SCIENTIA
FORESTALIS

Dynamic of assortment of *Pinus taeda* L. plantation in different site classes in Southern Brazil

Dinâmica do sortimento de plantios de *Pinus taeda* L. em diferentes classes de sítio no Sul do Brasil

Sintia Valerio Kohler[1], Neumar Irineu Wolff II[2], Afonso Figueiredo Filho[3] e Julio Eduardo Arce[4]

Abstract

The objective of this study was to examine the evolution of wood assortment in *Pinus taeda* stands, located in Paraná state. 144 trees were sampled in three site classes and complete stem analysis was applied. The average assortment volumes per tree were obtained in all age classes and sites. 7-9 year age classes predominantly contain volumes adequate for pulpwood. In 10-12 year classes larger volumes were obtained for sawnwood, with 51.09%, 47.63% and 37.89% of the total volume, respectively for sites I, II and III. Volumes for veneer are produced in the 13-15 year classes, representing 43.98 and 25.46% of total volume for sites I and II. Volumes for sliced veneer are produced in the 16-18 year classes with 30.8% and 14.85% of the total volume for sites I and II. Best sites produce larger logs sooner, suggesting that site has influences on wood assortment. Assortment dynamics also shows a change in the forest assortment after 13th year. This way, harvests after this age should be carefully analyzed, considering that anticipation of a few months or a year in cutting of the trees can make an important economic difference.

Keywords: Wood assortment, complete stem analysis, taper models, age.

Resumo

O objetivo deste estudo foi determinar a evolução do sortimento de madeira em povoamentos de *Pinus taeda* localizados no estado do Paraná. Foram amostradas 144 árvores em três classes de sítio, aplicando-se a técnica de análise de tronco completa. Os volumes médios por árvore para os sortimentos foram obtidos em todas as classes de idade e sítios do povoamento. Na classe 7-9 anos predominam volumes para celulose. Na classe 10-12 anos tem-se maiores volumes para serraria, que representa 51,09, 47,63 e 37,89% do volume total produzido, respectivamente para os sítios I, II e III. Volumes para laminação são produzidos na classe 13-15 anos, representado 43,98 e 25,46% do volume total, para os sítios I e II. Volumes para faqueado representam aos 16-18 anos 30,8 e 14,85% do volume total para os sítios I e II. Os sítios melhores produzem toras de maiores dimensões mais cedo, assim, o sítio influencia no sortimento. A dinâmica do sortimento também mostra que após o 13º ano, há uma considerável mudança no sortimento da floresta e assim, colheitas após essa idade deveriam ser cuidadosamente analisadas, considerando que uma antecipação de corte de alguns meses ou ano pode representar um importante diferencial econômico.

Palavras-chave: Sortimento, análise de tronco completa, modelos de afilamento, idade.

INTRODUCTION

Forest plantations in Brazil occupied a total area of about 6.66 million hectares in 2012, of which 76.6% were of the genus *Eucalyptus* and 23.4% were of the genus *Pinus*. *Pinus* stands are concentrated primarily in southern Brazil (ABRAF, 2013).

Pinus taeda has been singled out for its great potential for South of the country due to its high volumetric increment in the colder regions of the southern plateau. A complete cultivation cycle

[1]Forest Engineer. Doctoral Candidate. UFPR – Universidade Federal do Paraná. Pref. Lothário Meissner Avenue, 632. Jardim Botânico - 80210-170 – Curitiba, PR – Brazil. E-mail: sintiakohler@yahoo.com.br.

[2]Forest Engineer. Msc. UNICENTRO – Universidade Estadual do Centro Oeste. PO Box, 21, 84500-000, Irati, PR, Brazil. E-mail: neumarwolff@uol.com.br.

[3]Forest Engineer. Doctor. UNICENTRO – Universidade Estadual do Centro Oeste. PO Box, 21, 84500-000, Irati, PR, Brazil. E-mail: afigfilho@gmail.com

[4]Forest Engineer. Doctor. UFPR – Universidade Federal do Paraná. Pref. Lothário Meissner Avenue, 632. Jardim Botânico - 80210-170 – Curitiba, PR – Brazil. E-mail: jarce@ufpr.br

for fine wood products is possible within 25 years (SHIMIZU; HIGA, 1981; GONÇALVES, 2004). Currently, shorter rotations (between 16 and 23 years) are being used to generate high percentage of wood for sawnwood, veneer and sliced veneer.

Pinus taeda is most commonly managed for production of multiple products, generally prioritizing the large logs for use in mechanical processing (sawn wood, veneer, sliced veneer). In regions where a market exists for fine wood, the excess material (tips and thin or low quality trees often from the first thinning) goes to factories or exchanged for thick wood (SANQUETTA, 2002).

To ensure multiple use of a tree stem in forest stands, knowing the form of the stem is required, as well as the volume and size of the assortments, in order to plan and study the economic feasibility of the stand. Gaffrey et al. (1998) stated that the most important application of stem taper models is in predicting the assortment of individual tree or the distribution of the assortment of a stand or a sample.

Taper functions are powerful tools to biologically and economically evaluate forest tracts and inform forest management practices, since they permit detailed valuations of the yield of the stand (FISCHER et al., 2001).

Forest assortment is the term used to summarize the quality and quantity of marketable standing stock in the forest, based on a list of multiple products, and constitutes a tool for making decisions related to forest management (ARCE, 2000).

This same author affirms the rationale for first knowing, to an appropriate degree of accuracy, how many and what types of products could be obtained from a tree before cutting it. The same reasoning can be applied to stands and to an entire forest.

Jorge and Lara (1993) stated that assortment studies of forest stands is of great importance for planning and evaluation of forest management for timber potential, for observing aspects of management planning activities, design of mechanical wood processing facilities, as well as the sale of sawn wood. The taper functions allow logs to be directed toward its most profitable use (MULLER, 2004).

The use of a tree must be done in a manner that provides the greatest financial return. Thus when a single tree has many end uses, its added value is higher since it fetches prices from a diverse range in the market (MACHADO et al., 2004).

Thus, based on a forest inventory, the assortment of a forest can be estimated with sufficient accuracy at any time using taper functions. However, understanding how the assortment of forest evolves over the course of the rotation is a more complex task. It is essential however for proper management of the forest, as it allows one to define the appropriate time to intervene and to maximize yield of high-value timber, obtaining greatest economic return from the forest enterprise.

According to Schneider et al. (1996), one of the great difficulties in managing forests and, in particular, economic evaluations of forests, is the absence of appropriate assortment tables that would enable rapid determinations of wood stock for different types of use.

Few works in Brazil sought to assess the evolution of assortment over the course of the forest stand growth rotation, and particularly how the site (location) affects this dynamic. Gomes et al. (1997) evaluated the total volume and volume by assortment per unit area in *Pinus taeda* stands, subjected to different site and planting density conditions. Assortment analysis showed that wider spacing result in larger quantities of wood for finer purposes, such as sawn wood and veneer and that the effect of the site is more pronounced in timber production for higher value wood.

Figueiredo Filho (1991) studied the assortment evolution for *Pinus elliottii* stands, concluding that the assortment changes rapidly over a range of just a few years. That study showed that at 15 years only 6.21% of the total volume produced could be used for veneer, but by 19 years this percentage had increased to 33.09% of the total volume. This demonstrates the importance of understanding the dynamics of assortment in deciding the appropriate time to conduct a thinning or defining the rotation period of the stand.

Because of the importance of the topic, this study aimed to determine the evolution of wood assortment in *Pinus taeda* in three site classes using complete stem analysis.

MATERIAL AND METHODS

Study area

The research was conducted in 1 to 30 year old *Pinus taeda* stands belonging to the REMASA Reflorestadora Ltda company. The plantations were established between the 1992 and 2005 with initial spacing of 3.0 x 3.0 m, 3.0 x 2.5 m, and 2.5 x 2.5 m in the municipalities of Bituruna, Palmas and General Carneiro, South Central region of the state of Paraná. Generally, in these stands two thinnings were applied at ages 10 and 15 years.

According to Köppen classification, the climate of the region is subtropical humid mesothermal (Cfb) with average temperatures above 22°C in the warmest month and below 18°C in the coldest month. There is no dry season and summers are mild and winter include severe and frequent frosts. The altitude varies between 900 and 1,100 meters, and the topography is undulating to steeply sloped (MAACK, 1981).

Classification of production capacity

Considering that the aim of the research was to study the evolution of assortment in various site classes, we used the site curves for the region generated by Wolff II (2012). The Schumacher equation was used to represent the average curve (guide curve) and three site classes were defined by the cited author: 21 to 25 m (class I), 17 to 21 m (class II), and 13 to 17 m (class III). The equation for expressing site index at age 15 years is:

$$Ln(Hd) = LnS - 5.423688\left(\frac{1}{A} + \frac{1}{15}\right) \quad (1)$$

in which:
Hd = dominant height of the plot (m);
A = age (years);
S = site index (m);
Ln = natural logarithm.

Database

The data necessary to evaluate the evolution of height and diameter growth along the stem was derived from complete stem analysis. Trees were sampled after the site classification of each plot by the age and dominant height. Within each site class, trees were selected that represented all the variability in diameter at the various ages.

Next, 144 trees were sampled; 48 in each site class, with ages ranging from 5 to 18 years. For reasons inherent to the assortment, in this study trees aged 7 years or older were used, totaling 126 trees in the analysis, or 42, 43 and 41 trees sampled for site classes I, II and III, respectively.

The selected trees were felled and discs were obtained at absolute heights of 0.1 and 1.3 m above ground, and at the relative heights of 15%, 25%, 35%, 45%, 55%, 65%, 75%, 85% and 95% of the total height, thus assuring that 11 discs from each tree were analyzed.

The discs were identified, dried, sanded and their growth rings marked and measured using LINTAB 6.0 (*Frank Rinn Distributors*, Germany) and the TSAP (*Time Series Analysis Program*), which enables accurate measurements and generates a data base with time series for the growth rings.

The FlorExel® was used for processing the data obtained from the TSAP software, generating diameters inside bark for each tree at different heights of the stem for each age and the total height for each age.

Diameter outside bark estimates along the stem

Complete stem analysis involves measuring the diameter outside bark at the age of the tree the moment it is felled. For all prior ages, diameters are obtained under bark. The destination of the timber is defined by the market from top diameters outside bark and the commercial volume traded is also without bark. Thus, it was necessary to estimate the diameters outside bark along the stem for all previous ages of the tree. Since the trees were sampled at various ages, the Stepwise variable selection was used to solve the problem, generating a specific model for the study data. The dependent variable was the diameter outside bark along the stem and the independent variables tested were: d_{ib} (diameter inside bark along the stem), *A* (age in years), *ht* (total height at each age class), d_{ib}^2, ht^2, $d_{ib}.A$, $d_{ib}.A^2$, $ht.A$ and $1/A$.

Fitting the taper function

The fifth degree polynomial (2), widely used in southern Brazil for forest plantations (ROSOT, 1989; FIGUEIREDO FILHO et al., 1996; SCOLFORO et al., 1998; ASSIS et al., 2002; QUEIROZ et al., 2006; SOUZA, 2007; QUEIROZ et al., 2008; KOHLER et al., 2011; among others), was fitted with data from the diameter along the stem (d_i), partial heights (h_i); total height (ht) and diameter outside bark at 1.3 m (DBH) obtained in the complete stem analysis in the age classes older than 7 years for the 126 samples trees. Fits were made for each site class.

$$\frac{d_i}{DAP} = \beta_0 + \beta_1\left(\frac{h_i}{ht}\right) + \beta_2\left(\frac{h_i}{ht}\right)^2 + \beta_3\left(\frac{h_i}{ht}\right)^3 + \beta_4\left(\frac{h_i}{ht}\right)^4 + \beta_5\left(\frac{h_i}{ht}\right)^5 + \varepsilon_i \quad (2)$$

The goodness of fit was evaluated based on the coefficient of determination (R^2) and the standard error of the estimate as a percentage (S_{xy}%), beside to graphical analysis of the residuals.

Estimates of Assortment evolution

As already mentioned, the assortments are defined based on minimum use diameters (outside bark), called the "top diameter" and the lengths of the logs. Table 1 shows the assortment classes used in the study, which are used in the region by the REMASA Company which uses them in the commercialization of its logs.

Table 1. Assortment classes.
Tabela 1. Classes de sortimento.

Destination	Minimum diameter outside bark (cm)	Log length (m)
Energy wood	4	1.20
Pulpwood	8	2.20
Sawnwood	16	3.00
Veneer	25	2.65
Sliced Veneer	35	1.35

To estimate the volumes by assortment at various ages we used the forest inventory module of the FlorExel® program, which estimates the total volumes and per assortment volumes for the total number of trees using the fitted taper function. From these estimates graphs expressing the average assortment of the sample at each site were constructed.

RESULTS AND DISCUSSION

Diameter outside bark estimates

Using the stepwise variable selection method, the equation (3) was generated to estimate the diameters inside bark along the length of the stem. As expected, the variable diameter inside bark was the best when correlated with the dependent variable, and was thus inserted into the equation. The equation showed excellent fit and accuracy statistics as reported below.

$$d_{ob} = -2.1318 + 1.0680\,d_{ib} + 0.0009\,d_{ib}^{2} + 0.1865A - 0.0022\,d_{ib}A + 8.2825\left(\frac{1}{A}\right) - 0.0037\,htA \quad (3)$$

in which:
d_{ob}= diameter outside bark (cm);
d_{ib}= diameter inside bark (cm);
A= age (years);
ht= total height (m);
R^2 = 0.9992;
S_{yx} = 0.3559 cm;
S_{yx}% = 2.92%.

The distribution of residuals of the equation is shown in Figure 1. It can be observed that residuals are closer to zero where the diameters are larger, while dispersion is greatest for estimates of only the smallest diameters, i.e. above 95% of the total height. Thus, the model generated by the stepwise selection method can be considered adequate for estimating the diameter outside bark along of the stem. As was mentioned in the methodology, this was necessary considering that assortment for commercial purposes include the bark.

Taper model

The fifth degree polynomial was fitted for the 3 site classes. Statistics and coefficients are presented in Table 2. The taper equation for site I had the best statistics, with the highest R^2 (0.9858) and a standard error for estimating stem diameters of 7.8%. Sites II and III had very similar values, but somewhat lower than site I.

A graphical analysis of residuals (Figure 2) showed that the fifth degree polynomial results in greater dispersion amplitude in estimates of the diameters for the upper stem, with a slight tendency to underestimate the smaller diameters. This fact is not relevant because, in general, this part of the stem is intended for energy use or remains in the forest.

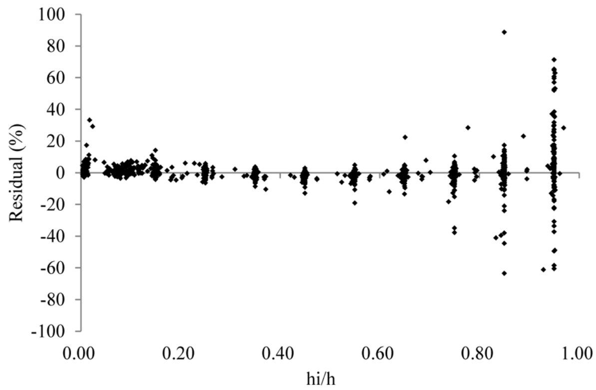

Figure 1. Distribution of residuals to estimate the equation for diameter outside bark, generated by the stepwise method.
Figura 1. Distribuição dos resíduos para estimar o diâmetro com casca da equação gerada pelo método de Stepwise.

Table 2. Coefficients and statistics for the fifth degree polynomial.
Tabela 2. Coeficientes e estatísticas do polinômio de quinto grau.

Site	R^2	S_{yx} (cm)	S_{yx} (%)	b_0	b_1	b_2	b_3	b_4	b_5
I	0.985	1.146	7.870	1.2270	-3.3655	13.5621	-29.738	27.4153	-9.0940
II	0.977	1.268	9.559	1.2338	-3.2907	13.1439	-28.958	26.9168	-9.0456
III	0.979	1.116	9.412	1.2657	-3.5288	14.4694	-32.813	31.3235	-10.716

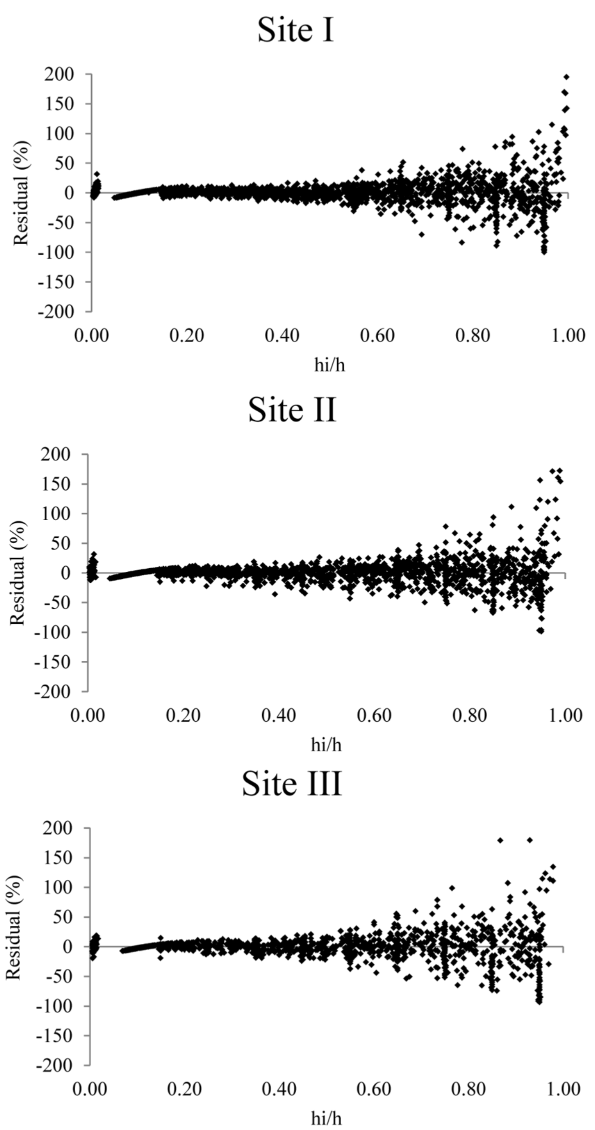

Figure 2. Distribution of residuals to estimate diameters obtained from the fifth degree polynomial in the site classes.
Figura 2. Distribuição de resíduos para estimar diâmetros obtidos com o polinômio de quinto grau em classes de sítio.

Estimation of assortment evolution

With the forest inventory module of the FlorExel® program, the volumes of assortments per tree for all ages and site classes were estimated. These estimates were derived from the insertion of the coefficients of taper functions listed in Table 2 for each site.

Thus, the evolution of average per tree assortment was determined for age classes up to 18 years for sites I and II, but only up to age 13 year for site III, since no stands older than this were available in this site class.

The evolution of volumes by assortment is shown in Figure 3. Of note is that the amount of wood intended for energy was low in all age groups, where on average 2.3 logs (1.2 m each) can be obtained at all ages. Wood for pulp showed constant volume at all ages. 7 years old trees already produce logs with diameters suitable for sawn wood, growing rapidly with age, but volumes in this assortment class rapidly decline as diameters more suitable for another assortment class (veneer) arise. Wood veneer diameters begin at an average of 10 years in all sites; however for site I increased volume for this assortment class is much greater than in other sites.

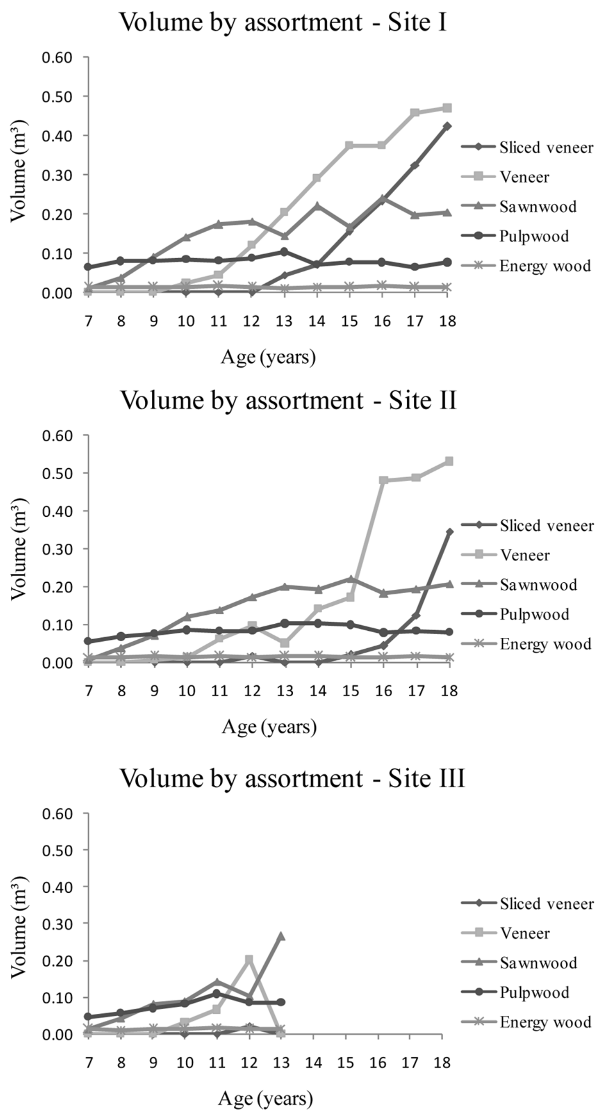

Figure 3. Evolution of volumes (m³) by assortment and by site class.
Figura 3. Evolução dos volumes (m³) por sortimento e por classes de sítio.

Logs with diameters suitable for sliced veneer are available by the 12th year in trees on sites I and II, while no volume for this assortment class was available at site III. Even though the volumes were different between the three sites, the growth trend was similar. This same trend was observed by Figueiredo Filho et al. (1992) for *Pinus elliottii*. These authors report that the volumes for sawn wood decrease with age, while diameters suitable for veneer increases. They add that since assortment aims to optimize the use of wood for fine products; first all material possible for sliced veneer; veneer; sawn wood and then for pulpwood. The trends for the evolution for sawn wood and pulpwood have not a clear definition, since the preference first is for veneer and sliced veneer. Thus changes in the volume appropriate for fine products also change the volumes destined for sawed and pulp wood.

Figure 4 shows the volumetric percentage of assortments for different age classes. It was observed that pulpwood volumes predominate in age classes 7-9 years, representing an average of 55% of the total volume of trees for the three site classes; however, logs for sawn wood have begun to emerge at this age, representing an average of 34% of the total volume. In the next age class (10 to 12 years) volume can be obtained for veneer, which increased rapidly at site I, representing 18.2% of the total volume, increasing to 43.9% in the next age class (13 to 15 years), and reaching higher fraction of the total volume. Volumes for sliced veneer represent just 13.21% and 1.25% of the total volume at sites I and II, respectively for the 13-15 year age class, increasing to 30.8% and 14.85%, at sites I and II, respectively for the next age class (16 to 18 years).

On the other hand site III yields volumes for veneer in the age class 10 to 12 years; however in the following age class volumes were not observed for this use, since sampling included too few trees in this age class as explained in the methodology. So beyond this age analyses for this site class were hampered.

Figueiredo Filho et al. (1992) studied a 23 year old stand of *Pinus elliottii* and found means per tree volumes of 0.345 m³ from 15 years old and that 34% of the wood was suitable for pulpwood and 57% for sawn wood. However, at age 23 the average volume grew to 0.727 m³, of which 48% could be used for veneer.

Machado et al. (2011) studied the evolution of assortment of *Pinus oocarpa* between ages 7 and 22 years. The average assortments of trees each year showed that the logs with minimum diameter measuring 25 cm for veneer are produced starting at age 15, increasing to 50% of the tree at 22. By age12 the predominant use is for pulpwood (8 to 15 cm at the minimum diameter).

Dossa et al. (2002) simulated the assortment of a 21 year old *Pinus* stand, with an initial density of 1,666 trees and two thinnings. At 21 years, the production volume for sawn wood and veneer in this stand represented 92% of total volume. In the present research, volumes for fine uses (sawn wood, veneer, and sliced veneer) represent 92.4% of the average volume for 18 years trees in site I and 92.07% at site II.

High growth rates were also observed for wood volumes for veneer and subsequently sliced veneer. In the highest yielding site, 18.24% of the total volume was appropriate for

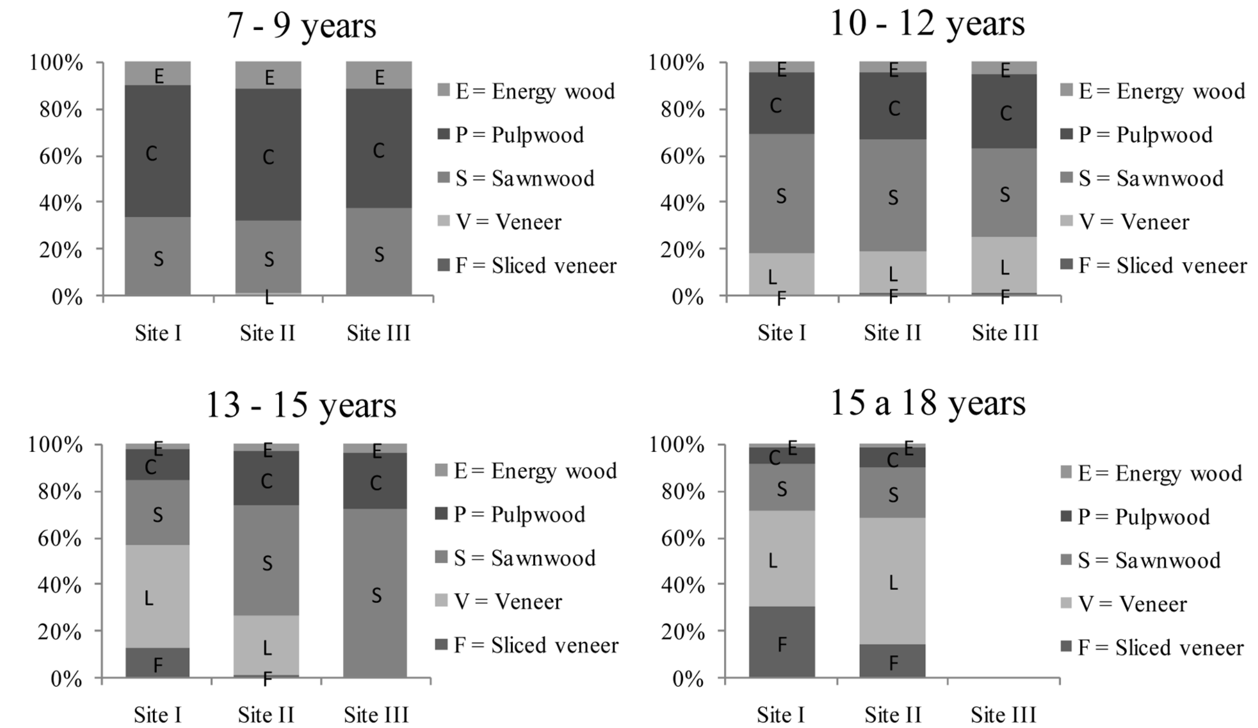

Figure 4. Volume percentage classified by use and age classes at different sites.
Figura 4. Percentual dos volumes classificados por tipo de uso e classes de idade nos diferentes sítios.

veneer (between 10 and 12 years); in the next age class (13-15 years) this volume increases to 43.98% of the total volume. In this same site, sliced veneer volume increased from 13.21% in the 13 to 15 year age class to 30.80% in the next age class.

This information is crucial for stand management planning, indicating the most appropriate times to intervene in the forest when maximizing production volumes for fine products and thus maximized economic gain are the goals.

CONCLUSIONS

The equation fitted by the stepwise variable selection method was adequate to obtain estimates of the diameters outside bark along of the stem at various ages, and therefore represents a valuable tool for indirectly and accurately obtaining the profile of a log outside the bark when using the complete stem analysis.

Until the age of 9 years there is predominance of pulpwood volumes (55% of the total volume produced), but in the three years following the sawnwood already surpasses the others with more than 50% for site class I.

There is a wide availability of wood for veneer in the age between 13 and 15 years, with site I already producing about 44% of the total volume, almost twice as much as site II (25.5%).

Volumes for sliced veneer are produced only after the 16th year, reaching a percentage of 30.8% of the total volume for the site I, two times higher (14.9%) than site II.

In the age class 13-15 years, site I produced 57.2% of the total volume for veneer and sliced veneer, greatly increasing this percentage in the next three years, when it reached 71.7%. At site II, this change was still greater and assortments of veneer and sliced veneer; increasing from 26.3% to 68.8%, thus almost equaling site I.

Site III analyzed until the age of 15 years, had not yet produced veneer volume. However, it had already produced more than 65% of the total volume for sawn wood.

We conclude that the best sites produce larger logs earlier and therefore the site influences assortment. The dynamics of the assortment also shows that after the 13th year, there is a considerable change in assortment of the forest and thus harvests after this age should be carefully analyzed, considering that anticipation of a few months or a year in cutting of the trees can make an important economic difference.

REFERENCES

ABRAF - Associação Brasileira de Produtores de Florestas Plantadas. **Anuário estatístico da ABRAF:** Ano base 2012. Brasília, 2013. 148 p.

ARCE, J. E. **Um sistema de análise, simulação e otimização do sortimento florestal em função da demanda por multiprodutos e dos custos de transporte**. 2000. 129 p. Tese (Doutorado em Ciências Florestais) – Universidade Federal do Paraná, Curitiba, 2000.

ASSIS, A. L.; SCOLFORO, J. R. S; MELLO, J. M.; OLIVEIRA, A. D. Avaliação de modelos polinomiais não-segmentados na estimativa de diâmetros e volumes comerciais de *Pinus taeda*. **Ciência Florestal**, Santa Maria, v. 12, n. 1, p. 89-107, 2002.

DOSSA, D.; SILVA, H. D.; BELLOTE, A. F. J.; RODIGHERI, H. R. **Produção e Rentabilidade de Pinus em Empresas Florestais**. Colombo: Embrapa Florestas, Dez. 2002, 6 p. (Embrapa Florestas. Comunicado Técnico, 82).

FISCHER, F.; SCOLFORO, J. R.; ACERBI JUNIOR, F. W.; MELLO, J. M.; MAESTRI, R. Exatidão dos modelos polinomiais não-segmentados e das razões entre volumes para representar o perfil do tronco de *Pinus taeda*. **Ciência Florestal**, Santa Maria, v. 11, n. 1, p. 167-188, 2001.

FIGUEIREDO FILHO, A. **Influência da resinagem no crescimento de *Pinus elliottii* Engelm. var. *elliottii* e sua avaliação econômica.** 1991. 138 p. Tese (Doutorado em Engenharia Florestal), Universidade Federal do Paraná, Curitiba, 1991.

FIGUEIREDO FILHO, A.; BORDERS, B. E.; HITCH, K. L. Taper equations for Pinus taeda in Southern Brazil. **Forest Ecology and Management**, Amsterdã, v. 83, n. 1, p. 39-46, 1996.

FIGUEIREDO FILHO, A.; MACHADO, S.; A.; HOSOKAWA, R. T.; KIKUTI, P. Avaliação econômica da resinagem em floresta de *Pinus elliottii*. **Instituto de Pesquisa e Estudos Florestais - IPEF**, Piracicaba, v. 45, p. 48-63, 1992.

GAFFREY, D.; SLOBODA, B.; MATSUMURA, N. Representation of tree stem taper curves and their dynamic, using a linear model and the centroaffine transformation. **Journal of Forest Research**, Tokyo, v. 3, n. 2, p. 67–74, 1998.

GOMES, F. S; MAESTRI, R.; SANQUETTA, C. R. Avaliação da produção em volume total e sortimento em povoamentos de *Pinus taeda* L. submetidos a diferentes condições de espaçamento inicial e sítio. **Ciência Florestal**, Santa Maria, v. 7, n.1, p. 101-126, 1997.

GONÇALVES, M. **Avaliação de investimento em reflorestamentos de *Pinus* sob condições de incerteza.** 2004. 113 p. Dissertação (Mestrado em Ciências Exatas e Tecnológicas), Universidade Federal do Paraná, Curitiba, 2004.

JORGE, L. A. B.; LARA, H. A. Programa de sortimento de madeira serrada de povoamentos de *Pinus elliottii* com alternativas de produtos padronizados. In: CONGRESSO FLORESTAL BRASILEIRO, 7., CONGRESSO FLORESTAL PANAMERICANO, 1., 1993, Curitiba. **Anais...** Curitiba: SBS/SBEF, 1993. v. 2, p. 539-544.

KOHLER, S. V.; RETSLAFF, F. A. S.; MÔRA, R.; FIGUEIREDO FILHO, A.; KOEHLER, H. S. Avaliação do afilamento e sortimento de *Pinus elliottii* Engelm na região centro-sul do Paraná. In: SIMPÓSIO LATINO-AMERICANO SOBRE MANEJO FLORESTAL, 5., 2011, Santa Maria. **Anais...** Santa Maria: UFSM, 2011, p. 446-453.

MAACK, R. **Geografia física do Estado do Paraná**. Curitiba: José Olympio, 1981. 450 p.

MACHADO, S. A.; URBANO, E.; CONCEIÇÃO, M. B.; FIGUEIREDO FILHO, A.; FIGUEIREDO, D. J. Comparação de modelos de afilamento do tronco para diferentes idades e regimes de desbaste em plantações de *Pinus oocarpa* Schiede. **Boletim de Pesquisa Florestal,** Colombo, n. 48, p. 41-64, jan./jun. 2004.

MACHADO, S. A.; SANTOS, A. A. P.; ZAMIN, N. T.; SILVA, L. C. R. Evolução do sortimento de *Pinus oocarpa* na região sudoeste do estado de São Paulo. In: SIMPÓSIO LATINO-AMERICANO SOBRE MANEJO FLORESTAL, 5., 2011, Santa Maria. **Anais...** Santa Maria: UFSM, 2011, p. 194-203.

MULLER, I. **Forma de tronco e sortimentos de madeira para *Eucalyptus grandis* Hill ex Maiden. manejado em alto fuste, na região sudeste do estado do Rio Grande do Sul**. 2004. 142 p. Tese (Doutorado em Engenharia Florestal) - Universidade Federal de Santa Maria, Santa Maria, 2004.

QUEIROZ, D.; MACHADO, S. A.; FIGUEIREDO FILHO, A.; ARCE, J. E; KOEHLER, H. S. Avaliação e validação de funções de afilamento para M*imosa scabrella* bentham em povoamentos da região metropolitana de Curitiba/PR. **Floresta**, Curitiba, v. 36, n. 2, mai./ago. 2006.

QUEIROZ, D.; MACHADO, S. A.; FIGUEIREDO FILHO, A. ARCE, J. E; KOEHLER, H. S. Identidade de modelos em funções de afilamento para *Mimosa scabrella* Bentham em povoamentos nativos da região metropolitana de Curitiba/PR. **Floresta**, Curitiba, v. 38, n. 2, abr./ jun. 2008.

ROSOT, M. A. D. **Estudo comparativo de métodos para a avaliação volumétrica por unidade de área em um povoamento de *Pinus taeda***. 1989. 163 p. Dissertação (Mestrado em Engenharia Florestal) Universidade Federal do Paraná, Curitiba, 1989.

SANQUETTA, C. R. Manejo. **Revista da Madeira**, Curitiba, n. 68, dez. 2002. Disponível em: < http://www.remade.com.br >. Acesso em: 19 dez. 2012.

SCHNEIDER, P. R. FINGER, C. A. G. KLEIN, J. E. M. TOTTI, J. A. BAZZO, J. L. Forma de tronco e sortimentos de madeira de *Eucalyptus grandis* para o estado do Rio Grande do Sul. **Ciência Florestal**, Santa Maria, v. 6, n. 1, p. 79-88, 1996.

SCOLFORO, J. R. S.; RIOS, M. S.; OLIVEIRA, A. D.; MELLO, J. M.; MAESTRI, R. Acuracidade de equações de afilamento para representar o perfil de *Pinus elliottii*. **Revista Cerne**, Lavras, v. 4, n.1, p. 100-122, 1998.

SHIMIZU, J. Y.; HIGA, A. R. Variação racial do *Pinus taeda* L. no sul do Brasil até o sexto ano de idade. **Boletim de Pesquisa Florestal**, Colombo, n. 2, p. 1-25, 1981.

SOUZA, C. A. M. **Avaliação de modelos de taper não segmentados e segmentados na estimação de altura e volume comercial de fustes de *Eucalyptus sp***. 2007. 94 p. Dissertação (Mestrado em Produção Vegetal) - Universidade Federal do Espírito Santo, Alegre, 2007.

WOLFF II, N. I. **Modelagem do crescimento e da produção de *Pinus taeda* L.** 2012. 62 p. Dissertação (Mestrado em Ciências Florestais) – Universidade Estadual do Centro-Oeste, Irati, 2012.

Recebido em 05/12/2013
Aceito para publicação em 11/04/2014