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WOODY RESOURCES OF WESTERN TSUMKWE

AN INVENTORY REPORT

National Forest Inventory Project
Directorate of Forestry
18.4.1997

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– 11°00' 20°15'

– 19°00

1. BACKROUND

The inventory area includes most southern parts of Okavango magisterial district (areas South from latitude 20 00 S) and western parts of Tsumkwe district (West from longitude 20 15 E and North from latitude 20 30 S). The area is drawn in a map in Appendix 1.

The woody resources were estimated with stratified systematic plot sampling. Vegetation Maps produced by Directorate of Forestry were applied to stratify the area in Forest land and Other land. Clusters of sample plots were located on a grid of 5 km by 5 km on Forest land and 10 by 10 km on Other land. Totally, 210 clusters were measured. There were 3 plots in each cluster with a distance of 100 m from each other. Thus, the total number of measured field plots was 630.

All trees inside the circular plot were measured. The size of the plot depends on the size of the tree so that the radius of the plot is 30 m for trees with breast height diameter (DBH) more than 45 cm; 20 m for trees with 45 < DBH < 20 cm; and 10 m for trees with 5 < DBH < 20 cm. Diameter, location, species, crown class, quality, length and quality of possible saw log were measured and recorded for each tree (called enumeration trees). Height, diameter of canopy, crown height, damages and phenology were recorded for all the trees on the first plot of each cluster (i.e. for one third of all the trees). These trees are called sample trees.

Additionally, shrubs and regeneration were measured using two 3.99 m radius circular plots. Woody plants with diameter at breast height less than 5 cm were recorded on the shrub and regeneration field form and bigger woody plants on the sample and enumeration tree field forms. Several variables describing the site, soil and tree cover were observed for each plot. Coverage of grasses and herbs were measured, also. All the measuremets are described in more detail in the field instructions (Field Instructions Western Bushmanland 1996).

An additional data of felled sample trees were collected for constructing volume and biomass functions for Burkea africana, Combretum collinum, Lonchocarpus nelsii, Pterocarpus angolensis and Terminalia sericea (Field Instructions: Collection of...). For other species (that were not so abundant in the data) one of these functions was applied for estimating volumes and biomasses. The estimated volume and biomass functions are in Appendix 2.

2. GENERAL DESCRIPTION OF THE AREA

The area belongs to the Forest Savanna and Woodland vegetation zone in the classification of Giess (National Atlas of South West Africa). Soil is always sand. The following land forms are present: dunes, dune valleys, dry river beds and sandy substrates. Annual rainfall is 300 - 400 mm. Elevation is 1100 - 1300 m over sea level.

The total land area is 607 949 ha. According to the Vegetation Maps (Directorate of Forestry) 473 905 ha is classified as forest (trees higher than 5 m), 132 439 ha as savannah, 1 187 ha as grassland, and 418 ha as non-classified land.

3. INVENTORY RESULTS

3.1 Measured data

Totally, 630 plots on 210 clusters were measured. According to the vegetation maps, 534 of the plots were on the Forest stratum and 96 on the stratum of Other land. Thus, each plot in the Forest stratum represents 887.46 ha and each plot in the Other land stratum represents 1396.29 ha. Totally, 3400 trees with diameter at least 5 cm were measured on the plots. Out of these, 1148 were sample trees. The number of measured trees by species is in Table 1. The number of all trees includes the sample trees.

Table 1. Number of measured trees and sample trees by species.

Species	No. of all trees	No. of sample trees
Acacia erioloba	55	10
Acacia fleckii	8	4
Acacia mellifera	10	
Acacia tortilis (heterecantha)	12	6
Baikea plurijuga	72	17
Boscia albitrunca	18	9
Burkea africana	1338	448
Combretum collinum	339	127
Combretum imberbe	2	
Combretum psidioides (dinteri)	271	121
Combretum psidioides (psidioides)	5	121
Combretum zeyheri	57	16
Commiphora angolensis	3	1
Croton gratissimus	5	
Dichapetalum cymosum	1	1
Dichrostachys cinerea	3	3
Guibourtia coleosperma	76	26
Lonchocarpus nelsii	91	36
Ochna pulchra	42	8
Ozoroa schinzii	5	
Peltophorum africanum	4	2
Pterocarpus angolensis	610	181
Schinziophyton rautanenii	46	21
Securidaca longepedunculata	4	
Strychnos cocculoides	7	
Strychnos pungens	39	12
Terminalia sericea	286	95
Unknown	7	
Ziziphus mucronata	2	
Total	**3418**	**1265**

3.2 Area estimates

The Vegetation Structural Type were derived for each vegetation unit with measured sample plots. The derivation of the Vegetation Structural Type is based on measured height of tree, shrub and grass cover and on measured coverage of each of these layers (Edwards 1983). The criteria are listed in Appendix 3.

The area and percentage of different Vegetation Structural Types are in Table 2. Woodlands (definition: tree cover > 0.1 % and shrub cover < 10 % if shrub height more than 1 m) cover 73 % of the area. The woodlands are mostly in the category Short Closed Woodland (definition: tree cover 11-75 % and tree height 5-10 m).

Table 2. Area by Vegetation Structural Types.

Vegetation Structural Type	Area in ha	Area in %
Tall Closed Woodland	55910	9.2
Short Closed Woodland	172310	28.3
Low Closed Woodland	11040	1.8
Tall Open Woodland	9514	1.6
Short Open Woodland	67341	11.1
Low Open Woodland	58218	9.6
Low Sparse Woodland	12176	2.0
Short Thicket	84451	13.9
Low Thicket	17501	2.9
Short Bushland	59744	9.8
Low Bushland	42243	6.9
Tall Closed Shrubland	2662	0.4
Low Closed Shrubland	2662	0.4
Low Open Shrubland	9514	1.6
Low Sparse Shrubland	2662	0.4
Total	**607949**	**100.0**

The crown coverage of each species was calculated for each cluster. The dominant and second dominant species were derived from these crown coverage estimates. Table 3 shows the areas and percentages of dominant species.

Burkea africana is the most common dominant species (on 264 003 ha or 43.4 % of the area) followed by Pterocarpus angolensis as the second most common species (122 115 ha or 20.1 %).

Table 4 shows the occurrence of second dominant species for each dominant species. For example, if Burkea is the dominant species most often the second species is Pterocarpus and vice versa. When Burkea is the dominant species then Pterocarpus is the second dominant species in 35.4 % of the Burkea dominated forest and savanna. When Pterocarpus is the dominant species then Burkea is the dominant species in 56.7 % of cases.

Table 3. Area (in ha and %) by dominant species.

Species	Area, ha	%
Acacia erioloba	13312	2.2
Acacia fleckii	4189	0.7
Acacia tortilis (heterecantha)	4189	0.7
Baikea plurijuga	10650	1.8
Boscia albitrunca	2662	0.4
Burkea africana	264003	43.4
Combretum collinum	35392	5.8
Combretum psidioides (dinteri)	39191	6.4
Croton gratissimus	4189	0.7
Guibourtia coleosperma	10650	1.8
Lonchocarpus nelsii	28541	4.7
Peltophorum africanum	6851	1.1
Pterocarpus angolensis	122115	20.1
Schinziophyton rautanenii	5325	0.9
Strychnos pungens	4189	0.7
Terminalia sericea	30813	5.1
Ziziphus mucronata	4189	0.7
Unknown	2662	0.4
No trees	14838	2.4
Total	**607949**	**100.0**

Table 5 shows the distribution of crown cover classes by dominant species. Pterocarpus dominated areas are most often in the cover classes 5 - 10 % and 20 - 25 %. Most of the Burkea dominated areas are in cover classes 5 - 10 %, 10 - 15 %, and 15 - 20 %. For other dominant species the crown cover is in most cases markedly lower.

Table 4. Occurrence of the first dominant and second dominant species. Figures in the table are percentages of the area of the first dominant species.

First dominant species	No 2nd species	ACAER	ACAFL	ACAME	BOSAL	BURAF	COMCO	COMPD	COMZE	DICCA	GUICO	LONNE	OCHPU	PTEAN	SCHRA	STRPU	TERSE	Unknown
	Second dominant species																	
ACAER	60.0							20.0				20.0						
ACAFL						100.0												
ACATH				100.0														
BAIPL						25.0		25.0						25.0	25.0			
BOSAL			100.0															
BURAF	7.8	1.0					13.7	6.1	2.0		10.1	1.0	6.1	35.4		1.0	14.8	1.0
COMCO	26.9	19.4				19.4						11.8		15.0		7.5		
COMPD	6.8	17.5				37.9	10.7					6.8		13.6			6.8	
CROGG												100.0						
GUICO						100.0												
LONNE	9.3	9.3			14.7	9.3	33.3										24.0	
PELAF	38.9											61.1						
PTEAN	5.6					56.7	13.4	12.2	4.4			3.4			2.2		2.2	
SCHRA						50.0		50.0										
STRPU							100.0											
TERSE	8.6	8.6				39.5	8.6			8.6		8.6	8.6	8.6				
ZIZMU						100.0												
Unknown							100.0											

Table 5. Percentage of crown cover classes by dominant species.

Species	Crown cover class, % 0-5	5-10	10-15	15-20	20-25	25+
Acacia erioloba	60	40				
Acacia fleckii	100					
Acacia tortilis (heterecantha)					100	
Baikea plurijuga						100
Boscia albitrunca		100				
Burkea africana	7	20	28	20	12	13
Combretum collinum	46	39		8	8	
Combretum psidioides (dinteri)	24	27	24	17		7
Croton gratissimus	100					
Guibourtia coleosperma	50			25		25
Lonchocarpus nelsii	85	15				
Peltophorum africanum	100					
Pterocarpus angolensis	8	20	16	17	26	13
Schinziophyton rautanenii					50	50
Strychnos pungens	100					
Terminalia sericea	35	31	9	9	17	
Ziziphus mucronata	100					
Unknown			100			

3.3 Volumes and number of stems

Total volumes, mean volumes, total number of stems and average number of stems per hectare for the whole area by species are in Table 6. Only living trees are included in the table. The most common species is Burkea africana (on average 33.16 stems per ha) followed by Terminalia sericea (12.60 stems per ha, Combretum collinum (12.47 stems per ha) and Terminalia sericea (17.4 stems per ha).

Burkea africana has also the highest mean and total volume (7.57 m3/ha). The second highest mean volume is for Pterocarpus angolensis (4.40 m3/ha) followed by Guibourtia coleosperma (1.70 m3/ha). Totally, there are more than 59 million trees in the inventory area.

Table 6. Number of stems and volume per hectare and for the whole area by species.

Species	No. of stems, 1000	Stems/ha	% of stems	Total volume, 1000 m3	Mean volume	% of volume
Burkea africana	20160	33.16	33.57	4601.42	7.57	42.48
Terminalia sericea	7662	12.60	12.76	307.21	0.51	2.84
Combretum collinum	7581	12.47	12.63	544.08	0.89	5.02
Pterocarpus angolensis	6740	11.09	11.22	2672.28	4.40	24.67
Combretum psidioides (dinteri)	6533	10.75	10.88	394.74	0.65	3.64
Lonchocarpus nelsii	2168	3.57	3.61	233.59	0.38	2.16
Combretum zeyheri	1353	2.23	2.25	119.75	0.20	1.11
Strychnos pungens	1051	1.73	1.75	32.72	0.05	0.30
Ochna pulchra	1014	1.67	1.69	101.08	0.17	0.93
Guibourtia coleosperma	932	1.53	1.55	1034.63	1.70	9.55
Acacia erioloba	873	1.44	1.45	99.09	0.16	0.91
Baikea plurijuga	749	1.23	1.25	274.36	0.45	2.53
Boscia albitrunca	602	0.99	1.00	29.76	0.05	0.27
Acacia mellifera	444	0.73	0.74	7.69	0.01	0.07
Schinziophyton rautanenii	362	0.60	0.60	260.55	0.43	2.41
Acacia fleckii	291	0.48	0.48	4.17	0.01	0.04
Acacia tortilis (heterecantha)	256	0.42	0.43	17.76	0.03	0.16
Strychnos cocculoides	198	0.33	0.33	4.04	0.01	0.04
Unknown	198	0.33	0.33	19.71	0.03	0.18
Croton gratissimus	190	0.31	0.32	4.79	0.01	0.04
Combretum psidioides (psidioides)	141	0.23	0.24	2.98	0.00	0.03
Ozoroa schinzii	141	0.23	0.24	3.34	0.01	0.03
Securidaca longepedunculata	129	0.21	0.22	15.97	0.03	0.15
Dichrostachys cinerea	85	0.14	0.14	1.51	0.00	0.01
Peltophorum africanum	66	0.11	0.11	8.61	0.01	0.08
Commiphora angolensis	64	0.10	0.11	15.01	0.02	0.14
Dichapetalum cymosum	28	0.05	0.05	1.73	0.00	0.02
Ziziphus mucronata	22	0.04	0.04	17.14	0.03	0.16
Combretum imberbe	14	0.02	0.02	2.97	0.00	0.03
Total	**60047**	**98.76981**	**100.00**	**10832.67**	**17.81839**	**100.00**

Table 7 shows the total volumes and total number of stems by diameter classes for Burkea africana and Pterocarpus angolensis in the whole inventory area. The stem size distribution is shown in graphical form in Appendix 4. It is remarkable that for Burkea the small sized trees are far more frequent than for Pterocarpus. In fact, the size distribution of Pterocarpus is fairly even.

Table 7. Total volume and number of stems by diameter classes for Burkea africana and Pterocarpus angolensis.

dbh class	Burkea africana Volume, 1000 m3	Number of stems, 1000	% of stems	Pterocarpus angolensis Volume, 1000 m3	Number of stems, 1000	% of stems
5-10	70.9	5757.7	28.6	53.6	1535.8	22.8
15-10	296.3	6172.7	30.6	124.3	1394.6	20.7
15-20	488.1	2740.9	13.6	175.5	1004.1	14.9
20-25	731.7	1838.4	9.1	161.9	563.0	8.4
25-30	1127.4	1769.9	8.8	241.8	537.8	8.0
30-35	1034.3	1168.4	5.8	394.1	603.7	9.0
35-40	556.3	495.4	2.5	378.4	416.8	6.2
40-45	250.7	187.7	0.9	434.3	353.2	5.2
45-50	40.2	25.9	0.1	283.3	172.1	2.6
50-55	5.5	3.1	0.0	227.7	104.0	1.5
55-60			0.0	105.3	36.3	0.5
60-65			0.0	10.8	3.1	0.0
65-70			0.0	62.6	12.6	0.2
70-75			0.0	18.7	3.1	0.0
Total	**4601**	**20160.0**	**100.0**	**2672.3**	**6740.1**	**100.0**

Most of the volume is in the northen part of the inventory area, near the border of Tsumkwe and Okavango magisterial districts (see Appendix 5). Especially, most of the densest P. angolensis forests are in this area.

The mean saw log volume of Pterocarpus angolensis trees is 0.31 m3/ha, totalling to 189 780 m3 for the whole area (see Table 8). There are 310 000 timber quality Pterocarpus trees with breast height diameter (dbh) larger than 45 cm. It is noticeable that most of the large trees are saw able. A tree was regarded saw able if it was possible to take at least 1.2 m long log.

Table 8. Distribution of Pterocarpus trees larger than 45 cm in quality classes.

Quality	Number of stems, 1000	Stems, 1/ha	Timber volume, 1000 m3	Mean timber volume, m3/ha
Code missing	6.28	0.01	3.48	0.01
Good quality	92.82	0.15	73.51	0.12
Medium quality	104.04	0.17	63.59	0.10
Poor quality	88.12	0.14	49.20	0.08
Not saw able	18.83	0.03	0.00	0.00
Total	**310.09**	**0.51**	**189.78**	**0.31**

Table 9 shows that the saw able part of the Pterocarpus angolensis trees is quite short: the saw log lenth is less than 3.2 m for more than 50 % of the stems. Typically the reason for short logs is forking and sweeping.

Table 9. Log length distribution of saw able P. angolensis trees.

Log length, m	Stems, 1000	%
1.2 - 2.2	40.25	13.8
2.2 - 3.2	116.60	40.0
3.2 - 4.2	61.44	21.1
4.2 - 5.2	51.01	17.5
5.2 - 6.2	15.69	5.4
6.2 +	6.28	2.2
Total	**291.26**	**100.0**

3.4 Damages

Damages were recorded both at cluster level (for the sampled vegetation unit) and at tree level (for the measured sample trees). Fire damages were found on 90 % of the clusters. Most of the damages were mild causing only noticeable but not serious damages to the trees.

The occurrence of fire damages for Burkea africana and Pterocarpus angolensis by severity classes is presented in Table 10. No damages were recorded for 82.9 % of the Burkea africana and 34.4 % of the Pterocarpus angolensis sample trees. For Pterocarpus angolensis, the damages are frequent but usually not very serious, though the amount of dead and dying trees is quite high. When some sample trees were felled for biomass data collection, it was noticed that most of the large Burkea africana trees were decayed inside even if no damages were visible outside. For Pterocarpus trees it was noticed that if the tree is damaged from the base, most of the stem is still sound and usable.

Table 10. Distribution of Burkea africana and Pterocarpus angolensis trees in damage classes.

Degree of damage	B. africana % of trees	P. angolensis % of trees
No damages	82.9	34.4
Noticeable damage	14.9	54.7
Mild damage	0.5	2.9
Severe damage	0.3	2.9
Fatal damage	1.3	5.1
Total	**100.0**	**100.0**

3.5 P. angolensis and B. africana woodlands

From forestry point of view, woodlands dominated by Pterocarpus angolensis and Burkea africana are most interesting. Table 4 shows that these two species are often found together. The estimated area of woodlands where P. angolensis or B. africana is the first or second dominant species is 316 860 ha (when open and low woodlands and thickets are excluded i.e. crown coverage must be more than 10 % and mean height more than 5 m). These woodlands (later called P. angolensis and B. africana woodlands) are studied in more detail in the following.

The stem size distribution of B. africana and P. angolensis trees is presented in Appendix 6. Naturally, the average stem number per hectare is higher for the P. angolensis and B. africana woodlands than for the whole area in general (see Appendix 4). Excluding the savanna and woodlands dominated by other species did not affect on the shape of the diameter distribution, however.

Table 11 presents the number of seedlings by height classes for P. angolensis and B. africana. Totally, there are 18.3 P. angolensis and 458.3 B. africana seedlings per hectare. Most of the few P. angolensis seedlings are less than 1.5 m high. It should be noted that Table 10 includes only seedlings less than 5 cm in diameter - larger stems were measured as trees.

Table 11. Number of B. africana and P. angolensis seedlings per hectare by height classes.

Height class	B. africana 1/ha	P. angolensis 1/ha
0 - 25 cm	36.5	0.0
26 - 50 cm	66.1	7.0
51 - 100 cm	251.3	7.8
101 - 150 cm	67.0	1.7
151 - 200 cm	15.7	0.0
201 - 250 cm	5.2	0.0
251 - 300 cm	13.0	0.9
> 300 cm	3.5	0.9
Total	**458.3**	**18.3**

3.6. Species diversity

Table 6 gives a figure on the frequency of different species on the inventory area. Tables 3 and 4 describe the occurrence of dominant species and also give an idea about the mixture of species. An other measure for species diversity is the number of clusters where each species was found. Table 12 shows this result for both trees less than 5 cm in diameter (icluding shrubs) and trees larger than 5 cm. Totally, 29 different species were recorded on the tree field form and 53 species on the regeneration and shrub field form. Terminalia sericea, Burkea africana and Ochna pulchra were recorded for more than 50 % of the 210 clusters. There are several species, like Acacia mellifera, Acacia tortilis, Steganotaenia araliacea, Strychnos cocculoides, and Ziziphus mucronata, that were found only on 1 cluster each.

Table 12. Number of clusters, where each species was found.

Species	Number of clusters dbh < 5 cm	dbh > 5 cm
Acacia ataxacantha	19	
Acacia erioloba	11	15
Acacia fleckii	12	3
Acacia mellifera	1	1
Acacia tortilis (heterecantha)	1	1
Baikea plurijuga	4	6
Baissea wulfhorstii	34	
Baphia massaiensis	98	
Bauhia petersiana	99	
Boscia albitrunca	3	4
Burkea africana	130	163
Combretum collinum	69	89
Combretum imberbe		1
Combretum engleri	2	
Combretum psidioides (dinteri)	89	83
Combretum psidioides (psidioides)	5	3
Combretum zeyheri	80	25
Commiphora africana	7	
Commiphora angolensis	20	1
Commiphora glandulosa	1	
Croton gratissimus	11	2
Dichapetalum cymosum	55	1
Dichrostachys cinerea	4	1
Euclea undulata	19	
Grewia avellana	34	
Grewia bicolor	7	
Grewia flava	2	
Grewia flavescens	1	

Table 12 continues.

Species	Number of clusters dbh < 5 cm	dbh > 5cm
Grewia retinervis	30	
Guibourtia coleosperma	5	29
Lannea edulis	1	
Lonchocarpus nelsii	38	37
Maerua schinzii	1	
Mundulea sericea	3	
Ochna pulchra	113	27
Ozoroa paniculosa	8	
Ozoroa schinzii	5	2
Parinari capensis	18	
Peltophorum africanum		2
Protasparagus sp	2	
Pterocarpus angolensis	20	135
Rhigoszum brevispinosum	1	
Rhus marlothii	7	
Rhus tenuinervis	4	
Salacia luebbertii	4	
Schinziophyton rautanenii	4	12
Securidaca longepedunculata		
Steganotaenia araliacea	1	
Strychnos cocculoides	1	5
Strychnos pungens	16	25
Strychnos spinosa	2	
Terminalia sericea	159	86
Vangueria infausta	4	
Ximenia americana var americana	1	
Ximenia caffra var microphylla	2	
Ziziphus mucronata	1	1

4. RELIABILITY OF THE RESULTS

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

In this work, spesific attention was paid to guarantee good quality of the field data. Field personnel were trained for measurements and plant identification. Specimens were taken and checked by late Dr. Mueller for all found tree and shrub species. Several cross checkings were done to find out possible errors and inconsistences in the data. Data processing programs were carefully designed and double checked.

The applied volume functions are propably the main source of errors. The size of the material collected for constructing the functions was moderate. The saw log volumes were estimated simply by multiplying the log height with the log basal area at breast height. These error sources effect on the volume estimates but not, for example, on the estimates of stem numbers and size class distributions.

The magnitude of sampling error was estimated with the formula of stratified random sampling using clusters (not sample plots) as sampling units. The applied sampling method was not random but the formula should be more or less valid since the distance between clusters was high. Propably the formula over estimates the sampling error.

For the mean volume estimate of all species the sampling error was 1.02 m^3/ha (i.e. 5.7 %). For the mean volume of Pterocarpus angolensis the sampling error was 0.40 m^3/ha (9.1 %). This means that the true mean volume is between 16.76 and 18.80 m^3/ha with the propability of 68 %. Correspondigly, the mean volume of P. angolensis is between 4.00 and 4.80 m^3/ha with the propability of 68 %. Since no sampling error is related to the area estimates of the two sampling strat, the total volume estimates have the relative sampling errors of 5.7 % and 9.1 % for the total volume of all species and P. angolensis, respectively.

5. CONCLUSIONS FOR MANAGEMENT PLANNING AND RESEARCH

Without additional knowledge on the growth, regeneration and removal it is not possible to estimate the amount of sustainable cutting. However, the inventory data indicate, that the timber resources are still remarkable. The possibilities for sustainable management of the woodlands is well worth a further feasibility study. Research is needed to produce information on sustainable management regimes for the woodlands in Western Tsumkwe. Some indications of the possibilities is obtained already with the results presented here.

The woodlands of Western Tsumkwe are mostly quite open and trees are sparsely distributed. However, the total area of woodlands is noticeable. Thus, the total number of trees, even of valuable P. angolensis trees, is relatively high. Naturally, most of the trees are far from roads and thus difficult to utilise as timber (Appendix 5).

Even though the total volume of Pterocarpus trees was found relatively high, further information need to be collected on the regeneration and dying of the trees. The almost even diameter distribution and especially the incredibly low number of Pterocarpus seedlings is alarming. It is obvious that during the last two decades the regeneration of Pterocarpus angolensis has been lower than in the past. The causes of the poor regeneration need to be found out and if possible, corrective measures taken.

Knowing that the inventory area represents the most South-Western natural distribution area of Pterocarpus angolensis, spesific care should be taken of not disturbing the natural regeneration of the trees. Excessive removal of large trees in the past might be one reason for the poor regeneration and low number of small trees at present. It is possible that the removal of big trees disturbs the ecosystem so that Pterocapus angolensis trees have no possibility to regenerate. Or, it is possible that conditions favourable to the regeneration of P. angolensis occur only seldom in Western Tsumkwe. This kind of phenomen has been found for several species in the extremes of their natural distribution areas.

Lacking of sound scientific knowledge on the processes of the ecosystems, the cutting practices in the area must be most conservative. For example, removal of all utilisable sized trees should not be allowed on any site. Also, changing of species composition radically by removing only one species from the upper layer should be avoided. Where ever concessions are given it should be ensured that reasonable amount of utilisable sized healthy P. angolensis trees are left standing.

The inventory project wil continue in the other parts of Namibia. The data to be collected will give unique possibilities for further studies on the Namibian woodland and savanna ecosystems. Information on the species composition (such as Table 4) on different sites as well as on the species diversity will be easily obtained by analysing the data (see Appendix 5).

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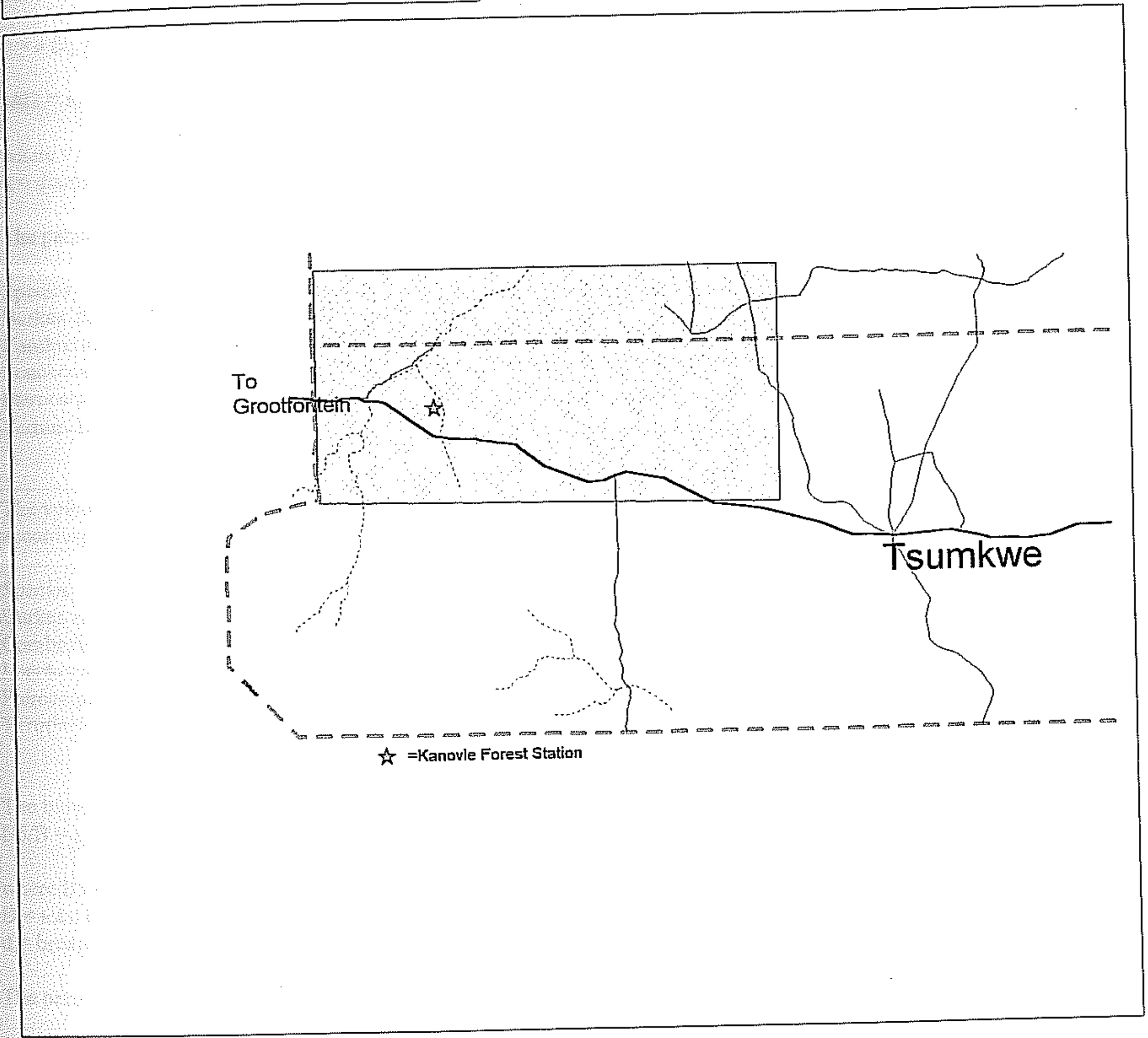
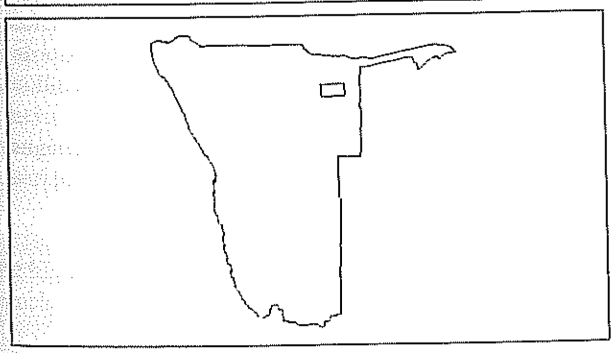
List of appendices

Appendix 1.
Location of the inventory area





Appendix 2. Biomass and volume functions.

Function (1) was found to describe well the relation between volume and diameter for Burkea africana and Terminalia sericea. For Combretum, Lonchocarpus and Pterocarpus, Function 2 was applied.

$$v = e\,(a_0 + a_1/d) \qquad (1)$$

$$v/d2 = a_0 + a_1{*}d + a_2{*}d^2 \qquad (2)$$

where v = volume, dm^3
d = diameter at breast height, cm

The parameter estimates for the volume functions are as follows

Species	a_0	a_1	a_2
Burkea africana	8.607856	-58.71163	-
Combretum collinum	0.131382	0.0180767	-0.0000905
Lonchocarpus nelsii	0.396588	0.0077865	-
Pterocarpus angolensis	0.667061	-0.008408	0.0002143
Terminalia sericea	7.158742	-39.232256	-

The volume is converted to biomass by multiplying with the basic density. The measured basic densities varied according to tree species and stem diameter as follows.

Species	Basic density, kg/dm3	Basic density,kg/dm3
Burkea africana	0.805, if d < 30 cm,	0.770, otherwise
Combretum collinum	0.881, if d < 25 cm,	0.770, otherwise
Lonchocarpus nelsii	0.977, if d < 25 cm,	0.854, otherwise
Pterocarpus angolensis	0.598, if d < 30 cm,	0.525, otherwise
Terminalia sericea	0.754, if d < 20 cm,	0.616, otherwise

The biomass of branches is estimated with Function (3).

$$B5/B = a_0 + a_1/d \qquad (3)$$

where B5 = biomass of branches less than 5 cm in diameter
B = total biomass
d = breast height diameter of the tree, cm

The parameter estimates are as follows.

Species	a_0	a_1
B. africana	0.0468932	2.9833058
C. collinum	0.0956231	1.3644359
L. nelsii	0.0713440	3.5334357
P. angolensis	0.0344962	2.9576978
T. sericea	0.1000000	4.5794900

The biomass of branches can be converted to volume by dividing it with following averaged basic densities of branches.

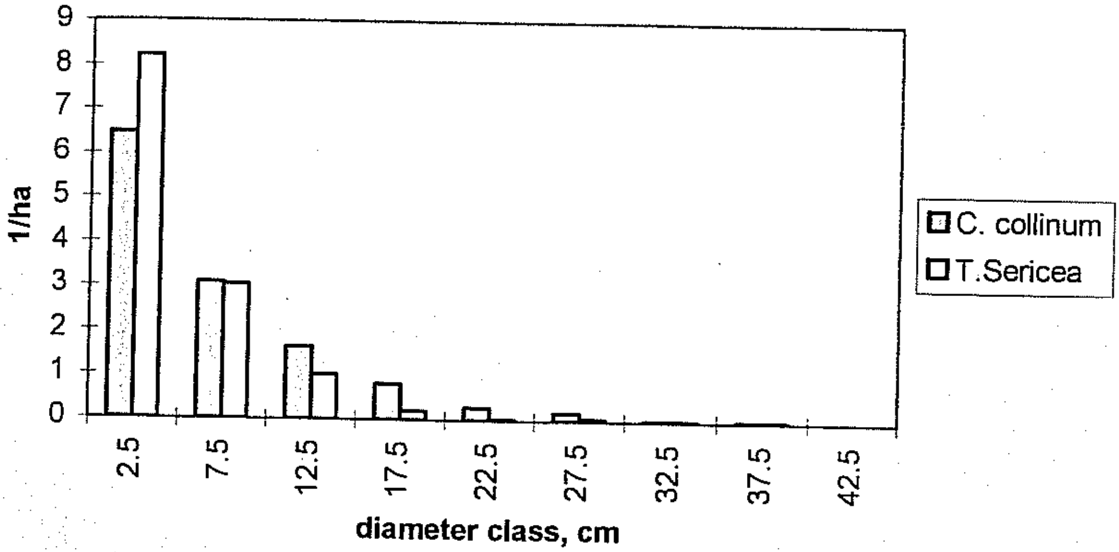
Species	Conversion factor
B. africana	0.7881
C. collinum	0.8366
L. nelsii	0.9229
P. angolensi	0.6141
T. sericea	0.6627

Appendix 3. Vegetational Structural Types (Edwards 1983).

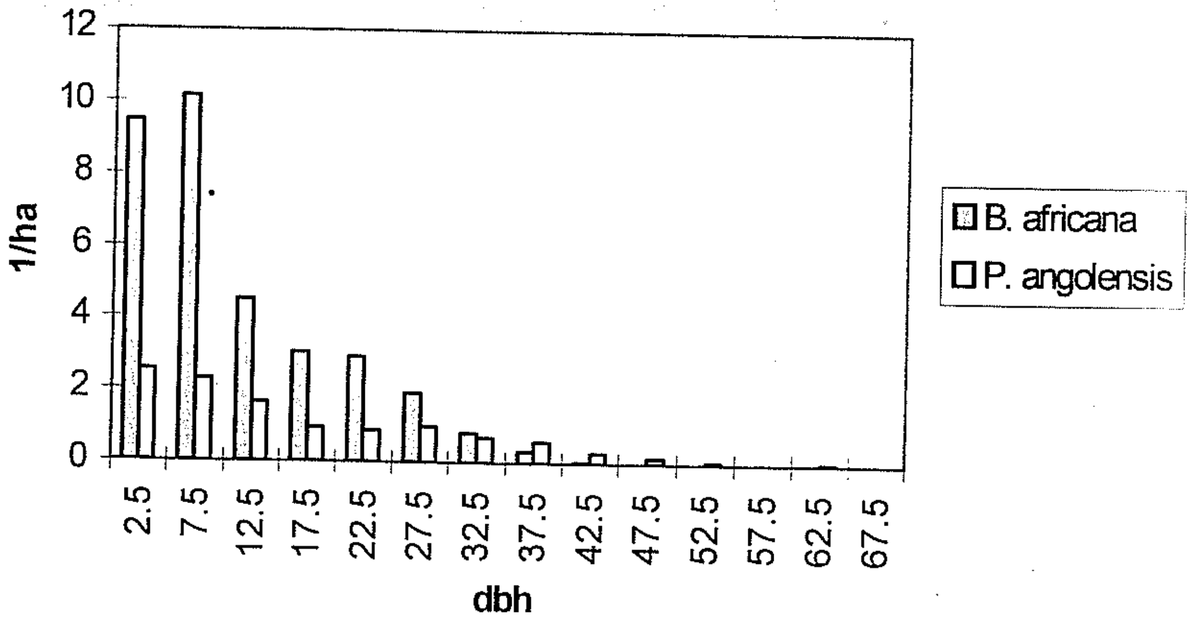
1a Tree cover > 0.1%	
2a shrub cover < 10%, if > 1m high	forest and woodland
3a tree cover > 75%	forest
4a tree height > 20m	high forest
4b tree height 11-20m	tall forest
4c tree height 5-10m	short forest
4d tree height < 5m	low forest
3b tree cover 11 - 75%	closed woodland
5a tree height > 20m	high closed woodland
5b tree height 11-20m	tall closed woodland
5c tree height 5-10m	short closed woodland
5d tree height < 5m	low closed woodland
3c tree cover 1 - 10%	open woodland
6a tree height > 20m	high open woodland
6b tree height 11-20m	tall open woodland
6c tree height 5-10m	short open woodland
6d tree height < 5m	low open woodland
3d tree cover < 1%	sparse woodland
5a tree height > 20m	high sparse woodland
5b tree height 11-20m	tall sparse woodland
5c tree height 5-10m	short sparse woodland
5d tree height < 5m	low sparse woodland
2b shrub cover > 10% and > 1 m high	thicket and bushland
8a tree cover > 10%	thicket
9a tree height > 5m	short thicket
9b tree height < 5m	low thicket
8b tree cover < 10%	bushland
10a tree height > 5m	short bushland
10b tree height < 5m	low bushland
1b Tree cover < 0.1%	
11a shrub cover >0.1%	shrubland
12a shrub cover > 10%	closed shrubland
13a shrub height > 2m	high closed shrubland
13b shrub height 1-2m	tall closed shrubland
13c shrub height < 1m	low closed shrubland
12b shrub cover 1 - 10%	open shrubland
14a shrub height > 2m	high open shrubland
14b shrub height 1-2m	tall open shrubland
14c shrub height < 1m	low open shrubland
12c shrub cover < 1%	open shrubland
15a shrub height > 2m	high sparse shrubland
15b shrub height 1-2m	tall sparse shrubland
15c shrub height < 1m	low sparse shrubland
11b shrub cover < 0.1 %	grassland and herbland

Appendix 4. Diameter class distributions of the most frequent species

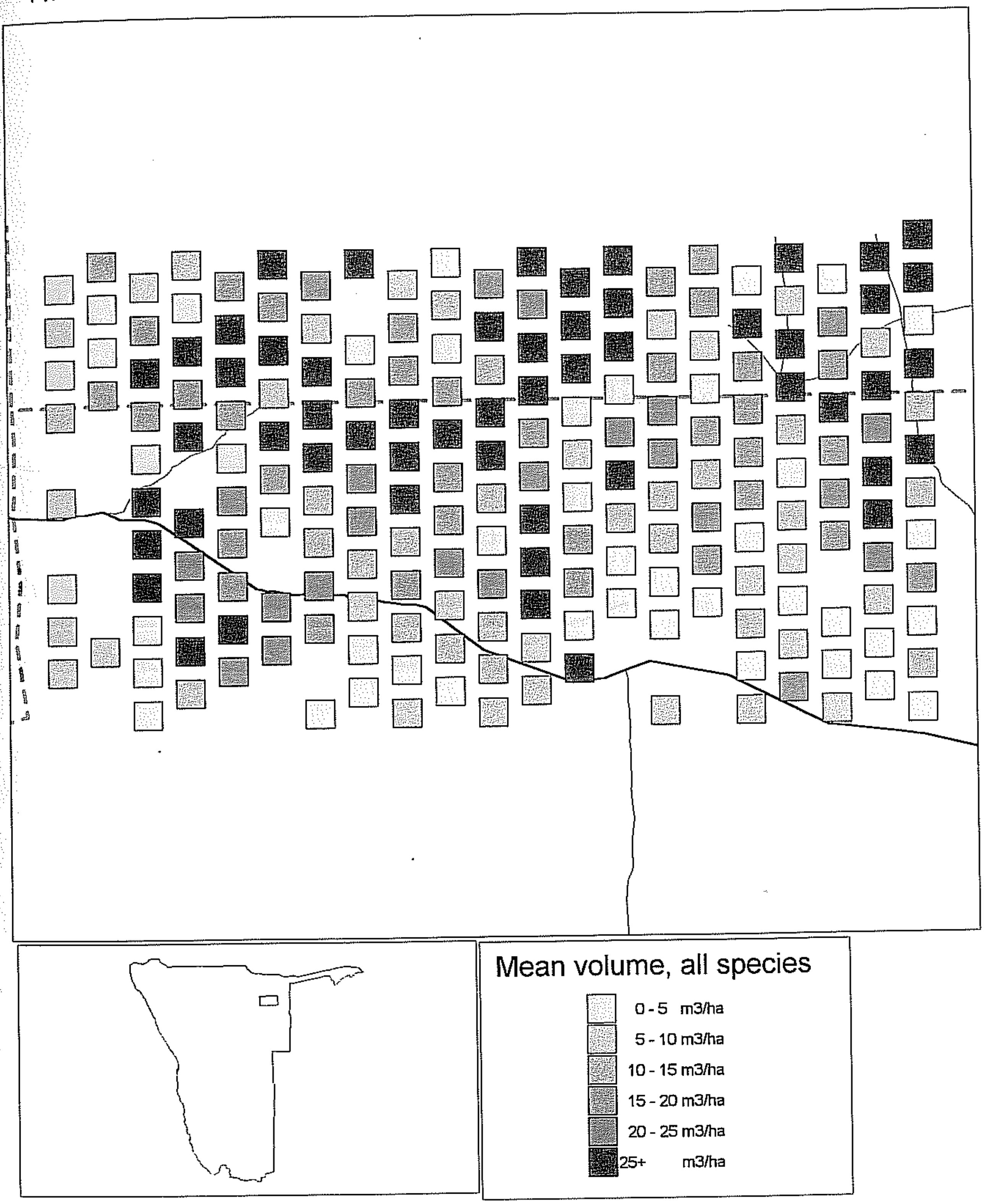
A. Combretum collinum and Terminalia sericea



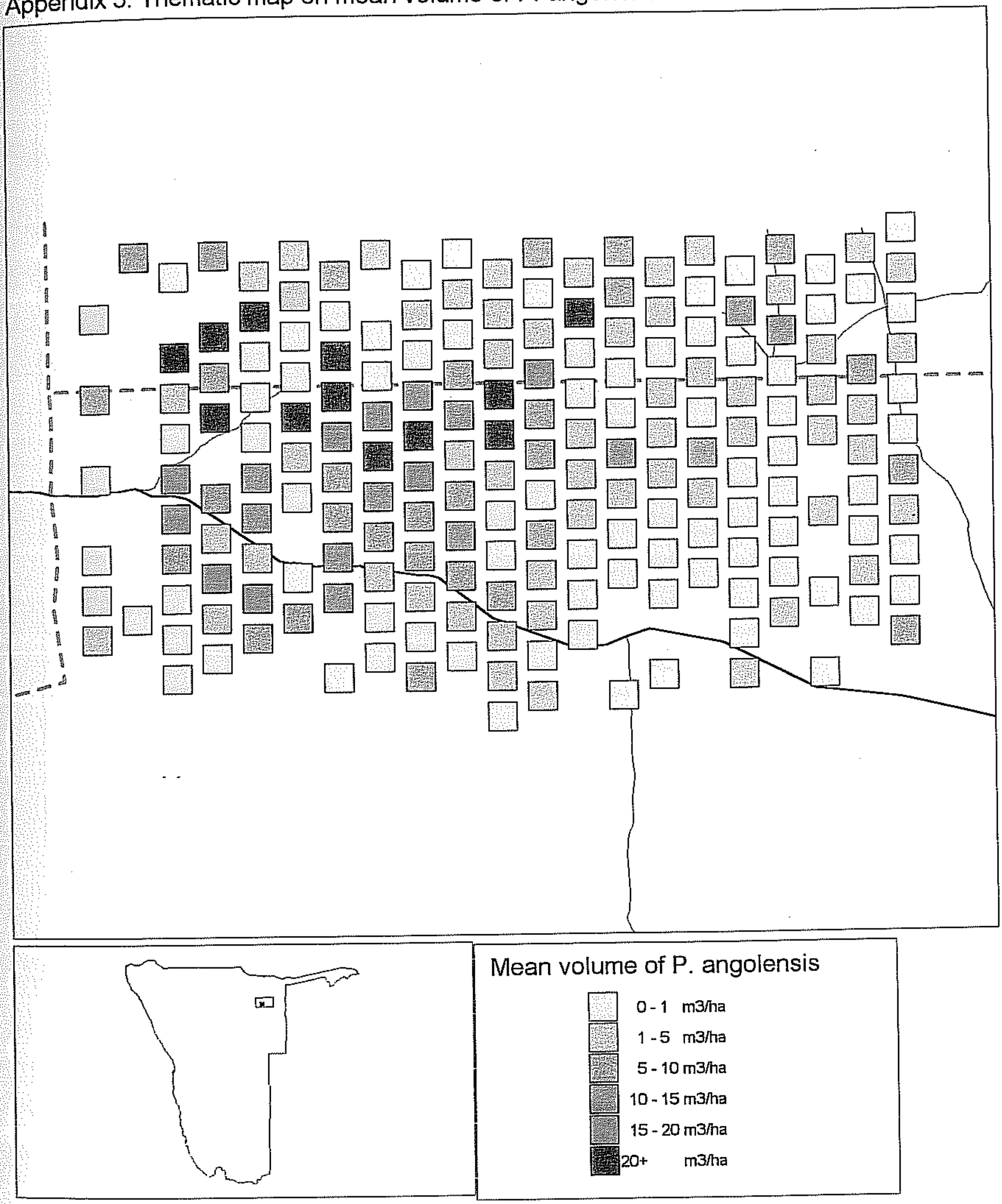
B. Burkea africana and Pterocarpus angolensis



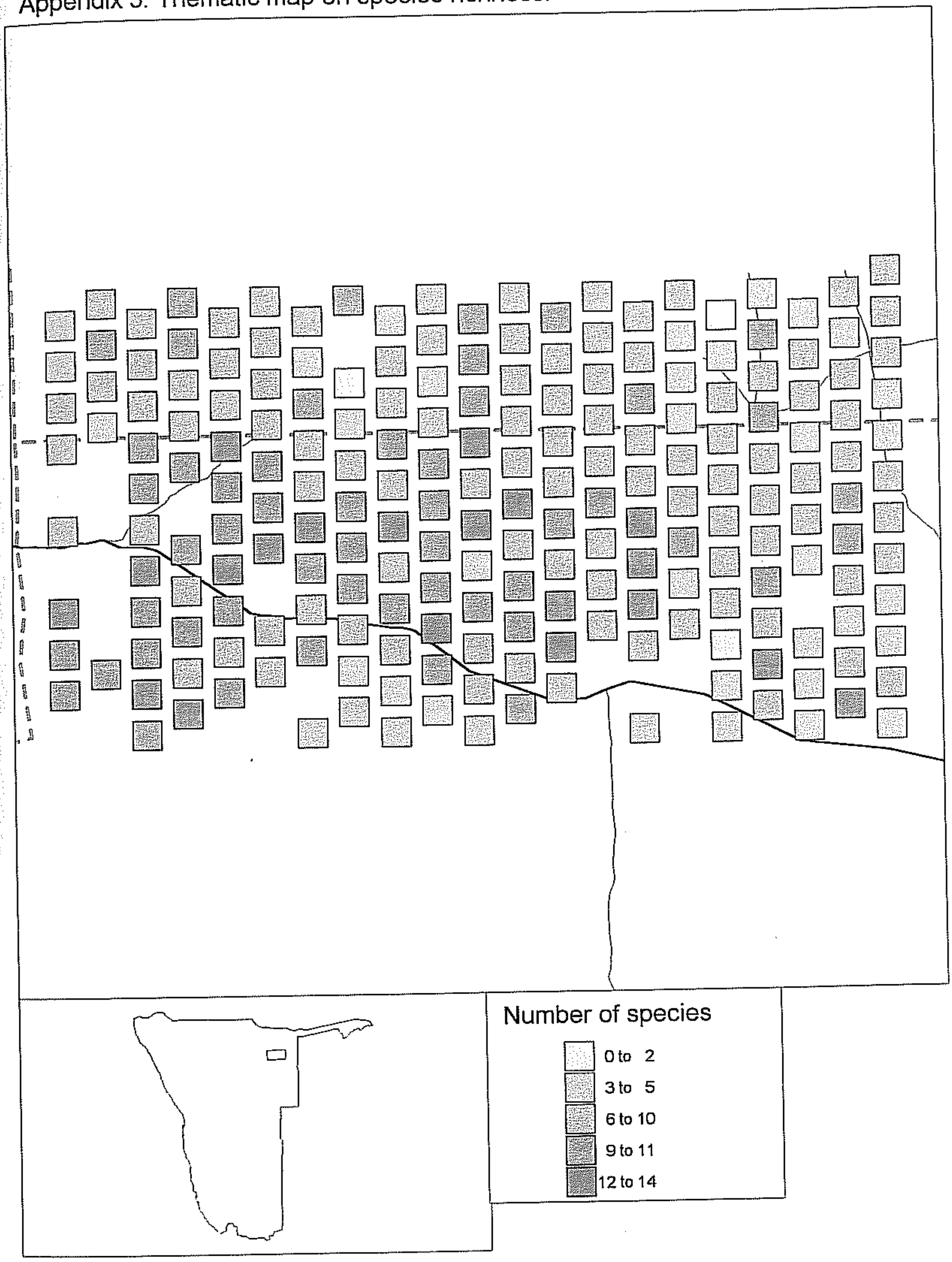
Appendix 5. Thematic map on mean volume.



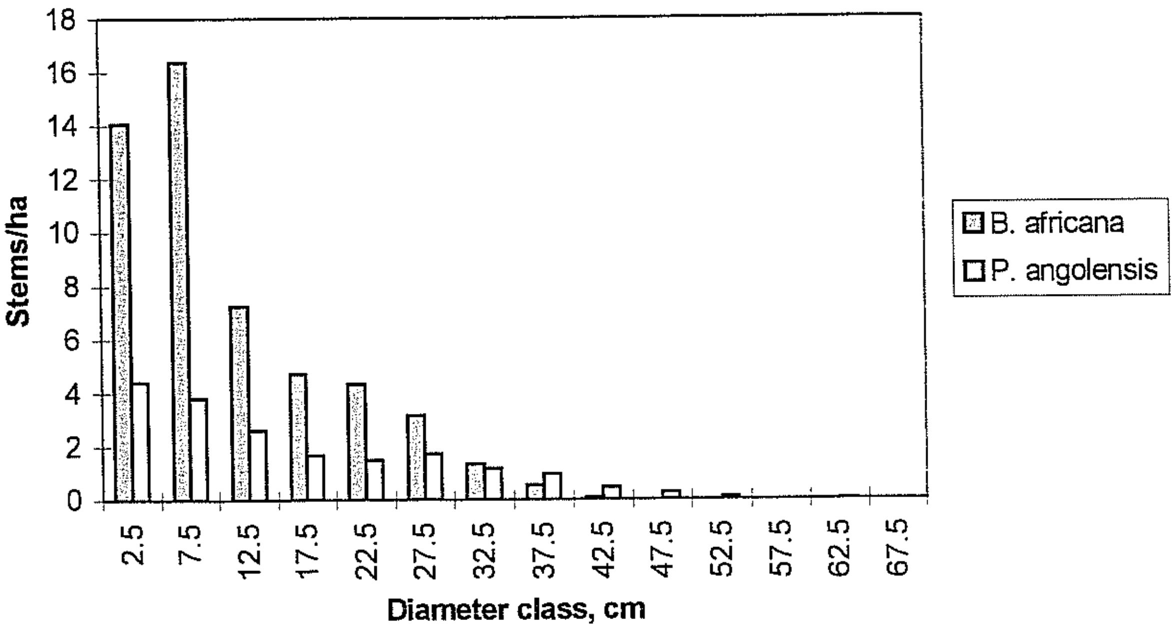
Appendix 5. Thematic map on mean volume of P. angolensis.



Appendix 5. Thematic map on species richness.



Appendix 6. Diameter distribution of Burkea africana and Pterocarpus angolensis on B. africana and P. angolensis woodlands.



Appendix 7. Acknowledgements

The successful completion of the Forest Inventory Exercise in Caprivi was a result of the cooperative efforts of the Steering Committee and many other individuals within the Directorate of Forestry and other institutions. The key personnel directly involved in the forest inventory project consisted of Directorate of Forestry and Government of Finland staff.

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