SCIENTIA FORESTALIS

ISSN 2318-1222 (online)

ORIGINAL ARTICLE

Katam Forest app for forest inventories

Aplicativo Katam Forest para inventários florestais

Vinicius Henrique Gris[1]*, Allan Libanio Pelissari[1], Vinicius Costa Cysneiros[2]

[1]Universidade Federal do Paraná – UFPR, Curitiba, PR, Brasil
[2]Universidade Federal de Santa Catarina – UFSC, Curitibanos, SC, Brasil

ARTICLE INFO

Financial support: This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001, and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) - Number 307034/2022-4, for the second author.
Conflict of interest: Nothing to declare.
*Corresponding author: viniciusvilett@gmail.com
Received: 9 March 2024.
Accepted: 11 July 2025.
Editor: Alexandre de Vicente Ferraz.

How to cite: Gris, V. H., Pelissari, A. L., & Cysneiros, V. C. (2025). Katam Forest app for forest inventories. *Scientia Forestalis*, *53*, e4079. https://doi.org/10.18671/scifor.v53.15

ABSTRACT

New methodologies for forest measurement have been developed to provide technological advancements and optimization in data collection for forest inventories. In this context, the Katam Forest app was developed for use on smartphones, aiming to measure dendrometric variables based on video recordings. The present study aimed to compare the estimates obtained through the app in a *Pinus taeda* plantation. For this purpose, random sampling units of 20 m × 20 m were installed, in which traditional measurements were conducted. In addition, data were collected using the app in independent sampling units within the study area embracing the optimal sampling intensity. Height-diameter and volume models were fitted using measured trees, aiming to estimate heights and volumes of the sampling, as well as heights based on the diameters collected by the app. Thus, average values of diameter, total height, basal area, volume, and tree density per sampling unit were obtained. The values obtained by the two methodologies were compared using t-tests and Mann-Whitney tests. The means of diameter and basal area showed non-statistical difference, as well as tree density. For total height, the estimate by the app differed significantly at 5%, while there was no difference when using the height-diameter model. Regarding the volume variable, there was a difference when considering the heights estimated by the app, but they did not differ when estimated by the height-diameter model.

Keywords: *Measurement applications; Automatic tree detection; Forest measurement.*

RESUMO

Novas metodologias de mensuração florestal têm sido desenvolvidas, a fim de proporcionar tecnificação e otimização na coleta de dados em inventários florestais. Diante desse cenário, o aplicativo Katam Forest foi desenvolvido para aplicação em smartphones, visando a mensuração de variáveis dendrométricas a partir de gravações de vídeos. O presente trabalho objetivou comparar as estimativas obtidas pelo aplicativo em um plantio de *Pinus taeda*. Para isso, foram aleatoriamente alocadas unidades amostrais de 20 m × 20 m, nas quais foram conduzidas a mensuração tradicional. Adicionalmente, dados foram coletados com uso do aplicativo em unidades amostrais independentes na área de estudo abrangendo o nível ótimo de intensidade amostral. Modelos de altura-diâmetro e volume foram ajustados por meio de árvores cubadas, objetivando estimar as alturas e os volumes da amostragem, bem como as alturas por meio dos diâmetros coletados pelo aplicativo. Assim, foram obtidos os valores médios de diâmetro, altura total, área basal, volume e densidade de árvores por unidade amostral. Os valores obtidos pelas duas metodologias foram comparados por meio dos testes t e Mann-Whitney. As médias de diâmetro e área basal não apresentaram diferença estatística, assim como para a densidade de árvores. Para a altura total, a estimativa pelo aplicativo diferiu significativamente a 5%, ao passo que, por meio do modelo de altura-diâmetro, não houve diferença. Para a variável volume, houve diferença ao considerar as alturas estimadas pelo aplicativo, porém, não diferiram quando estimadas pelo modelo de altura-diâmetro.

Palavras-chave: *Aplicativos de mensuração; Detecção automática de árvores; Mensuração florestal.*

1. INTRODUCTION

Forest inventories are essential for acquiring qualitative and quantitative data in forested areas. Decision-making for proper forest management is derived from the inventory (White et al., 2016). Traditional sampling methods, such as fixed-area plots, are typically chosen for this purpose, but they require a significant amount of labor and resources. Therefore, both the decision on the number of plots to be sampled and the choice of the sampling method are directly influenced by time constraints and precision requirements. These decisions should be guided by a cost-benefit analysis of the operation (Kershaw et al., 2017).

Given these factors and considering the advancement of technology and artificial intelligence, new methodologies for automatic tree detection and measurement of forest stand attributes have been developed to generate efficiency and cost reduction in obtaining data in forest inventories (Molinier et al., 2011; Kvochkin & Ustyugov, 2017; Liang et al., 2019; Kimsey Junior et al., 2021).

Recently, smartphones and their digital cameras have become the most popular and rapidly developing information devices. Smartphones are easy to use and carry around in a forest, enabling high-quality images at low cost (Molinier et al., 2016; Ucar et al., 2022). Considering this technological opportunity, the Swedish startup Katam Technologies developed the Katam Forest app to automate forest inventory data collection through the use of smartphones and artificial intelligence (Täll, 2020). Another digital tool designed for smartphone-based forest inventories is Arboreal. However, as it relies on Light Detection and Ranging (LiDAR) and augmented reality (AR) technologies, it requires an Apple device for operation (Howie & De Stefano, 2024).

In this study, a Katam free demo version of the application was used, in which video recordings are made in a forest stand for subsequent processing in a Simultaneous Localization and Mapping (SLAM) environment. The SLAM system is responsible for creating a 3D point cloud, where, in conjunction with convolutional neural networks, it detects the target trees and collects the necessary dendrometric variables (Täll, 2020). Furthermore, the SLAM algorithms used for forest applications are robust for use in environments with higher vegetation density (Tang et al., 2015).

As research evaluating the performance of these apps is still relatively recent, there are still gaps to be addressed. For instance, variations in environmental characteristics can affect data accuracy, such as understory competition, stand density, and plantation age. Hence, novel studies are still in need to assess the quality of data collected through forest measurement apps. Therefore, the objective of this study was to compare the estimates of dendrometric variables in a commercial area of *Pinus taeda* L. obtained through two data collection methodologies in forest inventory: traditional simple random sampling and the approach provided by the Katam Forest app. As a hypothesis, the Katam Forest app provides dendrometric estimates with accuracy and precision comparable to those obtained through traditional forest inventories.

2. MATERIAL AND METHODS

2.1. Study area

The study area is located in the municipality of Mallet, Paraná State, Brazil, under the geographical coordinates 25°47'46.60"S and 50°49'30.89"W. The property has 12.1 hectares (ha) of *Pinus taeda* planted in 2011 with an initial spacing of 2 m × 2 m. The plantation was systematically thinned in 2021 with an intensity of 50%. At the time of this study, the stand was free of weed competition due to the age of the plantation and the recent manual weeding.

2.2. Fitting height-diameter and volume relationship models

For fitting height-diameter and volume relationship models, 30 trees were randomly selected in the stand and scaling by the Smalian method, considering the measures of 0.1, 0.7, 1.0 and 1.3 meter (m), as well as in 10 relative positions of equal length distributed along the total tree height, excluding the first 1 m. Subsequently, height-diameter and volume models (Table 1) were fitted to the database (Figure 1).

The R statistical software version 4.2.1 (R Core Team, 2022) was used for fitting the statistical models by ordinary least squares (OLS), and the evaluation criteria included the significance of regression coefficients by the t-test at a 5% level, the adjusted coefficient of determination (R^2adj.), the standard error of estimation in percentage (Syx%), residual graphical analysis, and adherence to the assumptions of normality of residuals and homoscedasticity using the Shapiro-Wilk and Breusch-Pagan tests (Velten et al., 2024), respectively.

$$R^2_{adj.} = 1 - \frac{SQE}{SQT} \quad \text{(Eq.1)}$$

$$S_{yx}\,\% = \sqrt{\frac{SQE}{n-p}} \quad \text{(Eq.2)}$$

where SQE is the sum of squares of errors, SQT is the sum of squares of total, n is the sample size, and p is the number of model parameters.

2.3. Simple random sampling

The traditional methodology of simple random sampling involved the random allocation of seven fixed-area sampling units of 20 m × 20 m (400 m^2) defined based on the planting spacing, totaling 2,800 m^2 of sampling, including all trees inside the plot. The optimal sampling intensity was calculated considering a 95% probability and a 10% margin of error for the volume variable (Kershaw et al., 2017). For the estimation of both height and volume, the best-fitting model obtained from the scaling trees was used. Accordingly, the input variable was the DBH of each sampled tree.

Table 1 – Height-diameter and volume relationship models fitted for *Pinus taeda* stands

	Model	Author
(1)	$\ln(h) = \beta_0 + \beta_1 \ln(d) + e$	Stoffels & van Soest
(2)	$h = \beta_0 + \beta_1 d + \beta_2 d^2 + e$	Trorey
(3)	$\ln(h) = \beta_0 + \beta_1 \left(\frac{1}{d}\right) + e$	Curtis
(4)	$\ln(v) = \beta_0 + \beta_1 \ln(d) + e$	Husch
(5)	$v = \beta_0 + \beta_1 \left(d^2 h\right) + e$	Spurr
(6)	$\ln(v) = \beta_0 + \beta_1 \ln(d) + \beta_2 \ln(h) + e$	Shumacher-Hall

h is the total height (m), *d* is the diameter at 1.3 m above the ground (cm), *v* is the total volume (m^3), *e* is the random error, and β_i is the regression coefficients.

2.4. Sampling using the Katam Forest app

Based on the optimal sampling intensity calculated, the same size of sampling using the Katam Forest app was defined (Figure 2) and collected using a smartphone equipped with a 19 MP camera and a Snapdragon 845 processor was used, meeting the technical requirements of the Katam app to ensure georeferenced data collection. Videos were recorded along the planting rows, with a duration of 1:00 to 2:00 minutes. The number of recordings was planned to encompass possible spatial variabilities in the stand. Each recording was considered a sampling unit for subsequent statistical analyses and was taken randomly, ensuring that the locations did not coincide with those used in the traditional sampling.

The app allows for two approaches in processing the collected data, referred to as fixed depth and dynamic depth. In the fixed depth approach, all trees within a maximum field of view set by the operator are detected, which is applicable when the distances between trees and rows are known. In the dynamic depth approach, the app sets a maximum field of view limit. In this study, the fixed depth distance was set at 6 m (Figure 3), determined according to the planting spacing.

In addition, the app estimates tree heights using a specific height-diameter relationship for each species, incorporated into Katam's proprietary system and not accessible to users. However, it is also possible for the operator to input the average height in each recorded video. Both methods of height estimation were analyzed in the present study. For the process of entering average heights in each sampling unit, the diameters of the collected trees were exported. Then, the heights were estimated using the selected height-diameter relationship model, which was also the best-fitting model derived from the scaling trees.

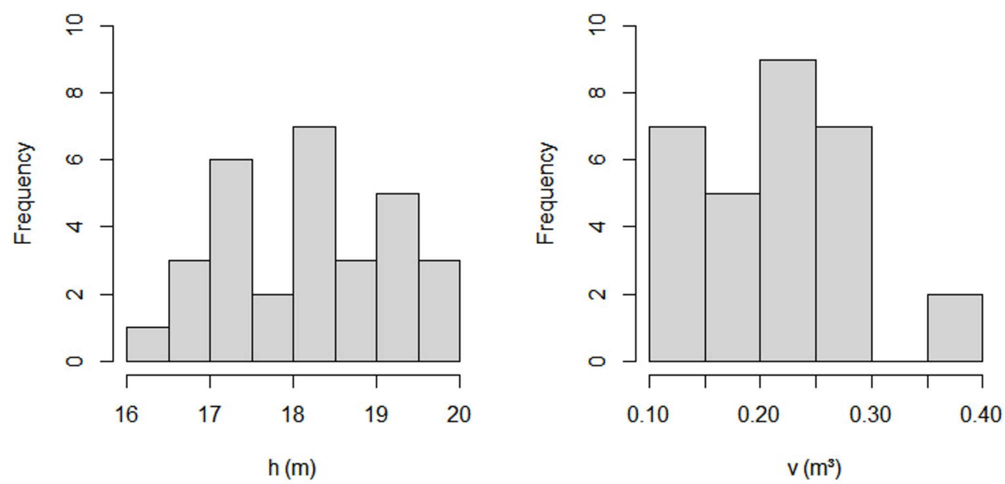

Figure 1 – Diameter and total height frequency distributions in a *Pinus taeda* stand

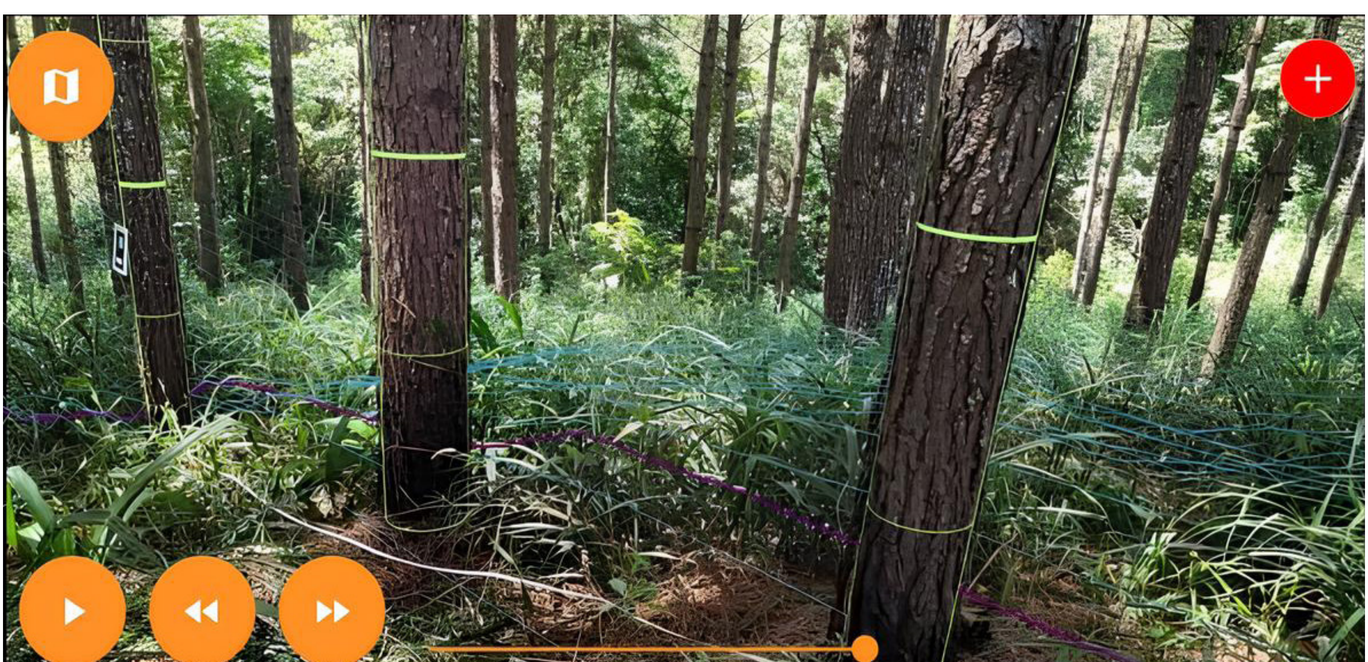

Figure 2 – View from the Katam Forest app showing the recorded video with detected tree stems and the highlighted DBH reference line

Figure 3 – Katam Forest app interface displaying the average results from one sampled line, processed with a fixed depth of 6 meters, along with the corresponding results for the entire plot

2.5. Statistical analyses

For the comparison of sampling methodologies, the means of the variables diameter at 1.3 m above the ground (cm), height (m), basal area ($m^2\ ha^{-1}$), volume ($m^3\ ha^{-1}$), and tree density per sampling unit were compared. First, the Shapiro-Wilk and Bartlett tests were employed, respectively, to test the normality of data and the homogeneity of variances at a 5% significance level.

For the statistical comparison of variables between sampling methodologies, the two-tailed t-test for independent samples was applied at a 5% significance level. In the absence of normality of data and/or homogeneous variances, a logarithmic transformation was considered to meet statistical assumptions. When not met, the comparison between means was carried out using the non-parametric Mann-Whitney test at a 5% significance level.

3. RESULTS

3.1. Height-diameter and volume relationship models

For the height-diameter relationship, the best results were obtained with the Stoffels & van Soest model, followed by the Curtis model (Table 2). On the other hand, the Trorey model had a non-significant regression coefficient (β_2) for estimating height. For volume estimation, the best statistics were obtained through the Schumacher-Hall model (Table 2). According to these statistical metrics, the Schumacher-Hall model was followed by the Spurr and Husch models. Additionally, the selected height-diameter and volume relationship models met the assumptions of residual normality, by the Shapiro-Wilk (SW) test, as well as homoscedasticity, by the Breusch-Pagan (BP) test, except for the Spurr model, which did not exhibit homogeneous variances (Table 2).

The graphical analysis of residuals supported the selection of the Stoffels & van Soest model for the height-diameter relationship and the Schumacher-Hall model for volume, as both provided a better fit and captured the variability in the observed data more effectively than the other models (Figure 4). These models showed an absence of tendency and heteroscedasticity in the dispersion of residuals for estimating heights and volumes in the *P. taeda* stand.

3.2. Comparison between sampling methodologies

The optimal intensity for simple random sampling was seven fixed area sampling units, considering a 95% probability and a 10% margin of error. Sampling via the Katam Forest app covered seven sampling units, respecting the optimal intensity. Thus, the sample sufficiency was ensured for subsequent statistical analyses.

Thus, the Shapiro-Wilk normality test and Bartlett's test for homogeneity indicated that the variables diameter at 1.3 m above the ground ($\bar{d}$), basal area ($\bar{G}$) and total volume ($\bar{V}$) met these assumptions for analysis using the t-test for independent samples. On the other hand, the total height variable ($\bar{h}$) was evaluated using the non-parametric Mann-Whitney test due to the absence of normality. Tree density (N), as a discrete variable, was also compared using the non-parametric Mann-Whitney test (Table 3).

The mean diameter at 1.3 m above the ground ($\bar{d}$) in the Katam Forest app sampling was statistically similar to random sampling (Table 3). Comparable results were observed for the variables basal area ($\bar{G}$) by the t-test and tree density (N). In contrast, volume ($\bar{V}$) showed a statistically significant difference. On the other hand, the Katam Forest methodology underestimated the mean heights, when compared to random sampling (Table 3).

When estimating heights with the Katam sampling using the selected height-diameter relationship model, normality and homogeneity were observed for this variable (Table 4). Furthermore, there was non-significant difference compared to random sampling (p-value > 0.05). With the

Table 2 – Statistics of the height-diameter and volume relationship models fitted for *Pinus taeda* stands

Model	β_0	β_1	β_2	R²aj.	Syx%	SW p-value	BP p-value
				Height			
Stoffels & van Soest	2.2095*	0.2408*		0.398	4.33	0.059	0.829
Trorey	11.9583*	0.4562*	-0.0058^{ns}	0.377	4.41	0.059	0.924
Curtis	3.1403*	-4.1808*		0.394	4.35	0.098	0.735
				Volume			
Husch	-7.6012*	2.0922*		0.837	13.85	0.993	0.998
Spurr	1.74×10^{-2}*	3.29×10^{-5}*		0.883	11.71	0.615	0.003
Schumacher-Hall	-12.0912*	1.6028*	2.0322*	0.902	10.74	0.186	0.409

β_i is the regression coefficients, * indicates significance at the 5% level by the t-test, ns indicates non-significance, R²aj. the adjusted coefficient of determination, Syx% is standard error of the estimation, SW is the p-value for the Shapiro-Wilk normality test, and BP is the p-value for the Breusch-Pagan homoscedasticity test.

Table 3 – Statistical comparison of random sampling and Katam Forest methodologies in *Pinus taeda* stands

Variables	Random Sampling		Katam Forest		Statistics (p-value)			
	Average	Standard Deviation	Average	Standard Deviation	Shapiro-Wilk	Bartlett	*t* Test	Mann-Whitney Test
$\bar{d}$ (cm)	20.24	0.68	19.50	0.91	0.311	0.507	0.111	
$\bar{h}$ (m)	18.77	0.16	16.40	0.26	0.003	0.226		5.83×10^{-4}
$\bar{G}$ (m² ha⁻¹)	40,74	2,44	37.14	1.91	0.896	0.540	0.258	
$\bar{V}$ (m³ ha⁻¹)	343,07	20,95	268.15	44.95	0.056	0.032	0.033	
N (trees ha⁻¹)	1246	91,77	1234	146.60	0.390	0.279		0.796

$\bar{d}$ is the mean diameter at 1,3 m above the ground, $\bar{h}$ é a is the average total height, $\bar{G}$ is the average basal area, $\bar{V}$ is the average total volume, and N is the average tree density.

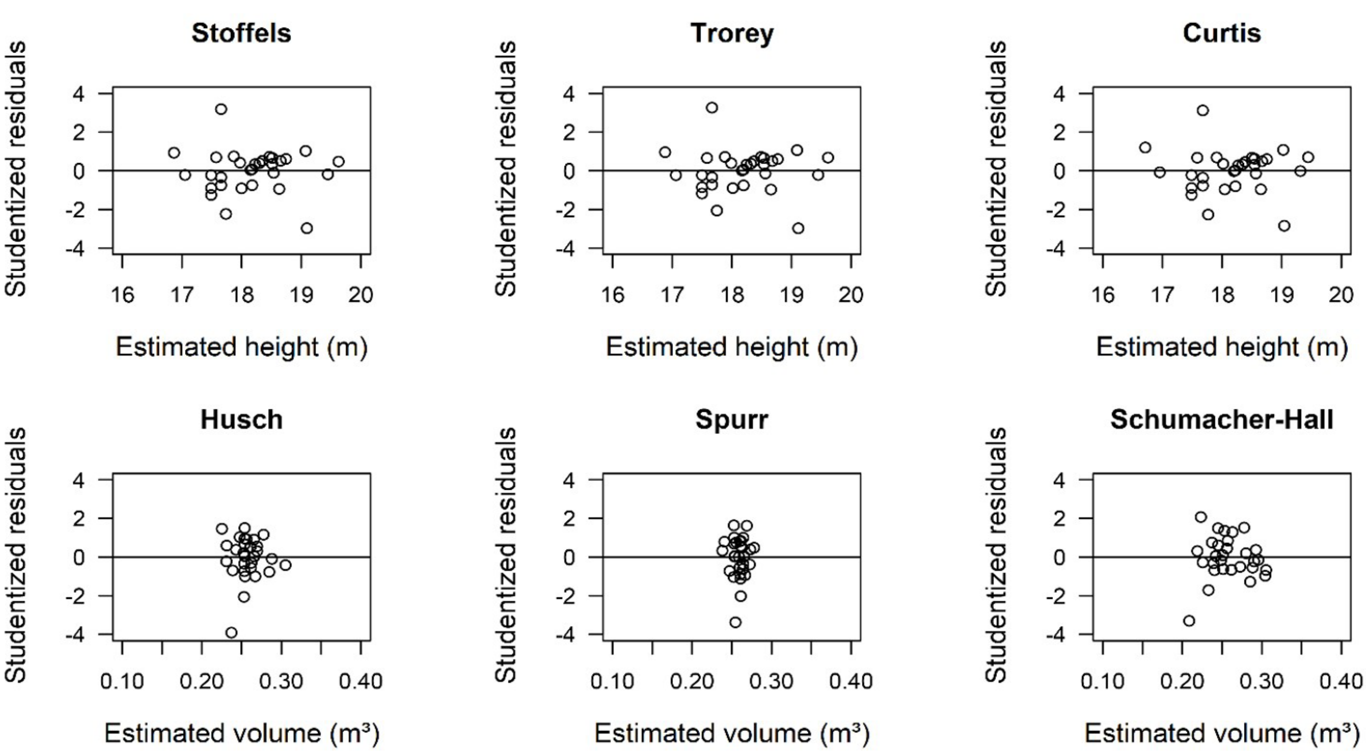

Figure 4 – Residuals of height-diameter and volume relationship models fitted to *Pinus taeda* stand

Table 4 – Statistics of random sampling and Katam Forest methodologies, with heights estimated by the model, in *Pinus taeda* stands

Variables	Katam Forest with height-diameter model		Statistics (p-value)		
	Average	Standard Deviation	Shapiro-Wilk	Bartlett	*t* Teste
$\bar{h}$ (m)	18.59	0.21	0.405	0.529	0.092
$\bar{V}$ (m^3 ha^{-1})	325.17	31.63	0.857	0.349	0.236

$\bar{h}$ is the average total height, and $\bar{V}$ is the average total volume.

use of height estimates from the height-diameter relationship model, the mean estimated volumes ($\bar{V}$) by the Katam Forest methodology did not show a significant difference (p-value > 0.05) compared to random sampling (Table 4).

4. DISCUSSION

The results of the present study met the proposed objective of comparing dendrometric variable estimates in a *P. taeda* stand using simple random sampling and the Katam Forest app approach. Thus, the absence of a significant difference in the means of diameter at 1.3 m above the ground ($\bar{d}$), basal area ($\bar{G}$) and tree density (N), at a 5% significance level corroborated the quality of data obtained via the app. On the other hand, the presence of a significant difference (Table 3) in the means of total height ($\bar{h}$) and total volume ($\bar{V}$) highlights the need for improvement in the automation of forest inventories, especially in acquiring variables that are difficult to measure.

Since volume is determined by the diameter and height variables, it was significantly influenced by the estimation from the app. In general, smartphone apps can be less accurate for height estimation (Curto et al., 2022). On the other hand, diameter can be accurately estimated using various methods, from sophisticated sensors to low-cost equipment (Ucar et al., 2022; Li et al., 2023). Since height-diameter models in general demonstrate accuracy for *Pinus* sp. stands (Nicoletti et al., 2016, 2020; Stepka et al., 2017), their incorporation is recommended to improve estimates, both for the Katam Forest methodology and other similar technologies.

Thus, the results of this research indicate that the adoption of new measurement technologies should consider the challenges of automating tree measurement (Kvochkin & Ustyugov, 2017) and the effects of biased estimates of dendrometric variables on the accuracy of forest inventories (Ucar et al., 2022). Therefore, validating predictions generated by apps against traditional methods is recommended. The results are also in line with previous studies that demonstrate the accuracy of the Katam Forest app, when compared to conventional inventory methods (Täll, 2020).

On the other hand, some authors have reported issues with the lighting in the environment as well as the quality of digital cameras (Vastaranta et al., 2015; Celes et al., 2019; Ucar et al., 2022) during the capture of tree images using measurement apps and smartphone cameras. In the present study this limitation was not observed with Katam Forest in the evaluated stand. Furthermore, difficulties reported in the literature regarding the operator's positioning in plots for capturing images of sampled trees (Vastaranta et al., 2015) were not observed in this study, as the sampling units are considered linear in the Katam Forest approach.

Costa & Mateus (2024) also conducted a study evaluating current technologies for volume estimation in planted forests. The study was motivated by the search for more efficient technological solutions for forest management. The authors compared a full forest census and traditional sample plot-based estimation with two different software solutions: Katam and Arboreal.

Finally, in this study, we aimed to meet the required sample intensity for random sampling, considering a 95% probability level and a 10% margin of error for the mean. Additionally, tree measurements using cameras with GPS receivers represents a low-cost source for forest data collection (Molinier et al., 2011; Ucar et al., 2022). This allows future research to take place, focusing on implementation costs and measurement of sampling units, therefore corroborating the efficiency in automating variables using the Katam Forest Approach.

5. CONCLUSIONS

The Katam Forest methodology for forest inventories proves to be a reliable alternative for diameter and number of trees data collection compared to traditional sampling in commercial plantations of *Pinus taeda*. The app allows the use of digital tools and data storage for real and visual evidence of forest stands. On the other hand, the incorporation of regression models fitted to the inventoried plantations is necessary for better estimation, in which the Stoffels & van Soest and Schumacher-Hall models were recommended for height and volume estimation, respectively.

6. REFERENCES

Celes, C. H. S., Araujo, R. F. D., Emmert, F., Lima, A. J. N., & Campos, M. A. A. (2019). Digital approach for measuring tree diameters in the Amazon forest. *Floresta e Ambiente*, *26*(1), e20160384. http://doi.org/10.1590/2179-8087.038416.

Costa, G. L., & Mateus, N. S. (2024). *Tecnologias atuais para estimativa volumétrica de florestas plantadas: uma análise das principais características distintivas* (22 p.). Piracicaba: Escola Superior de Agricultura "Luiz de Queiroz", Universidade de São Paulo.

Curto, R. D. A., Pinto, M. F., Wink, C., Araújo, E. J. G., & Kohler, S. V. (2022). Aplicativos e smartphones para mensuração da altura de árvores em plantio florestal. *Pesquisa Florestal Brasileira*, *42*(1), 1-12. http://doi.org/10.4336/2022.pfb.42e202002113.

Howie, N. A., & De Stefano, A. (2024). Measuring tree diameter using lidar equipped ipad: an evaluation of forestscanner and arboreal forest applications. *Forest Science*, *70*(4), 304-310. http://doi.org/10.1093/forsci/fxae017.

Kershaw, J. A., Ducey, M. J., Beers, T. W., & Husch, B. (2017). *Forest mensuration* (5th ed.). Chichester: John Wiley & Sons.

Kimsey Junior, M. J., Strimbu, B. M., & Mcgaughey, R. J. (2021). Advancements in forest mensuration and biometrics in the artificial intelligence era. *Canadian Journal of Forest Research*, *51*(8), v-vi. http://doi.org/10.1139/cjfr-2021-0175.

Kvochkin, D. O., & Ustyugov, V. A. (2017). Mobile device of the automated forest inventory. *Journal of Industrial Pollution Control*, *33*(1), 976-980. Retrieved in 2024, March 9, from https://www.icontrolpollution.com/articles/mobile-device-of-the-automated-forest-inventory-.pdf

Li, S., Fang, L., Sun, Y., Xia, L., & Lou, X. (2023). Development of measuring device for diameter at breast height of trees. *Forests*, *14*(2), 192. http://doi.org/10.3390/f14020192.

Liang, X., Wang, Y., Pyörälä, J., Lehtomäki, M., Yu, X., Kaartinen, H., Kukko, A., Honkavaara, E., Issaoui, A. E. I., Nevalainen, O., Vaaja, M., Virtanen, J.-P., Katoh, M., & Deng, S. (2019). Forest in situ observations using unmanned aerial vehicle as an alternative of terrestrial measurements. *Forest Ecosystems*, *6*(1), 20. http://doi.org/10.1186/s40663-019-0173-3.

Molinier, M., Andersson, K., & Hame, T. (2011). Automatic tree stem delineation supporting forest inventory. In *2011 IEEE International Geoscience and Remote Sensing Symposium* (pp. 836-839), Vancouver, BC, Canada. New York: IEEE. http://doi.org/10.1109/IGARSS.2011.6129458.

Molinier, M., López-Sánchez, C. A., Toivanen, T., Korpela, I., Corral-Rivas, J. J., Tergujeff, R., & Häme, T. (2016). Relasphone-mobile and participative in situ forest biomass measurements supporting satellite image mapping. *Remote Sensing*, *8*(10), 869. http://doi.org/10.3390/rs8100869.

Nicoletti, M. F., Souza, K., Silvestre, R., França, M. C., & Rolim, F. A. (2016). Relação hipsométrica para *Pinus taeda* L. em diferentes fases do ciclo de corte. *Floresta e Ambiente*, *3*(1), 80-89. http://doi.org/10.1590/2179-8087.051513.

Nicoletti, M. F., Lambert, L., Soares, P. R. C., Cruz, G. D. S., Almeida, B. R. S., & Stepka, T. F. (2020). Equações hipsométricas, volumétricas e funções de afilamento para *Pinus* spp. *Revista de Ciências Agroveterinárias*, *19*(4), 474-482. http://doi.org/10.5965/223811711942020474.

R Core Team. (2022). *R: a language and environment for statistical computing.* Vienna: R Foundation for Statistical Computing.

Stepka, T. F., Zeny Junior, G. A., Lisboa, G. S., Cerqueira, C. L., Pesck, V. A., & Roik, M. (2017). Modelos volumétricos e funções de afilamento para *Pinus taeda* L. na região dos Campos Gerais, Paraná, Brasil. *Revista Espacios*, *38*(21), 26. Retrieved in 2024, March 9, from https://www.revistaespacios.com/a17v38n21/a17v38n21p26.pdf

Täll, K. (2020). *Accuracy of mobile forest inventory application Katam Forest: Evaluation of accuracy in different forest types and comparison to conventional inventory methods* (Master's thesis). Swedish University of Agricultural Sciences, Alnarp. Retrieved in 2024, March 9, from https://stud.epsilon.slu.se/15936/7/tall_k_200824.pdf

Tang, J., Chen, Y., Kukko, A., Kaartinen, H., Jaakkola, A., Khoramshahi, E., Hakala, E., Hyyppä, J., Holopainen, M., & Hyyppä, H. (2015). SLAM-Aided stem mapping for forest inventory with small-footprint mobile LiDAR. *Forests*, *6*(12), 4588-4606. http://doi.org/10.3390/f6124390.

Ucar, Z., Değermenci, A. S., Zengin, H., & Bettinger, P. (2022). Evaluating the accuracy of remote dendrometers in tree diameter measurements at breast height. *Croatian Journal of Forest Engineering*, *43*(1), 185-197. http://doi.org/10.5552/crojfe.2022.1016.

Vastaranta, M., Latorre, E., Luoma, V., Saarinen, N., Holopainen, M., & Hyyppä, J. (2015). Evaluation of a smartphone app for forest sample plot measurements. *Forests*, *6*(4), 1179-1194. http://doi.org/10.3390/f6041179.

Velten, K., Schmidt, D. M., & Kahlen, K. (2024). *Mathematical modeling and simulation*: introduction for scientists and engineers. Germany: Wiley. http://doi.org/10.1002/9783527849604.

White, J. C., Coops, N. C., Wulder, M. A., Vastaranta, M., Hilker, T., & Tompalski, P. (2016). Remote sensing technologies for enhancing forest inventories: a review. *Canadian Journal of Remote Sensing*, *42*(5), 619-641. http://doi.org/10.1080/07038992.2016.1207484.

AUTHOR CONTRIBUTIONS:

VHG: data curation, writring - original draft, investigation;
ALP: writing – review & editing, supervision, methodology;
VCC: validation, supervision.