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Preliminary evaluation of the efficacy of the variable probability method in Miombo woodland

Evaluación preliminar de la eficacia del método con probabilidad variable en bosque de Miombo

Avaliação preliminar da eficácia do método da probabilidade variável na floresta de Miombo

Marisela Frías Tamayo^{1*}  <https://orcid.org/0000-0002-3854-5888>

Nheza Filomena Pereira Jay¹  <https://orcid.org/0000-0003-3421-7833>

Edilio Aldana Pereira¹  <https://orcid.org/0000-0002-3218-3302>

¹University of Pinar del Río "Hermanos Saíz Montes de Oca". Pinar del Río, Cuba.

*Corresponding author: mfrias@upr.edu.cu

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ABSTRACT

In the research, three factors of basal area were analyzed according to the theoretical basis of sampling with variable probability, with the objective of preliminarily evaluating the effectiveness of Bitterlich's variable probability method for the estimation of basal area in forests of the Miombo formation. By means of systematic sampling, 11 temporary circular plots of fixed area of 500 m² were established. In the center of each of these plots, measurement points were established with a mirror relascope, where the basal area factors (FAB) 1, 2 and 4 were used. The fixed area plots were taken as references and the results were compared for which the analysis was performed with the statistical package SPSS for Windows Version 19.0. There were no significant differences in the results of basal areas obtained between the different factors of basal area 1, 2 and 4, with respect to those obtained in the plots of fixed areas. In the time



analysis, basal area factor number four was the best with the least number of minutes during the measurement of the sampling unit.

Keywords: Horizontal point sampling; Basal area; Systematic sampling; Miombo.

RESUMEN

En la investigación, se analizaron tres factores de área basal conforme el fundamento teórico del muestreo con probabilidad variable, con el objetivo de evaluar preliminarmente la efectividad del método de probabilidad variable de Bitterlich para la estimación del área basal en bosques de la formación de Miombo. Mediante un muestreo sistemático se establecieron 11 parcelas temporales circulares de área fija de 500 m². En el centro de cada una de estas parcelas, se establecieron los puntos de medición con relascopio de espejos, donde se utilizaron los factores de área basal (FAB) 1, 2 y 4. Se tomaron como referencias las parcelas de área fija y se compararon los resultados para lo cual se realizó el análisis con el paquete estadístico SPSS para Windows Versión 19.0. No se presentaron diferencias significativas de los resultados de áreas basales obtenidos entre los diferentes factores de área basal 1, 2 y 4, con respecto a los obtenidos en las parcelas de áreas fijas. En el análisis del tiempo, el factor de área basal número cuatro resultó el mejor con la menor cantidad de minutos durante la medición de la unidad de muestreo.

Palabras clave: Muestreo puntual horizontal; Área basal; Muestreo sistemático; Miombo.

RESUMO

Nesta investigação, foram analisados três fatores de área basal de acordo com a base teórica da amostragem de probabilidade variável, a fim de avaliar preliminarmente a eficácia do método de probabilidade variável de Bitterlich para a estimativa da área basal nas florestas de formação de Miombo. Onze parcelas circulares temporárias de área fixa de 500 m² foram estabelecidas por meio de amostragem sistemática. No centro de cada uma destas parcelas, os pontos de medição foram estabelecidos com um relascópio espelho, onde foram utilizados os fatores de área basal (FAB) 1, 2 e 4. As parcelas de área fixa foram tomadas como referência e os resultados foram comparados para os quais a análise foi realizada com o pacote estatístico SPSS para Windows Versão 19.0. Não houve diferenças significativas nos resultados das áreas basais obtidos entre os diferentes fatores de área basal 1, 2 e 4, em relação aos obtidos nas parcelas de áreas fixas. Na análise temporal, o fator de área basal número quatro foi o melhor com a menor quantidade de minutos durante a medição da unidade de amostragem.

Palavras-chave: Amostragem pontual horizontal; Área basal; Amostragem sistemática; Miombo.



For the establishment of the variable probability plots with each of the basal area factors, the midpoint of the fixed area circular plots was taken as the center.

The Bitterlich mirror relascope with three basal area factors ($FAB = 1 \text{ m}^2\text{ha}^{-1}$, $FAB = 2 \text{ m}^2\text{ha}^{-1}$ and $FAB = 4 \text{ m}^2\text{ha}^{-1}$) was used for the survey.

Fixed area sampling plots

All the diameters at 1.30 m from the ground of all the trees included in each plot were measured with a forcepod. The basal area (G) was obtained by the diameters at 1.30 m height of the trees within the sampling unit and converted to cross-sectional areas (g), summed for the trees measured (m) and multiplied by the proportionality factor (F), to convert it to values per hectare using the following formula (Equation 2).

$$G = \left(\sum_{i=1}^m g_i \right) F \quad (2)$$

Bitterlich variable-probability sampling points

For the variable probability sampling points, all trees were counted whose diameters were greater than or equal to a given angle projected at a height of 1.30 m of the stem from the ground, known as the critical angle or basal area factor. The basal area by this method is easily obtained as follows (Equation 3).

$$\hat{G} = m(FAB) \quad (3)$$

Where:

m = number of trees included in the sampling point; FAB = basal area factor (m^2ha^{-1}).

The SPSS program (Statistica) was used to compare the results obtained by the methods studied. The results were evaluated by analysis of variance (ANOVA) and the comparison means by means of Tukey's test for a $p \leq 0,05$.

RESULTS AND DISCUSSION

Evaluation of basal areas per hectare

The variable probability method is not known to be used in Miombo woodlands. However, Couto *et al.*, (1990) used it to measure the height of dominant trees and number of trees per hectare in stands of *Eucalyptus saligna*; Monteiro and Santos (2012) used it in plantations of *Eucalyptus grandis* and Peña (2000) used the Bitterlich mirror relascope in the cubication of trees.



Taking into account that all the trees were measured in the fixed area plots, they were used as a standard to evaluate the effectiveness of the different basal area factors (FAB) corresponding to the Bitterlich variable probability method.

The dasometric variable to be evaluated is the mean basal area per hectare ($m^2 ha^{-1}$) as shown in Table 1 where the mean values per hectare of basal area in each of the 11 plots of fixed area and those obtained with the basal area factors (FAB) 1, 2 and 4 respectively (Table 1).

Table 1. - Mean basal areas in $m^2 ha^{-1}$ in the fixed area plots and with the variable probability method with FAB 1, 2 and 4

Nº Plots	Fixed area (Gm^2h^{-1})	Basal area ($m^2 ha^{-1}$)					
		Bitterlich					
		FAB = 1		FAB = 2		FAB = 4	
		<i>m</i>	Gm^2h^{-1}	<i>m</i>	Gm^2h^{-1}	<i>m</i>	Gm^2h^{-1}
1	21,12	19,5	19,5	9	18	4	16
2	9,59	10,5	10,5	6,5	13	3,5	14
3	17,47	13	13	7	14	3	12
4	20,75	10,5	10,5	6,5	13	3,5	14
5	6,12	3,5	3,5	1	2	1	4
6	11,68	3,5	3,5	1	2	1	4
7	19,34	11,5	11,5	6	12	3,5	14
8	8,98	3	3	1	2	0,5	2
9	15,96	7,5	7,5	4	8	1,5	6,0
10	14,33	20,5	20,5	7,5	15	4,5	18
11	20,53	17,5	17,5	9	18	5,0	20
Total	165,9		120,5		117		125,5
\bar{x}	15,1		11,0		10,6		11,6
S^2_x	3,39		5,41		4,33		6,05
S_x	±1,84		±2,33		±2,08		±2,46
S^2_{-x}	0,55		0,70		0,63		0,74
Cv%	12,2		15,4		13,8		16,3
LE%	±10		±10		±10		±10
E_r	±8,48		±14,31		±11,08		±12,05
N	8		22		16		13

Where:
 = mean ($m^2 ha^{-1}$), S^2_x = variance ($m^2 ha^{-1}$)², S_x = standard deviation ($m^2 ha^{-1}$), Cv = coefficient of variation (%), = standard error, LE%= limit of expected error, E_r = relative sampling error (%), n = required sample size.

Table 1 shows that, with respect to the fixed area plots, there is an underestimation of the basal area with the three FABs of Bitterlich's variable probability method, with a difference of 4.1 m^2h^{-1} with respect to FAB 1, 4.5 m^2h^{-1} with respect to FAB 2 and 3.5 m^2h^{-1} with respect to FAB 4. However, between the basal areas obtained with the three FAB 1, 2 and 4, there is practically no difference.



With the three FABs researched, error limits above $\pm 10\%$ were obtained. The reason for these results regarding the high values of the relative error lies in the fact that the necessary number of sampling points with the different factors of basal areas was not raised, because as shown at the end of the table, it was necessary to establish 22, 13 and 16 points for FAB 1, 2 and 4 respectively and only 11 sampling points were established, since they were made to coincide with the number of plots of variable area.

Carneiro *et al.*, (2015) in a *Tectona grandis* plantation, to determine the basal area and volume per hectare obtained that the best method was the Bitterlich variable probability method, as well as the relative efficiency for the estimation of all the variables studied.

Figure 2 shows the distribution of basal areas, where it is observed that except in plots 2 and 10 in the fixed area method, the estimated basal areas are higher than those obtained with the three FABs of Bitterlich, there is practically no difference between the three FABs (Figure 2).



Figure 2. - Distribution of basal areas in the sampling units, where FAB = fixed area and FAB 1, FAB 2 and FAB 4 are equivalent to Basal area factors 1, 2 and 4 respectively. Looking at the distribution of $G ha^{-1}$ in Figure 2, it is not possible to select the best FAB to estimate the basal areas in Miombo

Therefore, an ANOVA and multiple comparisons of means were performed for the dependent variable $G ha^{-1}$ with the three factors of basal areas.

Table 2 shows the analysis of variance where it is shown that there is a significant intergroup and intra-group difference (Table 2).



Table 2. - ANOVA for G ha⁻¹

	Sum of squares	gl	Quadratic mean	F	Sig.
Intergroups	124,075	3	41,358	1,004	,401
Intragroups	1647,198	40	41,180		
Total	1771,273	43			

Table 3 shows the multiple comparisons of the basal area means obtained with the Bitterlich method and with the fixed area plot method (Table 3).

Table 3. - Multiple comparisons of means for the dependent variable G ha⁻¹

(I) FAB	(J) FAB	Difference of means (I-J)	Typical error	Sig.	Confidence interval al 95%	
					Upper limit	Lower limit
1	2	-,45455	2,73629	,998	-7,7889	6,8799
	4	-2,81818	2,73629	,733	-10,1526	4,5162
	Fixed area	-4,08000	2,73629	,452	-11,4144	3,2544
2	1	,45455	2,73629	,998	-6,8799	7,7889
	4	-2,36364	2,73629	,823	-9,6980	4,9708
	Fixed area	-3,62545	2,73629	,553	-10,9599	3,7089
4	1	2,81818	2,73629	,733	-4,5162	10,1526
	2	2,36364	2,73629	,823	-4,9708	9,6980
	Fixed area	-1,26182	2,73629	,967	-8,5962	6,0726
Fixed area	1	4,08000	2,73629	,452	-3,2544	11,4144
	2	3,62545	2,73629	,553	-3,7089	10,9599
	4	1,26182	2,73629	,967	-6,0726	8,5962

It can be seen in Table 3 that for the estimation of basal areas with Bitterlich's variable probability method, FAB 1 or FAB 2 can be used, with a significance of 0.998, and the use of FAB 4 is rejected. However, when comparing the mean differences of the fixed area plot method with Bitterlich's variable probability method; it is observed that FAB 4 is the best, with a significance of 0.967.

Table 4 shows the time in minutes taken to measure all the trees in each of the fixed area plots and each of the trees that fell in the count with the respective FAB 1, 2 and 4.

As shown in Table 4, the time consumed in the survey with each of the FABs is much less than that consumed in the fixed area plots due to the reduction in the number of trees to be measured, decreasing this number from FAB 1 to FAB 4, registering in the latter the least time since very few trees were counted (Table 4).



Table 4. - Average time consumed in the survey of the fixed area plots and in each of the FAB 1, 2 and 4

PLOTS	Survey time in minutes			
	A Fixed	FAB 1	FAB 2	FAB 4
1	139	12	6	3
2	173	7	4	3
3	118	13	6	3
4	417	7	4	3
5	78	8	6	1
6	101	8	6	1
7	104	10	4	2
8	88,7	2	1	1
9	215	11	6	1
10	137	13	7	4
11	153	7	4	2
Media	156,7	8,9	4,9	2,1

Table 5 shows the multiple comparisons of means for the dependent variable of time and an analysis of variance is presented where there is no significant intragroup or intergroup difference (Table 5).

Table 5. - ANOVA for the time consumed in the survey of the plots

	Sum of squares	gl	Quadratic mean	F	Sig.
Intergroups	189332,212	3	63110,737	27,900	,000
Intragroups	90482,455	40	2262,061		
Total	279814,666	43			

In Table 6, it is observed that the difference of the mean of the fixed area plot with the three basal area factors of the Bitterlich variable probability method is significant at the 0.05 level. However, there are no differences in the means between the three basal area factors FAB 1, FAB 2 and FAB 4 (Table 6).

In the comparison of the means of the different FABs, there is a high correlation of 0.997 between FAB 1 and FAB 2, 0.987 between FAB 1 and FAB 4 and 0.999 between FAB 2 and FAB 4.

Silva *et al.*, (2016) point out that they found no statistically significant difference for the estimation of basal area and volume per hectare between the fixed-area and Bitterlich methods, independent of the basal area factor used in *Eucalyptus grandis* stands.



Table 6. - Multiple comparisons of the means of time as the dependent variable

(I) FAB	(J) FAB	Difference of means (I-J)	Typical error	Sig.	Interval of confidence to 95 %	
					Upper limit	Lower limit
1	2	4,00000	20,28014	,997	-50,3593	58,3593
	4	6,79091	20,28014	,987	-47,5684	61,1502
	Fixed area	-147,79091(*)	20,28014	,000	-202,1502	-93,4316
2	1	-4,00000	20,28014	,997	-58,3593	50,3593
	4	2,79091	20,28014	,999	-51,5684	57,1502
	Fixed area	-151,79091(*)	20,28014	,000	-206,1502	-97,4316
4	1	-6,79091	20,28014	,987	-61,1502	47,5684
	2	-2,79091	20,28014	,999	-57,1502	51,5684
	Fixed area	-154,58182(*)	20,28014	,000	-208,9411	-100,2226
Fixed area	1	147,79091(*)	20,28014	,000	93,4316	202,1502
	2	151,79091(*)	20,28014	,000	97,4316	206,1502
	4	154,58182(*)	20,28014	,000	100,2226	208,9411

*** Mean difference is significant at the .05 level.**

From the results of the time analysis, it can be concluded that the Bitterlich variable probability method saves working time with respect to FAB 1 and 2 and more with respect to the fixed area plot method.

CONCLUSIONS

The application of Bitterlich's variable probability method for the assessment of basal area in the Miombo forest formation is feasible, provided that the sample to be taken is representative of the forest stand.

For the estimation of basal areas with Bitterlich's variable probability method in the Miombo, FAB 4 was better with a significance of 0.967 with respect to the fixed area plot method that was used as a comparison standard, being also the most economical in terms of time and with practically the same estimation of the mean basal area as FAB 1 and 2.

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Conflict of interests:

The authors declare not to have any interest conflicts.

Authors' contribution:

Marisela Frías Tamayo: Conception of the idea, literature search and review, instrument making, instrument application, compilation of information resulting from the instruments applied, statistic análisis, preparation of tables, graphs and images, general advice on the topic addressed, drafting of the original (First version), review and final version of the article, article correction, authorship coordinator, translation of terms or information obtained, review of the application of the applied bibliographic standard.

Nheza Filomena Pereira Jay: Conception of the idea, literature search and review, instrument application, compilation of information resulting from the instruments applied, statistic análisis, preparation of tables, graphs and images, drafting of the original (first version), review of the application of the applied bibliographic standard.

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