Growth of Trees from Namibia - A Dendrochronological Study

by

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A consultant study for the Directorate of Forestry/Namibia-Finland Forestry Program

Introduction

In the frame of the National Forestry Inventory in the North Eastern part of Namibia two series of stem discs from seven indigenous species were sent to the Institute of Forestry Botany of the University of Göttingen with the task of increment estimation of the individual trees. The first series was sent in December 1998 and consisted of 76 discs of different size. These discs were from trees in western Caprivi region and are in this report referred to as Katima Mulilo discs. Discs were sampled in June 1998. The species are:

- *Baikiaea plurijuga*
- *Burkea africana*
- *Colophospermum mopane*
- *Combretum collinum*
- *Lonchocarpus nelsii*
- *Pterocarpus angolensis*
- *Terminalia sericea*

As additional information the climate data of the Katima Mulilo station in Namibia from the sampling area was provided. The period of record is from 1945 to 1977 and from 1987 to 1997.

A second set of discs arrived Göttingen in December 2000. The species were identical with the first shipment. Number of discs were 68, 67 could be investigated, one disc was broken as consequence of a hollow stem with to little wood left for examination. Origin of these discs was the Oshikoto region.

The base of the tree ring analysis is the reaction of woody plants to seasonal varying growth conditions throughout the year. Under unfavourable conditions deciduous tree species shed their leaves but the majority (evergreen as well!) stops the wood growth, because of a cambial dormancy. The cambial activity (cell division) is reduced almost to zero in that periods. The result of declining cambial activity is the production of late wood. The new vegetative period starts with increasing cambial activity and the production of early wood. This alternation between early wood and late wood becomes visible as a growth ring (Worbes 1995, 1999).

Methods

The stem discs were polished completely with sand paper up to a grain of 600. The surface was examined macroscopically for the occurrence of growth zones and the delimitation of their boundaries. Examples of the growth zones were given in figures 1 and 2. After this examination selected growth zones were predated for the radiocarbon dating following Worbes (1995).

The base of the radiocarbon dating of recent tropical trees is the nuclear weapon effect. The method is described in Worbes & Junk (1989) and Worbes (1995). For the procedure individual growth zones were predated and small pieces of wood were sawn out. In the laboratory of Isotopes at the University of Göttingen the concentration of ^{14}C was estimated. Selection of the samples followed the attempt to find the growth zone in the vicinity of 1965, the absolute peak of atmospheric radiocarbon. This part of the analysis serves not only for the dating of the selected growth zones but mainly for the confirmation of the predating. When the predating is correct, in general the existence of annual rings can be assumed. Radiocarbon estimations were carried out in four *species Terminalia sericea, Burkea africana, Pterocarpus angolensis* and *Lonchocarpus nelsii* with three growth zones of different age in every species.

The diameter increment was obtained from ring counting on the largest radius where generally rings are most distinct and wedging rings occur less frequent in comparison with small diameters. A couple of discs, in some species the majority shows a more or less big proportion of rotten inner part. In these cases we measured the radius of the visible part of wood, counted the rings and calculated the mean growth. The lists with individual estimations are added separately in two excel files.

Macroscopical photographs were taken with a digital camera on a Leitz microscope for small magnifications.

Results

The difference between the two sets of stem discs was obviously with the naked eye. Whereas the set from Katima Mulilo consists in majority with intact stems discs showing e.g. in *Terminalia sericea* high increments, the set from Oshikoto consisted of many discs with a rotten center with again in *T. sericea* considerably lower increments (Plate 1, Appendix 1)

The first task is to proof the existence of annual rings in the provided samples. Despite the fact that the occurrence of annual tree rings in tropical and subtropical regions is shown since almost 100 years (Coster 1927, 1928) this is still not textbook knowledge. In particular the proofs are carried out among many other species for *Pterocarpus angolensis* growing in Zimbabwe somewhat Northeast from the Namibian sites (Stahle et al. 1999). This careful

study shows doubtless the seasonality of growth in *P. angolensis* in a comparable climate as in Namibia.

All samples from the Namibian study show more or less distinct growth rings. Examples are given in an attached sheet with macroscopically photos (Plate 2, Appendix 2). In most cases beneath other features initial parenchyma bands delimit the growth ring boundaries. In the Leguminosae and the Combretaceae periodical patterns of alternating parenchyma and fibre wood tissue serve additionally for the identification of the growth zone boundaries together with density variations (s. a. Worbes 1995).

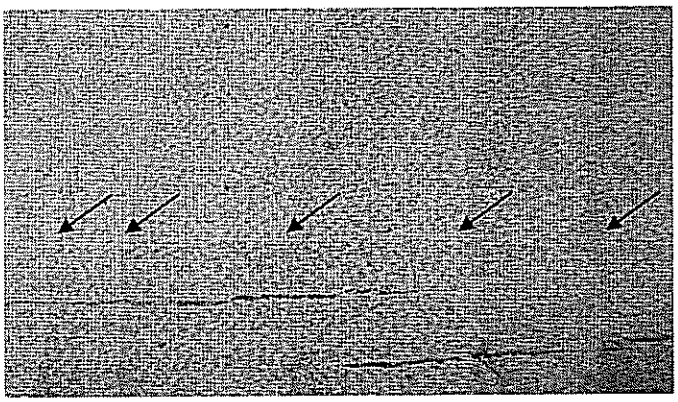

Fig. 1: Growth zones of Baikiaea plurijuga. Boundaries indicated by arrows.

The climate at the study site is extraordinary seasonal with a dry period of about five months and very little annual precipitation for tropical sites. Under these conditions the existence of annual rings is already very likely.

A common test for the existence of annual rings is the comparison between time series of precipitation and ring width patterns. Unfortunately there is a great lack within the precipitation time series in the most important recent period of more than ten years. Different measurement of ring width in *T. sericea* show similarities between the curves but a significant test requires longer overlapping sequences (fig. 2).

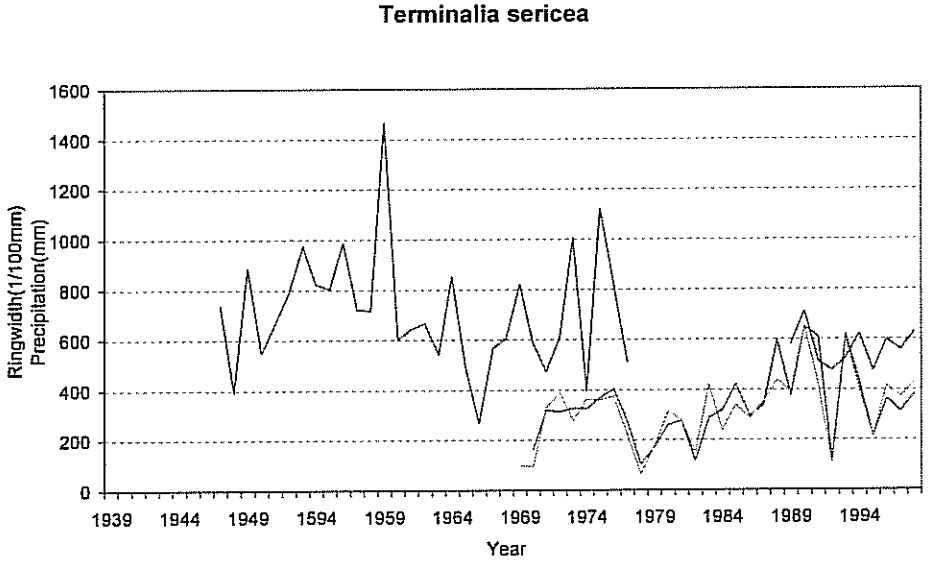

Figure 2: Time series of ring width of Terminalia sericea (red and green) and precipitation patterns (blue).

Therefore it was necessary to test the existence of annual rings with the above described radiocarbon dating. We compared the results of the radiocarbon estimations of the individually estimated growth zones with our predating and give examples in figure 3. From each tree three growth zones from different years were examined. The dating fit in the cases of *Terminalia sericea* and *Pterocarpus angolensis* exactly the curve of atmospheric radiocarbon in the southern hemisphere in the respective period. In *Burkea africana* there is a difference of one or two years between the predating (green) and the real age In *Lonchocarpus* there was a similar slight difference between the expected and the measured results. But this also might be in the margins of error of the measurements in the Isotopes Laboratory.

In total the results show doubtless the existence of annual rings in the investigated species and we conclude from the results of four species that the remaining three species show in the identical climate annual rings as well. So it was possible to estimate the mean annual diameter increment by carefully counting the rings and measuring the mean diameter of the discs. If there is any error the tendency seems to be that some rings had been overlooked. The increment rates therefore could imply in the case of *Lonchocarpus, Combretum, Colophospermum and Baikiaea* a slight overestimation of few percent in the range of the given standard deviation.

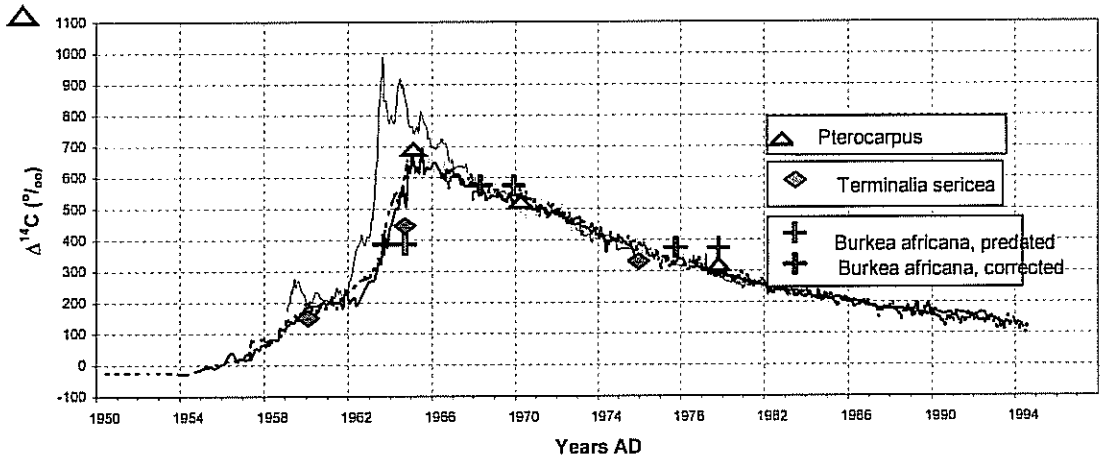

Figure 2 - Δ14C in the Sothern Hemisphere at middle latitudes. Lines and dots represent atmospheric and tree-ring data, respectively. Error bars are too small to be shown, from Hua et al 1999, and Radiocarbon estimations from individual growth zones from Namibian trees.

Vienna, Austria 47°N, 16°E, 1950-1983)(Levin et al. 1994) ..... Fianarantsoa, Mada

——— Wellington, New Zealand 41°18'S, 174°48'E (1954-1993)(Manning & Melhuish, 1994) - - - - - Pretoria, South Afric

Figure 3: D14C in the Southern Hemisphere at middle latitudes. Lines and dots represent atmospheric and tree-ring data, respectively. Error bars are too small to be shown, from (Hua et al 1999), and Radiocarbon estimations from individual growth zones from Namibian trees

Most species with exception of *Colophospermum mopane* and *Pterocarpus angolensis* show faster growth at the Katima Mulino site in comparison with the Oshikoto site. Highest individual increments we found for *Terminalia sericea* in a 10 years old tree from the Katima Mulino site (see Appendix 3). It is to be assumed that this tree grew under good light conditions without competition with neighbouring trees. The values for *P. angolensis* are in between those from two sites in Zimbabwe (Stahle et al. 1999). Most values are in the range of studies from other sites in tropical forests (Worbes 1997).

Table 1: Mean annual diameter increment of different species in cm at the two study sites in Namibia. For comparison growth data of *P. angolensis* from Zimbabwe (Stahle et al. 1999).

	Katima Mulino		**Oshikoto**		**Zimbabwe***	
Species	**Mean**	Stand.dev	**Mean**	Stand.dev.	Site 1	Site 2
Baikiaea pluriguga	**0,37**	0,08	**0,26**	0,05		
Burkea africana	**0,40**	0,08	**0,29**	0,05		
Colophospermum mopane	**0,17**	0,03	**0,22**	0,08		
Combretum collinum	**0,29**	0,08	**0,26**	0,09		
Lonchocarpus nelsii	**0,46**	0,08	**0,29**	0,08		
Pterocarpus angolensis	**0,34**	0,09	**0,37**	0,07	**0,29**	**0,41**
Terminalia sericea	**0,61**	0,20	**0,22**	0,07		

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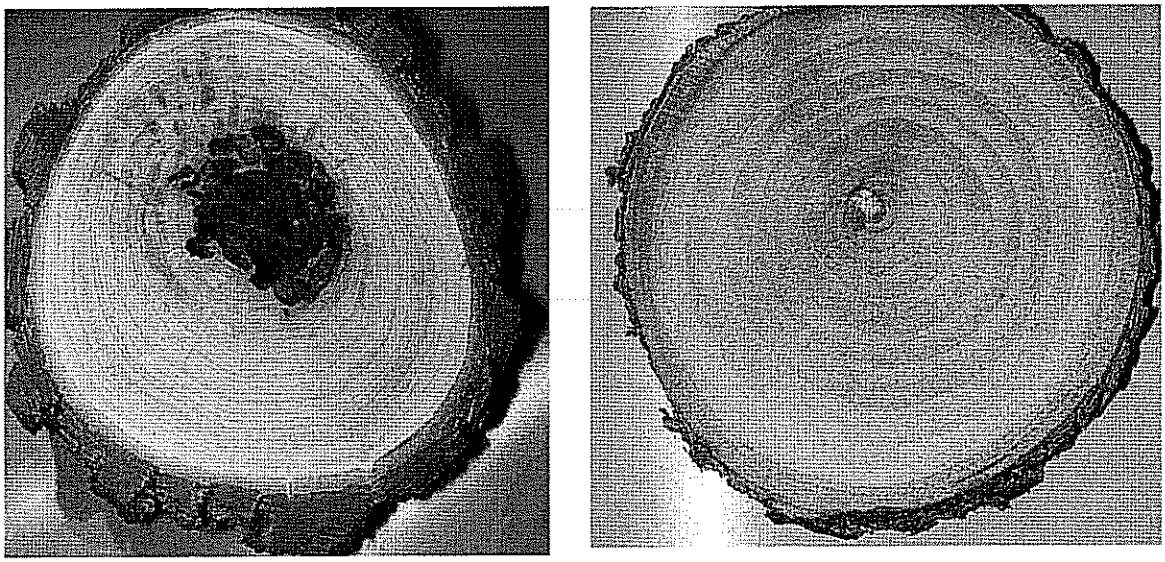
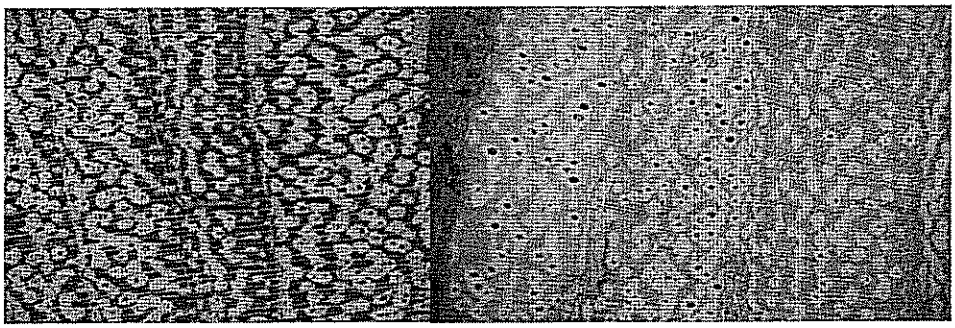
APPENDIX 1: Plate 1
Terminalia sericea from Oshikoto (left) and Caprivi (right), both 10 cm in diameter. The left was more than 30 years old, the right was 10 years old

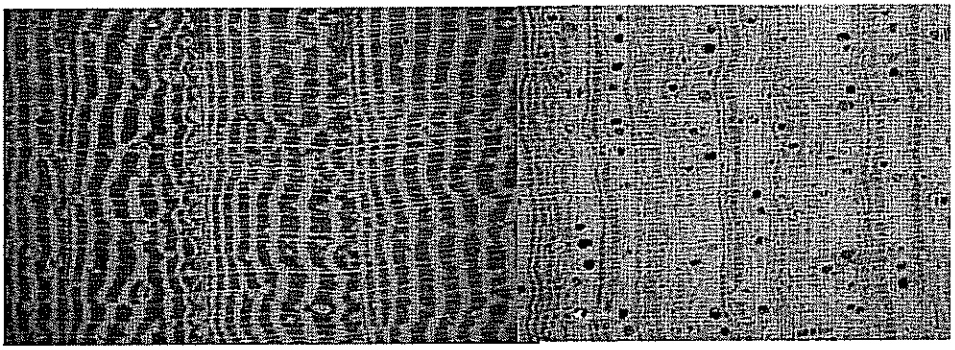


APPENDIX 2: Plate 2

Cross sections with tree rings of different tree species from Namibia



Burkea (left), Combretum (right)



Lonchocarpus (left, Pterocarpus (right)

APPENDIX 3: RESULTS FROM THE ANALYSIS OF THE CAPRIVI DISCS

ANALYSIS OF THE DISCS FROM CAPRIVI

(1)	(2)	(3)	(4)	(5)	(6)		(8)	(9)	(7)
Species	**Sample**	**Mean diameter (cm)**	**Length measured radius (cm)**	**No Rings**	**Mean diameter increment (cm) (3):(5) resp [2x(4)]:(5)**	**Deviation diameter increment**	**Height of tree (dm)**	**Date of sampling**	**Remark**
Lonchocarpus nelsii	25 (55?)	10.5		31	0.338709677		70	35988	
Lonchocarpus nelsii	67	33		71	0.464788732		174	36021	
Lonchocarpus nelsii	78	32		56	0.571428571		125	36021	14C-samples
Lonchocarpus nelsii	81	18		34	0.529411765		68	36023	
Lonchocarpus nelsii	83	28		59	0.474576271		160	36025	
Lonchocarpus nelsii	84	20.5		50	0.41		126	36025	
Lonchocarpus nelsii mean	**78.6**	**23.6666667**		**50.16667**	**0.46481917**	**0.083116443**	**120.5**		
Terminalia sericea	33	16.5		28	0.589285714		106	35965	
Terminalia sericea	34	15.5		30	0.516666667		34	35965	
Terminalia sericea	35	36		79	0.455696203		140	35965	Hollow stem
Terminalia sericea	38	35		74	0.472972973		50	35960	
Terminalia sericea	39	20.5		56	0.366071429		122	35960	
Terminalia sericea	42	49		64	0.765625		102	35967	Hollow stem
Terminalia sericea	43	10.5		10	1.05		63	35967	
Terminalia sericea	44	11		23	0.47826087		69	35967	
Terminalia sericea	45	29.5		67	0.440298507		90	35968	
Terminalia sericea	46 ?		19	62	0.612903226		119	35968	14C-sample, Hollow stem
Terminalia sericea	47	39	25	56	0.892857143		124	35968	
Terminalia sericea	48	56	27	86	0.627906977		128	35968	Hollow stem
T. sericea mean		**28.9545455**		**52.91667**	**0.605712059**	**0.203451348**	**95.58333333**		

Species	Sample	Mean diameter (cm)	Length measured radius (cm)		No Rings	Mean diameter increment (cm) (3):(5) resp [2x(4)]:(5)	Deviation diameter increment	Height of tree (dm)	Date of sampling	Remark
Burkea africana	27	20			73	0.273972603		148	35965	
Burkea africana	28	21			67	0.313432836				
Burkea africana	29	24			56	0.428571429		110	35963	14C-samples
Burkea africana	36	18.5			65	0.284615385		79	35963	
Burkea africana	40	11.5			25	0.46		72	35966	
Burkea africana	41	12.5			30	0.416666667		75	35966	
Burkea africana	88	43			87	0.494252874		179	36028	
Burkea africana	89	34			76	0.447368421		89	36028	
Burkea africana	92A	42			79	0.53164557		184	36030	
Burkea africana	92B	32			89	0.359550562		184	36030	
Burkea africana	90	38			99	0.383838384		144	35963	
Burkea africana	91	51			135	0.377777778		148	35963	
Burkea africana mean		**28.9583333**			**73.41667**	**0.397641042**	**0.08911193**	**128.3636364**		
Combretum collinum	2	31		13	95	0.273684211		135	35934	
Combretum collinum	8	16.5			71	0.232394366		92	35936	
Combretum collinum	16	37		11	68	0.323529412		139	35938	Center rotten
Combretum collinum	17	26		12	74	0.324324324		107	35938	Center rotten
Combretum collinum	18	17			70	0.242857143		108	35938	
Combretum collinum	19	10.5			56	0.1875		59	35938	Center rotten
Combretum collinum	64	10			49	0.204081633		89	35994	
Combretum collinum	65	36		18	115	0.313043478		146	35994	Center rotten
Combretum collinum	68	45			101	0.445544554		159	35997	
Combretum collinum		23		11	67	0.328358209		106	35936	Center rotten
Combretum collinum mean		**25.2**		**13**	**76.6**	**0.287531733**	**0.076108985**	**114**		

Species	Sample	Mean diameter (cm)	Length measured radius (cm)	No Rings	Mean diameter increment (cm) (3):(5) resp [2x(4)]:(5)	Deviation diameter increment	Height of tree (dm)	Date of sampling	Remark
Baikiea plurijuga	1	46.5		122	0.381147541		162	35933	
Baikiea plurijuga	4A	30.5	13	70	0.371428571		172	35935	
Baikiea plurijuga	5	20.5	13.5	78	0.346153846		115	35933	
Baikiea plurijuga	6	32		87	0.367816092		74	35933	
Baikiea plurijuga	7	10		49	0.204081633		74	35933	
Baikiea plurijuga	10	19.5		38	0.513157895		110	35933	
Baikiea plurijuga	11	30		73	0.410958904		152	35933	
Baikiea plurijuga	21	60		179	0.335195531		180	35939	
Baikiea plurijuga	22	30.5	19.5	85	0.458823529		113	35939	
Baikiea plurijuga	23	23	10	48	0.416666667		131	35940	
Baikiea plurijuga	24A	35		113	0.309734513		148	35940	
Baikiea plurijuga mean		**30**	**14.75**	**84**	**0.374105884**	**0.07573596**	**122.75**		
Pterocarpus angolensis	25	28.5		66	0.431818182		126	35963	14C-samples
Pterocarpus angolensis	28	22.5		57	0.394736842		131	35963	
Pterocarpus angolensis	30	37		84	0.44047619		130	35964	
Pterocarpus angolensis	42	18		73	0.246575342				
Pterocarpus angolensis	49	11.5		47	0.244680851		76	35970	
Pterocarpus angolensis	50	7		20	0.35		67	35970	
Pterocarpus angolensis	87	39	26	156	0.25		173	35970	
P. angolensis mean		**22.0714286**	**14.75**	**61.57143**	**0.336898201**	**0.088946355**	**108.7916667**		

Species	Sample	Mean diameter (cm)	Length measured radius (cm)	No Rings	Mean diameter increment (cm) (3):(5) resp [2x(4)]:(5)	Deviation diameter increment	Height of tree (dm)	Date of sampling	Remark
Colophospermum mopane	14	16		101	0.158415842		98	35998	
Colophospermum mopane	15	23		107	0.214953271				
Colophospermum mopane	50	12		74	0.162162162		73	35987	
Colophospermum mopane	51	15		120	0.125		82	35987	
Colophospermum mopane	52	11		91	0.120879121		79	35987	
Colophospermum mopane	53	15		92	0.163043478		73	35988	
Colophospermum mopane	54	16		104	0.153846154		99	35988	
Colophospermum mopane	60	42.5	17	197	0.215736041				
Colophospermum mopane	14		3	38	0.157894737				
Colophospermum mopane	15		3	30	0.2				
Colophospermum mopane	50		4	36	0.222222222				
Colophospermum mopane	51		3.5	48	0.145833333				
Colophospermum mopane	52		2.5	38	0.131578947				
Colophospermum mopane	53		4	44	0.181818182				
Colophospermum mopane	54		3	45	0.133333333				
Colophospermum mopane	60		3.5	40	0.175				
Colophospermum mopane mean		**21.125**	**4.83333333**	**66.91667**	**0.166357301**	**0.032849268**	**83.66666667**		

APPENDIX 4: RESULTS FROM THE ANALYSIS OF THE OSHIKOTO DISCS

Sample No	species	No of rings	diameter	radius	center rotten	diameter	remark	diameter	annual increment
		N	in cm	in cm		Kernfäule in cm		measured	
45	Baikaea pluriguga	127	33	19	0	0	funghus in center	33	0.25984252
46	Baikaea pluriguga	99	30	15.5	0	0		30	0.303030303
47	Baikaea pluriguga	60	13.5	9	0	0	two centers, diameter 38 cm	13.5	0.225
48	Baikaea pluriguga	119	42	18	0	0	3 centers	42	0.352941176
49	Baikaea pluriguga	65	34	11	1	13.5		20.5	0.315384615
50	Baikaea pluriguga	168	47	31	0	0		47	0.279761905
51	Baikaea pluriguga	98	26	15.5	0	0		26	0.265306122
52	Baikaea pluriguga	54	12.5	8	0	0		12.5	0.231481481
56	Baikaea pluriguga	67	14	8.8	0	0		14	0.208955224
57	Baikaea pluriguga	68	13	8.3	0	0		13	0.191176471
1	Burkea africana	70	29	7.5	1	16		13	0.185714286
7	Burkea africana	43	12	5	0	0		12	0.279069767
9	Burkea africana	106	38	16	1	18		20	0.188679245
16	Burkea africana	72	32	8	1	15		17	0.236111111
17	Burkea africana	112	30	16	1	6		24	0.214285714
22	Burkea africana	41	10	6,4	0	0		10	0.243902439
23	Burkea africana	37	10,5	5,7	0	0		#VALUE!	#VALUE!
24	Burkea africana	29	8	4,3	0	0		8	0.275862069
25	Burkea africana	65	19	10	0	0		19	0.292307692
27	Burkea africana	60	24	10	1	3		21	0.35
40	Burkea africana	38	12,5	6,3	0	0		#VALUE!	#VALUE!
42	Burkea africana	115	41	19	1	2.5		38.5	0.334782609
58	Burkea africana	122	42	22.5	1	1.5		40.5	0.331967213
59	Burkea africana	93	39	13.5	1	10.5		28.5	0.306451613
60	Burkea africana	188	54	32	0	0		54	0.287234043
74	Burkea africana	152	57	50	0	0		57	0.375

Sample No	species	No of rings	diameter	radius	center rotten	diameter	remark	diameter	annual increment
11	Cholospermum mopane	171	33	19.5	0	0	two centers, diameter 41 cm	33	0.192982456
12	Cholospermum mopane	75	23	10	0	0	3 centers, diameter 11;17,5; 10	23	0.306666667
62	Cholospermum mopane	180	32	16	1	4		28	0.155555556
2	Combretum collinum	48	9	4.5	0	0		9	0.1875
3	Combretum collinum	36	14	6	1	7		7	0.194444444
6	Combretum collinum	64	13	8	0	0		13	0.203125
10	Combretum collinum	91	19	10	1	3.5		15.5	0.17032967
14	Combretum collinum	52	14	6	1	2		12	0.230769231
19	Combretum collinum	58	10	6.2	0	0		10	0.172413793
28	Combretum collinum	80	35	16	1	6		29	0.3625
37	Combretum collinum	53	23	9.5	1	2		21	0.396226415
38	Combretum collinum	66	22	11.5	0	0		22	0.333333333
39	Combretum collinum	112	27.5	14	0	0		27.5	0.245535714
41	Combretum collinum	66	37.5	11	1	22		15.5	0.234848485
71	Combretum collinum	112	60	29	1	13		47	0.419642857
72	Combretum collinum	199	53	32	0	0		53	0.266331658
53	Lonchocarpus nelsii	101	35	21	0	0		35	0.346534653
55	Lonchocarpus nelsii	84	25	13	0	0		25	0.297619048
61	Lonchocarpus nelsii	50	17	9.5	0	0		17	0.34
63	Lonchocarpus nelsii	94	38	20	1	0.5	two centers	37.5	0.39893617
66	Lonchocarpus nelsii	66	15	6.3	1	3		12	0.181818182
67	Lonchocarpus nelsii	53	11	5.8	0	0		11	0.20754717
68	Lonchocarpus nelsii	49	11	6.4	0	0		11	0.224489796
26	Pterocarpus angolensis	123	36	18.3	0	0		36	0.292682927
31	Pterocarpus angolensis	123	54	30	0	0		54	0.43902439
32	Pterocarpus angolensis	117	42.5	21	0	0		42.5	0.363247863
33	Pterocarpus angolensis	85	39.5	18	1	8		31.5	0.370588235
34	Pterocarpus angolensis	31	11	6	0	0		11	0.35483871
35	Pterocarpus angolensis	103	28	15	0	0		28	0.27184466

Sample No	species	No of rings	diameter	radius	center rotten	diameter	remark	diameter	annual increment
36	Pterocarpus angolensis	72	22	12	0	0		22	0.305555556
54	Pterocarpus angolensis	130	61	31.5	0	0		61	0.469230769
64	Pterocarpus angolensis	51	22	12.5	0	0		22	0.431372549
13	Terminalia sericea	46	9.75	4.3	1	2		7.75	0.168478261
15	Terminalia sericea	50	13.5	4.7	1	6		7.5	0.15
18	Terminalia sericea	56	16	5.2	1	5		11	0.196428571
20	Terminalia sericea	59	11,5	6,6	0	0		#VALUE!	#VALUE!
21	Terminalia sericea	68	10.5	7	1	1		9.5	0.139705882
29	Terminalia sericea	48	14	9.7	1	1		13	0.270833333
43	Terminalia sericea	51	30	14	1	17		13	0.254901961
44	Terminalia sericea	72	24.5	13	0	0		24.5	0.340277778
65	Terminalia sericea	50	15	13	0	0		15	0.3