LOG AND SAWN LUMBER VOLUME RELATIONSHIPS FOR *Calycophyllum spruceanum*: A NATURALLY REGENERATING TIMBER RESOURCE FROM AMAZONIAN TIDAL FLOODPLAIN FOREST AMAPA-BRAZIL[1]

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ABSTRACT: In the state of Amapá, Brazil, *Calycophyllum spruceanum*, a timber species native to the tidal floodplains of the region, has become an increasingly important source of construction wood for nearby urban markets. *C. spruceanum* exhibits prolific regeneration in agricultural fallows, and some rural inhabitants manage such sites for its production. Using simple linear regression, we develop log and sawn lumber volume relationships for this species. Standard timber volume estimations using DBH and commercial height results in an adequate predictive model for measured commercial stem volume ($R > 0.90$). Similarly, at the small sawmill we investigated, individual log volume was a good predictor of sawn lumber volume ($R = 0.90$), with nearly half of the log volume converted to merchantable timber. The distribution of merchantable volume among standard board types varied between sawmills. We suggest that regional forestry practices would benefit from an applied research program aimed at quantifying the potential for increased production and more efficient processing of this and other native timbers.

KEYWORDS: Amazonian timber, *Calycophyllum spruceanum*, Forest Management, Pau-mulato, Tidal floodplain, Volumetric Equations.

RELAÇÕES VOLUMÉTRICAS PARA *Calycophyllum spruceanum*: UMA ESPÉCIE MADEIREIRA DE REGENERAÇAO NATURAL DA FLORESTA ESTUARINA DO AMAPÁ

RESUMO: O *Calycophyllum spruceanum*, uma espécie nativa da região estuarina com influência de maré, no Estado do Amapá, tem se tornado uma fonte de importância crescente de madeira para construção no mercado local. *C. spruceanum* exibe uma regeneração prolífica em áreas remanescentes de agricultura, e alguns agricultores manejam áreas de ocorrência desta espécie para produção. Usando regressão linear simples foram desenvolvidas equações de volume para madeira em tora e serrada desta espécie. As estimativas do volume padrão da madeira usando o diâmetro à altura do peito (DAP) e altura comercial resultou num adequado modelo de estimativa de volume comercial de toras ($R = 0{,}90$), com aproximadamente, metade do volume de toras convertido para madeira comercial. A distribuição do volume comercial entre os tipos padrões de madeira serrada variam entre as serrarias. Sugerem-se que as práticas silviculturais regionais sejam beneficiadas a partir de um programa de pesquisa aplicada focalizando a quantificação potencial para incremento da produção e mais eficiente processamento de *C. spruceanum* e de outras espécies nativas.

TERMOS PARA INDEXAÇÃO: Madeira da Amazônia, *Calycophyllum spruceanum*, Manejo Florestal, Pau-mulato, Várzea, Equações Volumétricas

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1 INTRODUCTION

Historically, timber exploitation in the floodplains of Amazônia has focused on a few valuable timber species which have been systematically depleted from readily accessible stands over relatively short periods. Most recently, intensive commercial exploitation of naturally dense stands of Virola surinamensis has virtually eliminated the presence of this forest type from most easily accessible regions (Macedo & Anderson, 1993). In other floodplain forest types, Virola and other historically valued timber species such as *Carapa guianensis, Ceiba pentandra*, and *Maquira coriacea*, were present in much lower densities. Extensive high-grading of such areas has occurred in the recent past, and typically has involved rural inhabitants exchanging logs for food, supplies, and money in a debt-peonage system reminiscent of the rubber boom (Uhl et al., 1997).

In the state of Pará, Brazil, Barros & Uhl (1995) report on a new extraction model in which a two person team extracts logs from the forests, buoys them to their own small cottage mill, in which the saw blades are run off of a small boat engine. As many as fifty species may be harvested and processed by such an operation. There are over a 1000 such mills in the state of Pará, filling regional demands for construction-grade boards in rapidly growing cities (Barros & Uhl, 1995). As costs for upland logging continue to rise with increased distances, timber from floodplain forests becomes more attractive economically, principally due to the relatively low cost of fluvial transport (Uhl et al, 1997).

In the neighboring state of Amapá, we have observed the development of a similar industry which at present is focused primarily on a fast-growing species in the Rubiaceae family, *Calycophyllum spruceanum*, popularly known as pau-mulato (Figure 1). *C. spruceanum* has emerged as an important timber species because of its quality for small dimension construction wood, its rapid growth rate, and its prolific regeneration. *C. spruceanum* is a pioneer species (sensu Swaine & Whitmore, 1988), with wind dispersed seeds. It is a common and often dominant component of agricultural fallows, and in some locales fallows are actually managed for its production - a notable anomaly among what has otherwise been an entirely extractive industry.

Here, we report on our analysis of log and sawn lumber volume relationships for this species. Such relationships are an important ingredient in the development of forest management plans, as their elaboration permits estimation of merchantable volume from stand measurement data. Volume equations also provide insight into the efficiency of conversion of logs into sawn lumber, which may be important for setting benchmarks for improvements in mill technology and training, even at the level of what is essentially a cottage industry. We also compare two adjacent sawmills to assess variability in the distribution of merchantable volume among board types.

2 MATERIAL AND METHODS

Data were collected from mills and forests along the Mazagão River, a minor tributary of the north channel of the Amazon River. Lumber from the mills is transported by boat to the port city of Santana, a three-hour journey, where it is sold primarily for use in construction in Santana and Macapá, the state capital. This portion of the Amazon is characterized by tidal fluctuations ranging from 3 to 4 m. Mean annual temperature is 27 degrees. Mean annual precipitation is 2550 mm. January through

May are typically the wettest months, with average rainfall in excess of 300 mm, while August through November average less than 100 mm.

We accompanied logging operations to record diameter at 1.3 m height (D_0) and commercial heights (H) of 76 individuals. Commercial height was limited by a minimum acceptable top diameter of 20 cm or by stem defects. Diameters of the individuals measured ranged from 30 to 75 cm; commercial heights ranged from eight to twenty meters. These trees were reportedly 20- to 30-years-old. Number of logs, log lengths and three diameters per log were recorded for each individual. Log volume was computed using Newton's formula (Avery & Burkhart, 1994; Philip, 1994) as follows:

$$V_L = \frac{L \pi (D_1^2 + 4D_2^2 + D_3^2)}{24}$$

where: V_L = Volume of log

L = Length of log (cm)

D_1 = Diameter at large end of log

D_2 = diameter at middle of log

D_3 = diameter at small end of log

For each stem, V_L data were summed to determine the commercial stem volume (V_S).

We accompanied skilled owner/operators at a new sawmill in order to determine the relationship between V_L and merchantable board volume (V_M). This small Acottage mill@ had a head and planing saw that ran off the same axle. The axle was rotated by a small gas-powered boat motor. Logs came in under a Aright arm@ arrangement, and boards were stacked on the opposite side of the mill. This mill was typical for the region, although design (board flow) and number of saws are variable. As logs were milled, the number of logs was tallied (n=50) and V_L data were calculated as described above. The boards sawn from each log were separated by dimension class and length and their respective volumes were measured. There were five dimension classes: tábua (2 cm by 16 cm), pernamanca (4 cm by 8 cm), régua (2 cm by 10 cm), ripão (3 cm by 5 cm), and ripa (1.5 cm by 5 cm), and two merchantable length specifications: 3 m and 4 m. Board volumes per log were summed to determine V_M for each log. A small number of non-merchantable boards were also cut (2 and ~2.5 m lengths), but were not included in this analysis.

Data were evaluated using standard mathematical models for the construction of volume tables (Husch et al, 1982) using the following equations:

$$V_S = aD_0^b$$

$$V_S = bD_0^2H$$

$$V_S = a + bD_0^2H$$

$$V_S = aD_0^bH^c$$

We also examined the relationship between V_M and V_L and compared the distribution of sawn timber among dimension classes between our selected sawmill and a neighboring operation.

3 RESULTS AND DISCUSSION

Prediction of V_S from D_0 alone is rather unsatisfactory (Figure 2). This is apparently due to marked variability in H at any given value of D_0. For this data set, there is little difference in the predictive power of the standard volume equations that employ both diameter and height; all give satisfactory predictions ($R > 0.90$) usable for most practical forestry applications (Figure 2). Figure 3 illustrates the relationships between V_M and V_L. The regression indicates a nearly 50% recovery rate of merchantable volume at the selected mill. Others have reported an estimate of 1 m^3

of sawn board volume for every 3 m^3 of log volume in Amazonian mills (Uhl et al. 1991). Increased efficiency may result from the involvement of mill personnel, including the owner/operator, in harvesting operations. Skill and experience levels of mill personnel may also be important factors, along with the age, maintenance and quality of milling equipment. For practical use and further testing, we used the regressions accompanying Figures 2 and 3 to produce a table of expected volumes for *C. spruceanum* stems across a range of H and D_0 (Table 1).

Differences within the distribution of merchantable volume among board types between the two mills surveyed (Figure 4) appear unrelated to price, as both dominant lumber types are equally valued. We made no investigation of market dynamics, but surmise that a number of factors influence the distribution of V_M among lumber types, including relationships with individual buyers, and temporal shifts in demand.

Cottage industry logging and milling operations are a dynamic and poorly-documented sector of the rural Amazonian economy. Although individual operations are small, their cumulative impacts on regional economies and environments are likely to be significant. The case of *C. spruceanum* is particularly interesting because of the combination of its current position as a dominant regional timber for the construction industry and its ecological aptness for sustained-yield management. These factors, and most particularly the nascent emphasis on fallow management for *C. spruceanum* timber production, make this species a viable subject for longer-term applied studies that traditionally have not been possible with the preceding succession of rapidly-exhausted Amazonian floodplain timbers.

4 CONCLUSION

Here we have shown that adequate estimation of V_M from easily collected stand data is feasible for *C. spruceanum*, and that conversion of logs to sawn timber may be more efficient at some mills than has thus far been reported in the literature. The former observation suggests that manipulative field trials to determine optimal stand stocking levels in managed agricultural fallows would be a logical and feasible undertaking. The latter observation indicates that targeted improvements in training and equipment at family-run cottage mills may translate to significant increases in milling efficiency. The prospects for improving regional forestry practices clearly warrant quantitative assessments of the potential for increased production and more efficient processing of *C. spruceanum* and other promising native timber species.

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ANEXOS

Table 1 - Merchantable volume estimates (m^3) for Calycophyllum spruceanum from tidal floodplain florest, Amapá, Brazil. Estimates were calculated using the regressions accompanying Figures 2c and 3. H = commercial height; D_0 = diameter at 1.3m height.

	H(m)				
D_0 cm	12	14	16	18	20
35	0.3	0.3	0.4	0.4	0.5
45	0.5	0.6	0.6	0.7	0.8
55	0.7	0.8	1.0	1.1	1.2
65	1.0	1.2	1.3	1.5	1.7
75	1.3	1.6	1.8	2.0	2.2

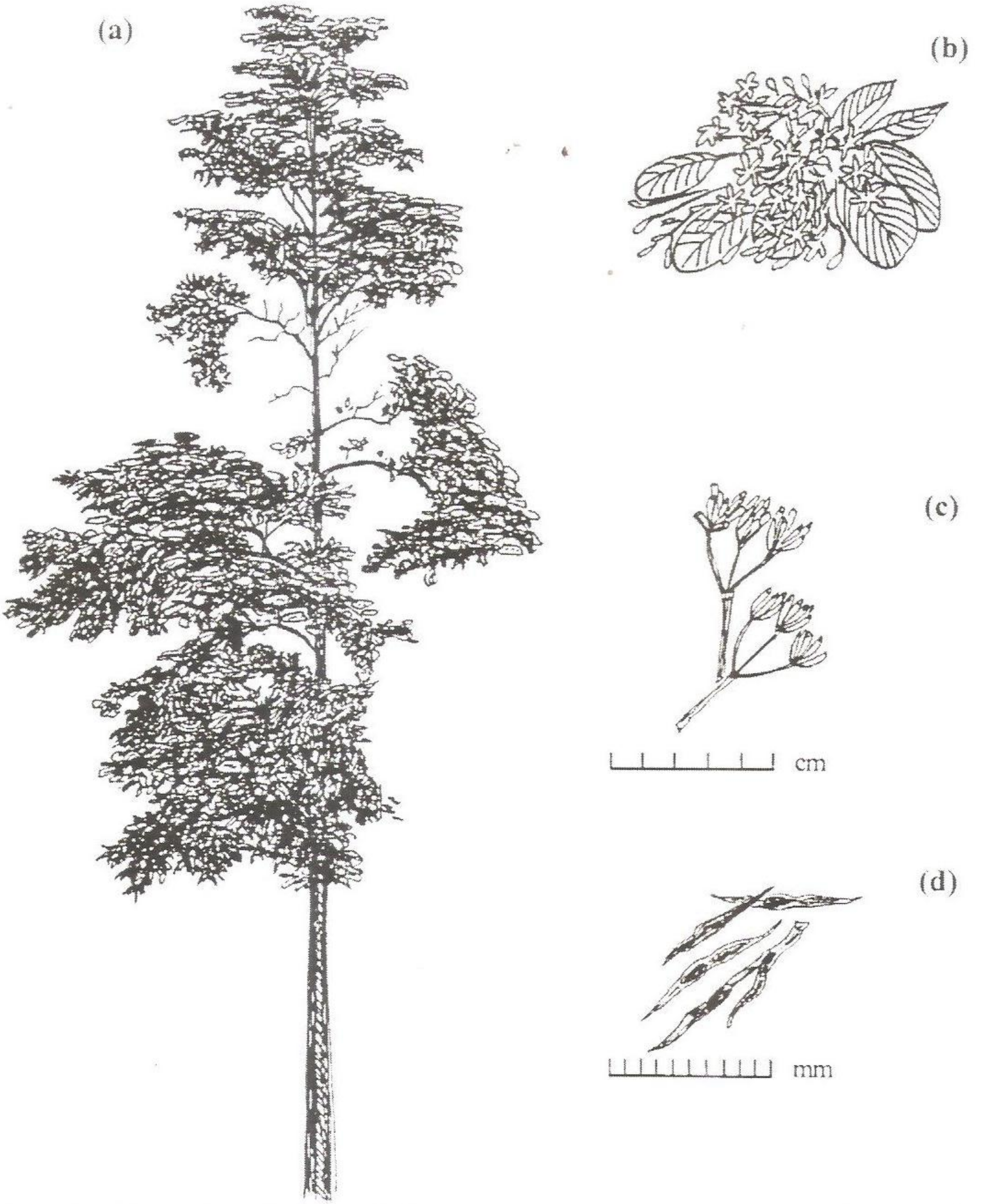

Figure 1 - Illustration of *Calycophyllum spruceanum,* Benth.: a) stem, b) flowers, c) fruits, d) seeds

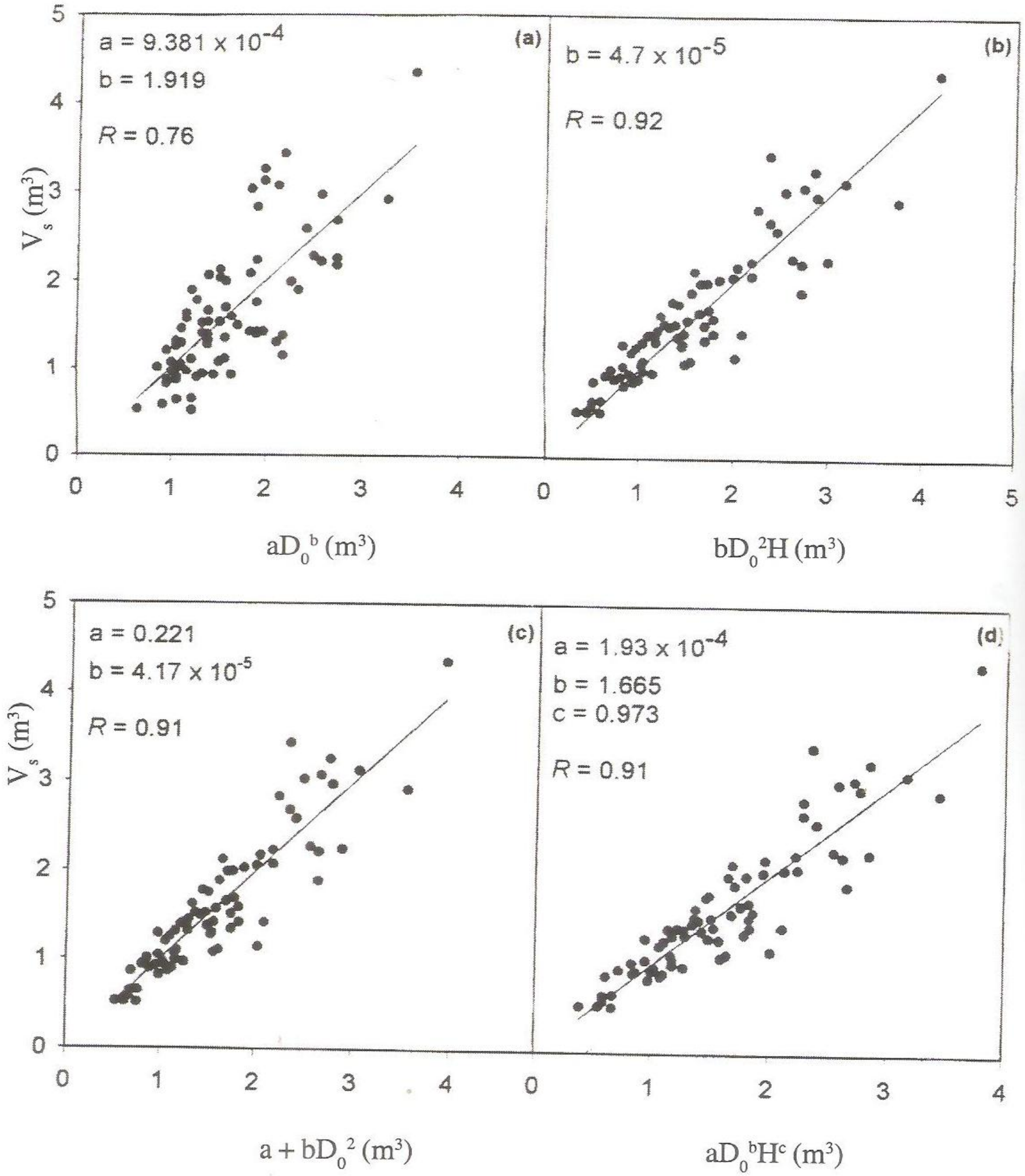

Figure 2 - Results of Evaluations of Standard Models for Volume Estimation. All for models are presented in the same graphic form for comparative purposes

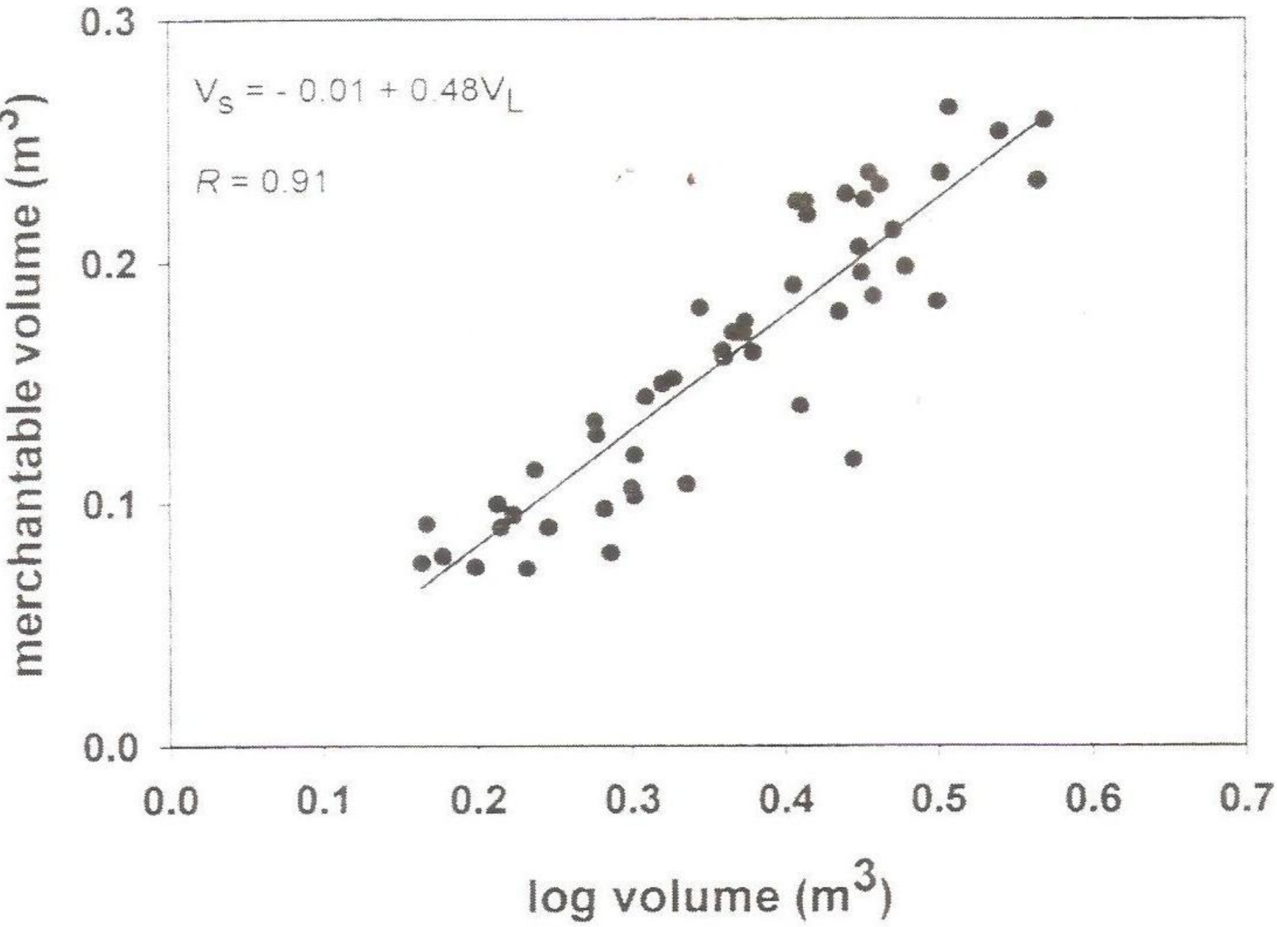

Figure 3 - Relationship between log volume (V_L) and merchantable sawn timber volume (V_m).

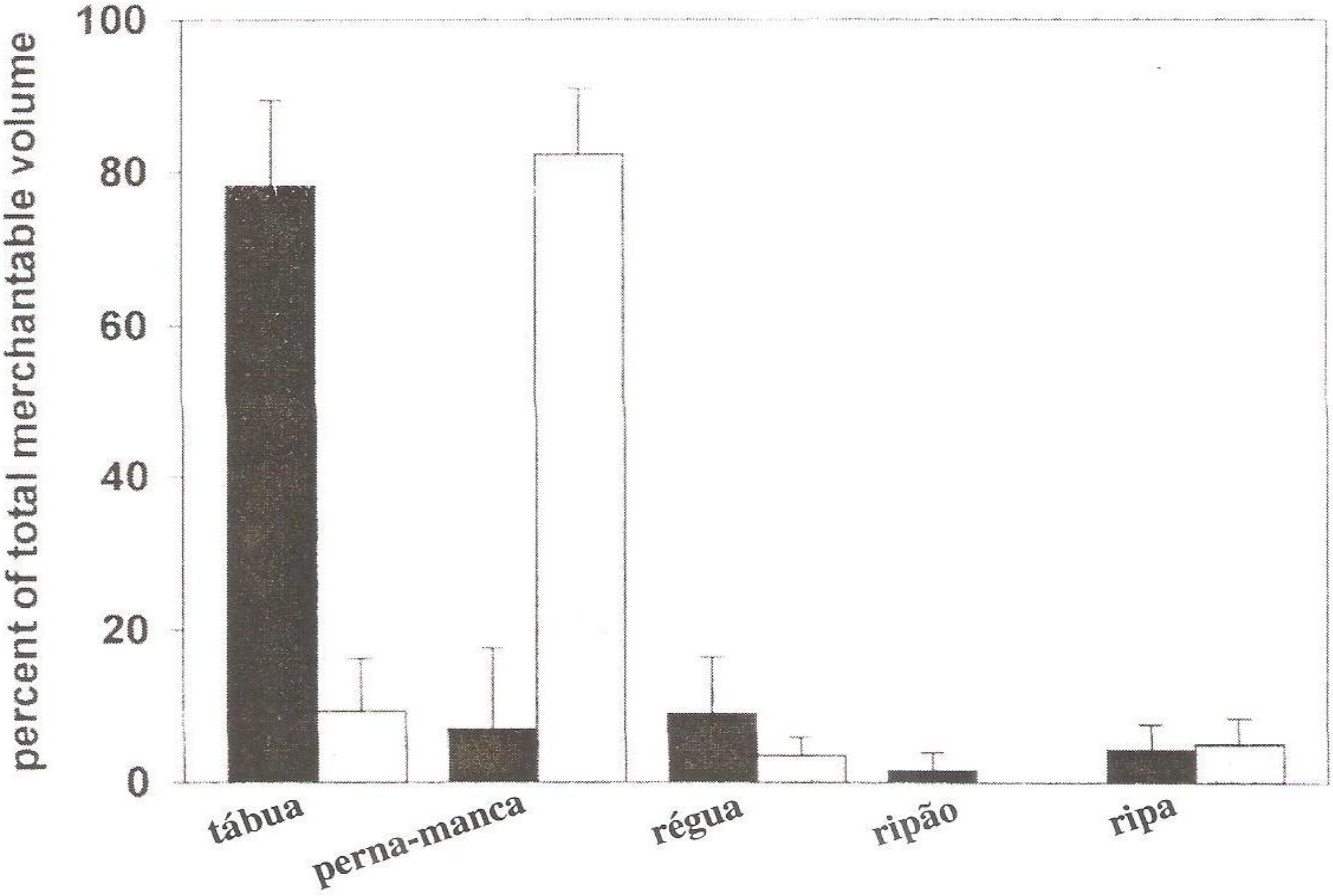

Figure 4 - Distribution of merchantable timber among board types at two mills: Mill 1-Black, Mill 2-Gray.