stem length classes, for stems > 1.2 m and Dbh > 45 cm. The trunk of a timber tree was regarded as sawable if it was possible to obtain at least a 1.2 m long log from the stem of the tree. These sawable stems exclude deformed bases.

Table 21: Distribution of sawable *B. Plurijuga* trees by DBH and log length classes

Baikiaea plurijuga (No of stems in 1000)

	Stem length class, in meters

Dbh class, cm	1.2-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	Total	% of total
40-50	17.3	35.7	32.0	31.5	4.2			2.1		**122.9**	28.6
50-60	31.5	46.2	63.0	12.6	18.9		4.2			**176.4**	41.0
60-70	6.3	14.7	27.3	10.5	4.2	2.1	2.1	2.1	2.1	**71.4**	16.6
70-80	4.2	6.3	6.8	6.3	6.3	2.1	2.1			**34.1**	7.9
80-90	4.2	2.1		4.2	4.2					**14.7**	3.4
90-100		2.1								**2.1**	0.5
100-110		4.2								**4.2**	1.0
110-120		2.1	2.1							**4.2**	1.0
Total	**63.5**	**113.4**	**131.3**	**65.1**	**37.8**	**4.2**	**8.4**	**4.2**	**2.1**	**430.1**	
% of total	14.8	26.4	30.5	15.1	8.8	1.0	2.0	1.0	0.5		100.0

Therefore, out of a total 604 950 *B. Plurijuga* trees 430 100 or 71% are sawable. The bulk of the sawable stems (86%) are in the Dbh classes 45 - 70 cm and the sawable part is for most of the trees (87%) 5 m or less.

Although the trees that are mature (DBH > 45 cm) are rather small in Dbh size (Table 21), the length of the logs that can be produced is rather good. The average harvestable saw log volume of sawable quality of *Baikea plurijug* is 2.53 m^3/ha (Table 19). With a recovery percentage of 30% this would give 0.759 m^3/ha of sawn timber. Hence, although the total volume of logs in the State Forest looks big, the potential income from timber cutting of *Baikiaea plurijuga* on a short term perspective is not so big. The size of the State Forest and the fact that the timber trees are scattered all over makes the logging time consuming and costly.

Table 22: Distribution of *sawable Pterocarpus angolensis* trees by Dbh and log length classes

Pterocarpus angolensis (no of stems in 1000)

	Stem length class, meters								
Dbh class, cm	**1.2-2**	**2-3**	**3-4**	**4-5**	**5-6**	**6-7**	**7-8**	**Total**	**% of total**
45-50	2.1		2.1	2.1	4.2			10.5	24.7
50-60	4.7	8.4	2.1	8.4		2.1		25.7	60.5
60-70					2.1		2.1	4.2	9.9
70-80				2.1				2.1	4.9
Total	**6.8**	**8.4**	**4.2**	**12.6**	**6.3**	**2.1**	**2.1**	**42.5**	
% of total	16.0	19.8	9.9	29.6	14.8	4.9	4.9		100.0

Out of the 57 240 *P. Angolensis* stems 42 500 or 74.2% are sawable. The average harvestable saw log volume of sawable quality per hectare is 0.27 m^3/ha. Assuming a 30% recovery percentage this would give 0.081 m^3/ha of sawn timber.

The size of the stems between *B. Prulijuga* and *P. Angolensis* is similar, the bulk (85%) of the stems being in the Dbh classes 45 - 60 cm. But the length of the sawable part is for *Pterocarpus angolensis* generally longer. Therefore, among the mature trees the length of the sawable part is good.

All the information so far presented in this report on *Pterocarpus angolensis* confirms that the volumes of sawable timber is rather limited and the trees scattered. Hence, the potential income from timber cutting of *Pterocarpus angolensis* is at the moment limited. And considering the information in Table 17 (p. 20) on the diameter distribution, without proper management the income is also in the future going to be rather limited.

3.8 Damage to trees and dead trees

Damages to trees were recorded both at stand level, for the sampled vegetation unit (Table 23), and at tree level (Table 24), for the measured sample trees.

Table 23: Damaging agent by severity of damage at cluster level, in Ha

	Severity of damage						
Damaging agent	**Fatal**	**Mild**	**Moderate**	**Serious**	**No Damage**	Total	**% of total area**
Forest fire	33259	28507	41573	5939		109278	**75**
Mammals domestic			4751			4751	**3**
Mammals wild		2376	2376	3563		8315	**6**
No Damage					23756	23756	**16**
Total	33259	30883	48700	9502	23756	146100	
% of total area	**23**	**21**	**33**	**7**	**16**		**100**

Table 23 shows the area in hectares of damaging agent by severity of damage. The most common damage is fire, on 75% of the Caprivi State Forest there is visible signs of damages to trees caused by fires. Most of the damages were moderate, 33%, that is, damages are decreasing the vitality of trees. It seems annual fires have an effect in reducing the vitality of trees. Therefore, measures must be put in place to contain this type of damage in order to revigorate the woodlands.

Table 24: Damaging agent and degree of damage to individual trees for 7 most common species

Damaging agent	Degree of Damage	B. plurijuga, % of trees	B. africana, % of trees	P. angolensis, % of trees	C. collinum, % of trees	G. coleosperma, % of trees	L. nelsii, % of trees	T. sericea, % of trees
Forest fire	Fatal, tree is dying or is already dead	0.3		1.7				
Forest fire	Mild, no harm for the tree	7.2	10.6	18.6	18.6	31.1	18.3	5.9
Forest fire	Moderate, degrades the vitality of the tree	6.2	15.2	18.6	8.3	15.6	1.7	4.4
Sub-total, Mild & moderate damage		**13.4**	**25.8**	**37.2**	**26.9**	**36.7**	**20.0**	**10.3**
Forest fire	Serious, vitality seriously reduced	1.2	3.0					
Mammals wild	Mild, no harm for the tree	0.1						
Mammals wild	Moderate, degrades the vitality of the tree	0.1						
Mammals wild	Serious, vitality seriously reduced	0.1						
No Damage		84.8	71.2	61.0	73.1	53.3	80.0	89.7
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 24 confirms that the most common damage is fire. The proportion of trees damaged by fire varies between 10 - 37%. Most of the damages are however mild or moderate. Very few are fatal, i.e. trees dying. *Pterocarpus angolensis* and *Guibourtia coleosperma* are the species with the most frequent fire damages.

On the other hand, a big proportion of the trees have no damages. Comparing Tables 23 and 24 shows that although there is signs of fires on a big part (75%) of the Caprivi State Forest, surprisingly few trees are damaged.

Another way to assess the damage to trees is to look at the status of the trees that were measured (Table 2, p. 7). The table shows that 8.6 % of the 1378 measured trees in the Caprivi State Forest were standing dead trees. The dead trees were to a big part (76%) either *Baikiaea plurijuga, Pterocarpus angolensis* or *Burkea africana*. Half of the dead trees are *Baikiaea plurijuga* trees.

3.9 Regeneration of the trees

Regeneration plays a critical role in the renewal and perpetuation of forest/woodland ecosystems. In view of the fact that the Caprivi State Forest is part of the unique *Baikiaea plurijuga* forest ecosystem in southern Africa, it is extremely important to ensure the survival of the regeneration in order to maintain this important woodland.

Table 25 shows the estimated area covered by regeneration. Note that this table includes both "species that are known to become trees" and "woody shrubs that do not grow into trees" in the region. Tables 26 (p. 28) shows the regeneration of woody species that are known to become tree size in the region. Hence the table gives information for the future timber management and differs from Table 27 (p. 29) where the woody species that occur only as shrubs (DBH < 5 cm) are shown.

Table 25: Extent of regeneration, in Ha

Regeneration	Area, in Ha	% of total area
No regeneration observed	15441	10.6
Seedlings or sprouts are present but only lower than 1.5 m	21380	14.6
Vital seedlings or sprouts higher than 1.5 m present	39198	26.8
Seedlings appear in bush-like bundles, several offspring apparently sharing the same root	70080	48.0
Total	**146100**	**100.0**

The last category in the table, "bush-like bundles", was aimed at finding out the extent and effect of repeated fires that burn down e.g. *Baikiaea plurijuga* regeneration and cause them to form a thick, up to 10-15 cm, main root, which coppices numerous thin, less than 1 cm, sprouts. Hence this regeneration will never grow into big trees.

There is regeneration visible on almost the whole (89%) of the State Forest. But on more than half of the area were regeneration is visible, there are seedlings in "bush-like bundles". Hence, although table 26 shows a good number of seedlings of species that are growing into tree size, a part of the seedlings are "bush-like bundles" and will never grow into trees.

Table 26 (p. 28) shows the regeneration in terms of number of seedlings by height classes and species in the State Forest. Note that this table includes only woody species that are known to grow into trees in the region.

There is on average 1275 seedlings per hectare of 25 different tree species in the State Forest. This is a considerable amount of seedlings. The status of the regeneration seems to be encouraging, in that if it is well managed, it will contribute to the continued existence of the woodland of the State Forest. Most of the seedlings (82%) are lower than 1.5 m in height.

The regeneration of the 6 most common tree species comprises 78% of the total amount of the seedlings found, but the regeneration between these species varies. The regeneration is the factor that is going to determine the species composition in the State Forest in the future. On average, there are 290 *Baikiaea* and 15 *Pterocarpus* seedlings per hectare in the whole State Forest. It seems, comparatively, that *Baikiaea* is regenerating reasonably well, as can be seen also from the stem diameter distribution in Figure 3 (p. 22). The regeneration of *Pterocarpus* raises concerns, and is a further confirmation on what has bees said on the future of that species in the Caprivi State Forest (p. 22, 25). Without proper measures the future of *Pterocarpus* looks bleak.
Regeneration for *Combretum collinum* and *Terminalia sericea* is satisfactory with more than 200 individuals per hectare of each species on average. On the other hand, regeneration of *Burkea africana* and *Lonchocarpus nelsii* is not good. Hence from this perspective the most common species in the future in the tree layer is going to be *Baikiaea plurijuga, Combretum collinum* and *Terminalia sericea.*

Table 26: Number of tree seedlings per hectare by height classes and species

	Height class, in cm									
Species	**0-25**	**26-50**	**51-100**	**101-150**	**151-200**	**201-250**	**251-300**	**300+**	**Total/ha**	**% of total**
Terminalia sericea	24	66	145	82	15	2	9	5	347	27.2
Baikiaea plurijuga	40	106	66	28	11	2	4	33	290	22.8
Combretum collinum	15	16	89	76	31	8	11		246	19.3
Combretum zeyheri	2	8	37	25	9	2	2	2	87	6.8
Lonchocarpus nelsii	6	7	25	7	5	1	4	6	60	4.7
Croton gratissimus		4	13	16	7		2	1	43	3.4
Burkea africana	7	2	12	7	2	2		1	31	2.4
Combretum psidioides (dinteri)			4	5	6	3	5	2	24	1.9
Ochna pulchra		4	4	7	2	1			18	1.4
Acacia fleckii	1	3	5	5	2		1	1	17	1.3
Erythrophleum africanum		2	13	2					16	1.3

Pterocarpus angolensis	1	1	2	7	2	1	1		15	1.1
Boscia albitrunca	1	1	5	2	2	2	1		14	1.1
Acacia erioloba		1	12						13	1.0
Combretum engleri			2	1	4			5	12	1.0
Schinziophyton rautanenii			1	2	3	2	3		12	1.0
Dichrostachys cinerea (Africana)		1	6	1	1	1		1	10	0.8
Colophospermum mopane				4					4	0.3
Guibourtia coleosperma			4						4	0.3
Dichrostachys cinerea (Setulosa)				3					3	0.3
Acacia Tortilis (spirocarpa)			2	1					2	0.2
Acacia nigrescens				1	1				2	0.1
Combretum elaeagnoides							1	1	2	0.1
Unknown1					1			1	2	0.1
Combretum psidioides (psidioides)								1	1	0.1
Total	**95**	**220**	**448**	**283**	**102**	**27**	**42**	**58**	**1275**	
% of total	**7.5**	**17.3**	**35.1**	**22.2**	**8.0**	**2.1**	**3.3**	**4.5**		**100.0**

3.10 The shrub layer

Table 27 shows the number of seedlings for shrub species. Note that the table only includes the woody species which do not appear as trees in the region. Hence, the combined total number of tree species and shrub seedlings that appear in the shrub layer is obtained by combining Tables 26 and 27.

There is a total of 45 (Table 6, p. 11) species appearing in the shrub layer in Caprivi State Forest. Of these species 25 also appear as trees (DBH > 5 cm) in the State Forest and are analysed in Chapter 3.9 "Regeneration of trees". The 20 species apperaing only in the shrub layer are shown in Table 27.

There is on average 3573 seedlings per hectare in the shrub layer. This is a considerable amount of seedlings. Of these seedlings , 2298 are from woody species apperaing only in the shrub layer. One shrub species, *Baphia massaiensis*, is dominating. More than half of the number of the seedlings in the shrub layer are from this species. Another common shrub species is *Bauhia petersiana*. Table 27 shows that when it comes to woody species appearing only in the shrub layer these two species are totally dominating.

Table 27: Number of shrub seedlings per hectare by height classes and species

	Height class, in cm									
Species	**0-25**	**26-50**	**51-100**	**101-150**	**151-200**	**201-250**	**251-300**	**300+**	**Total/ha**	**% of total**
Baphia massaiensis	217	480	635	371	97	7	11	12	1830	79.6
Bauhia petersiana	18	43	92	57	8	7	2	1	228	9.94
Markhamia acuminata	1	7	20	24	10		2	1	65	2.83
Grewia retinervis	10	5	16	9	5				45	1.95
Rhigoszum brevispinosum		10	7	6	2	5	2	3	34	1.49
Ozoroa paniculosa			3	7	3			1	15	0.64
Acacia ataxacantha			2	5	2	1	4	1	15	0.64
Commiphora africana		2	5			3			11	0.46
Commiphora angolensis		2	3	2	3		1		11	0.46
Vangueria infausta	1		1	1	2		2	3	9	0.39
Grewia villosa				1	2	2		2	7	0.32
Ximenia americana var americana		1	3	2					7	0.28
Elephentorrhiza elephantina		3	1	1		2			7	0.28
Ozoroa longipes		3	1	2					6	0.25
Euclea divinorum						1		2	3	0.14
Grewia bicolor		1	2		1				3	0.14
Strychnos pungens		2							2	0.07
Grewia flava			1						1	0.04
Mundulea sericea			1						1	0.04
Rhus marlothii		1							1	0.04
Total	246	559	792	487	135	28	24	26	2298	
% of total	10.7	24.337	34.45	21.19	5.87	1.238	1.061	1.13		100

3.11 The grass and herbs layer

Tables 28 and 29 show the grass and herbs cover in the different vegetation types in the State Forest. The inventory field work was carried out from September to November 1998, hence the grass and herbs cover reflects the situation during that period.

Table 28: Cover of grasses per vegetation type

	Vegetation type						
	Closed woodland	**Open woodland**	**Sparse woodland**	**Thicket**	**Bushland**	**Closed shrubland**	**Open shrubland**
Average % cover of grasses	11	11.8	8.3	13.6	5.6	3.2	4.5
% of land area	35	26.8	3.3	20.3	10.6	2.4	1.6

The grass cover is generally very low. One contributing factor to this is that the field work was carried out towards the end of the dry season, when the grass cover is at its lowest level. The highest grass cover are in the woodlands and in the thicket. The lowest grass cover can be found in the closed shrubland, which is logical since the shrubs here compete with the grass for the space.

Table 29: Cover of the herbs per vegetation type

	Vegetation type						
	Closed woodland	**Open woodland**	**Sparse woodland**	**Thicket**	**Bushland**	**Closed shrubland**	**Open shrubland**
Average % cover of herbs	6.4	3.3	2.4	4.7	3.8	8.5	1.0
% of land area	35	26.8	3.3	20.3	10.6	2.4	1.6

Also the herbs cover is very low. The highest herbs cover can be found in the closed shrub land. In fact, the herbs cover in this vegetation type is on average higher than the grass cover.

3.12 Human influence

3.12.1 Cutting

The information on the cutting was obtained by observing the area in and surrounding the sample plots. Hence, this information is describing the situation in the stand where the sample plots are located.

Table 30 shows that there is very little signs of cutting in the State Forest. Cutting can be observed only on 3 % of the total area of the State Forest. This is equivalent to 4751 Ha.

Table 30: Area of cutting in the different vegetation types

Accomplished	Closed	Open	Sparse	Thicket	Bush	Closed	Open	Area, in	% of total

measures	woodland	woodland	woodland		land	Shrub land	shrub land	Ha	area
No accomplished measures observed	49888	36822	4751	28507	15441	3563	2376	141349	97
Cuttings, fuelwood removed				1188				1188	1
Cuttings, timber sized trees removed	1188	2376						3563	2
Total	51076	39198	4751	29695	15441	3563	2376	146100	100

3.12.2 Utilisation of land for agricultural purposes

The information on grazing was obtained by observing in the lower vegetation and on branches of trees and bushes in and surrounding the sample plots. Hence, this information is describing the situation in the stand where the sample plots are located. Furthermore the intensity of grazing was noted.

Table 31 shows the intensity of grazing. Only, about 6.5% of the area shows signs of grazing of which 4.9% is moderate and 1.6% is intensive with vitality of vegetation clearly threatened. Therefore, grazing is not that extensive in the State Forest.

Table 31: Grazing

Grazing intensity	Area, in Ha	% of total area
No signs of grazing observed	136598	93.5
Moderate signs of grazing are visible, vegetation still alive	7127	4.9
Signs of intensive grazing visible, vitality of vegetation clearly threatened	2376	1.6
Total area	**146100**	**100.0**

3.13 Sampling error and confidence limits

3.13.1 General

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

Training
In this work, specific attention was paid to guarantee good quality field data. Field personnel were continuously trained on-the-job in forest measurements and plant identification. The field team undertook a re-fresher course in Tree Identification at the National Botanical Research Institute.

Field instructions were reviewed both in the office and in the field. Data processing programs were carefully designed and double checked. Several cross checkings were done to find out possible errors and inconsistencies in the data. The data processing and analysis, and reports were double checked.

Volume functions
The applied volume functions are propably the main source of errors. The size of the material collected for constructing the functions was moderate. In Caprivi only 95 trees were felled, mainly from East Caprivi, for stem analysis. However, the 53 trees from West Tsumkwe were combined with the 95 trees from Caprivi and the pooled data was then used to derive the volume functions. The saw log timber volumes were estimated simply by multiplying the timber log height with the timber log basal area at breast height because it was assumed that the cylindrical volume more or less estimated the log volume. These error sources have an effect on the volume estimates but not, for example, on the estimates of stem or tree numbers and size class distributions.

Sampling error estimator
The magnitude of sampling error, Table 32, was estimated with the formula of stratified random sampling using clusters, not sample plots, as sampling units. The applied sampling method was systematic, not random, but the formula is more or less valid. However, the formula may over estimate the sampling error.

3.13.2 Sampling error and confidence limits for tree volume

Table 24 shows the sampling error and confidence limits for tree volume for '*all species*', *B. Plurijuga*, *B. Africana* and *P. Angolensis*. For the estimate of average tree volume per hectare of "all species" the sampling error was 2.19 m^3/ha, that is, 6.59% of the average. Therefore, the true average tree volume for all species is between 28 and 37 m^3/ha with the probability of 95%.

Table 32: Sampling error and confidence limits for tree volume for the whole area

Item	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	4.82	2.19	33.28	6.59	28.98	37.58	95
B. plurijuga	3.79	1.95	22.33	8.72	18.51	26.15	95
B. africana	0.04	0.20	0.83	24.23	0.43	1.22	95
P. angolensis	0.15	0.39	1.61	24.05	0.85	2.37	95

For the average tree volume per hectare of *Baikiaea plurijuga* the sampling error was 1.95 m^3/ha (8.72%). Hence, the average tree volume of *B. plurijuga* is between 18 and 26 m^3/ha with the probability of 95%. For the average tree volume per hectare of *Burkea africana* the sampling error was 0.2 m^3/ha (24.23%). Hence, the average tree volume of *B. Africana* is between 0.43 and 1.22 m^3/ha with the probability of 95%. For the average tree volume per hectare of *P. Angolensis* the sampling error was 0.39 m^3/ha (24.05%). Hence, the average tree volume of *P. Angolensis* is between 0.85 and 2.37 m^3/ha with the probability of 95%.

The total volume estimates for the whole area have the relative sampling errors of 6.59% for all species, 8.72% for *B. Plurijuga*, and about 24% for *B. Africana* and *P. angolensis*, respectively. The tree volume per hectare and total volume estimates for the whole area are therefore more reliable for volume of '*all species*' and *B. Plurijuga* because of the small sampling error, less than 9%.

3.13.3 Sampling error and confidence limits for sawlog volume

Table 33 shows the sampling error and confidence limits for saw log timber volume for *B. Plurijuga*, *B. Africana* and *P. Angolensis*.

Table 33: Sampling error and confidence limits for saw log timber 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, %
B. plurijuga	0.2499	0.50	5.23	9.56	4.25	6.21	95
B. africana	0.0042	0.07	0.24	26.95	0.11	0.37	95
P. angolensis	0.0189	0.14	0.51	27.21	0.24	0.78	95

For the average sawlog timber volume per hectare of *Baikiaea plurijuga* the sampling error was 0.50 m^3/ha (9.56%). Hence, the average sawlog timber volume of *B. plurijuga* is between 4.25 and 6.21 m^3/ha with the probability of 95%. For the average sawlog timber volume per hectare of *B. Africana* the sampling error was 0.07 m^3/ha (26.95%). Hence, the average sawlog timber volume of *B. africana* is between 0.11 and 0.37 m^3/ha with the probability of 95%. For the average sawlog timber volume per hectare of *P. Angolensis* the sampling error was 0.14 m^3/ha (27.4%). Hence, the average sawlog timber volume of *P. Angolensis* is between 0.24 and 0.78 m^3/ha with the probability of 95%.

The total sawlog timber volume estimates for the whole area have the relative sampling errors of 9.56% for *B. Plurijuga*, 26.95% for *B. Africana* and 27.21% for *P. angolensis*, respectively. The sawlog timber volume per hectare and total sawlog timber volume estimates for the whole area are therefore more reliable for *B. Plurijuga* because of the small sampling error, less than 10%.

4. CONCLUSION

The Directorate of Forestry in 1994 proclaimed a part of the *Baikiaea plurijuga* woodland in eastern Caprivi to be a state forest. This area, 146,100 hectares in size, became the Caprivi State Forest. The purpose of the state forest is to protect and utilise the woody resources in the area by practising sustainable forest management .

The inventory was carried out to get information on the woody resources in the State Forest. The results can be used for operational forest management planning and, in future, as a basis for planning inventories, for example, determination of sample size to achieve a desired allowable error. A total of 246 plots were measured in the inventory, which means that each plot represents 594 hectares.

The woody species
A total of 45 woody species were found in the State Forest. Twenty seven (27) of these species occur as trees (DBH > 5 cm). *Baikea plurijuga* is the most common tree species and can be found virtually all over the area, 55% of the measured trees were from that species. *Pterocarpus angolensis*, an economically important tree species, is not very common in the State Forest. *Baphia massaiensis* is the most common species in the shrub layer, 18% of the measured shrubs are from that species.

Although there is a good number of woody species occurring in the State Forest, the bulk of the woody resource, both in the tree layer and the shrub layer, is formed by the six most common woody speciesin the layers. The six most common species in the tree layer are; *Baikea plurijuga*, *Combretum collinum, Terminalia sericea, Burkea africana, Lonchocarpus nelsii* and *Pterocarpus angolensis*. Of these species *Baikea plurijuga*, *Combretum collinum, Terminalia sericea* and *Lonchocarpus nelsii* also belong to the six most commonly found species in the shrub layer.

The species diversity is less than in the Caprivi Region as a whole. On the other hand, more species were found in the State Forest than in the inventories so far carried out in both Tsumkwe District and in the 4 O's Regions. This indicates that the species diversity in Caprivi is higher than in the other parts of northern Namibia.

The value of the Caprivi State Forest from a biodiversity point of view can be assessed by comparing the species and the number of them now appearing in the State Forest to the ideal situation in the *Baikea* woodlands.

The vegetation types
Edwards classification is used for the classification of the vegetation into vegetation types. There is a tree layer on a considerable part of the State Forest. But the tree cover is not dense enough to be classified as forest. The most common vegetation types are closed woodland (35%), open woodland (27%), thicket (20%) and bushland (11%). Woodland implies that the woody reosurce is concentrated to the tree layer, while bushland implies that the woody resource is in the shrub layer. Thicket implies that the woody resoure is in both the tree and the shrub layers. If the FAO vegetation type classification was used, 55% of the State Forest (closed woodland and thicket) would be classified as forest. On 32% of the area there is very little woody vegetation.

Baikiaea plurijuga is occuring in most stands regardless of vegetation type. A common species composition is *Baikea/Combretum collinum* and *Baikea/Terminalia sericea*. Otherwise there are no clear patterns on the species mixtures in the Caprivi State Forest.

It remains unclear, if a *Baikiaea* dominated woodland can become dense enough to be classified as forest. *Baikiaea* dominated woodlands represent a climax vegetation type which implies that the area will not develop a very dense tree layer. One topic for research could be to find the optimum density of a *Baikiaea* dominated woodland and to develop management prescription for this purpose.

The forest resource

The total tree volume in the State Forest is 4.86 million cubic meters. *Baikiaea plurijuga* dominates, 2/3 of the total tree volume comes from this species. The six most common tree species count for 84% of the total tree volume. The average tree volume per hectare is 33.3 m^3. The tree volumes varies considerably between the different vegetation types. The volumes per hectare in closed woodlands and thickets are 40-49 m3/ha and double that of the volumes in open woodlands and bushland.

Comparable figures for other areas inventoried so far are: Uukwaludhi Community Forest 6.31 m^3/ha; 21.4 m^3 /ha for Caprivi Region, 17.8 m^3/ha in West Tsumkwe; and 4.2 m^3/ha for "East and South Tsumkwe, Otjinene and Okakarara" area. The Caprivi State Forest, therefore, has the highest average tree volume per hectare of all areas so far inventoried.

Baikiaea dominated woodlands under similar conditions (rainfall, soils) in the Chobe Forest Reserve in Botswana have a higher average volume, on average 49 m^3/ha. This indicates that there is a potential for higher volumes also in the Caprivi State Forest.

The diameter distribution of *Baikiaea plurijuga* is good, with trees in all diameter classes and the bulk in the smaller classes. The situation is the same for *Burkea africana*, *Combretum collinum*, *Terminalia sericea* and *Lonchocarpus nelsii. Pterocarpus angolensis* has very few stems in the lower diameter classes, hence the distribution is not good from a management point of view. The same is the situation for *Guibourtia coleosperma.*

The following can be concluded on the economic utilisation of the Caprivi State Forest for timber in a short term perspective:

- *Baikiaea plurijuga*, *Burkea africana, Pterocarpus angolensis* and *Guibourtia coleosperma* are species found in the State Forest that are utilised by the wood carving, furniture and construction industry and hence have a financial value as timber trees.
- *Baikiaea plurijuga* is the only species that is feasible to be harvested at the moment. But also here the financial benefits are rather small. The size of the State Forest, and the fact that the timber trees are scattered all over makes the logging time consuming and costly. There is about 1/2 million *Baikiaea trees* with DBH more than 45 cm. This gives an average saw log volume of 2.69 m3/ha, wich is about 0.8 m3/ha of sawn timber.
- The potential for economic utilisation of *Pterocarpus angolensis* is very limited. The trees are few and very scattered. At the moment there is on average one harvestable (DBH>45 cm) *Pterocarpus angolensis* tree on every 3 hectares.
- The price for sawn timber of *Pterocarpus angolensis* was in Septemer 1999 N$6160 in Windhoek. There was no current price for *Baikea plurijuga*, since sawn timber was not available, the price in 1995 was N$2200. No other indigenous species are sold as sawn timber in Windhoek. According to a carpenter interviewed, the indigenous species would most probabably be utilised if they were available.

From a managment perspective the following can be concluded:

- The diameter distribution for *Baikea plurijuga* and *Burkea africana* are satisfactory, hence the proper management of smaller trees will enable harvesting in the future.
- There are few *Pterocarpus angolensis* and *Guibourtia coleosperma* stems in the smaller diameter classes. Hence, even a proper management of the now existing smaller trees will not considerably increase the harvesting possibilities in the future.

The regeneration

For sustainable forest management regenaration is important for renewal and perpetuation of forest/woodland ecosystems. The regeneration is the factor that is going to determine the species composition in the State Forest in the future.

There is a considerable number of seedlings in the shrub layer, on average 3573 seedlings/ha. One third of the seedlings are from species also occuring as trees in the State Forest, and therefore have the potential to grow into trees in the future. *Baikea plurijuga*, *Combretum*

collinum and *Terminalia sericea* have quite a good regeneration. In fact, these species count for 69% of the seedlings from species that grow into trees. Hence, these species are going to be the most common species in the tree layer in the State Forest also in the future.

The regeneration of *Pterocarpus angolensis, Burkea africana* and *Guibourtia coleosperma* is not good. If nothing is done to ensure the regeneration of these species, their future looks bleak in the Caprivi State Forest.

The following can be concluded on the management options for the regeneration:

- The status of the regeneration is encouraging in that if it is well managed it will contribute to the continued existence of the forest/woodlands in the Caprivi State Forest.
- If the management is built on the existing seedlings, the economic benefit from the State Forest is going to be concentrated to *Baikea plurijuga*, *Combretum collinum* and *Terminalia sericea* in the future. Since there is going to be very few *Pterocarpus angolensis, Burkea africana* and *Guibourtia coleosperma* trees, the economic benefits from these species is going to be limited.
- If the enhancement of the regeneration of other species is a part of the management, the future species composition in the State Forest can be decided through management decisions.

Damages on the woody vegetation

The most common damage to the woody vegetation is fire. The stand level classification indicates that, on 75% of the area there are visible signs of damages to trees caused by fires. Although the woody vegetation on a big part of the State Forest show signs of fire damage, surprisingly few trees are damaged, and the damage is mild or moderate.

However, it is clear that fire is the most common damage to the trees. Hence, there is need for concerted effort to protect the forest resources from uncontrolled wild fires. Concerted planning and action in fire control and management to save the woodlands from further degradation are therefore required. The endeavour should involve local communities to ensure long term success.

Human influence

There are very few signs of cutting in the Caprivi State Forest. Only on 4751 Ha (3% of the area) could such signs be observed. Also signs of utilisation of the area for agricultural purposes, in this case grazing, were few. Only on 2376 (1.6% of the area) could grazing be observed. Hence, except for the frequent fires, the human influence on the Caprivi State Forest is very limited.

The Caprivi State Forest in a larger perspective

Population

Caprivi Region had about 107 900 people according to estimates of the 1996 Demographic Survey. Most of these people are in East Caprivi where Caprivi State Forest is located. The majority of the people depend on the forest resources for fuelwood and poles for house construction and grass for thatching. Other plants are also used for nutrition and medicinal purposes. Domestic animals and game also depend on the forest resources for fodder and shelter. Therefore, the population pressure on the State Forest can therefore not be ignored. On the other hand, the potential contribution of the State Forest to the well being of the population could be substantial. Hence, there is need to maintain the forest bio-diversity of the area. Therefore, the population surrounding the State Forest have a major long term impact on the present and future existence of the resources of the forest.

Strategic plan

In 1997 the Directorate of Forestry began a comprehensive implementation of the Namibia Forestry Strategic Plan (NFSP) of 1996 through the new Namibia-Finland Forestry Programme which started in April 1997. The Strategic Plan (NFSP) identified the main challenges to sustainable forestry management as: forest *production* (production forestry, environmental

forestry, and processing of forest products); *protection* of forest resources; and people's *participation* in forestry development.

Forest Policy
The Directorate is at present in the process of revising the National Forest Policy of Namibia. The first stated aim of the forest policy is: *"Reconcile rural development with biodiversity conservation by empowering farmers and local communities to manage forest resources on a sustainable basis"*. The immense potential of the Caprivi forest resources in general and Caprivi State Forest in particular, which are mainly on communal lands, can, in the long run, only be effectively conserved through the active participation of the local communities in forest resource management and conservation. Furthermore the completion of the new Forest Bill to replace the Preservation of Trees and Forests Ordinance of 1952 and the Forest Act of 1968, will facilitate people's participation in forestry development.

Community participation and sustainable forest management
There is need to work closely with the local communities surrounding Caprivi State Forest in the difficult task of conserving the forest resources. In addition to the already on-going pilot Integrated Forest Fire Control exercise which is working with the communities to control forest fires, there is need for the Environmental Forestry component also to work closely with existing conservancies such as Salambala, to empower the communities to manage and conserve forest resources. This way the survival of the forest resources in Caprivi will be ensured. Otherwise the forest resource of Caprivi State Forest in particular will continue declining due to fires, clear cuts for agricultural expansions and other factors.

This report forms a very good basis for further discussions with the Regional Authorities, other stakeholders and particularly the communities surrounding the Caprivi State Forest on how best to conserve, manage and regulate harvesting of the resources of the area for the benefit of both present and future generations.

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