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Methodology for the assessment of aspects and qualitative data in forest inventory audit

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Abstract
Considering the importance of high quality data for the forest production planning, the concern to ensure good provision of services and to quantify the occurrence of errors in forest inventories, the objective of this study was to develop and apply a methodology to assess the installation of sample plots (qualitative aspects) and the qualitative classification of trees for a forest inventory (qualitative data). Six of a total of 120 plots from an *Eucalyptus* sp. stand forest inventory were randomly selected, retaking the data strictly according to the same methodology, that is, were measured again. Potential errors were classified and scored according to the magnitude of the influence of these errors on the forest production planning (Priority Hierarchy). The assessment of the plots was performed by multiplying the number of errors found by the respective scores, adopting as criteria of disapproval of plot the sum equal or higher than 21 points, and, for the evaluation of the inventory, the approval of at least 60% of the plots. Pareto graphs were also made for the occurrence of errors, affected wood volume and sum of the scores. All the audited plots presented errors, and two were reproved, the Pareto charts presented little difference and pointed out the most representative errors. It was verified that the forest inventory carried out presented a large number of errors. The audit methodology allowed the identification of the errors, in which plots these were found and provided accurate information for mitigating actions.
Keywords: Quality assessment; Error control; Non-sampling errors

Introduction

Providing raw material for numerous elements of the Brazilian forest-based production chain in a comparatively short space of time, plantations of trees belonging to the genus *Eucalyptus* occupy an area of approximately 5.6 million hectares, corresponding to 71.8 % of the total of 7.8 million hectares occupied by forest plantations, being thus the most planted species, and that best represents the Brazilian forest production system (Bti 2016).

The quantification and quality attribution to the wood stock of a forest evaluated by a forest inventory are the most important activities of the forest production planning (Nakajima et al. 2011). The quality of the data collected in these activities largely influence on the precision of forest management activities, and consequently, represent a decisive factor in the maximization of the economic and financial results of forest enterprises (Brandelero et al. 2009; Makinen et al. 2010).

Collecting information from all individuals of a forest stand generates high costs, making this activity economically unviable in the vast majority of cases. Therefore, the practicable alternative to quantify and attribute quality to the wood stock is the adoption of sampling processes (Augustynczik et al. 2013).

Sampling errors are associated to the adoption of the sampling process can be calculated and controlled by increasing sample intensity (Silva et al. 2007), stratification (Kanegae junior et al. 2007) and plot shape variation (Soares et al. 2009). The non-sampling errors occur when data collection, recording and analysis are incorrectly performed, which may adversely affect production planning, jeopardizing the forest business success.

Compared to the sampling errors, there are few studies approaching the techniques, calculations and control of non-sampling errors. Therefore, neglecting the occurrence of these errors creates uncertainties for the forest production planning, which may occasionally jeopardize the maximization of the forest enterprise results. (Gertner e Khol 1992; Berger et al. 2014).

In addition to the planning context, the characteristics of the Brazilian forest enterprises of occupying large areas and the high investment levels results in a high cost activity, which is a determining factor for carrying out forest inventory audits, considering that it is often an outsourced activity. When carried out by the company itself, monitoring activities in the field face serious difficulties, especially in technical and economic aspects (Binoti et al. 2013).

Identify and quantify the occurrence of these errors and develop methodologies for this purpose are one of the greatest challenges to mitigate its effects. The adoption of Quality Management tools such as the development of auditing methodologies in forest inventories could, in many cases, be a feasible activity to enhance precision in data collection, raising awareness of the dynamics of errors occurrence, providing the possibility of corrections through accurate estimates and adequate training of the measuring crews (Pollard et al. 2006).

In this context, the objective of this study was to develop a methodology to assess the installation of sample plots and the qualitative classification of trees of a *Eucalyptus* sp. forest inventory carried out in Mato Grosso do Sul state, in order to quantify and identify the occurrence of these errors in the forest inventory plots..

Material and Methods

Study area

The forest inventory used as basis for the present study was carried out in Mato Grosso do Sul state, in a 6-year-old forest stand of *Eucalyptus* sp., located in the Três Lagoas micro-region, that adopted an initial spacing of 3 x 2.5 m. The area landscape ranges from flat to slightly hilly; The climate, according to Köppen, is classified as Aw, tropical with dry season, and monthly precipitations lower than 40 mm in the driest month, and mean annual precipitation of 1400 mm (70% during the rainy season); mean annual temperature during the rainy season is around 24 °C and 17°C in the dry season (Santos 2014). The predominant vegetation in the study area is classified as dense or open arboreal savannah, or semi-deciduous seasonal forest (Otsubo et al. 2015).

Characteristics of the forest inventory for the audit

Aiming to assess the quality and quantity of the timber potential of *Eucalyptus* sp. plantation areas, the inventory adopted a systematic sampling method with sampling intensity of 2.4%, corresponding to 1 plot of approximately 720 m² for every 3 hectares of plantation.

It was installed rectangular plots with fixed length of 36 m and approximately 20 m width. In the forest inventory and audit processes, were collected the circumference at 1.3 m above the ground (cbh) of all trees, the total heights of the first 10 trees of the plot and the total heights of seven dominant trees, besides the qualitative information of all the trees.

The evaluation of the forest inventory audit was carried out by randomly selection of 5% of the plots inventoried until the moment of the audit, which corresponded to six plots audited from a total of 120 plots. The plots were evaluated using the concept of blind check, described by Pollard et al. 2006, which involves the re-installation of inventory plots performed by a qualified crew, in the possession of only information about the location of the plots to be audited, avoiding any interference on the audit process.

Data and qualitative aspects

Qualitative data are understood to be non-representable numerically or data that although can be numerically represented, are shown by its qualitative characteristics. Considering the data of the audit as parameter, the developed methodology had as objective to assess the data regarding the correct execution of the activities proposed in the forest inventory. The qualitative data evaluated in this study are related to the classification of tree stem quality, while the qualitative aspects are related to the installation of the plots.

Hierarchical classification of errors

The potential types of errors were surveyed, classified and assigned different scores according to the magnitude (Priority Hierarchy) of the influence of these errors on the inventory estimates, financial return and planning compromise. Table 1 presents the 36 types of errors that could be observed in the inventory activities performed.

Table 1 - Classification and score of the potential types of errors of the qualitative evaluation used in the forest inventory.

N°	Types of potential errors	Classification	Score
1	Plot placed in wrong location (Tolerance of 30 meters)	Reprobative	21
2	Error of counting trees on plots		
3	Error of counting planting lines on plot		
4	Sum of scores of other errors above 21 points		
5	Non-inclusion of tree on plots	Critical	07
6	Inclusion of an undue tree on plots		
7	Non-classification of dominant tree		
8	Undue classification of dominant tree		
9	Normal tree classified as fault	Serious	05
10	Normal tree classified as dead		
11	Normal tree classified as broken		
12	Normal tree classified as forked above 1.3 m		
13	Normal tree classified as forked below 1.3 m		
14	Normal tree classified as resprouting		
15	Normal tree classified as leaning or fallen		
16	Normal tree classified as tortuous		
17	Normal tree classified as Die-back		
18	Normal tree classified as ant-attacked		
19	Normal tree classified as tillered tip		
20	Normal tree classified as burned		
21	Pruned tree classified as unpruned		
22	Fault tree classified as normal	Moderate	03
23	Tree forked above 1.3 m classified as normal		
24	Tree forked below 1.3 m classified as normal		
25	Resprouting tree classified as normal		
26	Tortuous tree classified as normal		
27	Die-back tree classified as normal		
28	Tillered tip Tree classified as normal		
29	Unpruned tree classified as pruned		
30	Improperly marked tree for thinning		
31	Unmarked tree for thinning		
32	Dead tree classified as normal	Minor	01
33	Broken tree classified as normal		
34	Burned tree classified as normal		
35	Leaning or fallen tree classified as normal		
36	Ant-attacked tree classified as normal		

- Reprobative errors: These are gross errors in the execution of forest inventory activities or the high recurrence of errors of minor magnitude, which respectively have a direct influence on the estimation of timber volumes and classification of the various products, compromising the forest production planning. Reprobative errors not only affect the representativeness of the plot data, but also the representativeness of the area and the comprehensiveness of the sampling process.

• Critical Errors: Errors that may underestimate or overestimate the inventory estimates, however, they are more localized errors, of lesser scope and therefore do not compromise the sampling procedure.

• Serious Errors: These errors are related to the classification of the various products originating from forest stands, having the characteristic of classifying the raw material as being of inferior quality to the real, compromising the production planning of many products, the precision of silvicultural treatments, the reduction of costs and, ultimately, the maximization of the plantation economic results.

• Moderate errors: Also related to the classification of the different forest products and to the inadequate use of timber potential; differently from the serious errors, the moderate errors have the characteristic of classifying the raw material as being of superior quality to the real, compromising the production planning of some products, the precision of the silvicultural treatments and the reduction of costs, although with less influence on the economic results maximization.

• Minor errors: Although they have no lesser importance or influence on the production planning, those errors are considered as such mainly because the qualitative condition of the trees at the audit moment, which may depend on an event occurring in the period between the inventory and the audit activities, and cannot be attributed to the measurement crew.

Assessing the inventory and plots

After evaluating the occurrence of errors, it was carried out an assessment of the plots of the inventory. To this end, for each plot, the errors were multiplied by its respective scores and then adding these scores. For the evaluation of the plots was established the value of 21 points for disapproval, which is equivalent to 01 reprobative error, 3 critical errors, 4.2 serious errors, 7 moderate errors or21 minor errors. Therefore, any sum that exceeds 21 points results on a direct reprobation of the plot. To evaluate the forest inventory, a minimum approval of 60% of the audited plots was adopted.

Estimates of heights and volumes

With a database composed by 63 trees scaled by the Smalian Method for the estimates of volumes and total heights of the trees, the following mathematic models were adjusted, in order to describe the volumetric influence of the errors:

Total volume out-side bark for individual tree was based on logarithmic form of Schumacher & Hall model (Equation 1) and height-diameter equation for total height was based on Trorey model (Equation 2)

$$ln\, v = -9.63695 + 1.77922 * ln\ d + 1.14886 * ln\ h \qquad (1)$$

$$ht = 1.78427 + 1.78576 * d - 0.02615 * d^2 \qquad (2)$$

Where: d = diameter of tree stems at breast height, 1.3 meters above ground level (cm); h = total height of trees (m); v = individual volumes of trees (m^3).

The models presented, respectively, an adjusted coefficient of determination (adjusted - R^2) of 98.95 % and 47.30 % and a standard error of estimate (Syx) of 4.48 % and 8.06 %.

Pareto charts

As an important quality control tool, Pareto charts were developed to identify the most important problems. In order to observe the relationship between the hierarchy of importance, occurrence, and volume of wood affected by the errors, charts were elaborated for occurrence of errors, affected wood volume and sum of the scores.

Results

The results presented in Table 2 show the types of errors that occurred, in accordance with the numeration of Table 1, the number of occurrences and error percentage in each plot of the forest inventory.

Table 2 - Types of errors and occurrence in audited plots.)

Types of errors	Occurrence of errors in plots						Total	(%)	V (m^3/ha)
	01	02	03	04	05	06			
05	-	01	-	-	-	-	01	2.38	1.26
12	01	-	-	-	-	-	01	2.38	1.67
16	-	02	01	-	-	-	03	7.14	4.16
21	01	03	-	06	01	-	11	26.19	12.36
23	-	01	01	01	-	01	04	9.52	7.08
26	01	-	02	03	-	01	07	16.67	8.36
29	01	05	02	04	-	-	12	28.57	15.97
30	-	-	-	-	02	-	02	4.76	2.96
33	01	-	-	-	-	-	01	2.38	0.87

Where: (%) = percentage of the total of errors; V = estimate of affected timber volume.

Errors number 29, 21 and 26 correspond respectively to; “Unpruned tree classified as pruned”, “Pruned tree classified as unpruned” and “Tortuous tree classified as normal”. In that order, these errors were the most incidents and together represented approximately 71.5% of the total errors occurred.

Regarding the influence of the errors on timber volume, it was observed that 54.69 m^3, that is, approximately 17% of the total of 317.95 m^3/ha estimated for the audit plots, has some error in the qualitative classification of the stem, or was still underestimated in the inventory plots, as can be observed by the only error of number 5, “Non-inclusion of tree on plot” found in plot 02. In addition, it is noticed that the errors classified as moderate were the ones that occurred the most.

The results of errors found in the audited plots by survey are presented in Table 3, with the sum of scores and values found for each plot in the audit and inventory processes.

Table 3 - Result of the survey of errors occurred and verification of the situation of audited plots and forest inventory activities

Plot	N° of Trees	Classification	N° of errors	Sum	(%)	Situation
1	44	Reprobative Critical Serious Moderate Minor	00 00 02 02 01	17	10.8	Approved
2	32	Reprobative Critical Serious Moderate Minor	00 01 05 06 00	50	31.6	Disapproved
3	39	Reprobative Critical Serious Moderate Minor	00 00 01 05 00	20	12.7	Approved
4	41	Reprobative Critical Serious Moderate Minor	00 00 06 08 00	54	34.2	Disapproved
5	38	Reprobative Critical Serious Moderate Minor	00 00 01 02 00	11	7.0	Approved
6	43	Reprobative Critical Serious Moderate Minor	00 00 00 02 00	06	3.8	Approved
General	237	Reprobative Critical Serious Moderate Minor	00 01 15 25 01	158	100	Approved

Where: (%) = percentage of the total of errors in each plot.

The results of the errors observed on the survey shows that, although there was no presence of reprobative errors in any plots, the plots number 02 and 04 presented the highest concentrations of errors and were disapproved for presenting sums higher than 21 points. The plot 03 sums 20 points, just one point for disapproval, while plots 01, 05 and 06 presented satisfactory results.

The overall result of the audit showed a sum of 158 points, where most part of the errors were found in the plots classified as moderate, followed by the serious, critical and minor errors, presenting one occurrence each. All the audited plots presented errors and 42 of the 237 assessed trees presented some type of error in the qualitative assessment. Although the qualitative inventory has been approved, the sum of the scores was quite high, with only 19 points for disapproval. The percentage of disapproved plots was also very close to 40%, with approximately 33.4% of the plots disapproved.

Based on the information in Table 1, the Pareto charts for the number of errors, volume affected and total scores are shown in Figure 1

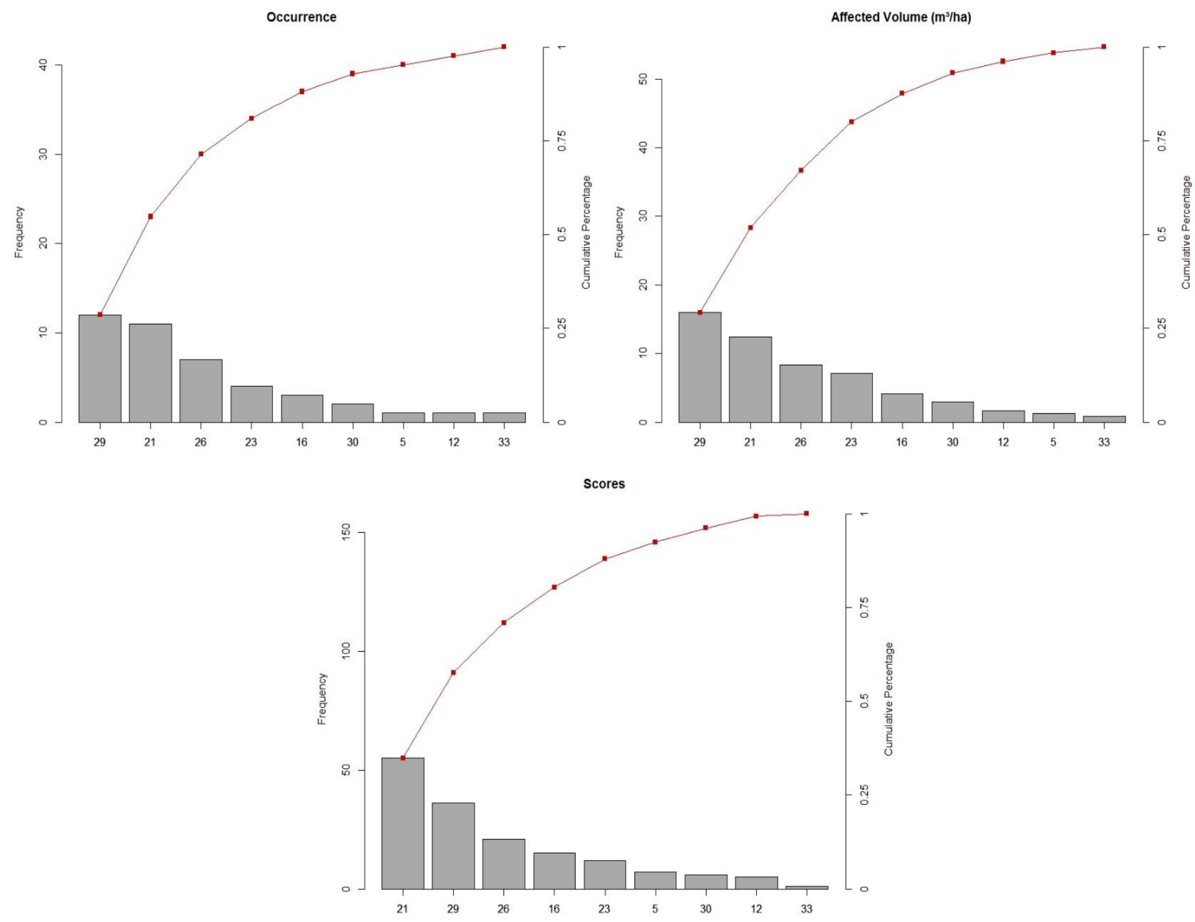

Figure 1 - Pareto charts of occurrence of errors, affected estimated volume and sum scores.

Pareto charts showed little difference in the position of the error number, however, presented a considerable difference in the frequencies. It is possible to observe that in the charts for the occurrence of errors and estimated volume of affected wood, the error of number 29 is the most representative. However, in the chart for sum of the scores, the error of number 21 assumes this position. Another type of representative error is number 26, which occupies the third position in all made charts.

Discussion

Such as Pollard et al. (2006) who assessed the quality of the data collected in the national forest inventory, carried out by the United States Forest Service, some assessment methodologies and studies on quality control of forest inventories can be found. However, the great majority of these studies are focused on the quantitative data, more precisely the dendrometric variables d and h (Measurement errors). Thus, methodologies that assess qualitative data in forest inventory audit processes are rare in the literature, making it impossible to draw any comparisons with previous studies.

The survey of trees qualitative aspects in the forest inventory is premised on the allocation of timber from plantations for several purposes, thus, selling superior quality timber by higher values and obtaining the maximum financial return (Guillemette et al. 2008). According to Maltamo et al. (2009) and Gasparini et al. (2009), due to it being closely tied to the objective and level of timber planning of each organization, the terminology for qualitative assessment of stems and the implantation method of sample units tends to vary according to the company, geographic region, product destination, forest species, among other aspects. Therefore, to apply the method developed in the present study, it is necessary to adapt it to the characteristics and needs of the forestry enterprise concerned.

Meadows and Skojac (2008) and Vibrans et al. (2010) state that, for depending of a quick and critical analysis, some errors classified as moderate and serious such as those of numbers; 16, 21, 26, and 29 (Table 1), are easily done by professionals with low experience in the activities of qualitative classification of trees, differently from the critical errors caused mainly by the lack of attention or problems associated to the equipment.

As qualitative classification of trees depend mainly on the human visual capacity (Persson et al. 1995), the time of day of the activities can also affect the quality of the data collection. The fatigue of the field crew and the low luminosity can be cited as the main factors influenced by the moment of measurement, which, for example, may have influenced the non-inclusion of one tree in plot 02. It is still important to note that, considering both factors, the last plots measured in the day would be the most susceptible to errors, which makes the plot measurement schedule an important element to be studied.

The spatial statistics of errors in forest inventories is also an important aspect to be addressed. Mainly because they may be more related to topographic aspects and other physical factors (Machado and Figueiredo Filho), it is believed that the measurement errors of dendrometric variables have a high probability of presenting spatial dependence. Already the errors in the collection of qualitative data probably do not have the same tendency, since they are more linked to the performance of the field crew.

As for the bias, Silva (2017) observed that in most forestry projects inventoried and later audited, measurement errors presented a random behavior, except in cases where they were mainly related to erroneous team procedures and / or uncalibrated instruments, such as already reported by Kershaw Junior et al. (2016). With respect to qualitative data, it is possible to affirm that in the majority of the cases presented systematic behavior. Such bias can be observed in the recurrence of errors of numbers 21, 23, 26 and 29 that appear in four of the six audited plots (table 2).

Regarding the training of the field crews, there is little variability of error types observed, considering that 09 types were found from a total of 36 possible. This favors more focused and less costly training in activities of higher necessity, in this case visual training. Moreover, according to the theory of statistical quality control presented by Montgomery (2009), when considering the Pareto charts results, we can observe that the theoretical proportionality, in which 80% of the consequences come from 20% of the causes is confirmed. Thus, if we consider the priority issue, the training would be even more focused.

Although the inventory was approved by the audit, it presented high scores and the disapproval of two plots. Due to the large number of errors, the high score demonstrated in the audit process leads to questioning the accuracy of the forest production planning, considering that approximately 17% of the total timber volume estimated is not correctly classified.

Considering technical constraints such as the identification of all plots that require reassessment and the economic impracticability of repeating the entire data collection process, corrective activities for negative audit results are difficult to apply. According to Westfall and Woodall (2007), the mitigation of the errors found in the audits should be carried out through preventive measures, such as: training of data collection crews, frequent examination of measurement equipment and continuity of audit activities. Therefore, the next step for the improvement of data collection is training the field crews in the classifications which presented the highest occurrence of errors and consequently compromised a larger volume of wood and sum of scores, respecting the results of the Pareto charts.

In order to increase control on the quality of data collection, it is suggested an inventory adopting blocks of plots, with a specified quantity of plots, and each block labeled by, at least, the designated crew and the date of the data collection. Thus, it is expected a higher precision of the quality control, by allowing to relate the performance to those responsible, and, if the reassessment of data is required, it could be performed with high precision and without major losses.

Regarding the practical application of the methodology, in addition to the adaptation of the classification according to the interests of the organization as previously discussed, it is recommended to use the performance of the crews as a basis on the assessment and training of the data collection crews. However, it is also suggested to perform the assessment and disapproval of plots (or its blocks) and the forest inventory in compliance to the criteria defined in contracts or according to the requirements established by the organization.

Conclusions

It is concluded that all the audited plots presented errors, and the moderate errors were that ones with the highest occurrence. The overall score of 158 points and the disapproval of 33.4% of the plots show that the forest inventory carried out presented a large number of errors and results close to disapproval.

The methodology for the assessment of aspects and qualitative data in forest inventory audit allowed to identify the most frequent errors and in which plots these were found, as well as mitigating actions more precisely.

References

Augustynczik ALD, Machado SDA, Figueiredo Filho A, Péllico Netto S (2013) Evaluation of a plot sizes and sampling intensities in forest inventories. *Scientia Forestalis*, 39 (99): 361-368.

Berger A, Gschwantner T, Mcroberts RE, Schadauer K (2014) Effects of measurement errors on individual tree stem volume estimates for the Austrian National Forest Inventory. *Forest Science*, 60(1): 14-24.

Brandelero C, Antunes MUF, Giotto E (2009) Precision silviculture: new technology for the forestry development. *Ambiência*, 3(2):269-281.

Binoti DHB. Binoti MLMS, Leite HG, Silva A (2013) Reduction in inventory costs in even-aged stand. *Revista Brasileira de Ciências Agrárias*, 8(1):125-129.

BTI - Brazilian Tree Industry. 2016. Annual Report BTI 2016. Brasília, 2016. 96 p. Available online at http://iba.org/images/shared/Biblioteca/IBA_RelatorioAnual2016_.pdf ; last accessed Jul. 25, 2017.

Gasparini P, Bertani RDE, Natale F, Di Cosmo L, Pompei E (2009) Quality control procedures in the Italian national forest inventory. *Journal of environmental monitoring*, 11(4):761-768.

Gertner G, Köhl M (1992) An assessment of some non-sampling errors in a national survey using an error budget. *Forest Science*, 38(3):525-538.

Guillemette F, Bédard S, Fortin M (2008) Evaluation of a tree classification system in relation to mortality risk in Québec northern hardwoods. *The Forestry Chronicle*, 84(6), 886-899.

Kanegae Junior H, Mello JM, Scolforo JRS, Oliveira AD (2007) Evaluation of spatial continuity of dendrometric characteristics of clonal stands of *Eucalyptus* sp. at different ages. *Revista Árvore*, 31(5):859-866.

Kershaw Junior JA, Ducey MJ, Beers TW, Husch B (2016). *Forest mensuration*. 5 th. John Wiley & Sons. 633p.

Machado SA, Figueiredo Filho A (2009) Dendrometria. 2 th Edition. Guarapuava: Unicentro. 316p.

Mäkinen A, Kangas A, Mehtätalo L (2010) Correlations, distributions, and trends in forest inventory errors and their effects on forest planning. *Canadian journal of forest research*, 40(7):1386-1396.

Maltamo M, Peuhkurinen J, Malinen J, Vauhkonen J, Packalén P, Tokola T (2009) Predicting tree attributes and quality characteristics of Scots pine using airborne laser scanning data. *Silva Fennica*, 43(3):507-521.

Meadows JS, Skojac DA (2008) A new tree classification system for southern hardwoods, *Southern Journal of Applied Forestry*, 32(2):69-79.

Montgomery DC (2009) *Introduction to statistical quality control.* John Wiley & Sons (New York), 2009.

Nakajima NY, Péllico Netto S, Druszcz JP, Yoshitani Junior M (2011) Precision comparison between line sampling and concentric circular plot sampling methods *in Pinus elliottii* stands. *Revista Acadêmica: Ciências Agrárias e Ambientais*, 9(2):131-139.

Otsubo HCB, Moraes MLT, Moraes, MAP, José Neto M, Freitas MLM, Costa RB, Resende M DV, Sebbenn AM (2015) Genetic variation for the silviculture caracter in three arboreous species of the south bolsão region in Mato Grosso do Sul state, Brazil. *Cerne*, 21(4): 535-543.

Persson B, Persson A, Ståhl EG, Karlmats U (1995). Wood quality of Pinus sylvestris progenies at various spacings. *Forest Ecology and Management*, 76(1-3), 127-138.

Pollard JE, Westfall JA, Patterson PL, Gartner DL, Hansen MH, Kuegler O (2006) *Forest inventory and analysis national data quality assessment report for* 2000–2003. USDA Forest Service. Gen. Tech. Rep. RMRS-181.43 p.

Santos AA (2014). Occurrence of trees in central and peripherical areas in Três Lagoas, MS *Monografias Ambientais,* 13(5):3926-3932.

Silva GFD, Xavier AC, Rodrigues FL, Peternelli LA (2007) Evaluation of the influence of varying sample sizes and composition on the precision of a hypsometric relation for *Eucalyptus grandis*. *Revista Árvore*, 31(4):685-694.

Silva SA (2017) *Proposta metodológica para auditoria em inventário Florestal com enfoque na avaliação de erros de medição*. Dissertation, Universidade Federal do Paraná. 87p.

Soares CPB, Rodello CM, Souza AL, Leite HG, Soares VP, Silva GF (2009) Comparison between sampling procedures for rare forest species and aggregated spatial distribution pattern. *Revista Árvore*, 33(3): 545-553.

Vibrans AC, Sevgnani L, Lingner DV, Gasper AL, Sabbagh S (2010) The floristic and forest inventory of Santa Catarina State (IFFSC): methodological and operational aspects. *Pesquisa Florestal Brasileira*, 30(64):291.

Westfall JA, Woodall CW (2007). Measurement repeatability of a large-scale inventory of forest fuels. *Forest Ecology and Management*, 253(1):171-176.