**Revista em Agronegócio e Meio Ambiente - RAMA**
DOI:10.17765/2176-9168.2023v16n2e10938
e-ISSN 2176-9168


# Size of sampling units aproppriate for management level forest inventory in Eastern Amazon, Brazil

*Tamanho das unidades de amostragem apropriada para o nível de manejo do inventário florestal na Amazônia Leste, Brasil*

***Carla Samara Campelo de Sousa[1], José Antônio Aleixo da Silva[2], Rinaldo Luiz Caraciolo Ferreira[3], Diego Armando Silva da Silva[4], Evandro Ferreira da Silva[5], Robson Borges de Lima[6]***

**ABSTRACT:** This study aimed to indicate the ideal sample size for continuous forest inventories in the tropical forest in Amapá. Data were obtained from a monitoring inventory started in 2010 and completed in 2016, in five permanent sampling units of 100m x 100m with an inclusion level of DBH ≥ 10cm. Randomly allocated sample subunits with five different dimensions ranging from 400 $m^2$ to 1600 $m^2$ were simulated within these units. The measurement times of each sampling unit, from the first to the last three, were timed. Dimensions were analyzed for their accuracy and relative efficiency. Given the above and depending on the purpose of the inventory, the standard sampling unit of 1 ha (100 m x 100 m) is recommended for the inventory variables. The 20 m x 20 m (400 $m^2$) square sampling unit was the most suitable for monitoring growth variables (annual increment in diameter, basal area, and volume), indicating that these sampling units for continuous inventories can become an essential alternative for use in monitoring inventory in the region.

**Keywords**: Forest dynamics. Annual periodic increase. Relative efficiency. Sustainability.

**RESUMO:** Este estudo teve como objetivo indicar o tamanho ideal da amostra para inventários florestais contínuos na floresta tropical do Amapá. Os dados foram obtidos a partir de um inventário de monitoramento iniciado em 2010 e concluído em 2016, em cinco unidades amostrais permanentes de 100m x 100m com nível de inclusão DAP ≥ 10cm. Dentro dessas unidades foram simuladas subunidades amostrais alocadas aleatoriamente com cinco dimensões diferentes, variando de 400 $m^2$ a 1600 $m^2$. Os tempos de medição de cada unidade amostral, da primeira às três últimas, foram cronometrados. As dimensões foram analisadas quanto à sua precisão e eficiência relativa. Diante do exposto e dependendo da finalidade do inventário, recomenda-se a unidade amostral padrão de 1 ha (100mx100m) para as variáveis do inventário. A unidade amostral quadrada de 20 m x 20 m (400 $m^2$) foi a mais indicada para monitorar as variáveis de crescimento (incremento anual em diâmetro, área basal e volume), indicando que essas unidades amostrais para inventários contínuos podem se tornar uma alternativa essencial para uso no monitoramento de estoque em a região.

**Palavras-chave:** Dinâmica florestal. Aumento periódico anual. Eficiência relativa. Sustentabilidade.

**Autor correspondente:** Robson Borges de Lima
E-mail: rbl_florestal@yahoo.com.br
*Recebido em: 09/02/2021*
*Aceito em: 03/05/2021*

[1] Mestre, Docente do Curso de Engenharia Florestal do Instituto Federal de Educação, Ciência e Tecnologia do Amapá - IFAP, Laranjal do Jari (AP), Brasil
[2] Doutor, Docente permanente do Programa de Pós-graduação em Ciências Florestais (PPGCF) da Universidade Federal Rural de Pernambuco, Recife (PE), Brasil.
[3] Doutor, Docente permanente do Programa de Pós-graduação em Ciências Florestais (PPGCF) da Universidade Federal Rural de Pernambuco, Recife (PE), Brasil.
[4] Mestre, Docente do Curso de Engenharia Florestal do Instituto Federal de Educação, Ciência e Tecnologia do Amapá - IFAP, Laranjal do Jari (AP), Brasil.
[5] Doutor, Docente do Curso de Engenharia Florestal da Universidade Federal do Pará - UFPA, Campus Altamira, Altamira (PA), Brasil.
[6] Doutor, Docente do Curso de Engenharia Florestal da Universidade do Estado do Amapá, Macapá (AP), Brasil. iD ORCID: (0000-0001-5915-4045)

## INTRODUCTION

The total area of native forests in Brazil is approximately 485.8 million hectares, corresponding to 58% of its national territory, the second largest forest area in the world, behind only Russia. Of this total, about 342 million hectares (70.4%) are in the Amazon, showing the most attractive potential for the region in terms of timber and non-timber products (SISTEMA NACIONAL DE INFORMAÇÕES FLORESTAIS, 2016).

In this way, the Amazon region presents relevant ecological and economic importance for its forest inventory, composition, structure, and forest growth and recovery dynamics. Therefore, its knowledge is fundamental to subsidize decision-making in the sustainable management and use of its resources to perpetuate this activity and maintain it for future generations (AUGUSTYNCZIK *et al*., 2013). Its contribution to the stability of the planet's climate is also worth mentioning, which its inadequate exploitation could lead to serious environmental consequences (FEARNSIDE *et al*., 2013).

In order to use the available forest resources efficiently and make the most of the existing potential, it is essential to have comprehensive and reliable information, which can be obtained through forest inventories. Forest inventory is the practice aimed at obtaining information about forest populations to characterize them for qualitative, quantitative, and dynamic aspects. For this, mapping, forest measurement, and sampling techniques are used, among others, in order to obtain accurate and reliable information at compatible costs (MEUNIER; SILVA; FERREIRA, 2001).

Obtaining information must be balanced in forest inventories, the level of accuracy desired, the available financial resources, and the time available to obtain them. This balance can only be reached by applying sampling methods and processes. A representative part of the population desired to know is measured to generate reliable information about the available resources (PÉLLICO NETTO; BRENA, 1997). In forest management plans in the Amazon and Amapá states, the continuous monitoring inventory is regulated as a legal regime for logging, indicating the normative procedures required to assess the productive potential of the forest (LIMA et al., 2021). It is the required installation of permanent sample units in management plans, indicating the sampling system, the dimension, and intensity of the sampling units with a 10% sample relative error at a 95% probability level (HIGUCHI; SANTOS; JARDIM, 1982).

In the context of forest concessions, for example, the installation of permanent sample units to monitor dynamics is one of the basic requirements by the Brazilian Forest Service (BFS) to ensure that the ecological functions of the forest are preserved in these areas defined by article 52 of the Federal Decree 6063/2007, which regulates the Law of Public Forest Management (Federal Law 11284, dated 02/03/2006) (BRASIL 2007). One of the problems that always arise during studies in the Amazon is choosing the dimensions of the sample units to represent the various conditions of the population and providing unbiased and accurate estimates of the parameters of interest. There is no intensity per area and dimension of sample units defined in the legislation for installing permanent sample units or for volume estimation, for example, in forest management areas in the Amazon. There is a guideline followed by professionals in the area for installing permanent sample units in the Brazilian Amazon, which can be consulted in the work of Silva *et al*. (2005).



For estimating basal area, volume, and the number of individuals per hectare, Execution Rule No. 1, dated April 24, 2007, provides for the Technical Guidelines for Elaboration of Sustainable Forest Management Plans (SFMP) but does not provide format or sample unit dimension. It only requires presenting statistical analysis with estimates of the actual average of the population, with a probability level of at least 95% and a maximum sample relative of 10% around the sample mean.

In order to evaluate forest growth by subsidizing forest exploitation planning throughout the cutting cycle, the permanent sample units of continuous inventory in the Amazon region are implemented following the guidelines of the Amazon Forest Dynamics Monitoring Network (REDEFLOR), as can be observed in the works of Augustynczik *et al*. (2013), Silva *et al*. (2016), Silva *et al*. (2015), Silva *et al*. (2014), and Sousa *et al*. (2012). Therefore, due to a lack of theoretical basis for determining the dimension of permanent sample units for growth and production studies, standard size of 1 ha (100mx100m) or a sample unit of 2500 $m^2$ (50mx50m) is recommended, according to Silva *et al*. (2005).

In the present study, the behavior of the sample unit dimension was evaluated according to the variables of annual increment in diameter (AID), annual increment in basal area (IBA), the periodic annual increase in volume (AIV), baseline area in the year 2016 (G16) and volume in 2016 (V16), and how the variation of sample unit dimension affects the assessment of spatial patterns of trees and settlement attributes. The analyzes carried out in a native forest area had the objective to test the following hypotheses: (1) increasing the number of sample units improves the accuracy of the analyzed variables and, consequently, the efficiency of the allocation in forest monitoring areas and areas that need to carry out a diagnostic forest inventory and (2) there is a difference of efficiency in the forest inventory as a function of the dimension and quantity of sample units, but maintaining the same sample intensity. In this context, considering the State Forest of Amapá (FLOTA) as the study object whose government intends to assign the process of forest concessions, this work aims to contribute to selecting the adequate dimension of sampling units for monitoring the arboreal stratum and the forest inventory of a Dense Ombrophilous Forest of Solid Land, in the State of Amapá-Brazil.

## 2. MATERIALS AND METHODS

The present study was developed in the Nova Canaã Settlement Project, located within the denominated conservation unit of sustainable use in the State Forest of Amapá, located in the city of Porto Grande, Amapá (Figure 1).

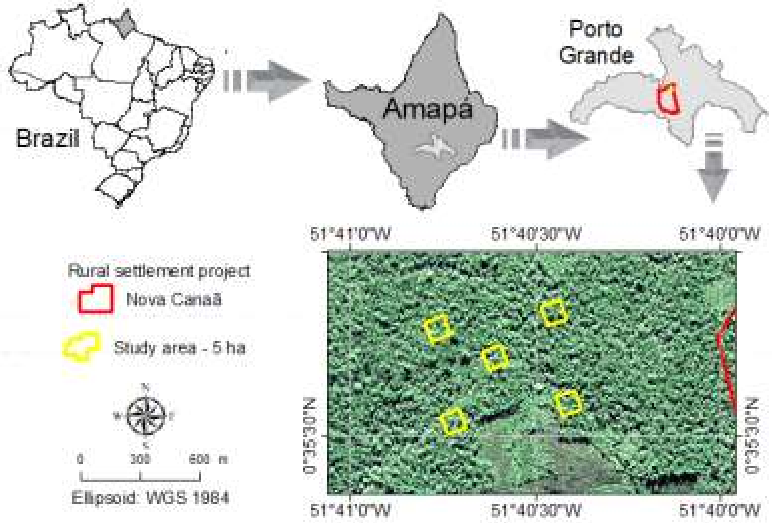


**Figure 1.** Location of the study area.

The forest cover of the studied area is typical Dense OmbrophilousForest of SolidLand, with a great diversity of woody and herbaceous species (SILVA *et al*., 2015). The climate of the region is Amtype, hot and humid, according to the Köppen classification, with average annual precipitation of 2300 mm (SOUZA; CUNHA, 2010). The average annual temperature ranges from 25°C to 26.7°C, and the average relative air humidity is between 80% and 86%. The rainiest months are from December to May (Amazonian winter), and the driest months are from August to November (Amazonian summer). The altitude varies from 60 m to 100 m. The predominant soil in the area is the Dystrophic Red-Yellow Latosol (IEPA, 2008; SOUZA; CUNHA, 2010).

The methodology adopted in the formulation of the present work is presented in Figure 2. It is divided into four main stages: Database, Plotsubdivision, Definition of new plot dimensions, and Technical analysis.

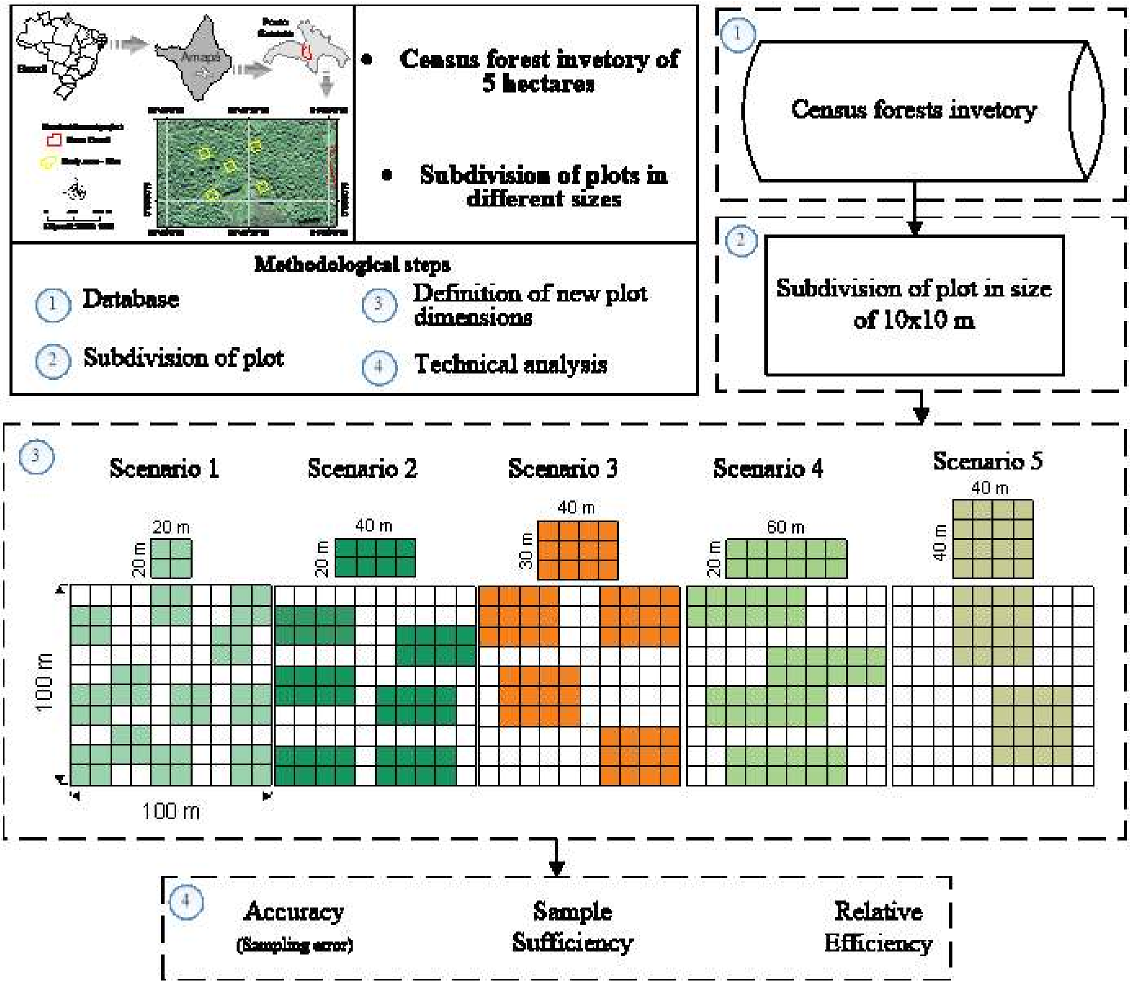


**Figure 2.** Methodological flowchart.

The sample units were established according to the Amazon Forest Dynamics Monitoring Network (REDEFLOR) criteria, which establishes guidelines for the installation and measurement of permanent sample units. According to these criteria, the inclusion level of trees with a diameter of 1.30 m (DBH) greater than or equal to 10 cm was considered (SILVA *et al*. 2005). The study area comprises five permanent sample units of 1 ha (100mx100m), distributed about 250 meters. The sample units of 1 ha (100mx100m) were subdivided into 100 subunits of 100 m$^2$ (10mx10m) to facilitate monitoring for the data collection. They were measured in the sample unit year of 2010, and remeasured in 2016, including all individuals DBH trees greater or equal to 10 cm.

Five scenarios were defined in addition to the five sample units of 1000 m$^2$ (100mx100m) as the control of the study analysis. Thus, the control sample units contain the values of the dendrometric variables of all trees in the area that were analyzed to have population parameters for the comparisons.

According to Silva *et al*. (2005), the appropriate intensity for installing permanent sample units in up to 1000 ha is one sample unit of 0.25 ha per 100 ha. Suppose the area is more significant than 1000 hectares, one sample unit of 0.25 hectares for every 250 hectares. In the case of estimating basal area, volume, and quantity of trees in hectares in the management areas, there are no established norms regarding the dimension of the sample inventory units, with it being only necessary to present statistical analysis with an estimate of the actual average of the population, with a probability level of at least 95% and a relative sample error of at most 10% around the sample mean.

Considering these assumptions, five scenarios with sample units of different dimensions were most commonly used in forest inventories in Amapá, Brazil, but with similar total areas, plus the sample control unit of the study (Table 1). The objective was to standardize the sample size so as not to influence the estimation of the variables considering different numbers of sample units but with the same total sample area (2.4 ha).

The dimensions of each scenario were randomly allocated within the area of the control sample units (Figure 2, item 3). For the relative efficiency calculation, which will be presented below, it was necessary to define a standard sample unit adopted as a control.

**Table 1.** Dimensions and intensity of analyzed sample units

| Scene | Area ($m^2$) | Sample units.$ha^{-1}$ | Sample units.5$ha^{-1}$ | Total area (ha) |
|---|---|---|---|---|
| Control | 10,000 | 1 | 5 | 5 |
| Scene 1 | 400 | 12 | 60 | 2.4 |
| Scene 2 | 800 | 6 | 30 | 2.4 |
| Scene 3 | 1,200 | 4 | 20 | 2.4 |
| Scene 4 | 1,200 | 4 | 20 | 2.4 |
| Scene 5 | 1,600 | 3 | 15 | 2.4 |

Two situations were considered in order to analyze the variables annual increment in diameter (AID), annual increment in basal area (IBA); annual increment in volume (AIV); G16 baseline area 2016(G16); 2016 volume(V16): sample units for permanent inventory and sample units for diagnostic inventory, which are those to obtain information promptly from the inventoried area.

Thus, the parameters established for the analysis were the relative sample error (Ea%), the sample adequacy (SA), and the relative efficiency (RE) method, having the control as the standard scenario.

## 2.1 SAMPLE RELATIVE ERROR

The Ea (%) was calculated at the 95% confidence level, represented by equation 1 below (KERSHAW *et al.*2016):

$$E_a = \left( \frac{t_{\alpha/2} s_{\bar{x}}}{\bar{x}} \right) 100 \tag{1}$$



Where: $E_a$(%) = Relative sampling error; $t_{\alpha/2}$ = Student's t-value at the 5% probability of error level; $S_{\bar{x}}$= standard error of the mean and x = mean.

## 2.2 SAMPLE SUFFICIENCY (SS)

The number of sample units of each representative size of the population was determined according to Kershaw *et al*. (2016), equation 2:

$$SA = \frac{CV^2 t_{\alpha/2}^2}{E^2} \tag{2}$$

Where: n = number of units required to achieve the stipulated error; Student's t-table at 5% probability of error, CV = coefficient of variation and E = stipulated error.

## 2.3 RELATIVE EFFICIENCY (RE)

RE is an efficiency index that considers the standard error, the cost, and the measurement time of a given size and shape of a sample unit compared to the sizes and shapes of other sample units (KERSHAW *et al*., 2016).

To evaluate the RE of the analyzed scenarios in estimating the variables of interest, the control was considered standard, in which the chosen standard was considered 100% efficient. To calculate relative efficiency, the average measurement time was obtained by summing the total times of each sample dimension divided by the number of units of each treatment. The time for each sample unit was obtained with the aid of a stopwatch, which started and ended with the first and last arboreal individual, plus the average walking time from one sample unit to another, which was obtained by the mean displacement velocity within the forest and distance traveled, which were processed in geographic information system (GIS) software.

The formula used for such a procedure is provided by Silva and Vasconcelos (1996) and adapted for the present study (equation 3):

$$RE = \frac{SE_P SA_P T_P}{SE_t SA_t T_t} \quad (3)$$

Where: RE = relative efficiency, SE = sample error for the sample units (p) and (t), (p) = standard sample unit, (t) = sample unit tested, SA = sampling adequacy for sample units (p) and (t) and T = remeasurement time in the sample units (p) and (t).



Suppose RE < 1, the sampling unit used as standard is more efficient than the one proposed. If RE> 1, the tested sample unit is more efficient. In this case, preference should be given to the type of sample unit being compared. If RE ≈ 1 or = 1, both areas and forms of sample units provide equally accurate estimates of the true mean of the parameter studied. The formula that calculates the RE considers the mediation time as a variable.

## 3. RESULTS

According to the results presented in Table 2, it was observed that minor sample errors in the increment estimates were obtained with sample units smaller than 400 $m^2$ (20m x 20m), followed by those of 800 $m^2$ (20m x 40m) and 1600$m^2$ (40m x 40m). In contrast, the standard sample units of 1 ha for evaluating the stocks of variables volume and growth enabled obtaining greater accuracy.

**Table 2.** Relative efficiency results for each dimension of the sample units in the estimation of the variables of interest analyzed for the Forest of Dense Ombrophilous Forest of Terra Firme

| Variable | Sample units | Area ($m^2$) | Time (h) | CV% | N | SE% | n | RE |
|---|---|---|---|---|---|---|---|---|
| **AID** | T(100mx100m) | 10000 | 8.54 | 12.8 | 5 | 12.20 | 8 | 1.00 |
| | C1(20mx20m) | 400 | 0.38 | 32.39 | 60 | 6.99 | 30 | 10.4 |
| | C2(20mx40m) | 800 | 0.78 | 26.65 | 30 | 8.27 | 21 | 6.15 |
| | C3(30mx40m) | 1200 | 1.13 | 32.69 | 20 | 12.38 | 31 | 1.92 |
| | C4(20mx60m) | 1200 | 1.04 | 19.69 | 20 | 7.61 | 12 | 8.77 |
| | C5(40mx40m) | 1600 | 1.47 | 18.49 | 15 | 8.41 | 11 | 6.12 |
| **IBA** | T(100mx100m) | 10000 | 8.54 | 16.45 | 5 | 15.69 | 12 | 1.00 |
| | C1(20mx20m) | 400 | 0.38 | 39.62 | 60 | 8.55 | 44 | 11.2 |
| | C2(20mx40m) | 800 | 0.78 | 30.15 | 30 | 9.35 | 26 | 8.47 |
| | C3(30mx40m) | 1200 | 1.13 | 39.14 | 20 | 13.20 | 35 | 3.07 |
| | C4(20mx60m) | 1200 | 1.04 | 24.99 | 20 | 9.66 | 19 | 8.42 |
| | C5(40mx40m) | 1600 | 1.47 | 20.48 | 15 | 9.32 | 13 | 9.02 |
| **AIV** | T(100mx100m) | 10000 | 8.54 | 18.02 | 5 | 17.18 | 15 | 1.00 |
| | C1(20mx20m) | 400 | 0.38 | 45 | 60 | 9.71 | 57 | 10.4 |
| | C2(20mx40m) | 800 | 0.78 | 33.34 | 30 | 10.35 | 32 | 8.51 |
| | C3(30mx40m) | 1200 | 1.13 | 36.51 | 20 | 14.12 | 40 | 3.44 |
| | C4(20mx60m) | 1200 | 1.04 | 28.65 | 20 | 11.08 | 25 | 7.63 |
| | C5(40mx40m) | 1600 | 1.47 | 21.15 | 15 | 9.78 | 14 | 10.9 |
| **$G_{16}$** | T(100mx100m) | 10000 | 8.54 | 8.42 | 5 | 8.02 | 4 | 1.00 |
| | C1(20mx20m) | 400 | 0.38 | 45.46 | 60 | 9.81 | 58 | 1.26 |
| | C2(20mx40m) | 800 | 0.78 | 29.59 | 30 | 9.18 | 25 | 1.53 |
| | C3(30mx40m) | 1200 | 1.13 | 35.88 | 20 | 13.87 | 38 | 0.45 |
| | C4(20mx60m) | 1200 | 1.04 | 29.18 | 20 | 11.28 | 25 | 0.93 |
| | C5(40mx40m) | 1600 | 1.47 | 20.54 | 15 | 9.34 | 13 | 1.53 |
| | T(100mx100m) | 10000 | 8.54 | 9.98 | 5 | 9.51 | 5 | 1.00 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **$V_{16}$** | C1(20mx20m) | 400 | 0.38 | 51.85 | 60 | 11.19 | 75 | 1.27 |
| | C2(20mx40m) | 800 | 0.78 | 35.03 | 30 | 10.88 | 35 | 1.36 |
| | C3(30mx40m) | 1200 | 1.13 | 41.77 | 20 | 16.15 | 52 | 0.42 |
| | C4(20mx60m) | 1200 | 1.04 | 32.84 | 20 | 12.70 | 32 | 0.96 |
| | C5(40mx40m) | 1600 | 1.47 | 24.14 | 15 | 10.98 | 18 | 1.39 |

Where: CV% = Coefficient of variation; N = number of total sample units allocated; SE% = calculated sampling error; n = number of units required; RE = relative efficiency; AID (annual increment in diameter); IBA (annual increment in basal area); AIV (annual increment in volume); G16 (baseline area 2016); V16 (2016 volume).



For the relative efficiency in estimating the variables annual increment in diameter, annual increment in basal area, and annual increment in volume, the square form dimension of 20 m x 20 m (400 $m^2$) was the one with the highest relative efficiency (REAID = 10.45, REIBA = 11.24 respectively), except for AIV, in which the most efficient dimension was 1600 $m^2$ (40 m x 40 m), with REV efficiency = 10.93. Considering the G16 and V16 inventory variables, the sample units that presented the greatest relative efficiencies were 800 $m^2$ (20m x 40 m) and 1600 $m^2$ (40m x 40m). For the growth variable, both dimensions had the same relative efficiency value (REG16 = 1.53). For the volume variable, the one with 40 m x 40 m presented higher relative efficiency (REV16 = 1.39), followed by 20 m x 40 m (REV16 = 1.36).

## 4. DISCUSSION

The relative sampling error is an important parameter to be analyzed because there is a direct relationship with the estimates generated in the analyzed variables and to meet legal criteria such as the census forest inventory in management areas. The maximum established error limit is 10%. In this way, addressing the established error with the highest possible efficiency becomes a challenge due to the numerous forest typologies, inventory purposes, and possible resource limitations.

For the annual increments in diameter and basal area variables, the higher relative efficiency of the 20mx20m scenario is related to the lower average measurement time and the minor sampling error in the other dimensions because, although it requires a more significant number of sample units, the average measurement time and the slightest error have determined its greater efficiency. Concerning the AIV variable, the unit of 40mx40m had higher efficiency due to its smaller number of sample units than the others, a minor error, and a smaller average measurement time than the standard unit of 1 ha (100m x 100m).

This information indicates that smaller sample units compensate in terms of effort of the sampled area and consequently in time, labor, and financial resources. It is clear that in determining the use of small sample units, the greater the number of sample units on-site, the less total area to be inventoried.

Vasconcelos (1990) reports that smaller units are more efficient than large ones. A large number of small sample units represents a better variation of a population than a small number of large sample units, and it is advisable to adopt the smaller size of sample unit for convenience and cost, to offer estimates with less time and lower financial costs without compromising the sampling process.

On the other hand, considering the G16 and V16inventory variables, the sample units that presented the greatest relative efficiency were 800 m$^2$ (20m x 40m) and 1600m$^2$ (40m x40m). For the growth variable, both dimensions had the same relative efficiency value (REG16 = 1.53). For the volume variable, the dimension 40m x 40m presented higher relative efficiency (REV16 = 1.39) followed by that of 20m x 40m (REV16 = 1.36). The higher relative efficiency of these sample units is related to their smaller sample errors and the smaller number of sample units, with these factors being determinants of their efficiency. Therefore, the sample units of 20m x 40m and 40m x 40m can be considered the most efficient for estimating these variables. However, according to Miranda *et al*. (2015), the inverse is not true, and the accuracy of the method is not directly associated with the relative efficiency, meaning the dimension that obtained the best results for precision need not necessarily present the best results for relative efficiency, since other variables influence the calculation.

Among the surveys of sample unit dimensions for the Amazon region trying to determine the ideal sample unit dimensions for evaluating different diametric categories of arboreal species in the Amazon, Oliveira *et al*. (2014) simulated 23 sample unit dimensions varying from 100 m² to 10,000 m² and verified that the best results were with sample units of 1000 m² (20 m x 50 m) (20 m x 60 m), 2000 m² (20 m x100 m) and 10000 m$^2$ (100 m x 100 m) for the minimum DBH categories of 5 cm, 10 cm, 20 cm, 25 cm, and 45 cm, respectively.

Considering other inclusion levels for studies aiming to evaluate the dendrometric variables, we can mention that of Ubialli *et al*. (2009) in an Ecotonal Forest in the State of Mato Grosso in comparing the basal area estimates obtained from processes, intensities, and sampling methods with values obtained for height groups of species and individual species with DBH ≥ 30 cm. Twenty-two sample unit dimensions ranging from 400 m$^2$ to 10,000 m$^2$ were applied, considering the overall accuracy and accuracy of the basal area estimates, and the sampling unit that obtained the slightest error was 2500 m$^2$ (125m x 20m).

In the region of Pará, Cavalcanti *et al*. (2009) sought to define the area and intensity of sampling units that met the legal requirements of IBAMA Technical Standard No. 01, which limits the sampling error for the abundance, basal area, and volume variables to 10% for tree individuals with DBH = 40 cm of commercial interest. Based on sample error and coefficient of variation (CV), the authors verified that stabilization of the CV occurred from the sample unit size of 0.75 ha. The unit that obtained the minor error was the sample unit of 2 ha (50m x 400m).

Also, in the region of Pará, Vianna *et al*. (2010) analyzed the variable carbon content. They determined the sample unit of 2.000 $m^2$ (10m x 200m) as an optimal dimension for different forests physiognomies in the Amazon with DBH≥10 cm.



In a fragment of Mixed Ombrophilous Forest in Paraná, estimates of basal area, number of trees, and cover value were obtained byAugustynczik *et al*. (2013) using five dimensions of sample units, which were then compared with the surveyed parameters at both global and species level with DBH ≥ 10 cm. Their analysis showed that the best results were obtained when using the sample unit of 1000 m² (20mx50m), a dimension that generated very reliable estimates.

It is possible to verify that different objectives require different sample operations. Indicating these units for the continuous inventories of the region can become an important alternative to be used in monitoring inventory in the study region since it enables taking inventory of the various conditions of population variation with precision and efficiency, as well as obtaining a series of essential information for management plans of the region. In summary, forest sampling for quantification of population parameters is essential to knowing the complexity of a given forested area. It has relationships with several factors such as forest structure, information purpose, forest typology, and variations within the same area. In this way, this study sought to demonstrate important information and parameters to achieve pre-established objectives.

## 5. CONCLUSION

Considering the above, and depending on the purpose of the inventory, such as those with high quantitative rigor for stock variables, the standard sample unit of 1 ha (100m x 100m) is recommended. Furthermore, sample units of 400 $m^2$ (20 m x 20 m) are recommended to monitor tropical rainforest variables' growth.

## REFERENCES

AUGUSTYNCZIK, A.L.D. *et al*. Avaliação do tamanho de parcelas e de intensidade de amostragem em inventários florestais. **Scientia Forestalis,** Piracicaba, v. 41, n. 99, p. 361-368, 2013.

BRASIL. Norma de execução nº 1, de 24 abril de 2007. Institui, no âmbito desta Autarquia, as Diretrizes Técnicas para Elaboração dos Planos de Manejo Florestal Sustentável - PMFS de que trata o art. 19 da Lei nº 12.651, de 25 de maio de 2012. **Diário oficial [da] República Federativa do Brasil**, Brasília, DF, 30 abr. 2007. Available in:

http://www.lex.com.br/doc_1123291_NORMA_DE_EXECUCAO_N_1_DE_24_DE_ABRIL_DE_2007.aspx. Access in: 5 fev. 2018.

CAVALCANTI, F.J.B.; MACHADO, A.S.; OSOKAWA, R.T. Tamanho de unidade de amostra e intensidade amostral para espécies comerciais da Amazônia. **Floresta**, Curitiba, PR, v. 39, n. 1, p. 207-214, 2009.

FEARNSIDE, P.M.; BARBOSA, R.I.; PEREIRA, V.B. Emissões de gases do efeito estufa por desmatamento e incêndios florestais em Roraima: fontes e sumidouros. **Revista Agro@mbiente On-line**, v. 7, n. 1, p. 95-111, 2013.

HIGUCHI, N.; SANTOS, J.; JARDIM, F.C.S. Tamanho de parcela amostral para inventários florestais. **Acta Amazonica**, Manaus, v. 12, n. 1, p. 91-103, 1982.

IEPA - Instituto de Pesquisas Científicas e Tecnológicas do Estado do Amapá **Macrodiagnóstico do Estado do Amapá**: primeira aproximação do ZEE/Equipe Técnica do ZEE-AP, Macapá, 2008.

KERSHAW J.A JR; DUCEY, M.J.; BEERS, T.W.; HUSCH, B. **Forest mensuration**, fifth. Blackwell: Wiley, 2016.

LIMA, R.B.; RUTISHAUSER, E.; SILVA, J.A.A.; GUEDES, M.C.; HERAULT, B. OLIVEIRA, C.P. *et al*. Accurate Esti-mation of Commercial Volume in Tropical Forests. **Forest Science**, v. 67, p.14-21, 2021.

MEUNIER, I.M.J.; SILVA, J.A.A.; FERREIRA, R.L.C. **Inventário florestal**: programas de estudo. Recife: Imprensa Universitária da UFRPE, 2001.

MIRANDA, D.L.C. *et al*. Precisão e eficiência relativa de métodos de amostragem em teca. **Pesquisa Floresta Brasileira**, Colombo, v. 35, n. 83, p. 247-254, 2015.

OLIVEIRA, M.M. *et al*. Tamanho e formas de parcelas para inventários florestais de espécies arbóreas na Amazônia central. **Ciência Florestal**, Santa Maria, v. 24, n. 3, p. 645-653, 2014.
PÉLLICO NETTO, S, BRENA, D.A. **Inventário florestal**. Curitiba: Universidade Federal do Paraná: Santa Maria: Universidade Federal de Santa Maria, 1997. 316 p.

SILVA, J.A.A.; VASCONCELOS, A.J.N. Application of the relative efficiency methodology to select plot area and shape in forest inventories of the caatinga of Pernambuco-Brazil, **The Commonwealth Forestry Review**, v. 75, n. 3, p. 243-246, 1996.

SILVA, J.N.M. *et al*. **Diretrizes para a instalação e medição de parcelas permanentes em florestas naturais da Amazônia Brasileira**. Embrapa Amazônia Oriental, Belém, Pará. 2005.

SILVA, K.E. *et al*. Tree species community spatial structure in a terra firme Amazon forest, Brazil. **Bosque**, Valdivia, v. 35, n. 3, p. 347-355, 2014.

SILVA, K.E. *et al*. Dinâmica florestal, estoque de carbono e fitossociologia de uma floresta densa de terra-firme na Amazônia Central. **Scientia Forestalis**, Piracicaba, v. 43, n. 105, p. 193-201, 2015.

SILVA, K.E. *et al*. Structure of 15 hectares permanent plots of terra firme dense forest in Central Amazon. **Revista Árvore**, Viçosa, v.40, n.4. 2016.

SNIF - **Sistema Nacional de Informações Florestais**. Serviço Florestal Brasileiro, v. 1. Dezembro, 2016. (Boletim Técnico).

SOUZA, E.B.; CUNHA, A.C. Climatologia de precipitação no Amapá e mecanismos climáticos de grande escala. *In*: CUNHA, A.C.; SOUZA, E.B. *et al*. (ed.). **Tempo, clima e recursos hídricos**: resultados do projeto REMETAP no Estado do Amapá. Macapá: IEPA, 2010. p. 216.

SOUZA, C.R. *et al*. Dinâmica e estoque de carbono em floresta primária na região de Manaus/AM. **Acta Amazonica***,* Manaus, v. 42, n. 4, p. 501-506, 2012.

UBIALLI, J.A. et al. Comparação de métodos e processos de amostragem para estimar a área basal para grupos de espécies em uma floresta ecotonal da região norte mato-grossense. **Acta Amazonica**, Manaus, v. 39, n. 2, p. 305-314, 2009.

VASCONCELOS, A.J.N. **Otimização de parcelas em levantamentos botânicos em áreas de solos brunos não cálcicos do Estado de Pernambuco**. 1990. 106f. Dissertação (Mestrado em Botânica) – Universidade Federal Rural de Pernambuco, Recife.

VIANNA, A.L.M. *et al*. Tamanho ótimo de parcela para estimativa de estoque de carbono da parte aérea lenhosa de fitofisionomias florestais na Amazônia oriental. **Floresta**, Curitiba, v. 2, p. 447-456, 2010.