ISSN:1991-8178

Australian Journal of Basic and Applied Sciences

Journal home page: www.ajbasweb.com

Effect of Projected Production with Site Index Built with and without Farm Grouping in *Eucalyptus grandis* Plantations

[1]Marcelo Roveda, [1]Afonso Figueiredo Filho, [2]Andrea Nogueira Dias, [2]Vanessa Scavinski, [3]Rodrigo Ribeiro de Castro

[1]*Federal University of Paraná (UFPR), Department of Forest Engineering. Address: 900, Prefeito Lothário Meissner Avenue, Jardim Botânico, 80210-170, Curitiba, Paraná, Brazil.*
[2]*State University of West Center (UNICENTRO), Department of Forest Engineering. Address: PR 153, Km 07, Riozinho, 84500-000, Irati, Paraná, Brazil.*
[3]*Measurement and Cartography Coordinator. Adress: Marechal Rondon Highway, Km 323, 17120-000, Agudos, São Paulo, Brazil.*

ARTICLE INFO

Article history:
Received 12 March 2015
Accepted 28 April 2015
Available online 5 May 2015

Keywords:
Growth, Permanent plots, Site index, Forest management

ABSTRACT

This study aimed to compare the final yield of *Eucalyptus grandis* W. Hill. Ex. Maiden at three ages through site curves built with and without farm grouping, using data from permanent plots located on three farms in São Paulo. Chapman Richards and Schumacher models were adjusted to estimate the height of dominant trees. The Clutter (1963) model was employed for growth and yield modeling process. In order to verify the influence on the yield through the site curves per farm (Method 1) or by grouping the site curves (Method 2), the mean percentage error of the intermediate site at the ages 48, 60 and 72 months was calculated and the results were compared with the volumes obtained by the permanent plots with the Dunnett test (p-value ≤ 0,05). The dominant height models presented suitable adjustments. The Clutter (1963) model presented satisfactory projections of basal area and volume. The production projection employing the model with and without farm grouping when classifying each region sites provided statistically similar volume projections per area unit. However, the small difference noticed between the two volumetric projections can be very important from the economic viewpoint when inferring the average yield of large areas of plantation. Therefore, the use of site curves per farm is recommended.

© 2015 AENSI Publisher All rights reserved.

To Cite This Article: Marcelo Roveda, Afonso Figueiredo Filho, Andrea Nogueira Dias, Vanessa Scavinski, Rodrigo Ribeiro de Castro., Effect of projected production with site index built with and without farm grouping in *Eucalyptus grandis* plantations. ***Aust. J. Basic & Appl. Sci.,*** *9(11): 76-83, 2015*

INTRODUCTION

The Brazilian forestry sector is a significant part of the National Gross Domestic Product, and the *Eucalyptus* outstands in the paper and cellulose industry, mainly regarding exportation (ABRAF, 2013). According to Tonini *et al*. (2004), the Brazilian eucalyptus forests are among the most productive in the world, mainly due to favorable environmental conditions and the evolution of silviculture, management and genetic improvement.

The employment of management integrated system aiming to optimize the use of forestry resources is successfully obtained through the forest productivity determination (Miguel, 2009), which is part of the forestry planning, management and research. Productivity is influenced by the site curves (Clutter *et al*., 1983; Prodan *et al*., 1997; Harrison and Daniels, 1998), which is a vital tool to guide the inventory, yield estimates, variety and species studies and the study of forestry management suitable practices (Batista and Couto, 1986).

Taking all that into consideration, growth and yield reliable models are essential for the long term planning and decision making. This is especially important in planted forests, where it is necessary to evaluate the plantation density, thinning regime alternatives, silviculture rotation and, possibly, trimming, fertilization, weed control, or clone choice (FINGER, 1992; GARCÍA *et al*., 2011).

Several models are presented in the literature, depending on the production desired. The information obtained through the forest inventory for paper and cellulose companies is the volume per unit area (m^3/ha), known as stand level models (CLUTTER *et al*., 1983). Burkhart*et al*. (1981) pointed out that stand level models estimate the stand volume aggregate value through variables at the stand level (age, site index, basal area or number of trees), but no information on volume of size classes is provided.

Corresponding Author: Marcelo Roveda, Federal University of Paraná, Department of Forest Engineering. Address: 900, Prefeito Lothário Meissner Avenue, Jardim Botânico, 80210-170, Curitiba, Paraná, Brazil. Tel:+55(42)9104-7545. E-mail: marcelo_roveda@hotmail.com

During the growth and yield modeling, quantitative factors such as diameter, total height, dominant height, basal area and volume are employed (Clutter*et al*., 1983; Vanclay, 1994) to support future intervention and forest harvesting decisions. Some difficulties should be mentioned that have important applications in the forest sector, as determining the farm grouping in the site classification might generate similar results in the production in volume when compared to each farm individual modeling. Regazzi (1999) explained that a set of equations can be represented by a common equation, that is, using all data. The result of applying one or more site equations between the farms can be quantified by means of production projection with and without grouping the farms, comparing them with the forest inventory estimates.

The main objective of this study was to estimate the *Eucalyptusgrandis* yield at different ages using the site curves built with or without grouping, comparing them with the permanent plots data on three farms in São Paulo.

MATERIAL AND METHODS

Study area and data characterization:

Data was collected from farms that presented humid subtropical climate, with a dry season from May to July and the highest rainfall occurring in January and February. The soil presented average sandy texture and the average rainfall was around 1330 mm/year (UNICAMP, 2014).

The *Eucalyptus grandis* plantations under study were characterized by different spacing, with 4,5 m² (2,5 x 1,8 m) to 7,5 m² (3,0 x 2,5 m) amplitude. The plots installed were rectangular with a 240 m² area and the measurements were carried out between the years 2001 and 2012. In Table 1 the amplitude and average value found on the three farms (AG I, AG II and AG III) included in this study are presented.

Table 1: Amplitude and mean values, at the farm level, by the age, dominant height (Hd), basal area (G), outside bark volume (V) and number of permanent plots.

Farm	Age (month)		HD (m)			G (m²/ha)			V (m³/ha)			Nº of plots	Total
	Min.	Max.	Min.	Med.	Max.	Min.	Med.	Max.	Min.	Med.	Max.		
AG I	21,3	75,8	11,3	21,6	32,9	4,9	17,6	32,7	17,2	158,5	409	67	429
AG II	22,9	77,0	12,1	22,3	33,3	7,6	19,8	33,9	27,8	181,3	418,7	277	
AG III	24,6	54,0	13,0	22,1	29,2	9,7	20,0	29,5	51,0	181,3	326,6	85	

Min: minimum; Max: maximum; Med: mean.

Site curves construction:

The site curves construction employed the guide-curve method. The Schumacher and Chapman-Richards (Table 2) methods were adjusted by the *Levemberg-Marquardt* algorithm in their non-linear form for each farm individually and grouping the farms, considering a 60-month index age.

Growth and yield curves construction and modeling:

For the growth and volumetric yield modeling, the Clutter (1963) model was employed.

This is a set containing two models, one for the future basal area projection and another to estimate the volume at a future age. The Clutter model was adjusted through the least square method in two stages.

$$Ln(V_{2_i})=\beta_0+\beta_2\left(\frac{1}{I_{2_i}}\right)+\beta_1 S_i++\beta_3 Ln(G_{2_i})+\varepsilon_i \quad (1)$$

$$Ln(G_{2_i})=\left(\frac{I_{1_i}}{I_{2_i}}\right)Ln(G_{1_i})+\alpha_1\left(1-\frac{I_{1_i}}{I_{2_i}}\right)+\alpha_2\left(1-\frac{I_{1_i}}{I_{2_i}}\right)S_i+\varepsilon_i \quad (2)$$

where: V_{2i}= volume (m³/ha) at I_2 age; G_{1i}= basal area (m²/ha) at I_1 age; G_{2i}= basal area (m²/ha) at I_2 age; I_{1i} = plantation current age, in months; I_{2i} = plantation future age, in months; S_i= site index (m) at I_1 age.

Table 2: Tested models for construction of site index curves by *Eucalyptus grandis*.

Author	Model	Equation
Schumacher	$HD=\beta_0 e^{\left(\frac{\beta_1}{I}\right)}+\varepsilon_i$	1
Chapman- Richards	$HD=\beta_0\left[1-e^{(-\beta_1 I)}\right]^{\beta_2}+\varepsilon_i$	2

HD: plot dominant height, in m; I = age, in month; e: base of the natural logarithm; β_0, β_1, β_2: model coefficients; εi: random error.

According to the Clutter growth and yield model, the mean monthly increment (MMI) and the current monthly increment (CMI) curves were built. The culmination of the mean monthly increment (ITC) was determined at the MMI peak.

Comparison of estimated yield from the site curves per farm (Method 1) and with site curves built per region (Method 2):

After building the site curves and the growth and yield model, the influence on the yield was verified from the site index through two methods: 1) site curves built per farm and 2) site curves grouping.

The yield volume obtained from the permanent plots was taken as reference volume (witness) and the volumes obtained in the yield projection with site classification per farm (Method 1) and site classification grouping all the farms (Method 2) were called "estimated yield". The plots selected were measured again at 24 and 96 months. In order to evaluate a common age, the plots were interpolated at 48, 60 and 72 months. Due to their higher

representativeness, the plots chosen for the analysis belong to the intermediate site, considering the site curves per farm.

Thirty permanent plots were randomly selected per farm, and the yield model was applied through the two methods to obtain the site index. Information regarding age and initial basal area in the first measurement were taken as reference to estimate the yield at 48, 60 and 72 months.

Volume information from the permanent plots and the estimated volume with site curve per farm and group of farms were submitted to the variance homogeneity test through the Bartlett test, using the p-valor $\leq$ 0,05. Homogeneous variances were identified, and the variance analysis was carried out in a completely randomized design and in this case, with significant F (p-valor $\leq$ 0,05). When the average equality hypotheses was rejected, the Dunnett (p-valor $\leq$ 0,05) test for average comparison was employed.

In addition to that, and to evaluate the magnitude of differences, the mean absolute ($RQEM_{m^3/ha}$) and relative ($EM_{\%}$) errors were calculated for yields estimated from the two methods of site classification regarding the observed yield as follows:

$$RQEM\ (m^3/ha) = \sqrt{n^{-1}\sum_{i=1}^{n}\left(Y_i - \hat{Y}_i\right)^2} \quad (3)$$

$$EM(\%) = \frac{RQEM\ (m^3/ha)}{\bar{Y}_i}\ x\ 100 \quad (4)$$

Where: Y_i = Volumetric yield (m^3/ha) observed per plot; $\hat{Y}_i$= Volumetric yield projection (m^3/ha) per plot; n= Number of plots. $\bar{Y}_i$= Volumetric average yield (m^3/ha) observed per plot.

Quality evaluation and model adjustment:

The models had their adjustment quality evaluated through the adjusted coefficient of determination ($R^2_{Adj.}$), estimate standard error through the interest and percentage variable (SEE) and residue graphic distribution.

RESULTS AND DISCUSSIONS

Site curves construction:

The coefficients and statistics employed to evaluate the models adjustment to build the site curves are presented in Table 3.

The statistics have close values with small superiority of the Schumacher model, with adjusted determination coefficient ranging from 0,7932 to 0,8414 and estimate standard error from 6,4 to 8,8%. The smallest adjusted determination coefficient (R^2_{Ajust}= 0,7932) and the best estimate standard error (S_{yx}= 6,4%) were found for the farm AG III. Determination coefficients lower than the ones found in this study were observed with the Schumacher model in *Eucalyptus* plantations by Demolinari *et al*. (2007).

However, the farm AG I presented opposite results, with higher adjusted determination coefficient (R^2_{Ajust}= 0,8414) and the worst estimate standard error (Syx= 8,8%). The adjustment with the three farms grouped presented the same estimate standard error for both models, with slight advantage of the determination coefficient for the Schumacher model.

Tabela 3: Coefficients and statistics for the models of Schumacher and Chapman-Richards tested to estimate dominant height as a function of age.

Model	Farm	Coefficients			$R^2_{Adj.}$	SEE (m)	SEE (%)
		β_0	β_1	β_2			
1	AG I	38,7128*	-25,6931*	-	0,8414	1,88	8,8
	AG II	39,0009*	-24,4411*	-	0,8356	1,66	7,5
	AG III	37,1062*	-20,1327*	-	0,7932	1,43	6,4
	AG I, II, III	38,2984*	-23,4559*		0,8323	1,77	8,0
2	AG I	34,7666*	0,0193*	1,1171*	0,8363	1,96	9,1
	AG II	34,5187*	0,0233*	1,0002*	0,8370	1,66	7,5
	AG III	31,8997*	0,0275*	1,0953*	0,7921	1,44	6,5
	AG I, II, III	33,4534*	0,0233*	1,0701*	0,8103	1,77	8,0

*: significant at 95% probability level; β_0, β_1, β_2: coefficients of the model.

The residue graphs were around ± 20% (Figure 1), except for some plots close to 24 months on farms AGII and AGIII and close to 40 months on farm AG I. In general, the residue distributions for the model employed presented similar variation pattern. Due to that, the choice of the most suitable model to estimate the dominant height as a function of the age was based on the evaluation statistics (Table 3). The best statistical results were presented by the Schumacher model.

The Schumacher model had already been chosen by other authors such as: Dias (2000) for eucalyptus plantations in the Northeast region of Bahia; Oliveira *et al*. (2008) in eucalyptus clone plantations in the State of Bahia; Leite *et al*. (2011) *Eucalyptusurophylla* x *Eucalyptusgrandis* clone plantations in the region of Santa Bárbara in the State of Minas Gerais; Jerez-Rico *et al*. (2011) in teak (*Tectonagrandis*L. F.) plantations in the Venezuelan plains.

The site index curves were built individually for each farm (Figure 2) with 4 meters amplitude. This amplitude was defined because it represented properly the data distribution, resulting in three sites

(I, II and III), referring to the high, medium and low productivity, respectively.

Growth and yield curves construction and modeling:

In Table 5 presents the estimated coefficients and the statistics summary per farm and per group.

Farms AG III and AG II presented the lowest and the highest volume determination coefficient (0,7437 and 0,9268), respectively. When this region basal area statistics was evaluated, the lowest determination coefficient was seen on the farm AG III and the highest coefficient was found on the farm AG I. The basal area estimate standard error ranged from 5,2% to 6,9% and from 6,7% to 10,1% regarding volume on both farms AG II and AG I, respectively.

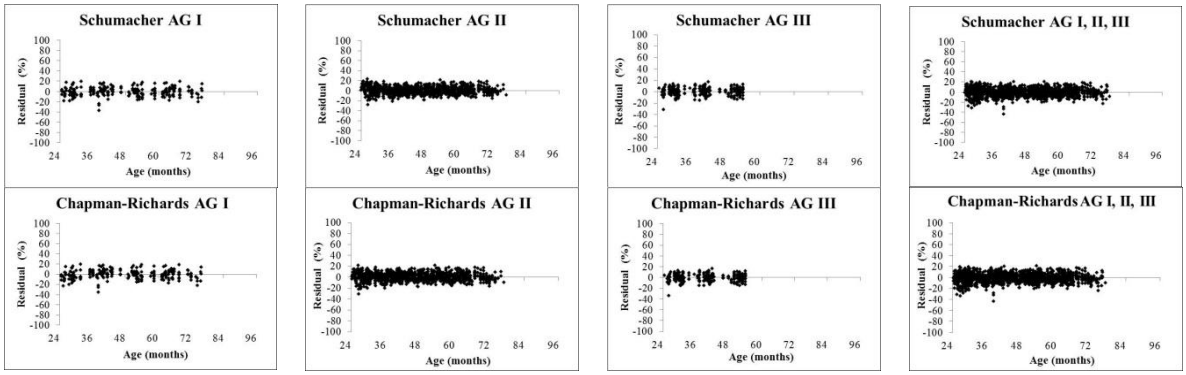
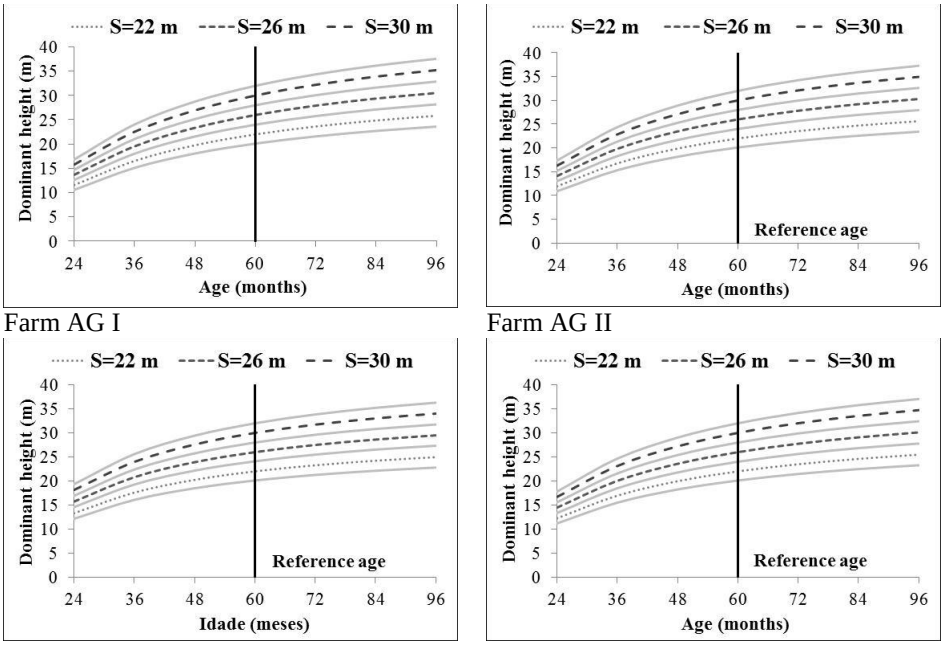


Fig. 1: Distribution of residues of dominant height as a function of age for the Schumacher and Chapman-Richards models.



Farm AG I | Farm AG II

Farm AG III | Farm AG I, II, III

Fig. 2: Site index curves constructed by farm and region, based on index age of 60 months, constructed by the guide curve method for *Eucalyptus grandis*.

Table 4: Coefficients and Statistics of the Clutter model (1963) per farm (AG I, AG II e AG III) and grouping all the farms (AG I, II, III) to *Eucalyptus grandis*.

Farm	Coeffcients						Volume (m³/ha)		Basal Area (m²/ha)	
	β_0	β_1	β_2	β_3	α_0	α_1	$R^2_{Adj.}$	SEE.(%)	$R^2_{Adj.}$	SEE.(%)
AG I	1,3994	-24,9476	0,0233	1,2436	2,6431	0,0381	0,9163	10,1	0,9007	6,9
AG II	1,5926	-19,8617	0,0141	1,2234	3,0949	0,0218	0,9268	6,7	0,8798	5,2
AG III	1,5234	-15,0395	0,0076	1,2811	3,0657	0,0195	0,7437	8,4	0,6582	6,2
AG I, II, III	1,7058	-22,2855	0,0225	1,1358	3,4118	0,0089	0,9003	8,1	0,8631	5,9

In relation to the farm grouping, the statistics reached intermediate values when compared to those adjusted individually, indicating both gain and loss of precision in the initial adjustments. The adjustments with basal areas had lower R^2_{Ajust}. When compared to the volume adjustment. This fact is due to the lower age and basal area correlation, when compared to the volume.

The basal area and volume adjustments residual distribution regarding the three farms can be seen in Figures 3 and 4. The basal area residue distributions were seen to present a slight tendency to overestimation from the 48 months on in the four adjustments. In general, the highest residue variation occurred in the interval ±20% and, therefore, the estimates were considered satisfactory.

In Figure 4 shows the volume equation residue distribution. Some of the plots on the farm AG I aged between 48 and 60 months and farm AG II aged from 40 to 60 months overestimated the yield up to 40%. At the remaining ages and on the farm AG II the residues oscillated uniformly around ±20%. At the time of the adjustment of one single equation for all the farms, some of them were noticed again to present yield overestimation at the early ages, with up to 50% residue.

In Figure 5, the different sites volumetric growth and yield curves are presented, employing the Clutter (1963) model, and the respective ITC are identified by the vertical line. The thinning technical ages followed a trend that had been expected, with more productive sites reaching maximum growth earlier, in addition to higher yield in the best sites.

The site indices for both farms were 22, 26 and 30m. The worst and the best performance in the average yield analysis in basal area and volume were observed on farms AG I and AGIII, respectively.

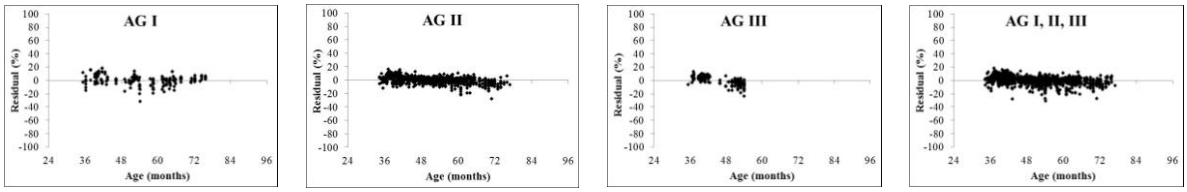


Fig. 3: Dispersion of residuals for the basal area equation (m²/ha) of the Clutter model.

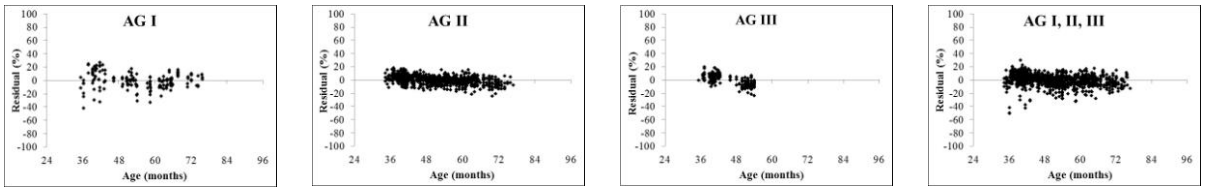
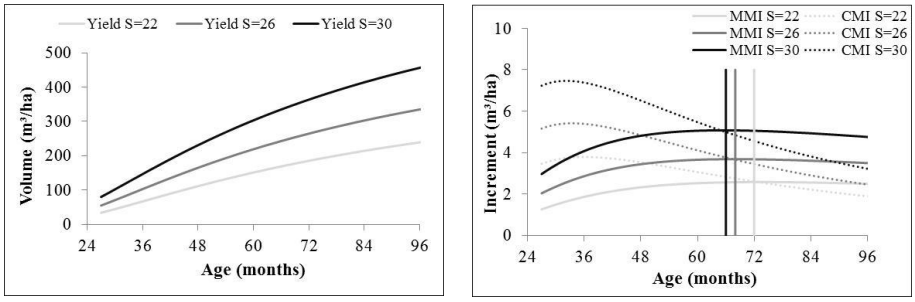
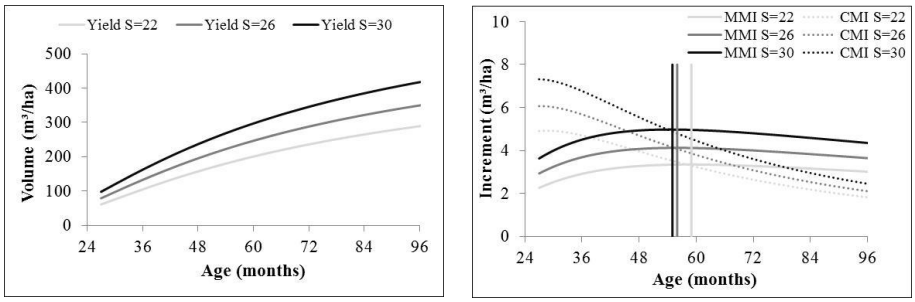


Fig. 4: Dispersion of residues for the equation of volume (m³/ha) of the Clutter model.



Farm AG I



Farm AG II

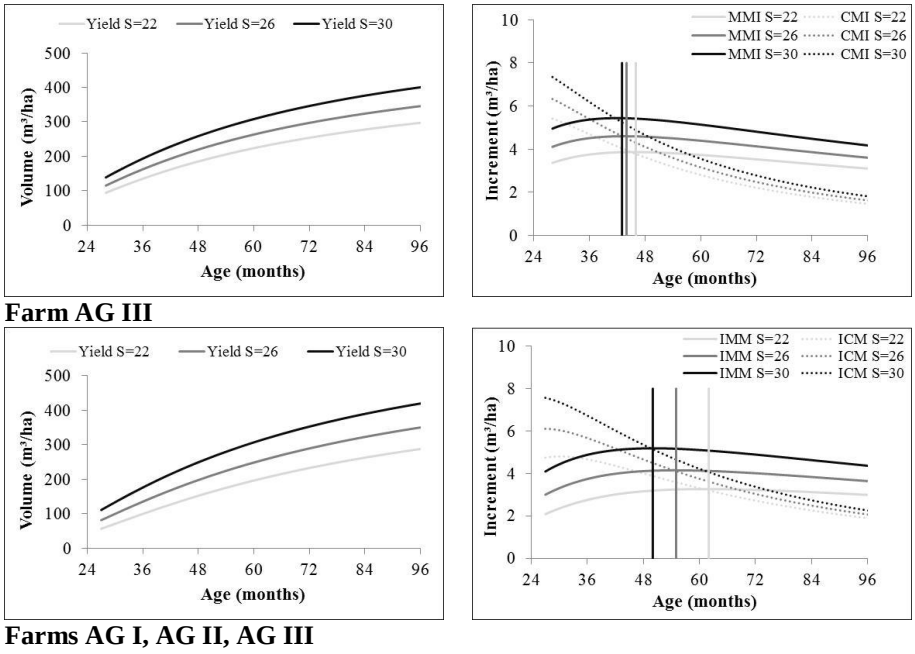


Fig. 5: Curve of mean monthly increment, current monthly increment and production (yield) for the sites at each farm.

The corresponding thinning technical age for farm AG I was 72 months (S=22), 68 months (S=26) and 66 months (S=30). On the farm AG II, the difference between thinning technical ages was three months between the least productive site and the intermediate, with 55 months for the most productive site (S=30 m). Farm AG III presented the lowest ITC when compared to the other ones at 46 months (S=22 m), 44 months (S=26 m) and 43 months (S=30 m). When the farm grouping was carried out, the thinning technical age presented the largest amplitude among all farms, with a 50-month ATT in the best site, 55 months in the intermediate site and 62 months in the least productive site.

Comparison of estimated yield from the site curves per farm (Method 1) and with site curves built per region (Method 2):

In Table 6 presents a summary of the volume yield average value for the plots selected at three different ages, besides the mean absolute and relative error and the Dunnet average comparison test.

The volume yield average for the permanent plots, estimated volume with methods 1 and 2 were submitted to the Bartlett (p-valor $\leq$ 0,05) test, indicating that the variances were homogeneous. The variance analysis did not indicate significant differences (p-valor<0,05) between the average projections with the site curves per farm modeling (Method 1), grouping the farms (Method 2) and the permanent plots average. Thus, it was not necessary to employ the Dunnet average test. However, the estimates through the two methods under analysis generated mean errors that ranged from 4,4% to 7,7% with method 2, with a slight advantage for method 1, which varied from 3,9% to 6,7%.

The volumes estimated through the two methods overestimated the yield observed on the farm AG II at the three ages and on the farm AG I at 60 and 72 months. The amplitude of volume relative estimate standard error was between 3,9% and 5,6%, in the projection with Method 1 and 4,6% to 4,8% in the projection employing Method 2 at 48 months.

Table 5: Yield projection statistics (48, 60 and 72 months) for an average site class simulated in 30 plots, using the average site index per farm (Method 1) and the average site index grouping the farms (Method 2).

Months	Farms	Average of yield (m³/ha)			RQEM (m³/ha)		EM (%)	
		Operation cruise	Method 1	Method 2	Method 1	Method 2	Method 1	Method 2
48	AG I	169,8	164,4	168,2	9,5	7,8	5,6	4,6
	AG II	173,2	173,8	178,0	6,8	7,9	3,9	4,6
	AG III	203,6	204,1	197,3	9,3	9,8	4,6	4,8
60	AG I	212,2	217,2	217,3	11,8	13,6	5,6	6,4
	AG II	216,5	224,3	228,2	11,0	14,1	5,1	6,5
	AG III	254,5	248,0	247,7	11,4	12,2	4,5	4,8
72	AG I	255,6	261,9	258,1	17,2	19,6	6,7	7,7
	AG II	259,8	266,0	269,4	12,5	14,9	4,8	5,7
	AG III	296,8	282,4	288,4	19,8	16,1	6,7	5,4

Averages followed by the same letter in the line are considered statistically similar by the Dunnet test p-value $\leq$ 0,05. Where: RQEM (m³/ha) refers to the mean absolute error and EM (%) is the relative one;

The lowest mean absolute error was found on farm AG II at 48 months, with 6,8 m³/ha and 7,9 m³/ha mean absolute error with method 1 and method 2, respectively. Regarding farms AG I, AG II and AG III at 60 months, the mean absolute errors were 5,6; 5,1 and 4,5%, with method 1. The lowest mean absolute errors at 72 months were 17,2 m³/ha (farm AG I); 12,5 m³/ha (farm AG II) with method 1and 16,1 m³/ha (farm AG III) with method 2.

The highest projection error with method 1 at the three ages was found on farm AG I. The three farms in this region presented ± 8,0% absolute estimate standard error.

When both projections, with and without grouping the site curves, were compared to the inventory intervals, two situations revealed the highest percentage of mean absolute error with method 1. This occurred on farm AG I at 48 months and farm AG III at 72 months. The remaining ages and farms showed the highest yield projection errors with method 2.

Although the results are statistically similar regarding both projection methods and the errors relatively low, method 2 presented a slight advantage when compared to method 1, with 1,4% more accurate projections or 3,1 m³/ha in yield and should therefore be employed to the projections.

Conclusions:

The yield projection at 48 months can be carried out by grouping the site curves in the region without losing accuracy. For the remaining ages it is advisable to project the production through site curves per farm.

The methodology employed revealed that the modeling with site curves per farm and by grouping the farms presented logical and statistically similar values. However, a slight difference between the two volumetric projections generated by the two methods under analysis can be very important from the economic viewpoint when carrying out extrapolations of average yield for large planted areas. Site curves per farm are, therefore, recommended for eucalyptus commercial plantations.

REFERENCES

Associação Brasileira de Produtores de Florestas Plantadas, 2013. Anuário estatístico da ABRAF 2013: ano base 2012/ ABRAF.

Batista, J.L.F. and H.T.Z. do Couto, 1986. Escolha de modelos matemáticos para aconstrução de curvas de índice de sítio para florestas implantadas de *Eucalyptus* sp. no Estado de São Paulo. IPEF, 32: 32-41.

Burkhart, H.E., Q.V. Cao, K.D. Ware, 1981. A comparison of growth and yield prediction models for loblolly pine. Blacksburg: Virginia Polytechnic Institute and State University, School of Forestry and Wildlife Resources.

Clutter, J.L., J.C. Fortson, L.V. Pienaar, G.H. Brister, R.L. Bailey, 1983. Timber management: a quantitative approach. New York: John Wiley e Sons.

Demolinari, R.A., C.P.B. Soares, H.G. Leite, A.L. Souza, 2007. Crescimento de plantios clonais de eucalipto não desbastados na região de Monte Dourado (PA). Revista Árvore, 31(3): 503-512.

Dias, A.N., 2000. Modelagem e avaliação econômica de plantações de eucalipto submetidas a desbastes. M. S. thesis, Federal University of Viçosa, Viçosa, MG.

Finger, C.A.G., 1992. Fundamentos de Biometria Florestal. Santa Maria: UFSM/FATEC/CEPEF.

García, O., H.E. Burkhart, R.L. Amateis, 2011. A biologically-consistent stand growth model for loblolly pine in the Piedmont physiographic region, USA. Forest Ecology and Management, 262(11): 2035-2041.

Harrison, W.C. and R.F. Daniels, 1988. A new biomathematical model for growth and yield of loblolly pine plantations. In Forest growth modelling and prediction, Proc. IUFRO Conf. US For. Serv. Gen. Tech. Rep. NC, 120: 293-304.

Jerez-Rico, M., O.E. Moret-Barillas, O.E. Carrero-Gámez, R.E. Macchiavelli, A.M. Quevedo-Rojas, 2011. Curvas de índice de sitio basadas en modelos mixtos para plantaciones de teca (Tectona grandis L.F.) en los llanos de Venezuela. Agrociência, 45(1): 135-145.

Leite, H.G., R. Castro, A. Silva, C. Júnior, D. Binoti, A.F. Castro, M. Binoti, 2011. Classificação da capacidade produtiva de povoamentos de eucalipto utilizando diâmetro dominante. Silva Lusitana, 19(2): 181-195.

Miguel, E.P., 2009. Avaliação biométrica e prognose da produção de *Eucalyptus urophylla* (S.T. Blake) na região norte do estado de Goiás. M. S. thesis, Federal University of Parana, Curitiba, PR.

Oliveira, M.L.R., H.G. Leite, G.S. Nogueira, S.L.R. Garcia, A.L. Souza, 2008. Classificação da capacidade produtiva de povoamentos não desbastados de clones de eucalipto. Pesquisa Agropecuária Brasileira, Brasília, 43(11): 1559-1567.

Prodan, M., R. Peters, F. Cox, P. Real, C.R. San Jose, 1997. Mensura Forestal. Deutsche Gesellschaft für Techniche Zusammenarbeit (GTZ), Instituto Internacional de Cooperacion para la Agricultura (IICA).

Regazzi, A.J., 1999. Teste para verificar a identidade de modelos de regressão e a igualdade de parâmetros no caso de dados de delineamentos experimentais. Revista Ceres, 46(266): 383-409.

Tonini, H., C.A.G., Finger, P.R. Scheneider, 2004. Crescimento de clones de Eucalyptus saligna

Smith, na depressão central e serra do sudeste, Rio Grande do Sul. Ciência Florestal, 14(2): 61-77.

Unicamp, 2014. Centro de Pesquisas Meteorológicas e Climáticas Aplicadas à Agricultura,[Online].Available: http://www.cpa.unicamp.br/index.html. Acessed: 10 october 2014.

Vanclay, J.K., 1994. Modelling Forest Growth and Yield: Applications to Mixed Tropical Forest. Wallingford: CAB International.