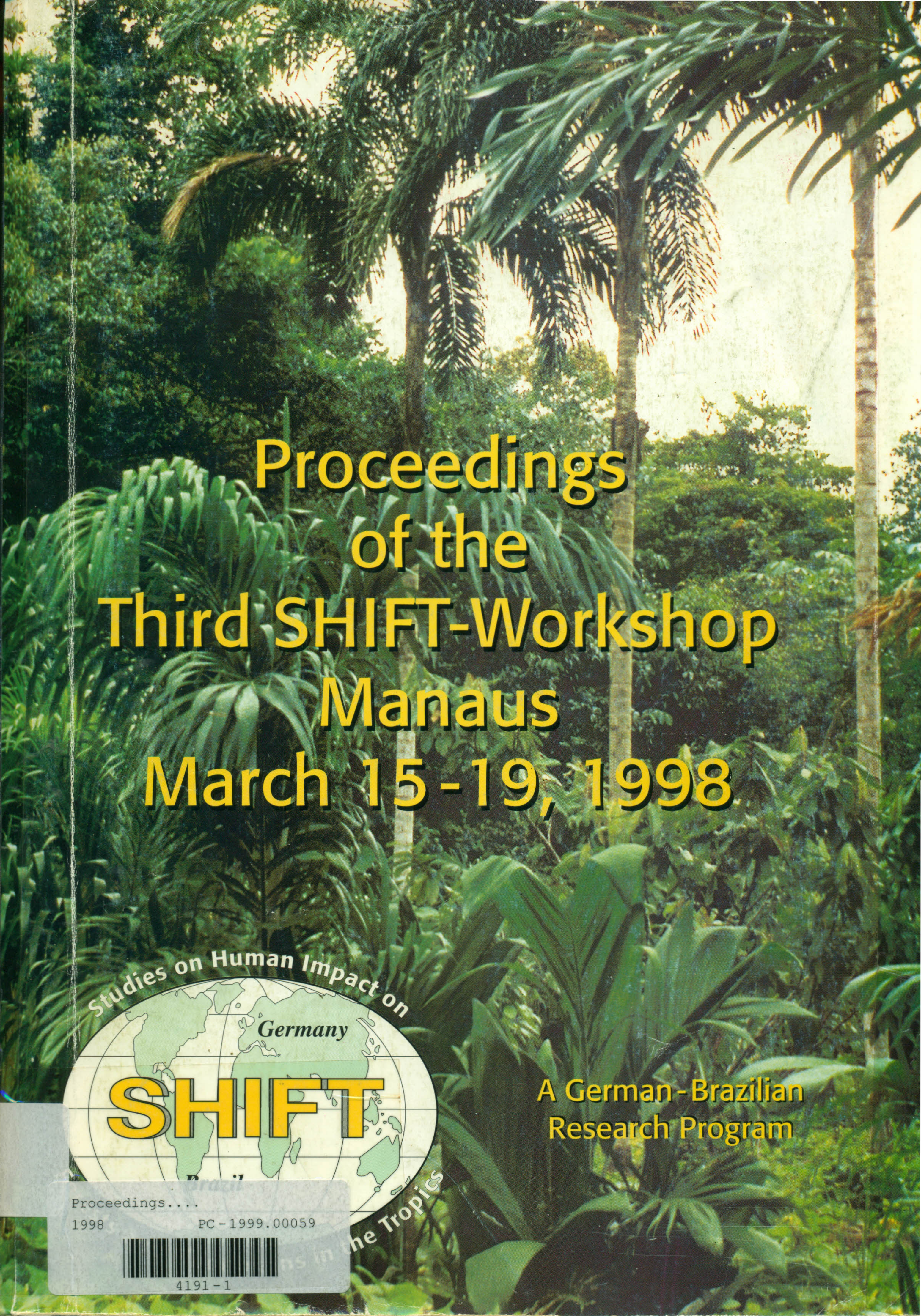

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Wood characteristics of *Ceiba pentandra* cultivated in upland and floodplain ecosystems

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ABSTRACT

The present work was carried out with native, adult and young trees of the species *Ceiba pentandra*, cultivated in floodplains (várzea) and in upland (terra firme) ecosystems. The objective was to obtain information about growth patterns of the species and to correlate them with different environmental conditions (floodplain and upland), as well as to investigate anatomical and physical parameters of the wood. In the present study, the wood quality of adult native trees was compared with the wood quality of young trees cultivated on floodplains (várzea) and upland (terra firme). Investigations were carried out on the radial variations of density and anisotropy, as well as on the wood anatomical structure on the pith-bark direction on the samples of wood taken at breast height (DBH).

From the results obtained, it can be concluded that the cultivated trees on the floodplain and in the upland ecosystem, as well as the native trees, presented an increase of density from pith to bark. The structural density of the cultivated trees at the upland ecosystem was higher, followed by the trees cultivated at the floodplain, when compared with native sumauma: The anisotropy contraction index indicates that sumauma is highly dimensionally unstable. Therefore, its range of use in the area of construction is limited.
Key words: sumauma, physical and anatomical characteristics, wood quality

RESUMO

O presente trabalho foi desenvolvido com árvores de sumaúma (*Ceiba pentandra*), nativa adulta e árvores jovens plantadas em ecossistemas várzea e terra firme, tendo como objetivo, obter informações sobre o padrão de crescimento da espécie e relacioná-la as diferentes condições ambientais (várzea e terra firme), bem como investigar parâmetros anatômicos e físicos da madeira objetivando correlacionar a qualidade da madeira de árvores nativas adultas com madeiras de árvores jovens plantadas na várzea e na terra firme. Foram estudadas as variações radiais da densidade e anisotropia, bem como as estruturas anatômicas da madeira no sentido medula casca nas amostras de madeira obtidas na altura do DAP.

Pode-se concluir, a partir dos resultados obtidos que: as árvores plantadas nos ecossistemas de várzea e terra firme, assim como nativas, apresentaram um aumento de densidade no sentido médula-casca; a densidade foi maior nas árvores plantadas no ecossistema de terra-firme, seguido das árvores plantadas na várzea, quando comparado com a sumaúma nativa; os valores dos coeficientes de anisotropia de contração encontrados,

demonstram que a sumaúma é altamente instável dimensionalmente, apresentando, portanto, limitações para uso em esquadrias; os dados médios da densidade estimados, com a equação de regressão ajustada por ecossistema, são superiores aos medidos para sumaúma nativa.
Palavras-chave: sumaúma, características físicas-anatômica da madeira, qualidade da madeira

ZUSAMMENFASSUNG

Die vorliegende Studie beinhaltet einen Vergleich des Wachstums von *Ceiba pentandra* unter natürlichen und Plantagen-Bedingungen in der Várzea und der Terra Firme. Hierfür wurden anatomische und physikalische Eigenschaften des Holzes dieser Bäume geprüft. In Brusthöhe (DBH) wurden Scheiben entnommen und die Dichte und die anatomischen Merkmale vom Kambium bis zum Mark untersucht.

Generell nahm bei allen Bäumen die Dichte von Mark bis Kambium zu, wobei die auf der Terra Firme gepflanzten Bäume die höchste Dichte aufwiesen, gefolgt von den Plantagen in der Várzea. Insgesamt eignet sich *Ceiba* aufgrund der geringen Dichte nicht im Konstruktionsbereich.

INTRODUCTION

The species *Ceiba pentandra* (L.) Gaertn., family *Bombacaceae* (sumauma) of floodplains is a frondous tree. It may reach heights above 60 metres, and diameters at breast height over 2.4 m, the average height being 40 to 50 cm, with diameters at breast height (DBH) of 130 to 180 cm. The trunk is straight and cylindrical and until 2/3 of the height without branches; the base of the trunk is clearly reinforced with well-pronounced buttresses that can reach heights of 8.0 m (Lamprecht, 1990). When young, the tree's branches and trunk dispose of bulky conic aculeus, independently of solitary growth (Loureiro and Silva, 1968). The wood is very light (0.30 to 0.37 g/cm^3) and is especially used for plywood. The species occurs in flooded tropical forests or swampy floodplains and also in the elevated upland on clayey and fertile soil.

The world's need for natural forest conservation is increasing and forcing the timber industries to change the source of suppliers. Some industries promise to plant millions of sumauma seedlings to substitute the native trees, the exploration of which means their gradual drive to extinction on the way to obtain wood with appropriate quality. The influences of the environment on the wood formation of these species at the floodplains and upland are very important, because of sumauma's natural distribution in both ecosystems of the Central Amazon. These environments present characteristics that differentiate them morphologically, although they functionally are complementary.

Junk (1989) estimates that there are approximately 10,000 km^2 of floodplain forest along the large rivers. The shorter passages of these floodplains are occupied by flat border lakes, "floodplain lakes". All of the Amazon rivers are subjected to a period of inundation during which the water overflows the river bed and invades the border areas with the high water reaching different water-marks. Most of these rivers draw in their water amounts of sediments and during the overflow, this mineral and organic detritus is deposited and accumulated on the inundated plains, giving them fertility and enabling the intensive production of food. The process is valid for all inundated areas, and the fertilization by inundation resulting from the new deposits allows the agricultural exploration of these areas in the subsequent years, without a productivity reduction. In this way, the floodplain fulfils the role of a great biological transformation that receives nutrients from the Amazon river and changes them into organic matter, which will be used by plants and animals of the system.

In spite of the dense vegetation which is developed on the "terra firme", the Amazonian high plains which are far from the reach of the river and its tide, normally are soils of low fertility. The predominating soil of the edaphic system originated in the early formation of the Amazonian Basin (Tertiary and Pleistocene) with the most recent deposit at more than 100,000 years. Beside this, dystrophic latossols and unusually eutrophics prevail on this environment (Schubart and Salati, 1982; Veloso et al., 1991). The same way, Fernandes and Serrão (1992) and Falesi (1986) emphasize the different characteristics of the latossols (Oxisols) and the podsols (Ultisols) that occur in the upland, saying that 75% are acid soils of low fertility, characterized by the poor supply of nutrients, high aluminium toxicity and low availability of phosphorus.

According to Shimoyama (1990), the quality of the wood refers to its adaptation to a specific use or of its ability to fulfil the requirements needed for the manufacture of specific products. Knowing the quality of the raw material and the process to be used, it is possible to obtain the optimization between both and in the end product. Therefore, the quality of the timber is the result of the agreement of the physical, chemical, and anatomical properties. As concerns the determination of the wood quality, the basic density is the most frequently used index, because the basic density affects the wood properties and consequently the products made from it.

All of the different site conditions influence the wood characteristics which leads to a variety of properties, which the trees develop. These changes are intrinsic in the growth of the tree and must be taken into consideration in any study on wood quality (Larson, 1962; Brazier, 1977). The changes in wood formation within the species in view of the chemical, physical, and anatomical composition are considerable. Changes even occur within plants of the same site, especially as concerns the age and the genetic and environmental factors (Browning, 1963). The increase in the growth rate, within certain limits, causes an increase in wood density. Timber density is also affected by tree age. In general, the density considerably increases during the young period. Later on, the growth rate slackens until it becomes more or less constant after reaching the adult phase. The modifications in the wood density due to fertilization or to irrigation are similar to those caused by changes in growth rate.

Behavioral studies on the dimensional change of the wood are essential to its industrialization, especially in the production of plywood. The relation existing between density, humidity, and retractability of the wood is of fundamental importance for the correct utilization. Species can be limited in their utilization purposes when dimensional stability is an important factor. The selection of wood of higher stability can only be based on data obtained in laboratories (Galvão and Jankowsky, 1985).

In this context, the present work primarily aims at obtaining information about the sumauma growth pattern and the correlation of the findings with different environmental conditions (floodplain and upland). Secondly, it as well aims at the investigation of the anatomical and physical characteristics of the wood of young cultivated trees at the floodplains and the upland to draw parallels to the wood quality of adult native trees.

MATERIAL AND METHODS

In this work, sumauma trees (*Ceiba pentandra*) were used. The trees were cultivated in two different systems: firstly, in a floodplain ecosystem in an experimental area of INPA, located at the Costa do Caldeirão - Iranduba city; secondly, in an upland ecosystem at an experimental area of the EMBRAPA, located on Km30, AM-010 Highway. The native trees of floodplains were collected by GETHAL - AMAZONAS S. A., Industry of plywood, located at Itacoatiara city, Amazon state.

I Characterization of the study area

Floodplain ecosystem

The study was executed with cultivated sumauma trees at Iranduba city in the region of Costa do Caldeirão, Ariaú Station from INPA-CPCA, west of the Solimões river, 50Km above the point where the rivers Negro and Solimões meet. The cultivation was carried out in October 1992, and in January 1993. Two trees were cut and measured dendrometrically. Measurements of overall height (Ht) and diameter were taken at breast height (DBH), as shown in Table 1.

Table 1: Dendometrical characteristics of sumauma trees cultivated at the floodplains and upland ecosystems

Tree	Ecossystem	DBH (cm)	Ht (m)
01	Floodplain	21.1	8.45
02		21.3	6.92
01	Upland	26.8	14.8
02		32.3	17.3

Iranduba city, Amazon state, covers an overall area of 2,354 km^2, corresponding to approximately 0.15% of Amazon state area. The city is situated between the latitude 3°00' and 4°00' S and 60°00" and 61°00" W Greenwich longitude. It is located in the Medium Amazon, established to a large part on recent Quaternary ground, the soils of which annually receive deposits by inundation. (Brazil, 1979).

The area climate is Afi, a rainy tropical climate, classified according to the climatological classification of Köppen (1948), cited by Ribeiro (1976): **A** - tropical climate practically without winter, the average temperature of which in the colder months never is below 18°C; **F**- rain during the whole year; **I** - indicates isotherms, i.e., there is no exact differentiation between summer and winter season, as the annual oscillations of average temperature move within an amplitudinal range of 5°C. The distribution of the precipitation throughout the year is around 2,000 mm.

The meteorological data observed in the period from 1991 to 1994 by the Meteorological Station of the Experimental Field of Caldeirão-EMBRAPA Amazônia Ocidental, is indicated in Table 2. The water regulation of Solimões river from 1990 to 1997 presented the normal patterns, with an average maximum height of the water level of 28.02 m and a minimum of 17.13 m at low tide. The amplitude on average is around of 10.89 m, according to Figure 1.

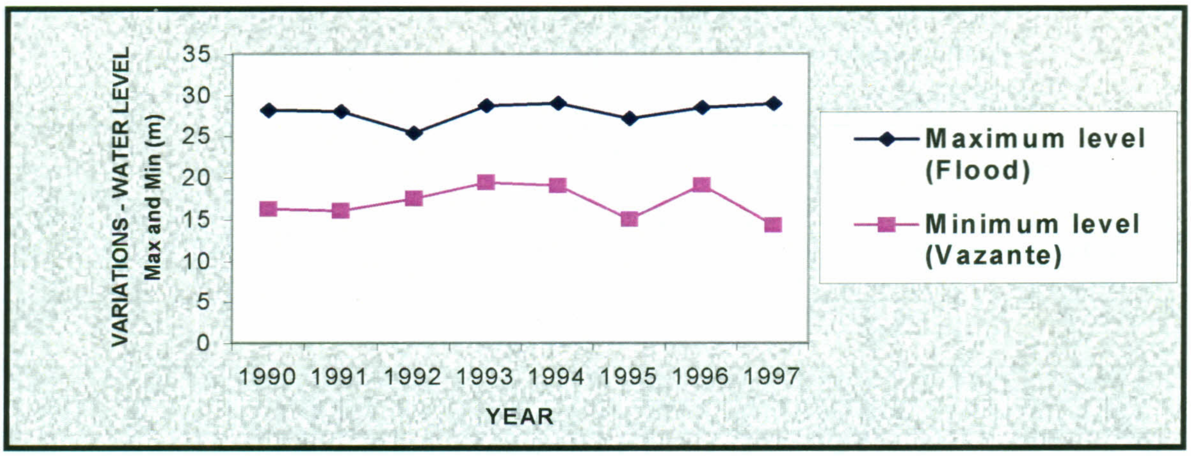

Figure 1: Changes in the water regulation of Solimões river at the period of 1990-1997.

The cultivation was carried out in a soil described and classified by Xavier et al. (s/d) as Gley, only slightly humid, according to the classification of Plant and Soils Analysis Department of EMBRAPA Amazônia Ocidental. The soil was collected on the surface to a depth of 0 to 20 cm. The results of the fertility analysis and texture are presented in Table 3.

Upland ecossystem (Small Tree)

The cultivation of sumauma was carried out in January 1992 in the upland ecosystem of the experimental field of the EMBRAPA Amazônia Ocidental, located at Km 24 of AM-010 Highway (Manaus - Itacoatiara). The trees were planted in lines on full soil, with ten trees in a spacing of 3.0 m between plants and 3.0 m between lines. The area is located between the coordinates 59 52'40" and 59 58'00" of east longitude and 03 00'00" of south latitude (Ribeiro, 1976). Two trees were cut, and measurements of total height (Ht) and diameter at breast height (DBH) were taken (see Table 1).

According to Ribeiro (1976), the climate of the area belongs to the tropical rainy climates, classified as type Afi according to Köppen, characterized by average temperatures never below 18 °C; and rain throughout the year. As the annual amplitude of the average temperature does not reach 5 °C, there is no seasonal distinction. Furthermore, the precipitation in the drier months is superior to 60 mm.

The climatological data observed in the period between 1991 to 1996 by the Meteorological Station of EMBRAPA Amazônia Ocidental are indicated in Table 2.

The type of soil occurring in the area is characterized as yellow latossol, with a very clayey texture, and a pH of around 4.5 (Pamplona et al., 1995). According to the classification of the Plant and Soil Analysis Department of EMBRAPA Amazônia Ocidental, the soil was collected on the surface to a depth of 0 to 20 cm. The results concerning fertility and texture are presented in Table 3.

Table 2: Monthly averages of temperature, precipitation and solar bright at the Caldeirão region (floodplain ecosystem) in the period from 1991 to 1994 and on the upland ecosystem in the period from 1992 to 1996.

Event	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	Floodplain Ecosystem											
1991												
Temp Min	22.5	21.1	20.9	22.2	22.6	22.0	20.1	*	*	*	22.1	22.1
Temp Max	30.6	30.9	31.0	30.8	30.6	30.8	30.5	29.9	30.5	30.2	31.8	31.0
Prec Max	*	81.0	117.8	*	40.6	30.4	56.7	30.1	28.8	66.0	23.8	20.0
Solar bright	3.5	4.8	2.8	4.1	4.2	6.7	7.2	6.9	6.6	7.5	7.9	4.5
1992												
Temp Min	23.9	23.5	23.4	23.9	23.8	22.6	22.4	22.3	23.1	23.3	23.4	23.1
Temp Max	31.2	30.6	29.9	30.9	31.8	32.0	31.0	30.4	32.3	32.0	31.5	29.8
Prec Max	69.5	90.5	47.5	81.5	51.5	25.5	32.5	40.5	55.5	36.0	53.0	71.5
Solar bright	5.0	3.9	4.5	4.3	8.3	9.1	7.6	6.1	7.6	6.4	5.3	2.6
1993												
Temp Min	22.9	23.0	23.0	23.3	23.7	23.5	22.9	22.6	23.2	23.1	23.2	23.5
Temp Max	30.0	29.7	29.7	30.0	30.6	30.9	30.6	31.3	32.6	31.7	30.8	30.9
Prec Max	69.5	90.5	47.5	81.5	51.5	25.5	32.5	40.5	55.5	36.0	53.0	71.5
Solar bright	4.9	4.5	4.3	4.5	6.1	5.5	7.0	8.1	6.9	6.3	4.9	4.7
1994												
Temp Min	23.1	23.2	23.2	23.2	23.4	23.0	22.6	23.1	23.4	23.3	23.6	23.7
Temp Max	29.3	29.3	30.3	30.3	30.4	29.8	30.8	32.1	32.7	33.0	32.2	30.7
Prec Max	118.0	39.5	44.5	51.5	44.0	15.0	25.0	35.0	22.5	30.0	74.0	44.0
Solar bright	3.6	3.0	3.7	4.5	5.8	6.1	7.6	7.8	6.5	7.4	5.7	5.9
	Upland Ecosystem											
1992												
Temp Min	23.5	23.1	23.0	23.0	22.9	22.0	21.5	21.3	22.2	22.4	22.1	21.8
Temp Max	32.1	31.4	30.6	31.7	32.5	32.2	31.3	31.5	33.4	33.4	32.1	30.2
Prec Max	81.3	84.3	52.9	42.6	51.1	20.5	19.0	37.6	41.2	71.7	47.6	47.6
Solar bright	162.2	138.7	128.4	161.1	234.8	247.4	215.9	166.9	204.2	191.9	137.5	109.9
1993												
Temp Min	21.9	22.5	22.2	22.5	22.7	22.2	21.7	21.6	22.1	21.9	22.0	21.7
Temp Max	29.5	29.8	30.0	30.0	31.1	31.1	30.7	31.6	31.9	31.1	30.0	30.1
Prec Max	45.8	57.8	86.5	48.0	22.8	19.3	17.0	9.8	33.0	63.2	57.2	37.3
Solar bright	138.1	107.1	134.6	125.8	197.5	207.9	208.0	225.4	201.1	173.2	147.3	150.3
1994												
Temp Min	22.1	22.3	22.4	22.1	22.5	21.9	21.8	21.9	22.0	22.1	22.5	22.3
Temp Max	29.5	29.7	30.3	30.5	30.7	30.0	30.7	31.8	32.0	32.2	31.5	29.8
Prec Max	58.0	81.2	65.0	87.7	33.7	37.5	24.5	17.6	28.8	55.3	39.1	51.3
Solar bright	69.8	76.1	102.6	93.5	134.0	137.6	197.0	182.2	161.4	174.8	155.5	137.5
1995												
Temp Min	22.3	23.0	22.5	22.8	22.3	22.0	21.9	22.0	22.1	22.1	22.1	22.2
Temp Max	30.5	30.1	30.1	30.5	30.4	30.5	31.7	32.7	32.8	21.2	30.6	30.8
Prec Max	41.9	44.8	37.2	88.9	50.0	46.1	10.0	10.4	52.3	28.5	85.5	28.4
Solar bright	139.8	129.6	117.2	111.6	134.3	145.2	184.5	216.6	194.0	175.7	111.8	144.2
1996												
Temp Min	21.7	22.2	22.6	22.6	22.5	21.7	22.1	21.9	22.2	22.2	22.0	21.5
Temp Max	29.2	29.2	30.2	30.5	30.7	29.7	30.9	32.7	33.3	32.6	32.0	31.8
Prec Max	44.0	46.5	78.8	60.0	24.6	35.7	26.5	28.2	29.7	20.0	49.6	57.2
Solar bright	91.8	90.8	112.7	107.2	120.6	95.2	127.2	146.6	131.1	127.6	120.5	83.7

* broken instrument

Table 3: Results of fertility analysis and physics of soil at the line of the plantation of sumauma floodplain, during August 14^{th}, 1996 to August 14^{th}, 1997 and upland on September, 1996.

Month	PH (H_2O)	P Ppm	K Ppm	Ca Me%	Mg Me%	Al Me%	C %	N %	Sand (%)		Clay Tot(%)	Silte (%)
									Coarse	Fine		
Floodplain Ecosystem												
09/96	5.02	30	92	14.34	3.57	0.762	1.038	0.29	0.55	3.22	27.35	68;88
10/96	4.92	92	98	11.08	2.94	0.609	1.015	0.27	1.13	13.49	19.35	66.03
11/96	4.75	40	98	12.99	3.38	1.227	1.187	0.29	0.36	3.81	28.05	67.78
12/96	4.90	38	110	14.12	3.61	0.897	1.156	0.29	0.64	3.16	28.20	68.00
01/97	4.92	72	116	13.11	3.38	0.702	0.935	0.28	0.66	6.97	22.80	69.57
02/97	5.09	36	104	12.77	3.15	0.955	1.164	0.33	0.35	3.02	28.00	68.63
03/97	5.19	33	100	14.06	3.44	0.824	1.049	0.28	0.49	3.95	26.75	68.81
04/97	5.39	36	116	15.13	3.28	0.390	1.132	0.27	0.99	2.96	28.85	67.20
07/97	4.93	29	118	11.82	3.15	1.100	-	0.130	0.61	2.81	31.50	65.08
08/97	5.35	22	106	12.56	3.05	0.820	-	0.137	0.98	2.54	28.20	68.28
Upland Ecosystem												
08/96	4.70	11	24	0.67	0.14	1.50	2.03	0.21	0.93	3.24	31.32	64.51

II Physical and anatomic properties of wood

Density determination

Samples of 1x1x1 cm were prepared according to Schuster (1996), containing also the change of density from cambium to pith. The method used to determine the density was on oven-dry condition, according to Resende et al. (1993).

Determination of anisotropy coefficient

The anisotropy coefficient is given by radial, tangential, and linear shrinkage ratio. The samples used for this assay were the same as for density. The measurements were carried out by using the micrometer. The humid volume was obtained by maintaining the samples in the freezer. Dry weight and volume were obtained by oven drying at $103 \pm 2\,^{\circ}C$.

Anatomical characteristics

For the anatomical microscopic description of wood, samples of 1x1x1 cm were prepared according to Schuster (1996). They were prepared as blocks. The small blocks were embedded in wax to prevent rupture during sectioning. For sectioning, a sliding microtome was used. The sections (30 μm thickness) were stained with safranine and astrablue and were embedded in "Entellan".

Requirements for anatomical microscopy characterization

For anatomical characterization, the structure of sumauma followed the Copant Norm (1974). The frequency of vessels, rays, fibers and parenchyma was observed with magnification of 10x, coupled by the binocular microscopy of Bausch & Lomb. The measurements of vessels, rays, fibers, and parenchymas were converted by a correction factor of 2x.

RESULTS AND DISCUSSION

Several factors affect the physical and anatomical properties of wood. Due to their heterogeneity, some are difficult and others simple to control.

Figure 2 shows the variation in density in the direction from pith to bark, in the native sumauma, as well as in trees planted in floodplains and in the upland. The density increases in the direction indicated, showing minimal values of 0.11 g/cm^3 and maximum values of 0.43 g/cm^3. Nevertheless, in the native species, the density showed a tendency of decrease next to the bark. Similar results were described by Amaral et al (1971) and by Rolim and Ferreira (1974) for *Araucaria angustifolia*.

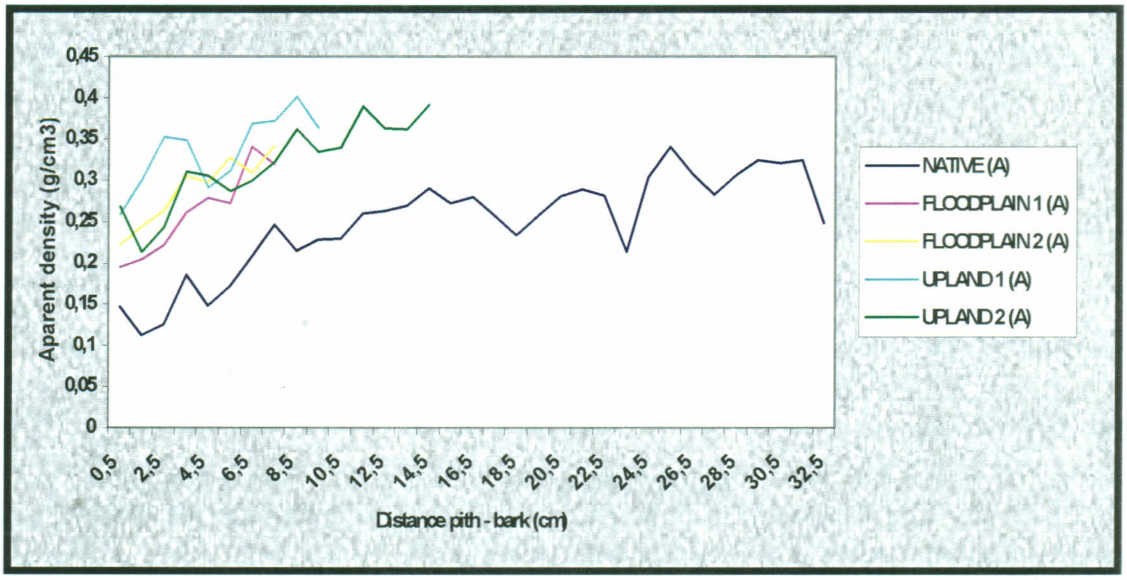

Figure 2: Change of density at the direction pith - bark, at the sumauma wood of floodplain, upland and native.

By observing the environments, it could be verified that the planted tree at the upland, followed by the floodplain ecosystem, showed higher values than native sumauma trees. It is likely that this behavior is due to the environment, as this factor influences the anatomical structure of the wood and its density. Figure 3 and Table 4 show that the frequency of the vessels and rays in per cent is relatively constant within the tree, regardless of the environment.

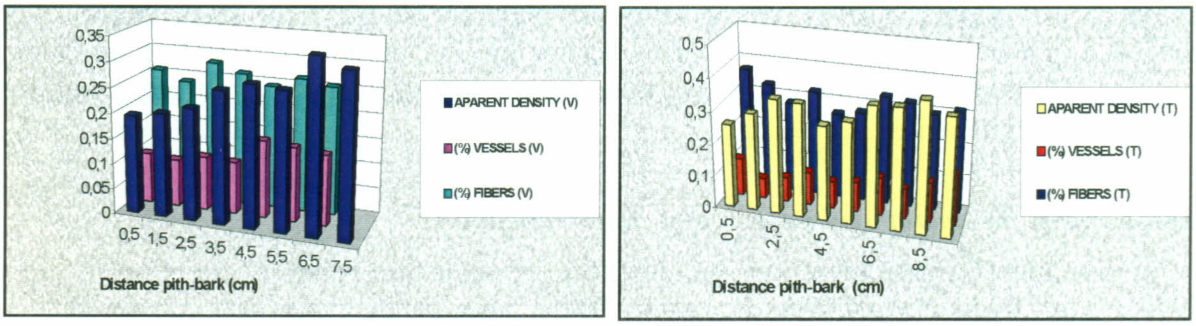

Figure 3: Variation of density, fibers and vessels in per cent of cultivated wood at the floodplain (V) and upland (T) ecosystem, in the direction pith-bark.

Table 4: Anatomical characteristics of cultivated sumauma at floodplain and upland ecosystem.

Elements	Distance pith-bark (cm)																Statistics		
	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	μ	σ^2	σ
Floodplain Ecossystem – Tree 1																			
Vessels	10.00	9.33	10.67	10.33	15.33	14.67	14.00										12.05	2.5129	6.3148
Rays	19.00	13.00	18.67	26.00	19.33	23.00	13.67										18.95	4.6478	21.6019
Fiber	25.65	23.67	28.00	26.33	24.33	26.33	25.33										25.66	1.4266	2.0352
Parenchma	45.33	54.00	42.67	27.33	41.00	36.00	47.00										41.90	8.4920	72.1138
Floodplain Ecossystem – Tree 2																			
Vessels	8.70	10.00	9.30	14.30	13.00	20.30	18.00	16.30									13.74	4.2711	18.2427
Rays	19.30	15.30	27.30	22.40	22.30	16.30	26.30	16.30									20.69	4.6323	21.4584
Fiber	25.00	28.00	21.00	16.30	26.30	23.70	21.00	28.40									23.71	4.1122	16.9098
Parenchma	47.00	46.70	42.40	47.00	38.40	39.70	34.70	39.00									41.86	4.6696	21.8055
Upland Ecossystem – Tree 1																			
Vessels	11.67	6.33	7.67	10.33	8.33	9.33	11.67	9.33	12.33	16.00							10.30	2.7650	7.6451
Rays	10.33	23.33	20.67	22.33	23.33	24.67	22.00	19.33	20.33	17.00							20.33	4.1610	17.3143
Fiber	37.00	33.00	28.00	32.33	26.33	27.67	33.33	32.33	29.67	31.33							31.10	3.2084	10.2938
Parenchma	41.00	37.33	43.67	35.00	43.67	38.33	33.00	37.33	38.00	35.67							38.30	3.5408	12.5370
Upland Ecossystem – Tree 2																			
Vessels	15.67	13.00	7.00	6.33	6.67	9.67	6.33	6.67	9.33	9.00	11.33	11.67	10.67	13.00	15.33	16.67	10.52	3.4965	12.2253
Rays	16.00	17.00	16.00	20.33	20.33	21.00	18.33	21.67	24.67	21.33	12.33	15.67	16.33	14.00	14.00	15.00	17.75	3.4484	11.8917
Fiber	23.67	28.33	33.67	31.00	31.00	27.67	23.00	24.67	24.00	25.33	23.00	22.33	28.33	30.33	22.33	29.00	26.73	3.6360	13.2208
Parenchma	45.00	42.00	43.33	42.33	44.00	41.67	52.33	47.00	43.67	44.00	44.67	50.33	45.00	43.67	49.00	39.00	44.81	3.3983	11.5486

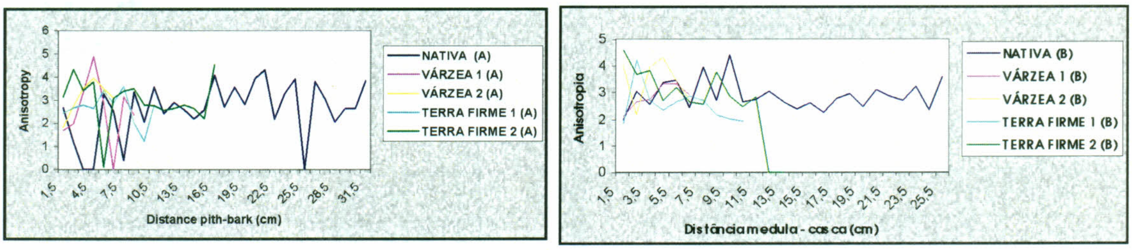

Figure 4: Characteristics of anisotropy in direction from pith-bark in wood from cultivated sumauma trees.

The results indicated in the Tables 5 and 6 and in the Figure 5 show that the density and the ratio of the distance from pith to bark are logarithmical.

By observing the results, see Table 5, it is shown that the estimated values for the density at cultivated sumauma ecosystems on floodplains and upland are higher than the values observed in native sumauma (0.24 g/ cm^3). By these results, it can be assumed that some precautions have to be taken for the establishing of sumauma plantations, as the quality of cultivated wood seems to differ slightly from native wood, considering the parameter of density and with it the wood quality. On the one hand, the low density of native wood trees is favorable in a low-cost plywood manufacture. This result could limit the future use of cultivated trees of both ecosystems. On the other hand, the higher wood density in cultivated trees would favour the production of more durable plywood, and consequently, the wood could be used to produce plywood of better quality.

Table 5: Estimated values for the density at cultivated sumauma ecosystems of floodplain and upland, and native sumauma.

Ecosystem	Equation	R^2	Estimated Density (g/m^3)	Observed Density (g/m^3)
Upland 1	Y = 0.0377Ln(x)+0.286	0.608	0.417	-
Upland 2	Y = 0.0457Ln(x)+0.24	0.677	0.400	-
Foodplain (1)	Y = 0.0514Ln(x)+0.2034	0.782	0.382	-
Foodplain (2)	Y = 0.044Ln(x)+0.2389	0.891	0.392	
Native	Y = 0.0533Ln(x)+0.1152	0.749	0.301	0.248

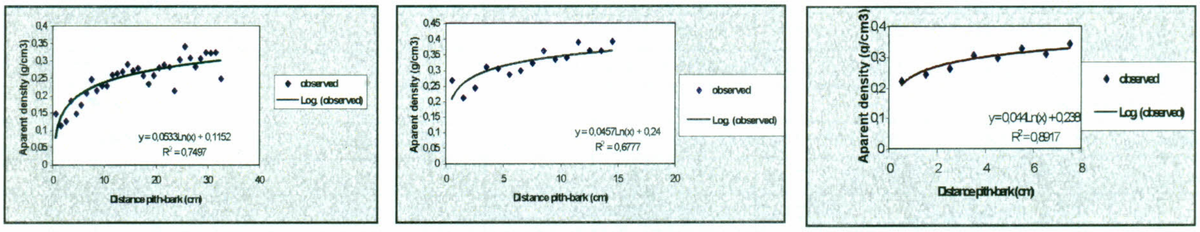

Figure 5: Regression equation for native sumauma and cultivated at the upland and floodplain ecosystems.

Table 6: Radial variation of density (g/cm^3) on the pith-bark direction for sumauma cultivated trees at the floodplain and upland ecosystems.

Ecossistema	Direção	Variação Radial da Densidade (g/cm^3 (Direção medula – casca)																															Estatística		
		1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.5	21.5	22.5	23.5	24.5	25.5	26.5	27.5	28.5	29.5	30.5	31.5	32.5	μ	σ^2	σ
Nativa	A	0.11	0.13	0.18	0.15	0.17	0.21	0.25	0.21	0.23	0.23	0.26	0.26	0.27	0.29	0.27	0.28	0.26	0.23	0.26	0.28	0.29	0.28	0.21	0.30	0.34	0.31	0.28	0.31	0.32	0.32	0.32	0.25	0.25	0.004	0.059
	B	0.20	0.18	0.17	0.18	0.19	0.17	0.18	0.23	0.24	0.23	0.22	0.24	0.27	0.30	0.32	0.28	0.27	0.30	0.33	0.37	0.31	0.33	0.31	0.34	0.34								0.26	0.004	0.063
Várzea (1)	A	0.20	0.22	0.26	0.28	0.27	0.34	0.32																										0.26	0.003	0.053
	B	0.18	0.33	0.22	0.19	0.32																												0.24	0.005	0.070
Várzea (2)	A	0.24	0.26	0.31	0.30	0.33	0.31	0.34																										0.29	0.002	0.042
	B	0.24	0.28	0.31	0.35	0.39																												0.31	0.003	0.055
Terra firme (1)	A	0.30	0.35	0.35	0.29	0.31	0.37	0.37	0.40	0.36																								0.34	0.002	0.004
	B	0.27	0.31	0.33	0.36	0.32	0.31	0.36	0.32	0.33	0.41																							0.33	0.001	0.036
Terra firme (2)	A	0.21	0.24	0.31	0.31	0.29	0.30	0.32	0.36	0.33	0.34	0.39	0.36	0.36	0.36	0.39	0.21	0.30	0.34	0.31	0.28	0.31	0.32	0.32	0.32	0.25								0.32	0.003	0.005
	B	0.23	0.26	0.28	0.32	0.34	0.32	0.33	0.34	0.39	0.34	0.37	0.41	0.44	0.34																			0.33	0.004	0.060

Table 7: Radial variation of the anisotropy on the pith-bark direction for the sumauma cultivated trees at the upland and floodplain and native floodplain ecosystems.

Ecossistema	Direção	Variação Radial da Anisotropia (Direção medula – casca)																														Estatística		
		1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.5	21.5	22.5	23.5	24.5	25.5	26.5	27.5	28.5	29.5	30.5	31.5	μ	σ^2	σ
Nativa	A	2.67	1.17	0.00	0.00	3.26	2.51	0.39	3.35	2.06	3.56	2.41	2.90	2.59	2.18	2.57	4.08	2.71	3.57	2.81	3.92	4.32	2.19	3.30	3.91	0.00	3.81	3.04	2.07	2.64	2.65	3.84	2.60	1.44	1.20
	B	1.96	3.04	2.55	3.37	3.45	2.43	3.98	2.71	4.43	2.65	2.74	3.07	2.63	2.40	2.61	2.25	2.77	2.95	2.46	3.11	2.90	2.66	3.26	2.34	3.62							2.89	0.31	0.56
Várzea (1)	A	1.68	1.97	3.33	4.88	2.87	0.00	3.14	2.35	-																							2.53	1.42	2.01
	B	2.11	2.67	2.76	3.32	3.31	2.93	-	-	-																							2.85	0.21	0.45
Várzea (2)	A	1.81	2.72	3.51	3.96	3.51	3.11	-	-	-																							3.10	0.57	0.75
	B	4.01	2.16	3.95	4.34	3.47	2.74	-	-	-																							3.45	0.70	0.83
Terra firme (1)	A	2.43	2.66	2.79	2.63	3.41	2.85	3.59	2.02	1.23	2.76																						2.64	0.44	0.66
	B	1.84	4.24	2.69	2.33	2.66	2.90	2.71	2.15	2.02	1.95																						2.55	0.48	0.69
Terra firme (2)	A	3.13	4.34	3.41	3.78	0.08	3.08	3.39	3.51	2.79	2.76	2.55	2.63	2.78	2.63	2.21	4.55																2.98	1.01	1.01
	B	4.58	3.69	3.82	2.72	3.21	2.66	2.57	3.78	2.88	2.46	2.84	0.00	0.00																			2.71	1.82	1.35

CONCLUSIONS

From the results, it can be concluded that:

- Cultivated trees at floodplains and upland ecosystems, as well as native trees, show an increase in density from pith to bark;
- Compared with native sumauma trees, the wood density was higher in the cultivated trees in the upland ecosystems, followed by trees cultivated in the floodplains;
- The values of anisotropy coefficients show that the wood of the sumauma species dimensionally is highly unstable, therefore showing limitations in the use for window frames;
- The logarithmic model was the most adequate regarding the data of density versus pith-bark distance;
- The influence of the ecosystems on the percental proportion of the cell elements was not evident;
- The average data estimated according to the density, with regression equation for the respective plantation are higher than the ones measured for native sumauma.

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