On cattle farms the eucalyptus in fencerows have not shown any tendency to reduce the growth of the pasture, but to the contrary have been valuable as shade for the cattle while they are producing an additional income for the farm.

LITERATURE CITED

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FAST GROWING TREES

ESTIMATIVA DA REMOÇÃO DA BIOMASSA E DOS NUTRIENTES EM PLANTAÇÕES DE *Eucalyptus grandis* EM REGIME DE MINI-ROTAÇÃO.

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Resumo

Vinte e quatro árvores, incluindo todas as classes de diâmetro de um talhão de Eucalyptus grandis (com 2,5 anos - 5333 árvores/ha) foram selecionadas, cortadas e seus componentes (folhas, galhos e tronco) pesados. Amostras dos componentes foram secos em estufa para determinação da umidade e para estabelecer as relações entre as folhas, os galhos e o tronco. Foram, também estimados os nutrientes removidos pelos componentes do estande. Observou-se que 9% da biomassa é contida nas folhas, 7% nos galhos e 83% nos troncos. Todavia, 37% dos nutrientes são contidos nas folhas, 10% nos galhos e 53% nos troncos. Face à baixa fertilidade dos solos de cerrado, principalmente com relação ao P e K, seria oportuno evitar a remoção das folhas, galhos e cascas do "site".

BIOMASS AND NUTRIENT ESTIMATES REMOVAL IN SHORT ROTATION INTENSIVELY CULTURED PLANTATION OF *Eucalyptus grandis.*

Summary

Twenty four trees, including all diameters of an Eucalyptus grandis stand (2.5 years old - 5333 trees/ha) were weighted by component parts (leaves, limbs and stems). Samples were oven-dried to determine moisture content and to establish: leaves, limbs, crown, stem weight-relationships. Also macro and microelements of each tree component were analysed to estimate the nutrient contents removed by bolewood, harvest or complete trees utilization. Biomass distribution among the components of the stand is about 9% leaves, 7% limbs and 83% stems. However nutrients content in the stand biomass are about 37% in the leaves, 10% in the limbs and 53% in the stems. Because "cerrado" soil (Savanna) is very low in available form of nutrients, mainly P and K, it is suggested to avoid the remotion of leaves, limbs and bark from the site.

Introduction.

Escalating costs of oil and energy shortage have forced wood users to consider maximizing total tree use. In fact, crown biomass and tree bark may become sources of energy. Therefore, intensive management of forest plantations will increase significantly biomass production.

In this area several papers have been published in Europe and North America (HANSEN & BAKER, 1979), however only a few studies were conducted in Brazil. Preliminar data have been published by POGGIANI, COUTO & SIMÕES (1979) regarding biomass production . nutrient accumulation in forest stand of Eucalyptus grandis planted in the State of São Paulo.

According to HANSEN & BAKER (1979), intensive management of plantations may significantly increase biomass production (3 to 5 times), however it increases also nutrient removal from the site and a strong fertilization must become an integral part of such management.

POGGIANI (1980) reports some data regarding Eucalyptus and Pinus plantations in the states of São Paulo and Minas Gerais and believes to be primordial to evaluate silvicultural and ecological consequences of intensively cultured plantations and short rotations in tropical areas. "Cerrado" soils (Brazilian Savannas) have in general low fertility, mainly in P and K and high concentrations of iron, manganese and aluminium.

This papers discusses the distribution of biomass and nutrients in a stand of Eucalyptus grandis (2.5 years old). Equations predicting the dry biomass of the total tree and its components are presented.

Nutrient removal by conventional bolewood harvest and complete tree utilization are also discussed.

Material and Methods.

Site and stand description.

Seedlings of Eucalyptus grandis (Hill ex-Majden) were produced from seeds provenient from Coff's Harbour (Australia) and planted in November 1976. The area of this experiment, located in Bom Despacho (Minas Gerais) presents the tipical climate of Brazilian savannas: annual mean temperature around 19.5ºC with occasional frost in the winter; annual rainfall about 1400 mm, with 80% of the total rain-fall concentrated on the hot-wet season (October-March).

Each seedling planted in the initial spacing of 1.0 by 1.5 m was fertilized with 150 g of N-P-K (10:28:6) and B and Zn.

The planting area was previously occupied by a kind of savanna vegetation (Cerrado) and the soil is a clay latosol very deep and with a low content of avaliable nutrients such as: phosphorus 33 Kg/ha, potassium 99 Kg/ha, calcium 312 Kg/ha and magnesium 220 Kg/ha (0-120 cm depth).

The survival rate was around 80% at the end of the experiment.

Field and laboratory methods.

A random sample of 150 trees was selected from the 2.5 years old plantation of Eucalyptus grandis. D.B.H. and the total height data of each tree were determined and the sample was divided in nine diameter classes. Two to four trees from each D.B.H. class from 2.0 to 11.0 cm (total 24 trees) were selected, felled and limbed. Each component of the tree (leaves, limbs and stem) was separated and weighted in the field.

Three samples (about 150 g) of leaves and small sections of the limbs collected from the median part of the crown and a disk collected from the median part of the stem were weighted and sealed in polyethylene bags for laboratory analysis. All the samples were oven-dried at 80ºC until constant weight. After this moisture content of the different components were determined and the dry weight of each tree calculated. Weighted values for moisture content in the samples were used to convert component green weight to oven-dry weight.

Chemical analyses.

After oven-drying, leaves, limbs and stem samples (sections of the disks including wood and bark taken at half of the tree total height) were ground in a Wiley mill and passed throgh a 20 mesh screen. The chemical analyses were performed according to SARRUGE & HAAG (1974). Nitrogen by the micro-Kjeldahl method, phosphorus by the vanadomolybdate method and all other nutrients were determined from the acid solution by atomic absorption spectrophotometry.

Analytical Procedure.

In order to estimate biomass content of the E. grandis stand, regression models were determined and the parameters were estimated using the S.A.S. (Statistical Analysis System) computer package.

For choosing the best model, to estimate dry biomass components of the tree, a step-wise procedure was performed using as independent variables D.B.H. and total height, and their transformed values.

Results and Discussion.

Biomass production.

Leaves, limbs and stems biomass as dependent variables of the D.B.H. are shown in Figure 1. Also tree total height as dependent variable of diameter is shown in Figure 2.

Equations of the figure 1 show that D.B.H. has good correlation with stem and leaves biomass, but only regular correlation with limbs. However, the best equations found by step-wise procedure include also tree height as an independent variable usefull to improve the correlation. The following models proved to give the best fit.

TABLE-1. BIOMASS DISTRIBUTION(Kg/ha) OF A *Eucalyptus grandis* STAND FOR DIFFERENT DIAMETER CLASSES.

TABELA-1. DISTRIBUIÇÃO DA BIOMASSA (Kg/ha) NO TALHÃO DE *Eucalyptus grandis* NAS DIFERENTES CLASSES DE DIÂMETRO.

CLASSES D.B.H. D.A.P. (cm)	TREES /ha Árvores	LEAVES Kg/ha Folhas	LIMBS Kg/ha Galhos	CROWNS Kg/ha Copa	STEMS Kg/ha Tronco	TOTAL TREES Kg/ha Árvore total
1) 2.1-3.0	267	20.3	106.8	127.8	180.2	307.3
2) 3.1-4.0	213	36.4	76.4	112.8	339.0	451.8
3) 4.1-5.0	480	209.3	208.3	417.6	1,722.7	2,140.3
4) 5.1-6.0	747	564.0	404.1	968.1	5,354.5	6,322.6
5) 6.1-7.0	1,013	1,167.0	772.9	1,939.9	11,108.5	13,048.4
6) 7.1-8.0	1,013	1,661.3	1,170.0	2,831.3	15,833.2	18,664.5
7) 8.1-9.0	907	1,892.0	1,454.0	3,346.0	18,038.4	21,384.4
8) 9.1-10.0	480	1,350.2	1,039.2	2,389.4	12,885.6	15,275.0
9) 10.1-11.0	213	717.4	553.4	1,270.8	6,849.2	8,120.0
TOTAL	5,333	7,617.9	5,785.1	13,403.0	72,311.3	85,714.3
%	(100%)	(8.9%)	(6.7%)	(15.6%)	(84.4%)	(100.0%)

a) Leaves dry biomass (Biomassa seca das folhas)

$Y = -0.0277 + 0.0020\ D^2 \cdot H \qquad R^2 = 0.94^{**}$

b) Limbs dry biomass (Biomassa seca dos galhos)

$Y = 0.9448 - 0.1049\ H + 0.0330\ D^2 \qquad R^2 = 0.80^{**}$

D=D.B.H.
H=Height

c) Stem dry biomass (Biomassa seca do tronco)

$Y = -0.3145 + 0.0197\ D^2 \cdot H \qquad R^2 = 0.99^{**}$

Table 1 shows the dry biomass data for all classes of diameter and the total biomass produced by the stand of *E. grandis*.

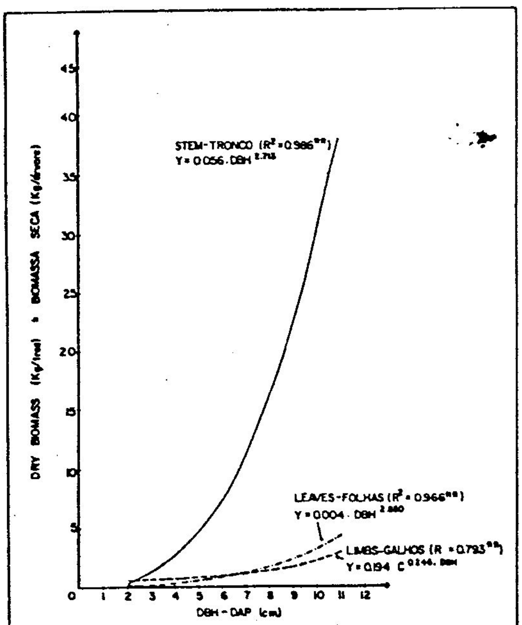

Figure 1.

Changes in dry biomass of *Eucalyptus grandis* components by tree diameters (D.B.H.)

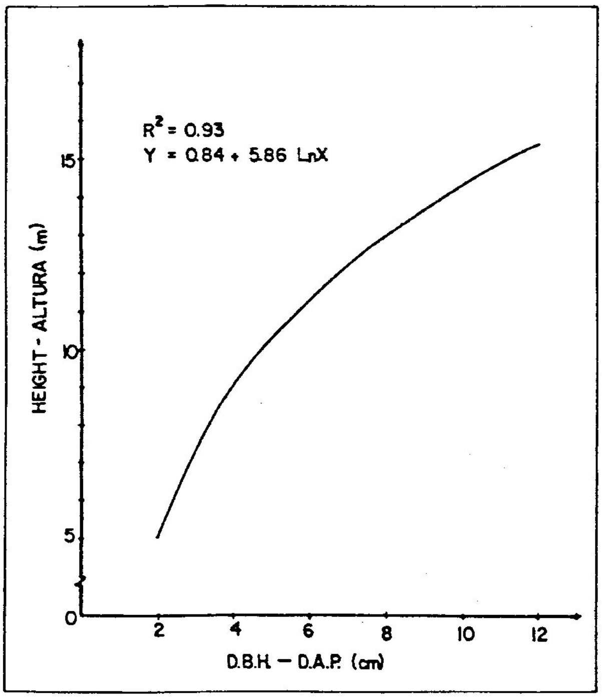

Figure-2.

Tree total height as dependent variable of diameter (D.B.H.)

If the complete tree utilization is considered, the total biomass amounts 85,7 tons per hectare. Conventional bolewood harvest of the stand would provide 72.3 tons of wood biomass (About 29 tons/ha per year).

These data compared with several data presented by HANSEN & BAKER (1979) including biomass production per year of some fast growing trees species in temperate zones show clearly the strong potential of *Eucalyptus* for wood production in the tropics.

Spacing has also a strong influence in biomass produced by short rotations. Very closed spacings, according to BELANGER & PEPPER (1978) increased biomass production in sycamore plantations, however the rate of survival became lower in very closed spacings ($0.4\ m^2$).

Presentely several experiments with closed spacings and short rotations are conducted by the Department of Silviculture of São Paulo University (Piracicaba). Preliminar data show the spacing 1.0 by 1.0 as the best for Eucalyptus saligna and Eucalyptus alba plantations,one year old,with a survival rate of 94%.

Anyway,short rotation increase strongly the biomass production. Comparing the biomass produced in this experiment with an 8 years old stand of E.grandis planted in the conventional spacing-3.0 by 2.0 m -(BELLOTE,1979 and POGGIANI,1980)it is possible to conclude that short rotations have twice the potential for wood production than usual rotations for Eucalyptus trees in Brazil.

In short rotations biomass distribution is also different comparing with conventional plantations.According to BELLOTE(1979)an Eucalyptus grandis stand- 2 years old and 3.0 by 2.0 m spacing-presented the following proportion for biomass distribution in the different components of the trees: 68.3% in the stem,12.2% in the leaves and 19.5% in the limbs.The present experiment found for E.grandis(2.5 years old plantation)83.2% of the biomass in the stem,8.9% in the leaves and 7.9% in the limbs.It indicates more closed spacings in short rotations increase stem biomass.However more experiment must be carry out in this sense.

In the table 2 are shown the dry biomass data per tree,for each class of diameter.Crown weight of the lower class is 41.3% of the total tree weight,although in the higher class crown weight is only 15.6% of the tree.This remark will be discussed in the item 3.4

TABLE -2. BIOMASS DISTRIBUTION ON THE AVERAGE TREE FOR DIFFERENT DIAMETER CLASSES.

TABELA-2. DISTRIBUIÇÃO DA BIOMASSA NA ÁRVORE MÉDIA DAS DIFERENTES CLASSES DE DIÂMETRO.

CLASSES Classes	D.B.H. D.A.P. cm	LEAVES Folhas Kg	LIMBS Galhos Kg	CROWN Copa Kg	STEM Tronco Kg	TOTAL TREE Árvore total Kg
1	2.1-3.0	0.076 (6.6%)	0.400 (34.7%)	0.476 (41.3%)	0.675 (58.7%)	1.151 (100.0%)
2	3.1-4.0	0.171 (8.0%)	0.357 (16.8%)	0.528 (24.8%)	1.594 (75.2%)	2.122 (100.0%)
3	4.1-5.0	0.436 (9.8%)	0.434 (9.7%)	0.870 (19.5%)	3.589 (80.5%)	4.459 (100.0%)
4	5.1-6.0	0.755 (8.9%)	0.541 (6.4%)	1.296 (15.3%)	7.168 (84.7%)	8.464 (100.0%)
5	6.1-7.0	1.152 (8.9%)	0.763 (5.9%)	1.915 (14.8%)	10.966 (85.2%)	12.881 (100.0%)
6	7.1-8.0	1.640 (8.9%)	1.155 (6.3%)	2.795 (15.2%)	15.630 (84.8%)	18.425 (100.0%)
7	8.1-9.0	2.085 (8.8%)	1.604 (6.8%)	3.689 (15.6%)	19.888 (84.4%)	23.577 (100.0%)
8	9.1-10.0	2.813 (8.8%)	2.165 (6.8%)	4.978 (15.6%)	26.845 (84.4%)	31.823 (100.0%)
9	10.1-11.0	3.368 (8.8%)	2.598 (6.8%)	5.966 (15.6%)	32.156 (84.4%)	38.122 (100.0%)

Nutrient concentration in the tree components.

Means and standard errors of nutrient concentration are included in table-3.For all the components nutrient concentrations in the biomass are as follows: N>K>Ca>Mg≥P>Mn>Fe>Zn>Cu.

Nutrients concentration is for all the elements higher in the leaves than in the stem: 12 times for Nitrogen, 4.5 times for phosphorus,2.8 times for potassium,6.5 times for calcium and 9.5 times for magnesium.

In general,nutrient concentrations found in this experiment are similar to the concentrations presented by HAAG et alii(1976) and BELLOTE(1979) for E.grandis plantations in "Cerrado" soil,however they are lower than concentrations presented by LUBRANO(1967) for Eucalyptus viminalis planted in Italy.

TABELA-3.
MÉDIA E ÊRRO PADRÃO DA CONCENTRAÇÃO DE NUTRIENTES NOS COMPONENTES DAS ÁRVORES DE Eucalyptus grandis(2,5 ANOS)

TABLE-3.
MEAN AND STANDARD ERROR OF NUTRIENT CONCENTRATIONS IN THE TREES COMPONENTS OF Eucalyptus grandis.(2.5 YEARS OLD)

COMPONENTS Componentes	N	P	K	Ca	Mg	Fe	Cu	Mn	Zn
	ELEMENTS								
	%					ppm			
LEAVES Folhas	1.850	0.110	0.650	0.590	0.200	296.0	4.0	953.0	12.5
S.Er.	± 0.020	± 0.012	± 0.050	± 0.060	± 0.014	± 33.0	± 0.2	± 102.0	± 0.6
LIMBS Galhos	0.460	0.040	0.370	0.260	0.040	93.0	3.6	396.0	5.7
S.Er.	± 0.017	± 0.003	± 0.030	± 0.023	± 0.007	± 10.1	± 0.1	± 26.3	± 0.4
STEMS Troncos	0.150	0.024	0.230	0.090	0.021	38.6	1.5	185.0	5.3
S.Er.	± 0.009	± 0.003	± 0.007	± 0.006	± 0.002	± 2.4	± 0.1	± 13.8	± 0.3

Certainly N-P-K fertilization in the planting (150 g -10:28:6) makes available a regular supply of N and K,but P is strongly fixed by aluminium in the soil(pH 4.6),that is also very poor in calcium.Also high levels of Mn and Fe were observed in the leaves due to soil acidity,however no symptoms of toxicity were evident in the trees.

Nutrient content in the biomass of the stand.

Recently in Brazil some foresters believe to be suitable whole tree utilization,mainly for energy supplies.In this sense several researches are conducted in Brazil and in other countries.A critical evaluation about this problem was published by SWITZER,NELSON & HINESLEY(1978)but only for temperate zone.It is necessary to point out the problem is more complicated in the fragile ecosystems of the tropics,because the ecological and economical implications.

Table 4 presents the data on biomass and nutrients distribution in the stand.

TABLE-4. BIOMASS AND NUTRIENTS CONTENT(Kg/ha)IN AN Eucalyptus grandis STAND,2.5 YEARS OLD(5,333 TREES/ha).

TABELA-4.BIOMASSA E NUTRIENTES CONTIDOS(Kg/ha) NUM TALHÃO DE Eucalyptus grandis AOS 2,5 ANOS DE IDADE.(5.333 ARVORES/ha)

COMPONENTS Componentes	BIOMASS Biomassa	N	P	K	Ca	Mg	Fe	Cu	Mn	Zn	TOTAL NUTR.
TOTAL TREE Arvore tot.	85,714.3	275.9	28.0	237.2	125.0	32.7	5.5	0.16	22.8	0.52	727.7
LEAVES Folhas	7,617.9	140.9	8.4	49.5	44.9	15.2	2.2	0.03	7.2	0.09	268.4
LIMBS Galhos	5,785.1	26.6	2.3	21.4	15.0	2.3	0.5	0.02	2.3	0.03	70.4
CROWN Copa	13,403.0	167.5	10.7	70.9	59.9	17.5	2.7	0.05	9.5	0.12	338.8
STEM Tronco	72,311.3	108.4	17.3	166.3	65.1	15.2	2.8	0.11	13.3	0.40	388.9

TABLE-5. AVERAGE OF BIOMASS(Kg)AND NUYTIENTS CONTENT(g) PER TREE OF *Eucalyptus grandis*, 2.5 YEARS OLD.

TABELA-5. MÉDIA DA BIOMASSA(Kg) E DO CONTEUDO DE NUTRIENTES(g) POR ÁRVORE DE *Eucalyptus grandis* aos 2,5 anos de idade.

COMPONENTS Componentes	BIOMASS Biomassa	N	P	K	Ca	Mg	Fe	Cu	Mn	Zn	TOTAL NUTRIENTS Total nutrientes
		g/tree									
TOTAL TREE Árvore tot.	16.071 (100%)	51.7	5.2	44.5	23.4	6.0	1.0	0.038	4.3	0.0,4	136.2 (100%)
LEAVES Folhas	1.428 (8.9%)	26.4	1.6	9.3	8.4	2.8	0.4	0.005	1.4	0.018	50.3 (36.9%)
LIMBS Galhos	1.084 (6.7%)	5.0	0.4	4.0	2.8	0.4	0.1	0.004	0.4	0.006	13.1 (9.6%)
CROWN Copa	2.512 (15.6%)	31.4	2.0	13.3	11.2	3.2	0.5	0.009	1.8	0.024	63.4 (46.5%)
STEM Tronco	13.559 (84.4%)	20.3	3.2	31.2	12.2	2.8	0.5	0.020	2.5	0.070	72.8 (53.5%)

Leaves and limbs constitute 15.6% of the total biomass, but contain 46.6% of the nutrients (338.8 Kg/ha). Stems content is 388.9 Kg/ha. Nitrogen is the nutrient highly accumulated in the crown and potassium in the stem.

According to POGGIANI(1980) total biomass production of a stand of *E.grandis* in short rotation intensively cultured plantation might reach, in an eight years period, twice the production of a conventional rotation stand (3.0 by 2.0 m spacing). However the short rotation removes three times more nutrients than conventional plantations.

With the purpose to reduce the strong nutrient remotion by short rotations other alternatives of management and exploitation must be developed. Moreover new species provenances and clones with a higher "utilization efficiency" for closed spacings and short rotations must be introduced in silviculture practices.

According to HANSEN & BAKER(1979) we use "utilization efficiency" to express the weight of biomass produced per unit weight of nutrients.

Fertilization versus nutrients removed by trees harvest.

As was shown before, the "Cerrado" soil where this experience was laid down is poor in available nutrients (P-33 Kg/ha, K-99Kg/ha, Ca-312 Kg/ha and Mg- 220 Kg/ha.). Comparing nutrient content of above ground biomass of *Eucalyptus* stand, as shown in Table 5, with soil nutrients (0-120 cm depth), it can be seen that this soil does not support for a long time a forest plantation intensively exploited.

In fact, nutrient content in the soil is almost equivalent to nutrient content in the biomass of the *Eucalyptus* stand. Mainly for potassium, phosphorus and calcium, will be necessary to pay a supplementary attention. In such case is necessary to supply the nutrients removed by harvesting with a suitable fertilization to maintain the stand productivity.

In this experiment each tree received as fertilizer 150g of N-P-K(10:28:6) corresponding to 15 g of nitrogen, 18.3 g of phosphorus and 7.5 g of potassium.

Probably nitrogen is also fixed from the air by symbiotic and asymbiotic process, however a large rate of P is fixed by aluminum in the soil and potassium is accumulated in the plant tissues. Low content of potassium in the soil can become very critical for the next rotations. Calcium is also a scarce element in the soil and must be supplied by fertilization. This calcium scarcity is evident if we compare its concentration in the trees tissues with some data reported by LUBRANO(1967) for *Eucalyptus viminalis* in Italy. Probably soil liming before planting may result in more available nutrients for root systems and better economy in fertilizers.

Final considerations.

Some considerations are also essential to preserve nutrients in the site. Leaves and crown exploitation seem to be not convenient under an ecological and silvicultural point of view, mainly for dominated trees that present a large proportion of crown biomass with high rate of nutrients.

Therefore, to mitigate the loss of soil fertility in tropical zones, would be suggested to avoid crown exploitation mainly in short rotation regime.

Another suggestion would be to encourage research for species and clones selection with high "utilization efficiency" in order to improve biomass production with a lower nutrient remotion from the site. According to BAKER & COOPER(1978) and BOWERSOX & WARD(1976) considerable variation in nutrient concentration has been noted in eastern cottonwood and in young hybrid poplars growing in closed spacing.

Fertilization studies are also primordial to develop more appropriated know-how for tropical soils of the Brazilian savannas.

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