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# Total tree weight for *Eucalyptus globulus* Lab. (\*)

By

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## *Keywords*

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## *RESUMO*

Este estudo foi executado no sentido de quantificar as várias componentes da biomassa eucaliptal potencialmente utilizáveis na indústria de pasta de papel. O estudo em referência diz respeito à Serra de Ossa que se pode considerar representativa da região sub-mediterrânea.

Do presente estudo conclui-se que para o eucaliptal em estudo, os valores de desperdícios em bicadas e casca em relação à exploração tradicional atingem 2,3 e 17% respectivamente, o que representa para as duas componentes 2,17 t/ha e 11,6 t/ha.

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Os modelos preditivos dos desperdícios na idade do 1.º corte (10 anos) revelaram que os vários componentes considerados podem ser preditos com inteira segurança, utilizando como variável descritiva o DAP ou a variável combinada (DAP)·H.

#### SYNOPSIS

This study was undertaken to determine the potencial of whole *Eucalyptus globulus* Lab. trees explored in a 10 year rotation as a source of wood pulp, employing the kraft process. The first part related with wood production in a site representative of sub-mediterranean region is here discribed.

It was concluded from this study that approximately 2.3 % of top wood and 17 % of bark in relation to actual merchantable wood amounting to 2.17 ton/ha and 11.6 ton/ha respectively are now wasted by the industry that faces its major drawback for expansion in the lack of wood raw material.

Regression equations were studied to predict total dry tree components weight. The models developped showed that tree weight can be confidently used by applying DBH alone or, the combined variable (DBH)·H or sp. gr. of an increment core to the equations given.

#### INTRODUCTION

The growth of the actual mill capacity of the portuguese pulp industry based in eucalipts wood, that represents 75 % of total wood pulp produced, finds in the lack of suitable wood supply its major expansion bottleneck. The surpassing of this situation, vital for the maintenance of their competitivety capacity in the european market, advises the application of the total wood production now still left on the ground as wastes. This necessity is still stressed by the actual economics of the practice of forestry in Portugal were labor costs showed a sharp increase in the last 3 years and the stumpage price are low as compared to other european countries.

The implementation of any action towards a better utilization of *E. globulus* wood production demands a different emphasis in the quantitative measurement of the sample trees. The units of volume of the merchantable bole or merchantable size trees which are at present time being exclusively used in portuguese forest inventories is no longer an adequate perspective for those concerned with untraditional uses of wood.

The writers are advocates of the Complete Tree Concept: biological and technological investigation of the entire tree as have been advocated by Young (1966, 1968), Keays (1968) and Hakkila (1971).

Within the framework of this basic philosophy our Institution started a comprehensive, biological and technological investigation on *E. globulus* stands in order to find out the ecological impact on the balance of nutrients and water as a result of a more intensive exploitation as well as the pulping potencial of forest residuals, mainly tops and bark, that are the main foreseeable fibre resource usually left on the *E. globulus* forest ground.

This paper reports volumes, and dry weight of *E. globulus* main components. Regression equations are presented to predict total (aboveground) dry tree weight within a sizable eucalipt plantation at Serra de Ossa we may consider representative of sub-mediterranean region in Portugal. These are not supposed to be used for the entire range of *E. globulus* plantation in Portugal. The best results will be certainly obtained when prediction models are made in a broader site areas where *E. globulus* has been planted. However, this information will make it easier to evaluate the economics of removing the components unused in total-stand harvesting situations as well as their impact from the technological and economic mill point of view.

#### SITE CHARACTERIZATION

All climatic data of Serra de Ossa (38° 44' to 38° 46' N — 1° 32' to 1° 33' W) were obtained from Portugal Weather Bureau from weather reporting stations in close proximity of the sampled plots. According to SROA, the ecological site classification is of the sub-mediterranean and Atlanto-mediterranean-sub-mediterranean, type.

The eucalipt plantations are on grauwacks and schists lithosols belonging to E or in a small scale to D+E land capability classes. <sup>(1)</sup>

TABLE 1 — Climatic data at the two near weather reporting station

	Precipitation, (mm)	Temperature, (°C)	Total Insolation, (hours)	Total Evaporation, (mm)
Evora	716.8	15.6	2 900.9	2 050.8
Portalegre	948.6	15.2	2 573.5	1 729.5

Mean values 1966-1970)

(1) In Portugal, SROA (Soil Surveying and Mapping Bureau) works with 5 land capability classes identified in decreasing order of capability from A to E.

## EXPERIMENTAL PROCEDURE

### *Field procedure*

Two plots were selected as representative of Serra de Ossa, plantations were *E. globulus* has been extensively planted (6 000 ha) and is at the moment the biggest contiguous eucalipt area. Each plot was demarcated to contain 100 trees numbered serially along the planting rows.

From each plot, 4 trees were randomly selected subject to the following restrictions: a) trees with marked sweep along the stem length were excluded: b) trees with marked abnormal crown or with any evidence of die-back were also excluded.

In each plot, breast height diameter was measured by a forest caliper and recorded. The height of a random sample of ten trees in each plot was also measured with a Blum Leise hipsometer, together with the heights of the ten trees of greatest girth, to serve as an estimate of mean height of dominants.

### *Within tree sampling*

After the trees were felled, total height was remeasured with a tape from the tip to the terminal shoot adding thereafter the stump height.

From each sampled tree, cross sectional bolts, 0,40 m length, were taken at the following percentage levels of total height: 5 %, 15 %, 35 % and 75 %. An increment core was also taken at DBH height and sealed in a polyethylene bag to minimize moisture loss during transport to the laboratory. Top wood was defined as that part of the main stem with a diameter less or equal to 0.06 m.

### *Laboratory procedure*

In the laboratory, discs 0.05 m thick, were sawn from the middle of the 0.40 m length bolts. The green diameters, outside and inside bark, to the nearest 1 mm was measured. The actual green weight of both sample components were determined to the nearest 0.1 gr while green volumes were determined by a modified displacement procedure described by FPL (USA, 1956). The oven dry weights were also determined. Because of the within tree variation in moisture content

(fig. 1), an average moisture content for each entire tree was calculated by weighting the average moisture content of the two consecutive discs by the volume of the section between two discs. A similar method was used to calculate a weighted average bark moisture content whose within tree variation was also recorded (fig. 2).

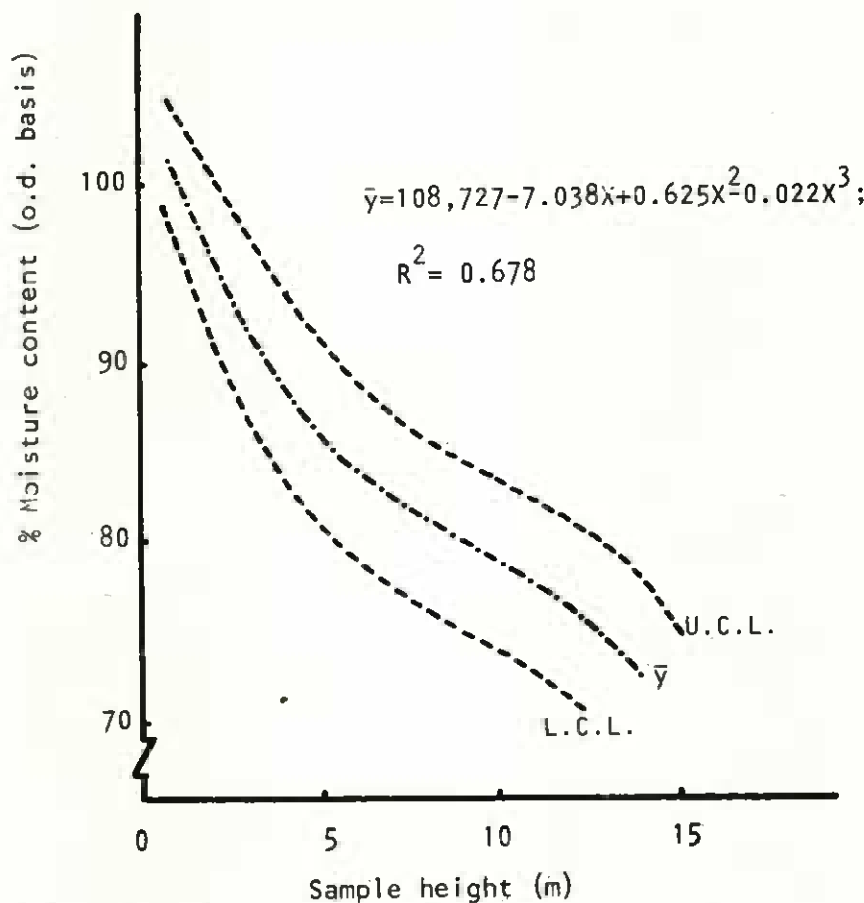


Fig. 1 — Wood moisture content (o. d. basis) variation with tree height.

Specific gravity was determined on a green volume o.d. basis and moisture was computed on an o.d. weight basis.

Because specific gravity varies with height within a tree (fig. 3), a weighting procedure, similar to that described above for determining a weighted average moisture content, was used to calculate a weighted average specific gravity for each tree so that:

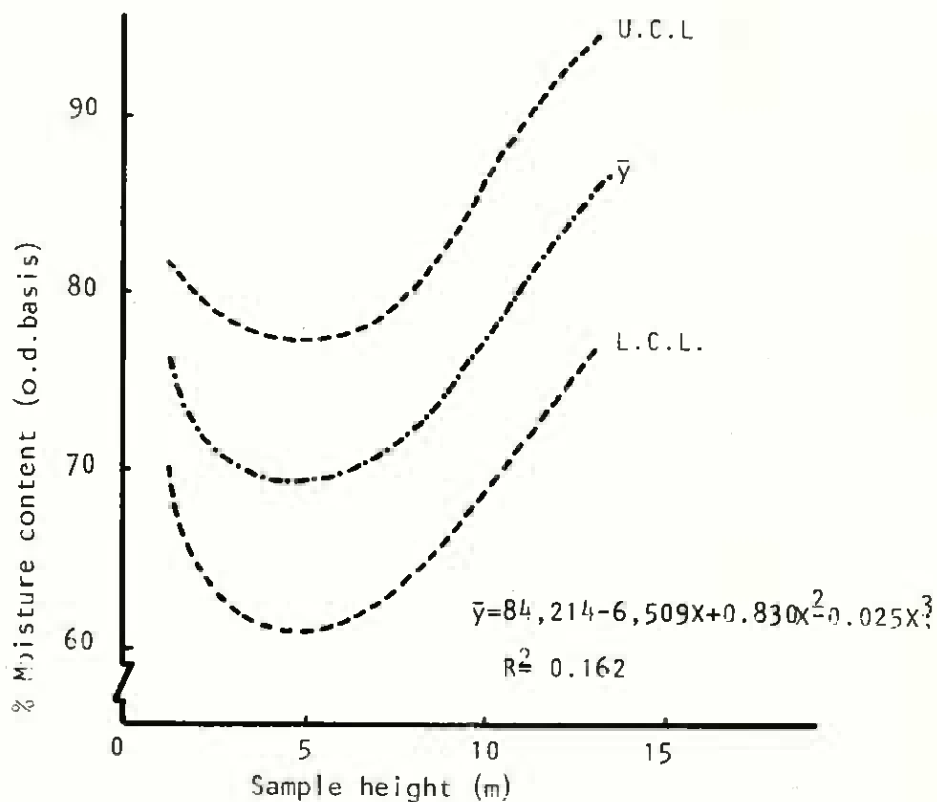


Fig. 2 — Bark moisture content (o. d. basis) variation with tree height.

$$Tsg = \frac{1}{2} \sum_i^n \left[ H_i (R_i^2 + R_{i+1}^2 + R_i R_{i+1}) (G_i + G_{i+1}) \right] / \sum_i^n \left[ H_i (H_i^2 + R_{i+1}^2 + R_i R_{i+1}) \right]$$

Where:

Tsg = tree specific gravity, g/cm<sup>3</sup>.

i, ..., n = disc levels.

H<sub>i</sub> = bolt height at ith level, cm.

R<sub>i</sub> = average disc radius at ith level, cm.

G<sub>i</sub> = disc sp. gr. at ith level, g/cm<sup>3</sup>.

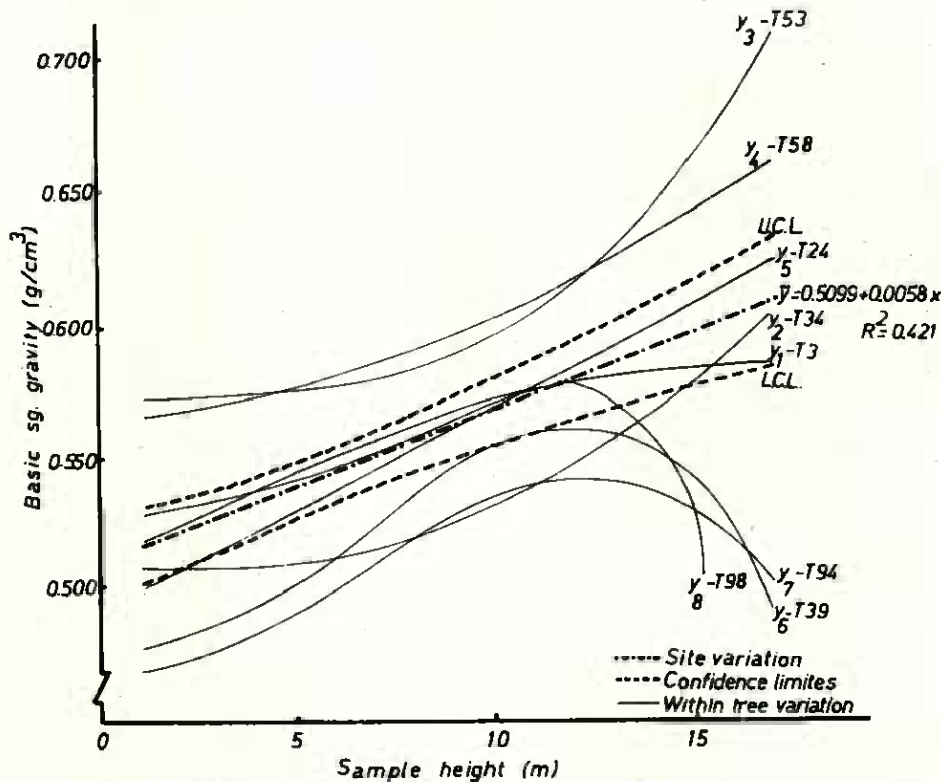


Fig. 3 — Variation of basic sp. gr. with tree height.

## RESULTS AND DISCUSSION

### Tree volumes

Average total-tree volume at the end of a ten year rotation ranged from 171.6 to 229.1 m<sup>3</sup>/ha. In terms of mean plot tree components the bark volume ranged from 26.1 to 31.7 m<sup>3</sup>/ha. In relation to total-tree barked volume this still unused fibre material represents 16.0 to 17.9% and 2.1 to 2.5% in relation to the actual used wood material for bark and top wood respectively.

### Tree weights

The total standing crop dry-weight and its distribution by components for the two plots are listed in table 2.

Table 3 presents the means and the confidence limits of the variables used in this analysis.

TABLE 2 — *Plot characterization*

	Plot P <sub>1</sub>	Plot P <sub>2</sub>
N.º of trees/ha	833	813
N.º of falls/ha	278	437
Mean DBH, cm	18.88 ± 2.37	17.21 ± 1.20
Mean height, m	20.45 ± 1.25	19.20 ± 0.73
Total comercial green volume (o. b.), m <sup>3</sup> /h	229.1 ± 50.6	171.6 ± 23.7
Total comercial green volume (u. b.), m <sup>3</sup> /ha	197.4 ± 41.9	145.5 ± 18.4
Top wod green volume, m <sup>3</sup> /ha	4.13 ± 1.28	3.62 ± 0.58
Top wod percentage (green basis)	2.27 ± 1.54	2.51 ± 0.51
Bark volume, (green basis), m <sup>3</sup> /ha	31.67 ± 12.21	26.09 ± 9.20
Bark percentage <sup>(1)</sup>	15.89 ± 1.87	17.81 ± 2.04

<sup>(1)</sup> Calculate in relation to u. b. comercial wood.

The potencial wood and bark material production for the first rotation of 10 years, provided their quality should prove acceptable, is about 2.17 ton/ha of top wood and 11.6 ton/ha of bark.

TABLE 3 — *Statistical values of the variables charaterizing Serra de Ossa E. globulus productivity*

Componentes	Mean	Confidence limites
<i>Commercial wood</i>		
Green volume (m <sup>3</sup> /ha) <sup>(1)</sup>	171.5	30.2
Green yield (m <sup>3</sup> /ha/year)	17.1	3.0
Dry weight (ton/ha) <sup>(1)</sup>	94.1	19.6
Dry yield (ton/ha/year)	9.4	2.0
<i>Bark</i>		
Green volume (m <sup>3</sup> /ha) <sup>(1)</sup>	28.9	12.0
Green yield (m <sup>3</sup> /ha/year)	2.9	1.2
Dry weight (ton/ha) <sup>(1)</sup>	11.6	3.7
Dry yield (ton/ha/year)	1.2	0.4
<i>Top wood</i>		
Green volume (m <sup>3</sup> /ha) <sup>(1)</sup>	3.8	0.6
Green yield (m <sup>3</sup> /ha/year)	0.38	0.06
Dry weight (ton/ha) <sup>(1)</sup>	2.17	0.25
Dry yield (ton/ha/year)	0.22	0.03

<sup>(1)</sup> Ten years rotation.



As can be seen from the proceeding results and in fig. 4, there is not a significant difference in the distribution of dry weight by components between the two plots, although initial planting spacing was clearly different (1,111 plants/ha and 1,250 plants/ha for plot P1 and plot P2 respectively). It is interesting to note what seems to be the existence of an optimum plant stocking in accordance with the soil moisture availability. In fact we can see a high rate of mortality 36 % in plot P2 as compared with 25 % in plot P1, both under the same silvicultural and management technique. Although we still have not conclusive quantitative results in soil moisture variation, soil water

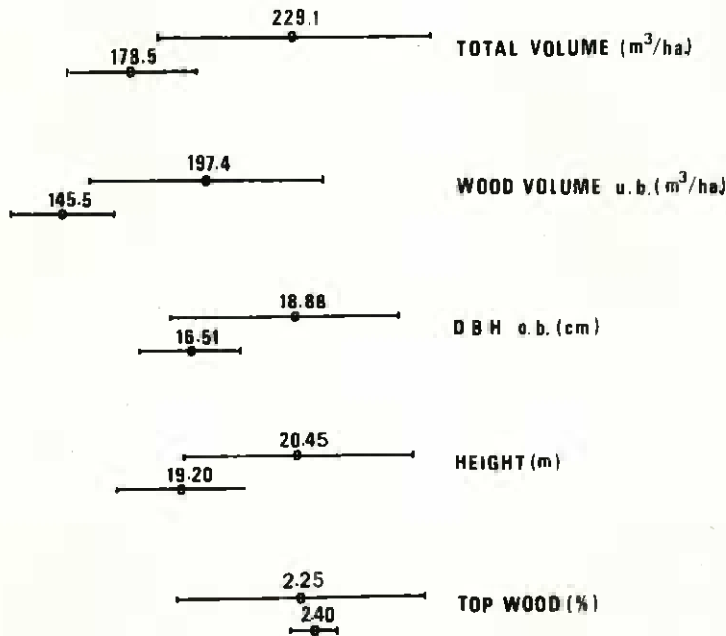


Fig. 4 — Dendrometric sample plot characteristics

retention and depletion under *E. globulus* plantation and their relations to the stocking, it seems the water is likely to be the limiting factor on eucalypts wood production in sub-mediterranean region. Although the number of plots was very small to make it possible to try any regression analysis relating the influence of the number of stems/ha, and DHB or basal area/ha to total tree wood biomass/ha the results presented do not seem to suggest an inverse relationship between that number of stems and total standing crop as it is gene-

rally described in the literature. This undoubtedly seems to reflect the fact that as the number of stems decreases, live crown and thus the amount of foliage per ha. have not increased significantly leading to an increased growth. However this inverse relationship stands true for top wood weight percentage.

From the point of view of tree sp. gr. the influence of compass plantation and the controverse influence of rate of growth in that characteristic was not clearly seen in this study. However, the development of sp. gr. within the tree seems to be in a way affected for in plot P2, that shows clearly a different trend (fig. 3). This further demonstrates, when comparing within tree trends, the need to account for both stocking (area occupancy) and stand density (crowding within the area stocked) when considering the growth and yield of *E. globulus* stands. The influence of compass plantation and their relationship with crown struture and specific gravity will be in the future throughly investigated.

#### *Regression equations*

To provide a means of determining the potencial yield of *E. globulus* plantations through easier dendrometric measurements, standard regression and multiple regression analysis were applied to data (Steel and Torrie, 1960).

The results (Table 4) showed that volumes and weights can be confidently determined by applying DBH alone to the appropriate equations in table 4. The coefficients of determination ranged from 0.945 to 0.960, indicating a strong relationship between those dependent variables and DBH. The analysis made also showed that DBH alone is a better predictor than total height. The improvement made in the predictive capacity of the models by inclusion of tree height or  $(DBH)^2 H$  was very small for comercial dry wood and total wood weights respectively (range 4.2 to 2.3 %). For the bark models no benefit could be found even when we tried the allometric model as has been described in previous researches (Johnstone, 1973; Phillips, 1977). This is probably due to the fact that *E. globulus* is exploited in even-aged plantations (8-10 years old revolution) and the similarities in plot soil factors. Assuming this to be true, as can be sug-

TABLE 4 — Regression models to predict total *E. globulus* tree weight components on tree characteristics

Dependent variables	Regression models	R <sup>2</sup>	F
Comercial dry wood weight, Kg	$y_1 = -225.3 + 18.8 \text{ DBH}$	0.945	104.0 ***
	$y_1 = 2552.0 - 267.3 \text{ H} + 7.3 \text{ H}^2$	0.578	3.4 *
	$y_1 = 28.15 + 0.02 (\text{DBH})^2 \text{ H}$	0.987	471.3 ***
Total dry wood weight, Kg	$y_2 = -254.0 + 21.2 \text{ DBH}$	0.960	145.5 ***
	$y_2 = -358.0 + 24.5 \text{ H}$	0.497	5.9 *
	$y_2 = -30.420 + 0.024 (\text{DBH})^2 \text{ H}$	0.983	352.1 ***
	$y_2 = -136.71 + 17.21 \ln (\text{DBH})^2 \text{ H}$	0.708	14.6 **
Dry bark weight, Kg	$y_3 = -96.6 + 9.7 \text{ DBH} - 0.2 (\text{DBH})^2$	0.813	10.9 **
	$y_3 = 21520.4 - 3193.0 \text{ H} + 157.7 \text{ H}^2 - 2.6 \text{ H}^3$	0.510	1.4 N.S.
	$y_3 = -2.3 + 2.5 (\text{DBH})^2 \text{ H}$	0.697	13.8 **
	$\ln y_3 = -8.189 + 1.231 \ln (\text{DBH})^2 \text{ H}$	0.684	13.0 **
	$y_3 = -136.706 + 17.20 \ln (\text{DBH})^2 \text{ H}$	0.708	14.5 **
Top wood % (weight basis)	$\ln y_4 = 4.075 - 0.178 \text{ DBH}$	0.851	34.2 ***
	$y_4 = 5.29 + 145.72/\text{H}$	0.316	2.3 N.S.
Total green volume, m <sup>3</sup>	$y_5 = -1519.49 + 606.92 \ln (\text{DBH})$	0.956	131.3 ***
	$y_5 = -679.71 + 68.71 \text{ DBH} - 0.97 \text{ DBH}^2$	0.956	54.5 ***
	$y_5 = -3.391 + 0.038 (\text{DBH})^2 \text{ H}$	0.979	282.9 ***

gested from the mean height data presented in fig. 4, any attempt to assess *E. globulus* site productivity in terms of the conventional height-age relationship may result in erroneous conclusions. From the results presented, comparisons of productivity in terms of tree biomass — considering the components here included — seems to be also unadvisable and requiring increasing sampling effort.

Since there is evidence that sp. gr. appears to be under genetic control it seems clear the desirability, from the point of view of wood

quality and for genetic selection, the overall assessment of the entire tree sp. gr. from small wood samples from the standing trees.

The weighted increment borings sp. gr. were calculated by the formula:

$$C_{sg} = (I_{CA} \times 0.111) + (I_{CB} \times 0.333) + (I_{CC} \times 0.556)$$

were  $C_{sg}$  stands for increment core sp. gr. and the subscripts A, B and C refer to the three discrete portions of the increments cores (the third near the pith, in the center of the core, and the third near the bark, respectively).

The results listed in table 5 showed that the weighted sp. gr. of DBH increment borings can be confidently used to predict total tree basic density ( $R^2=0.740$ ).

It was also showed that a clear improvement in the predictive capacity of the model could be reached using the core portion  $I_{CC}$  ( $R^2=0.932$ ) or even core portion  $I_{CA}$  ( $R^2=0.800$ ). This last positive relationship means that sp. gr. of young trees may, therefore, be used to estimate their sp. gr. in later years. It was also found (see Table 5) that trees with a high specific gravity at an early age (core portion A) continue to produce wood with a high sp. gr. during subsequent growth.

TABLE 5 — Regression models to predict basic specific gravity of comercial wood increment cores

Regression models	$R^2$	F
$y = 0.036 + 0.974 C_{sg}$	0.740	17.1 **
$y = 1.138 - 0.286/I_{CA}$	0.800	24.0 **
$y = 0.035 + 1.145 I_{CB}$	0.585	8.5 *
$y = 0.075 + 0.881 I_{CC}$	0.932	81.9 ***
$I_{CC} = 1.180 - 0.312/I_{CA}$	0.792	22.8 **

y = Basic sp. gr. of comercial wood ( $g/cm^3$ );  $C_{sg}$ ,  $I_{CA}$ ,  $I_{CB}$  and  $I_{CC}$  are also expressed in  $g/cm^3$ .

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