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VARIATION IN TIME AND SPACE OF LEAF AREA INDEX IN A ZAMBESIAN OPEN FOREST OF WETTER MIOMBO TYPE (LUBUMBASHI, ZAIRE) [1]

Variation temporelle et spatiale de l'indice de surface foliaire d'une forêt claire zambézienne de type miombo humide (Lubumbashi, Zaïre)

F. MALAISSE *

RÉSUMÉ

Une forêt claire à Julbernardia paniculata *et* Brachystegia boehmii *des environs de Lubumbashi a été étudiée pendant une année. Son indice de surface foliaire maximale est de 3,07 et le rapport entre valeur maximale et valeur minimal est de 3,72. Ces résultats sont discutés et comparés aux autres valeurs publiées pour les forêts tropicales.*

ABSTRACT

An open forest dominated by Julbernardia paniculata *and* Brachystegia boehmii *has been observed for twelve months. Maximum value of L.A.I. is 3.07, ratio between maximum and minimum is 3.72. These results are discussed as compared with other values available for tropical forests.*

INTRODUCTION

Data available regarding leaf area index (L.A.I., i.e. the ratio of total leave surface - one side - of plants of a plot to the plot's surface) of tropical forests have been discussed recently by ALEXANDRE (1981) on the basis of a literature analysis. This author distinguishes four different approaches (optimal means, leaf biomass, allometric methods and results derived from litterfalls) and considers that the L.A.I. of tropical rain forests seems fairly constant and can be assigned a maximal annual value of 8.2, whilst structural heterogeneity and seasonality are important sources of variability.

[1] Note 61 of the "Contribution to the study of the open forest ecosystem (Miombo)"

* Laboratoire d'Ecologie, Phytogéographie et Phytosociologie - Faculté des Sciences Agronomiques de l'Etat - B-5800 Gembloux, Belgique.

Lastly the analysis of ALEXANDRE (1981) pinpoints the variation of specific leaf surface according to their position in crown (KATO *et al.*, 1978) and the consequently importance of sampling. The lack of seasonal or monthly values of L.A.I. appears clearly, with the exception of two measurements conduced by GOLLEY and its team at Panama, respectively during dry and rainy season (GOLLEY *et al.*, 1975). Recently bimensual values of L.A.I. have been published for a Zambezian dry evergreen forest (MALAISSE, 1984).

The woodlands, which cover 2,864,650 km^2 or 9.1 % of Africa in the Zambezian region alone, according to the A.E.T.F.A.T. map (WHITE, 1981) are found in no less than 8 countries (Angola, Zambia, Mozambique, Tanzania, Zaire, Zimbabwe, Malawi and Burundi). In the Zambezian region four main types of woodlands may be recognized, namely :

	Area (km^2)	% age of the Zambezian region
Wetter Zambezian miombo open forest	1 239,975	33.35
Drier Zambezian miombo open forest	730,875	19.66
Colophospermum mopane woodland	354,900	9.54
Undifferentiated open forest and woodland	538,900	14.49
North Zambezian	(247,500)	(6.65)
South Zambezian	(136,575)	(2.89)

The wetter Zambezian miombo open forest ecosystem has been the subject of many studies, which have been reviewed recently (MALAISSE, 1978). Although data relating to leaf size, anatomy, sclerophylly and light troughfall (MALAISSE *et al.*, 1982; VAN DER MEULEN & WERGER, 1984), to leaf biomass (MALAISSE *et al.*, 1972) and to litterfall (MALAISSE *et al.* 1975) are available, data on the leaf area index are lacking. This paper proposes to remedy this deficiency.

MILIEU

The macroclimate of the Lubumbashi region is characterized by a wet season (November to March), a dry season (May to September) and two transition months (October and April). The annual precipitation is ca. 1.270 mm, but large differences occur from year to year (716 to 1.758 mm). Half the daily precipitations are less than 5 mm, but these represent less than 10 per cent of the total rainfall; daily rainfalls exceeding 50 mm represent 24 per cent of the total and occur on 4.3 days a year. On average there are 118 rainy days.

The average temperature is ca. 20° C. It is lowest at the beginning of the dry season (mid-May to mid-July). The night minimum is most frequently ca. 06.00 h. Absolute minima of 0° C are very rare but occur some years. October, or sometimes November, is the hottest month with a daily maximum of 31-33° C. The daily thermal range is small in the wet season and large in the dry season. The humidity of the air depends on the rainfall; it is minimal in October and maximal in February. The annual global radiation is 16.8 x 10^9 kcal/ha, of which 61 per cent is as direct radiation.

The climate belongs to Koppen's Cw type, with a dry season lasting an average of 186 days and an average rainfall of 1,270 mm.

Observations were made in the Miombo at the Kasapa, an open forest dominated by *Julbernardia paniculata* and *Brachystegia spiciformis*, 9 kms NE of Lubumbashi, and whose floristic composition (MALAISSE & MALAISSE-MOUSSET, 1970) as well as its transect (MALAISSE, 1976) have been described elsewhere.

METHODS

We have distinguished between the woody layers (tree and shrub layer) and the grass layer. The methods used differ according to the layer studied.

Woody layers

Several methods were used. They differ according to the composition of the open forest; namely monospecific type composed of diverse *Brachystegia*, notably *B. boehmii*, and mixed open forest where numerous tree species are observed.

Monospecific type : On a plot almost entirely dominated by *Brachystegia boehmii*, an average tree was chosen. It was felled and various characteristics were established, among which the total number of leaves. The total leaf area is deduced from density per hectare of trees in relation to the average specimen chosen.

Mixed type : A plot of 25 m x 25 m was chosen for study purposes. During the rainy season, the total number of leaves of each individual in the woody layers was established by a continual count of each of the branches. This work was undertaken from ground level for shrubs and small trees, and by climbing into the canopy for trees. These values are used to establish the leaf area.

Several methods were proposed for the estimation of leaf area, namely photoplanimetry (VAN SEVEREN, 1969), planimetry by correlation which consists in establishing linear regression equations based on the product of the lamina's lenght x width and the comparison with standards (leaf image) (HELLER, 1971). We proceeded as follows. Leaves were collected at random at different heights of the crown foliage. In the case of compound leaves, on a sample of 1000 leaves, we firstly established the average number of leaflets. Then, for simple leaves and for leaflets, we established a diagram covering the frequency of the lenght relationship of the lamina from a sample of 500-1000 leaves, taking into account the variability of these dimensions. Figure 1 shows the stereogram thus obtained for *Parinari curatellifolia*.

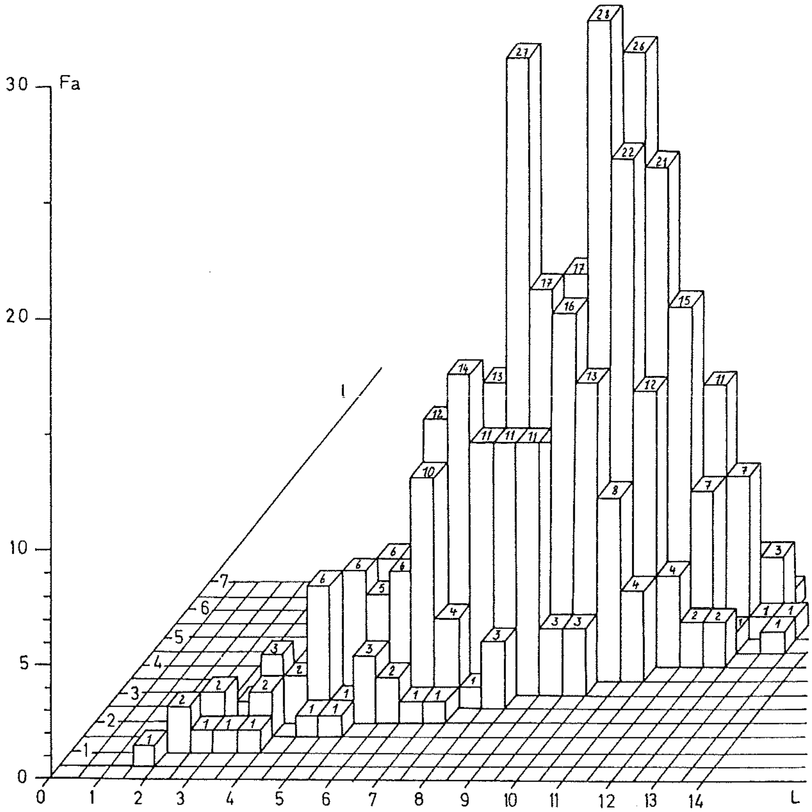

Fig. 1 : Stereogram obtained for 500 leaves of *Parinari curatellifolia* from the Kasapa miombo open forest.

The average area of each cell in the bivariata frequency table is calculated either by planimetry (in the case of irregularly shaped leaves) or by assimilation (with, in general, a correction factor) for simple geometric forms, mainly an ellipse. From this last value and the number of the cell we deduce the mean area of the lamina for each of the species considered. For vertical repartition, the leaf numbers per metre height was established for each individual. We did not take into account an eventual difference in leaf size according to position in the canopy.

For time variation, for each species, all the leaves on several test branches were counted on the 1st and 15th of each months. The values obtained on February 1st act as a reference. For species that lose all their leaves, this method presents no difficulties, as long as it is used from one defoliation period to the next. For evergreen species it is necessary to adjust the results. In the budding period, the mean leaf area was established each week.

Grass layer

20 plots of 1 m^2 were sample each week. They were sorted into biomass and necromass as well as into monocotyledons and dicotyledons. The leaf area of a fresh sample of material collected towards the middle of the months was mesured and afterwards dried, and this ratio matched with weekly dry matter weight for the two biomasses respectively.

RESULTS

A. Woody layers

Monospecific type

The quick method used allowed us to establish a preliminary estimation for the main rainy season (MALAISSE *et al.*, 1972), i.e. 2,129,000 leaves of *Brachystegia boehmii* per hectare, this forming 2,600 kgs dry of matter and a leaf area index of 3.47.

Species	Total number of leaves	Mean weight of one leaf (g dry matter)	Biomass (g dry matter)	Average area of one leaf (cm^2)	Leaf area (m^2)
1. *Albizia adianthifolia*	3 909	1.304	5 097	218.19	85.29
2. *Anisophyllea boehmii*	31 183	0.130	4 054	15.42	48.08
3. *Baphia bequaertii*	8 794	0.272	2 392	30.34	26.69
4. *Brachystegia boehmii*	16 663	2.129	35 476	235.13	391.79
5. *Brachystegia spiciformis*	27 674	1.089	30 137	109.94	304.25
6. *Diplorhynchus condylocarpon*	1 995	0.217	433	19.54	3.90
7. *Ficus dekdekena*	6 545	0.239	1 564	14.70	9.62
8. *Julbernardia paniculata*	26 287	2.037	53 547	243.66	640.50
9. *Monotes africanus*	34 261	0.103	3 529	23.97	82.12
10. *Monotes katangensis*	4 788	0.825	3 950	41.24	19.75
11. *Ochna schweinfurthiana*	4 071	0.311	1 266	17.86	7.27
12. *Parinari mobola*	29 535	0.394	11 637	29.48	87.07
13. *Pavetta schumaniana*	4 178	0.137	572	14.23	5.95
14. *Pericopsis angolensis*	751	0.855	642	132.14	9.92
15. *Pterocarpus angolensis*	884	2.242	1 982	178.09	15.74
16. *Schwartzia madagascariensis*	3 184	0.948	3 018	89.87	28.62
17. *Syzygium macrocarpum*	7 623	0.580	4 421	34.07	25.97
18. *Tapinanthus erianthus*	1 725	0.120	207	6.04	1.04
19. *Uapaca kirkiana*	575	1.143	657	127.89	7.35
20. *Uapaca nitida*	3 714	0.601	2 232	44.83	16.65
21. *Uapaca pilosa*	812	0.999	811	183.19	14.88
Total for the experimental plot (1/16 ha)	219 151		167 625		1 832.45
Values per hectare	3 506 416		2 682 003		29 319.04

Table I : Numbers of leaves, leaf area and leaf biomass of the Kasapa miombo (February, 1977).

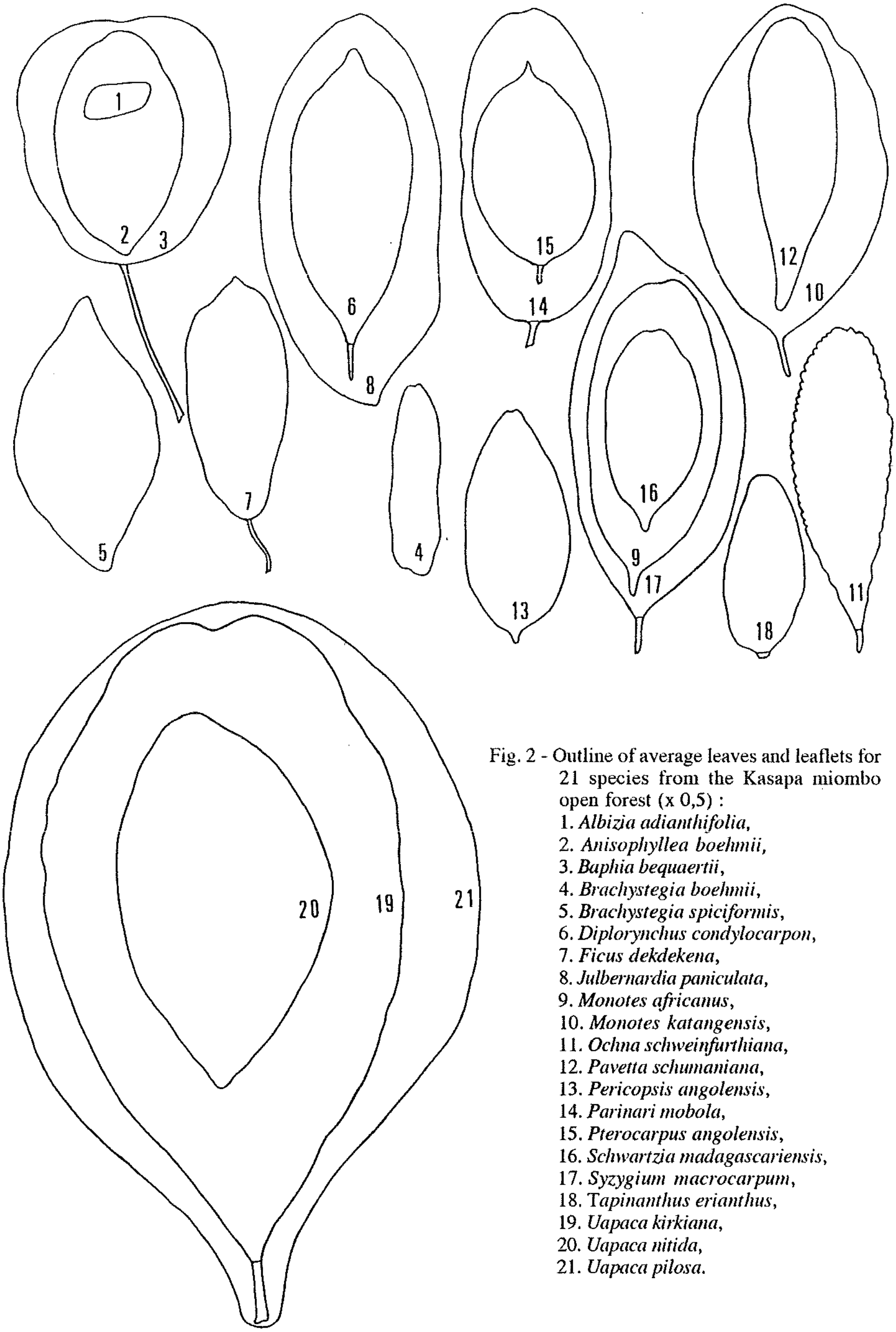

Fig. 2 - Outline of average leaves and leaflets for 21 species from the Kasapa miombo open forest (x 0,5) :
1. *Albizia adianthifolia*,
2. *Anisophyllea boehmii*,
3. *Baphia bequaertii*,
4. *Brachystegia boehmii*,
5. *Brachystegia spiciformis*,
6. *Diplorynchus condylocarpon*,
7. *Ficus dekdekena*,
8. *Julbernardia paniculata*,
9. *Monotes africanus*,
10. *Monotes katangensis*,
11. *Ochna schweinfurthiana*,
12. *Pavetta schumaniana*,
13. *Pericopsis angolensis*,
14. *Parinari mobola*,
15. *Pterocarpus angolensis*,
16. *Schwartzia madagascariensis*,
17. *Syzygium macrocarpum*,
18. T*apinanthus erianthus*,
19. *Uapaca kirkiana*,
20. *Uapaca nitida*,
21. *Uapaca pilosa*.

Mixed type

The experimental plot contained 21 species. Table I presents the leaf number, biomass and leaf area in February in the Kasapa miombo open forest. The outline of leaf and leaflet corresponding to the mean area of each of the 21 species is drawn in Figures 2. Figures 3 and 4 sum up the results obtained for total leaf area for the woody layers. They show that in vertical distribution, the tree layer is not easily distinguished from that of shrubs. This is due to the existence on the Kasapa site of tall and medium trees in the tree layer, and of the growth of several stems out of the shrub and into the tree layer.

The diversity of the shrubs of 1 to 5 metres height is however clear. Figure 4 which shows the variation of leaf area in the woody layer in time shows that the Zambezian open forest of Miombo type, in spite of the great seasonal development of the leaf canopy is never completely bare, at least when fire is absent. For the woody layers, the minimal leaf area is between 1st and 15th September (Fig. 5). By interpolation this would be on the 12th September, the day on which the area of new leaves would exceed that of the old. On the other hand, leaf area remains very stable from 1st November to 15th February, i.e. for the greater part of the rainy season.

Foliation, or more generally the renewal of vegetation activity is a phenomenon which depends largely on fire occurring or not. It is possible to indicate groups of species having early, average, late, and very late foliation. In the case of fire, the date of fire pasage (early or late) and its intensity will influence renewal of activity, whose time span will be disturbed. Most often a shortening of the renewal period may be observed after late fire.

We were able to establish, when fire is absent, the following classification as the average season of foliation for the main species in the Miombo :

- Early foliation : *Brachystegia spiciformis, Albizia adianthifolia, Baphia bequaertii, Ochtocosmus glaber, Strychnos inocua, Ekebergia benguelensis, Diplorynchus condylocarpon.*

- Average foliation :*Brachystegia boehmii, Pericopsis angolensis, Monotes katangensis, Schwartzia madagascariensis, Uapaca kirkiana, Dalbergia boehmii, Strychnos cocculoides, Hymenocardia acida, Annona senegalensis, Pseudolachnostylis maprouneifolia, Syzygium guineense* subsp. *macrocarpum, Vitex mombassae, Julbernardia paniculata, Erythrophleum africanum.*

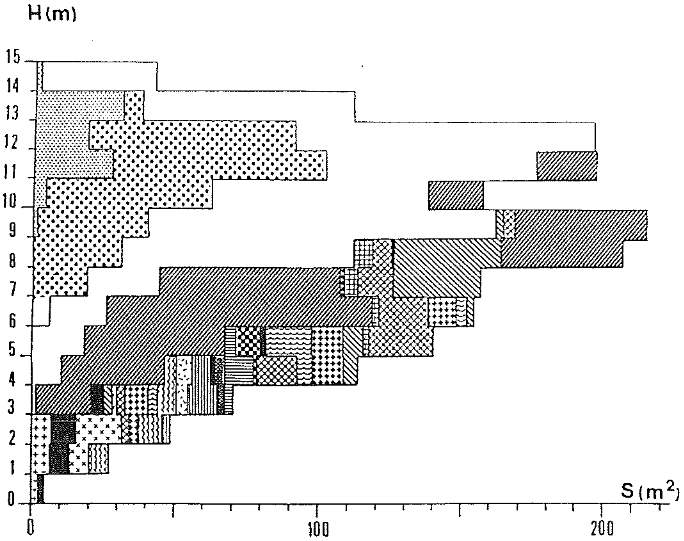

Fig. 3 : Vertical repartition of woody layers' of leaf area in the Kasapa miombo open forest (February 1977).

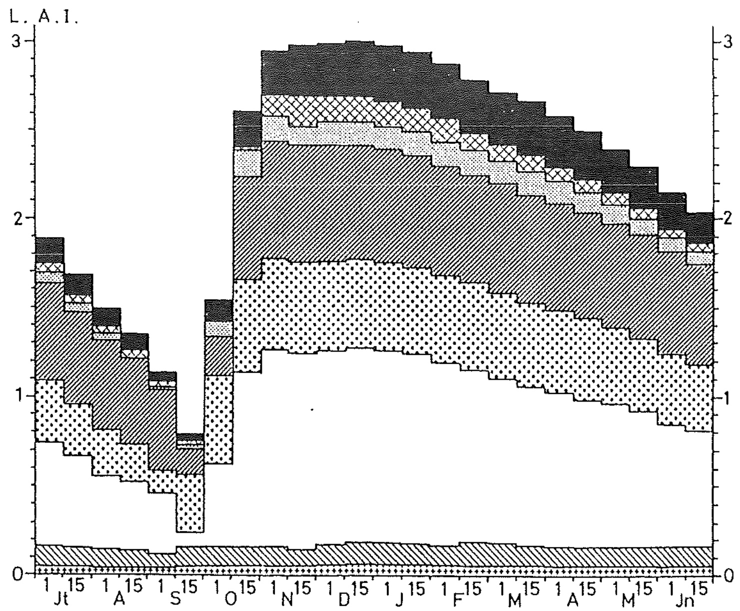

Fig. 4 : Fornigthly woody layers' leaf area index in the Kasapa miombo open forest (climatic year : 1976-1977).

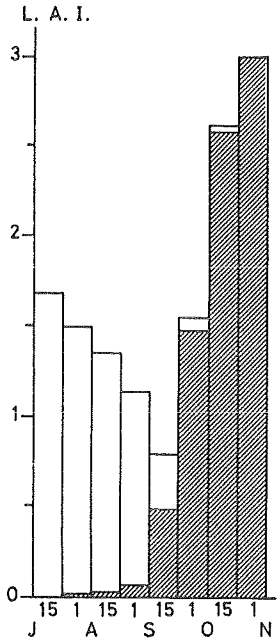

Fig. 5 : Replacement of old leaves (white) by new leaves (hatched) in the woody layears during the 1977 southern spring in the Kasapa miombo open forest.

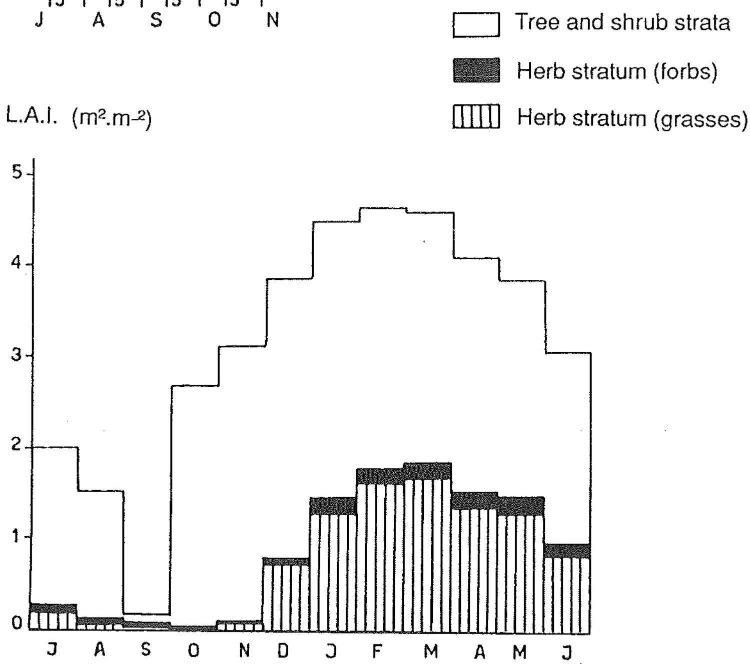

Fig. 6 : Relative importance of monocotyledon and dycotyledon leaf areas throughout the year in the Kasapa miombo.

- Late foliation : *Pterocarpus angolensis, Monotes africanus, Combretum mollis.*

- Very late foliation : *Pavetta shumaniana.*

B. Grass layer

Data relating to the grass layer are presented in Figure 6 which shows the relative and absolute importance of monocotyledons and dicotyledons throughout the year when fire is absent.

On the other hand the grass layer, as much throughout the year as during the rainy season, shows important variations in blade area.

DISCUSSION

Several comments arise from the analysis of the data presented here. Our results can easily be integrated into the few values available about tropical forests' L.A.I. (Table II). It should be remembered that most of the studies dealing with forests take only the tree layer into account, while research conducted in savannas are frequently devoted to the grass layer. Tree and shrub layers values for miombo are comprised between those of South Asian monsoon tropical forests (KIRA *et al.*, 1976) and Australian *Eucalyptus* forests (CARBON *et al.*, 1979).

Regarding seasonality, ALEXANDRE (1981) assumes that for tropical rain forests, at the time of maximum defoliation, the L.A.I. could diminish at half the maximum value, if Golley team's results (GOLLEY *et al.*, 1975) may be generalized. The 2.11 ratio observed at Panama agrees very well with the 1.91 observed for a Zambezian dry evergreen forest. When seasonality is stronger, as in the miombo open forest for instance, this ratio will increase. For the Kasapa miombo it was of 3.72 in absence of fire. However L.A.I. measurements in a subtropical dry forest of Porto Rico show no more than c. 50-percent reduction in foliage area between wet an dry periods over the 30-months observation period (MURPHY & LUGO, 1986).

At Kasapa miombo, severe late fires strongly reduce the importance of leaves' canopy or even induce complete defoliation of both the tree and shrub layers. Effect of fire has not been the subject of a particular study. Variability of impact both on

Plant community (species dominant)	Location (Country)	L.A.I. ($m^2 . m^{-2}$)	References
Tropical rain forest (*Cavanillesia plantanifolia*)	Santa Fe (Panama)	22.4	Golley *et al.* ,1975
Tropical rain forest	Khao-Chong (Thailand)	12.3	Kira *et al.*, 1964
Tropical rain forest	Pasoh (Malaysia)	8.0	Kato *et al.*, 1978
		7.46	Kira, 1978
Subtropical wet forest	El Verde (Porto Rico)	7.34	Weaver *et al.*, 1986
Seasonal evergreen forest (*Dipterocarpaceae*)	South-western Cambodia (Cambodia)	7.34	Hozumi *et al.*, 1969
Monsoon tropical forest (*Shorea robusta*)	Mirzapur (India)	6.8	Misra *et al.*, 1967
Tropical rain forest	Manaus (Brazil)	6.6	Nonato da Conceicao,
		6.6	1977
Tropical rain forest (*Dacryodes excelsa*)	El Verde (Porto Rico)	6.6	Jordan, 1969
		6.4	Odum *et al.*, 1970
Tropical rain forest (*Artocarpus hirsuta* and *Palaquium ellipticum*)	Agumbe (India)	6.08	Rai, 1979
Tropical rain forest	Lower Rio Negro (Brazil)	6.0	Williams *et al.*, 1972
Mountain rain forest (*Cyrilla racemiflora* and *Chaetocarpus globosus*)	Mull Ridge (Jamaica)	5.7	Tanner, 1980
Mountain rain forest (*Lyonia octandra* and *Chaetocarpus globosus*	Mor Ridge	5.5	Tanner, 1980
Montane rain forest (*Dacrycarpus cinctus* and *Podocarpus archboldii*)	Marafunga (New Guinea)	5.5	Edwards & Grubb, 1977

Table II - Leaf area index (L.A.I.) of tropical forests

Plant community (species dominant)	Location (country)	L.A.I. ($m^2 . m^{-2}$)	References
Mixed tropical rain forest	San Carlos (Venezuela)	5.2	Jordan & Uhl, 1978
Tall Amazon Caatinga forest (*Micranda sprucei*)	San Carlos (Venezuala)	5.08	Klinge & Herrera, 1983
Dry evergreen forest (*Entandrophragma delevoyi*)	Luiswishi (Zaïre)	5.0	Malaisse, 1984
Tropical rain forest	French Guyana	5.0	Bonhomme *et al.*, 1973
Flooded forest	Lower Rio Negro	4.9	Williams *et al.*, 1972
Subtropical dry forest (*Gymnanthes lucida* and *Exostema caribaeum*)	Guanica (Porto Rico)	4.2	Murphy & Lugo, 1986
Monsoon tropical forest (*Lagerstroemia calyculata* and *Dipterocarpus obtusifolius*)	Ping Kong (Thailand)	3.9	Kira *et al.*, 1967
Lowland rain forest	(Ivory Coast)	3.7	Müller & Nielsen, 1965
Miombo open forest (*Julbernardia paniculata* and *Brachystegia boehmii*)	Kasapa (Shaba, Zaïre)	3.47	Malaisse *et al.*, 1972
		3.07	Present study
Eucalyptus forest (*E. marginata* and *E. calophylla*)	Western Australia (Australia)	2.4	Carbon *et al.*, 1979
Subtropical dry forest	Guanica (Porto Rico)	2.02	Weaver *et al.*, 1986
Lower mountain rain forest (*Tabebuia rigida* and *Eugenia borinquensis*)	Luquillo (Porto Rico)	1.99	Weaver *et al.*, 1986
Guinean preforested savannah	Olokemeji (Nigeria)	1.46	Hopkins, 1968
Eucalyptus forest (*E. diversicolor*)	Western Australia (Australia)	1.3	Carbon *et al.*, 1979

Table II - (Continued)

structure and biomass of time of burning has frequently been commented upon elsewhere (TRAPNELL *et al.*, 1976; GELDENHUYS, 1977; LAWTON, 1978; RUTHERFORD, 1981; TROLLOPE, 1982) and will not be reviewed here.

The absence of climbers in the study plot and their scarcity in miombo in general should be compared with their importance in tropical rain forests : 36 % of the leaf biomass at Ipassa in Gabon (HLADIK, 1974), over one third of the rain forest in Thailand (OGAWA *et al.*, 1965), 16.8 % of the L.A.I. in a Zambezian dry evergreen forest (MALAISSE, 1974).

This second approach of L.A.I. in miombo of wetter type also avoids the various aspects of herbivory. Few informations are available about the impact of foliivores in Zambezian open forests and woodlands, with the exception of caterpillars spectacular defoliations (MALAISSE, 1978) whose main dietary sources are, as far as miombo is concerned, Caesalpiniaceae (MALAISSE, 1983). ALEXANDRE (1981) reports that an adequate mean value for foliar losses by herbivorous animals is 7.8 % in tropical forests, but he considers that herbivory on leaf area is negligible !

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Height (m)	1. *Albizzia adianthifolia*	2. *Anisophyllea boehmii*	3. *Baphia bequaertii*	4. *Brachystegia boehmii*	5. *Brachystegia spiciformis*	6. *Diplorynchus condylocarpon*	7. *Ficus dekdekena*	8. *Julbernardia paniculata*	9. *Monotes africanus*	10. *Monotes katangensis*	11. *Ochna schweinfurthiana*	12. *Parinari mobola*	13. *Pavetta schumaniana*	14. *Pericopsis angolensis*	15. *Pterocarpus angolensis*	16. *Schwartzia madagascariensis*	17. *Syzygium macrocarpum*	18. *Tapinanthus erianthus*	19. *Uapaca kirkiana*	20. *Uapaca nitida*	21. *Uapaca pilosa*
15	109							1659													
14	1413					630		3017													
13	866			27	6562			4265													
12	1243			914	6746			2990													
11	206			836	5237			3071													
10	72			1981	3489			4973	1583			750			10						
9		542		1829	2776			3302	2812			12496			372						
8		1095		2671	1685	139		1024	5162			10261			244						
7		6570		3925	549	267		796	7159			926			141	415					
6		7151		2074		102	5519	747	9405	139	869	2292			117	1751		30		853	
5		6947	1233	1553		347	663	401	5761	1553	717	1605		381		618		1561	240	2157	
4		5604	2135	846		362	315	42	1328	2531	1289	1026	20	297		390	490	134	160	704	
3		2481	2805	7		422	48		1051	539	804	129	1233	73		10	4870		166		364
2		793	2489			334				26	392	50	1989				2128		9		327
1			132			22							936				127				121
0																					
Total	3909	31183	8794	16663	27674	1995	6545	26287	34261	4788	4071	29535	4178	751	884	3184	7623	1725	575	3714	812

Appendix 1 - Vertical distribution of the number of leaves per species at the Kasapa Miombo (values are for the experimental plot of 1/16 ha, 1 February 1977).

Height (m)	1. *Albizzia adianthifolia*	2. *Anisophyllea boehmii*	3. *Baphia bequaertii*	4. *Brachystegia boehmii*	5. *Brachystegia spiciformis*	6. *Diplorynchus condylocarpon*	7. *Ficus dekdekena*	8. *Julbernardia paniculata*	9. *Monotes africanus*	10. *Monotes katangensis*	11. *Ochna schweinfurthiana*	12. *Parinari mobola*	13. *Pavetta schumaniana*	14. *Pericopsis angolensis*	15. *Pterocarpus angolensis*	16. *Schwartzia madagascariensis*	17. *Syzygium macrocarpum*	18. *Tapinanthus erianthus*	19. *Uapaca kirkiana*	20. *Uapaca nitida*	21. *Uapaca pilosa*	TOTAL 1/16 ha	TOTAL per hectare	%
15	238							4042														42.80	684.80	2.34
14	3083				693			7351														111.27	1780.32	6.07
13	1890			063	7214			10392														195.59	3129.44	10.67
12	2712			2149	7417			7285														195.63	3130.08	10.68
11	449			1966	5758			7483														156.56	2504.96	8.54
10	157			4658	3836			12117	379			221			018							213.86	3421.76	11.67
9		084		4300	3052			8046	674			3684			662							205.02	3280.32	11.19
8		169		6280	1853	027		2495	1237			3025			435							155.21	2483.36	8.47
7		1013		9229	604	052		1940	1716			273			251	373						154.51.	2472.16	8.43
6		1103		4877		020	811	1820	2254	057	155	676			208	1574		002		382		139.39	2230.24	7.61
5		1071	374	3652		068	097	977	1381	641	128	473		503		555		094	307	967		112.88	1806.08	6.16
4		864	648	1989		071	046	102	318	1044	230	302	003	392		351	1.67	008	205	316		70.56	1128.96	3.85
3		383	851	016		082	007		252	222	144	038	175	096		009	16.62		212		667	48.16	770.56	2.63
2		122	755			065				011	070	015	283				7.25		012		599	26.57	425.12	1.45
1			040			004							134				0.43				222	4.43	70.88	0.24
0																								
Total	8529	4808	2669	39179	30425	390	962	64050	8212	1975	727	8707	595	992	1574	2862	2597	104	735	1665	1488	1832.45	29319.04	
%	465	262	146	2138	1660	021	052	3495	448	108	040	475	032	054	086	156	142	006	040	091	081	99.98		100.00

Appendix 2 - Vertical distribution of leaf area in the Kasapa miombo
(values are given in m^2 for the experimental plot of 1/16 ha, as on 1 February 1977 and taking one side into account).

Species	July		August		Septembre		October		November		December	
	1	15	1	15	1	15	1	15	1	15	1	15
1. *Albizia adianthifolia*	34,25	25,16	21,67	0,0	6,12	18,27	57,67	96,72	90,50	85,98	85,98	85,39
2.*Anisophyllea boehmii*	38,43	37,45	36,37	35,34	34,93	41,43	41,12	43,28	44,16	44,42	49,78	53,65
3.*Baphia bequaertii*	25,15	24,66	24,14	22,44	13,58	2,00	9,23	24,62	27,34	27,24	27,00	26,94
4.*Brachystegia boehmii*	339,46	326,85	310,26	302,38	280,94	89,24	136,17	361,82	414,68	410,95	407,17	404,06
5. *Brachystegia spiciformis*	209,49	183,73	161,20	130,24	82,94	200,38	306,27	322,39	319,86	318,17	314,80	312,34
6. *Diplorynchus condylocarpon*	1,32	0,55	0,26	0,17	0,08	0,00	0,00	4,03	4,16	4,16	4,15	4,10
7.*Ficus dekdekena*	0,12	0,12	0,07	0,02	0,01	5,82	12,73	15,79	18,17	21,19	20,49	20,84
8.*Julbernardia paniculata*	368,60	319,46	261,19	241,43	209,00	46,17	287,25	612,55	688,67	684,04	680,93	676,29
9.*Monotes africanus*	28,76	27,52	24,89	23,55	20,59	17,44	0,00	8,59	73,91	96,12	89,58	90,63
10.*Monotes katangensis*	9,94	7,09	6,80	6,69	3,75	0,37	9,96	10,13	11,35	13,04	17,51	20,17
11.*Ochna schweinfurthiana*	0,37	0,17	0,11	0,02	0,00	0,07	1,38	5,81	7,41	7,39	7,34	7,32
12.*Pavetta schumaniana*	1,98	1,14	1,06	0,25	0,16	0,03	0,00	0,00	0,01	0,38	2,47	2,85
13.*Paricopsis angolensis*	6,62	2,47	0,44	0,08	0,00	0,16	0,23	3,62	9,80	10,07	10,06	10,02
14.*Parinari mobola*	89,29	82,39	75,48	74,37	59,44	83,00	86,70	80,29	82,63	72,39	87,07	93,61
15.*Pterocarpus angolensis*	2,11	0,09	0,01	0,00	0,00	0,00	0,00	0,02	0,59	14,97	15,79	15,76
16.*Schwartzia madagascariensis*	3,91	2,33	0,99	0,24	0,00	0,00	8,87	22,48	29,57	29,48	29,39	29,22
17.*Syzygium macrocarpum*	16,95	12,15	11,28	8,01	2,81	2,55	5,22	15,98	16,23	18,36	20,98	22,88
18.*Tapinanthus erianthus*	0,08	0,03	0,03	0,00	0,00	0,90	0,94	1,03	1,11	1,11	1,33	1,33
19.*Uapaca kirkiana*	4,84	3,63	3,81	3,68	3,50	2,97	2,30	2,61	6,98	7,13	7,17	7,38
20.*Uapaca nitida*	9,12	6,79	6,58	6,53	5,49	1,86	15,89	16,61	16,92	17,49	17,86	18,82
21.*Uapaca pilosa*	8,28	7,35	7,29	7,25	2,98	2,58	5,70	8,53	10,46	11,92	12,64	12,07
Total for the experimental plot (1/16 ha)	1199,07	1071,13	953,93	862,69	726,32	515,24	987,63	1656,90	1874,51	1896,00	1909,49	1915,67
Values per ha	19185,12	17138,08	15262,88	13803,04	11621,12	8243,84	15802,08	26510,40	29992,16	30336,00	30551,84	30650,72

Appendix 3 - Fortnightly leaf area per species in the Kasapa miombo (1976-1977 climatic year, values are given in m^2 per 625 m^2)

Species	January		February		March		April		May		June	
	1	15	1	15	1	15	1	15	1	15	1	15
.1. *Albizia adanthifolia*	85,37	85,32	85,29	84,58	83,53	81,78	75,14	69,55	65,00	55,22	49,63	44,39
2. *Anisophyllea boehmii*	51,48	49,78	48,08	46,58	46,22	44,78	41,99	40,96	40,18	39,93	38,43	38,38
3. *Baphia bequaertii*	26,84	26,79	26,69	26,47	26,33	26,26	26,12	25,99	25,92	25,83	25,67	25,50
4. *Brachystegia boehmii*	399,82	396,14	391,79	386,07	383,79	380,22	376,94	371,01	366,16	364,09	358,45	352,81
5. *Brachystegia spiciformis*	309,82	306,96	304,25	301,89	298,09	295,67	291,39	285,96	267,72	256,50	244,90	233,77
6. *Diplorynchus condylocarpon*	4,04	3,96	3,90	3,88	3,86	3,84	3,81	3,78	3,75	3,73	3,58	2,98
7. *Ficus dekdekena*	20,78	17,50	9,62	8,94	8,24	7,54	6,79	6,61	4,58	2,32	0,47	0,18
8. *Julbernardia paniculata*	671,15	659,86	640,50	601,23	574,02	556,28	538,47	511,99	491,79	469,57	426,87	402,11
9. *Monotes africanus*	88,48	86,78	82,12	63,20	61,26	60,58	51,50	49,73	47,17	38,74	32,25	30,05
10. *Monotes katangensis*	20,14	19,91	19,75	18,93	16,86	15,01	13,74	13,43	13,26	13,10	11,08	10,63
11. *Ochna schweinfurthiana*	7,31	7,29	7,27	7,22	7,12	6,98	6,86	6,11	5,73	3,24	2,00	0,90
12. *Pavetta schumaniana*	2,85	2,78	5,95	5,83	4,04	5,89	6,04	6,09	5,90	5,03	5,00	2,96
13. *Pericopsis angolensis*	9,99	9,95	9,92	9,90	9,86	9,79	9,55	8,88	8,78	8,65	8,50	8,36
14. *Parinari mobola*	93,61	92,62	87,07	102,24	97,43	87,93	87,44	87,31	86,83	85,98	86,45	88,55
15. *Pterocarpus angolensis*	15,75	15,74	15,74	15,73	15,73	15,72	15,64	15,35	14,76	12,71	9,95	5,87
16. *Schwartzia madagascxariensis*	28,93	28,70	28,62	28,43	28,29	27,96	27,42	26,19	24,11	21,87	19,06	7,61
17. *Syzygium macrocarpum*	22,90	22,92	25,97	25,02	31,17	40,35	36,79	32,05	27,74	25,52	22,55	22,25
18. *Tapinanthus erianthus*	1,32	1,32	1,04	0,86	0,72	0,51	0,14	0,13	0,06	0,01	0,01	0,05
19. *Uapaca kirkiana*	8,24	8,76	7,35	6,94	6,85	6,01	6,44	6,28	6,01	5,97	5,31	5,23
20. *Uapaca nitida*	18,47	17,73	16,65	16,05	12,91	12,67	12,79	11,58	11,34	10,99	10,30	9,87
21. *Uapaca pilosa*	12,35	12,77	14,88	13,12	12,00	12,09	12,88	12,22	10,78	11,41	10,11	9,21
Total for the experimental plot (1/16 ha)	1899,64	1873,58	1832,45	1773,11	1728,32	1697,86	1647,88	1591,20	1527,57	1460,41	1370,57	1301,66
Values per ha	30394,24	29977,28	29319,20	28369,76	27653,12	27165,76	26366,08	25459,20	24441,12	23366,56	21929,12	20826,56

Appendix 3 - (Continued)