Planted forest area estimation in Santa Catarina using random sampling point

Fabrício Baumgarten Cardoso[1], Julio Cesar Refosco[2], Moacir Marcolin[3] and Matheus Eneas Schefer Gervin[4]

Abstract — Management of planted forests depends, among other information, on the knowledge of their extensions and spatial distribution. The current information about the area of planted forests in the state of Santa Catarina comes from sources without proper accuracy assessment. This work aimed to evaluate the use of random point sampling in estimating the planted forest area in the state of Santa Catarina. A minimum sample of 200 points per municipality was used, with a maximum standard error of 2%. The results indicated a total planted forest area of 1,135,481ha, with a standard error of 0.12%, in the state of Santa Catarina. The municipalities with the largest planted forest areas are in the mesoregions Serrana, Oeste Catarinense, and Norte Catarinense. The random point sampling methodology showed a precise result for the state of Santa Catarina in a simple and objective way, and may be effective for decision-making in planning.

Index terms: Reforestation; Agricultural statistics; Satellite images; Geographical information systems.

Estimativas de área de florestas plantadas em Santa Catarina com amostragem por pontos aleatórios

Resumo — A gestão de florestas plantadas depende, dentre outras informações, do conhecimento da sua extensão e distribuição espacial. Os dados atuais sobre a área de florestas plantadas no Estado de Santa Catarina provêm de fontes sem a devida avaliação de acuracidade. Este trabalho teve como objetivo avaliar o emprego da amostragem pontual aleatória na estimativa da área de florestas plantadas no Estado de Santa Catarina. Foi utilizada uma amostra com no mínimo 200 pontos amostrais para cada município e um erro padrão aceitável de 2%. Os resultados apontaram uma área total de 1.135.481ha, com erro padrão de 0,12%, de florestas plantadas no Estado de Santa Catarina. Os municípios com as maiores áreas de florestas plantadas estão localizados nas mesorregiões Serrana, Oeste Catarinense e Norte Catarinense. Conclui-se que a metodologia de amostragem pontual aleatória apresentou um resultado preciso para o Estado de Santa Catarina, de forma simples e objetiva e pode ser eficaz para o planejamento e a tomada de decisão.

Termos para indexação: Reflorestamento; Estatísticas agrícolas; Imagem de satélite; Sistemas de informação geográfica.

Introduction

Planted forest management requires qualitative and quantitative information such as: species/clone, plant health, planted area, age, tree density, wood volume and mass. This information is essential for business investors and for private and public planning institutions to establish policies and guidelines for the forest sector.

The state of Santa Catarina established the Working Group on Forestry Policy of Santa Catarina (GT-PEFSC), officiated in 2012 by CONSEMA/SDS 060/2012. This expert group has discussed implementing periodic studies to obtain data on the forest plantations. Similarly, at the national level, Decree 8,375/2014, which sets agricultural policy for planted forests, states in its article 7 that the Ministry of Agriculture "shall draw up a plan with diagnosis and inventory of planted forests" (BRASIL, 2014).

Compared with natural forests, planted forests show a higher dynamism degree in terms of land cover and use. The shorter rotation cycles for the Eucalyptus genus have between 6 and 8 years, and the longest between 20 and 21 years (PAIVA & LEITE, 2015; GONÇALVES et al., 2015). The Pinus genus has rotation cycles between 16 and 30 years (JUNIOR, 2014). This highlights the importance of studies for researching and improving the update information on planted forests.

Currently, three primary sources bring information specifically related to planted forests in Santa Catarina: the "2015 Statistical Yearbook" of the Association of Forestry Companies of Santa Catarina (ACR, 2016), the study "Production of Vegetal Extraction and Silviculture" (PEVS) produced by the Brazilian Institute of Geography and Statistics (IBGE, 2014), and, finally, the study performed by the Transparent World, which mapped the planted forests in seven countries around the world, including Brazil (TRANSPARENT WORLD, 2016). The three sources, however, have disparate information, with differences approaching 100%, demonstrating the need for improvement. Some

Received on 09/05/2023. Accepted for publication on 04/08/2023. Doi: http://doi.org/10.52945/rac.v36i2.1618

[1] Forestry Engineer, MSc, Regional University of Blumenau (FURB)/Postgraduate Program in Forestry Engineering (PPGEF),CEP 89030-000, Blumenau, SC, Brasil, e-mail: fbc@florestal.eng.br.
[2] Forestry Engineer, Dr, FURB/PPGEF, e-mail: refosco@furb.br.
[3] Forestry Engineer, MSc, FURB/Departamento de Engenharia Florestal (DEF), e-mail: marcolin@furb.br.
[4] Forestry Engineer estal, FURB/ Undergraduate Course in Forestry Engineering, e-mail: matheus.esg@hotmail.com.

information sources about land use like "MonitoraSC" (VIBRANS et al., 2021) and "Mapbiomas" (SOUZA et al., 2020) also bring information on planted forest.

Among the various methodologies for studies on planted forests, the spatial sampling surveys, including the random sampling point (RSP), is an alternative for quantifying land coverage, serving as a first level of information. Thus, it fills an important gap between the laborious traditional field research on forest inventory and the mapping by conventional remote sensing, requiring advanced technologies and relatively high expenses (AUNE-LUNDBERG et al., 2016).

For land use statistics, point sampling has been applied in several countries like the United States, Canada, England, France, Sweden, Switzerland, and Norway. In some cases, these methods were preferable, considering their rapidity in obtaining the data (SÆBØ, 1983). In Brazil, the spatial sampling method was evaluated to estimate yields in agriculture (EPIPHANIO et al., 2002; LUIZ, 2003; ADAMI et al., 2010).

However, recent studies have also used this technique. Nowak & Greenfield (2010) estimated the tree crown cover and impervious surface of the United States with random sampling points (RSP) placed over the Google Earth images. Vibrans et al. (2013) estimated the proportion of natural forest area in Santa Catarina using field samples of the floristic and volumetric inventory of Santa Catarina (IFFSC), assuming a simple random sampling. Jacobs et al. (2014) estimated the Earth's coverage of urban and semi-urban areas in 139 municipalities in Australia, using random sampling points. Richardson & Moskal (2014) estimated the world tree crown coverage for Seattle by RSP.

Thus, seeking to test a methodology for estimating planted forests cover, quickly and accurately, as an alternative to advanced remote sensing techniques, this research aimed to identify, locate, and calculate the planted forest area for the state of Santa Catarina, its municipalities and meso-regions, by RSP over aerial and orbital images by comparing the results with data from the planted forests area from other studies.

Material and methods

The study area is the State of Santa Catarina, which has an area of 95,736km² and is in the southern region of Brazil. Figure 1 shows the state divided into its six meso-regions.

The three subdivisions of Atlantic Rainforest cover the study area: the Dense Ombrophilous Forest, which covered originally 32.9% of the territory; the Mixed Ombrophilous Forest, which covered originally 42.5%; and the Semideciduous Seasonal Forest, covering 9.6% of Santa Catarina. The remaining natural forest cover is 29% of the original (VIBRANS, 2015).

To estimate land cover classes, the application i-Tree Canopy (USDA FOREST SERVICE, 2016) was used, and to analyze data and organize planted forests data sets the Microsoft Excel was used. The ArcGis 10.1 was used for processing spatial data and map elaboration. The map with the municipal division for Santa Catarina was provided by IBGE (2013). The i-Tree Canopy tool uses images from google satellite whose update frequency can vary in time. The date of the images was controlled ensuring accurate comparisons with other studies.

Three data sources were used for comparison. The first was the "2015 Statistical Yearbook" of the Association of Forestry Companies of Santa Catarina (ACR, 2016). This study is a public production report of the biggest companies that industrialize forest products in Santa Catarina. The second was the report of Production of Vegetal Extraction and Silviculture (PEVS) of 2014 for Brazil (IBGE, 2014), containing the planted forest area by municipality among other information. The data was researched in agricultural establishments, industries, and other sector's actors. The third was the Transparent World (TRANSPARENT WORLD, 2016) study. It was conducted in seven countries using remote sensing, more specifically a semi-automatic classification of Landsat 8 satellite images/OLI of 2013 and 2014, complemented with manual interpretation of images from Google Maps, Bing Maps, and Open Landscape Partnership. No accuracy test was conducted (PETERSEN et al., 2016). Table 1 compares the three selected data sources.

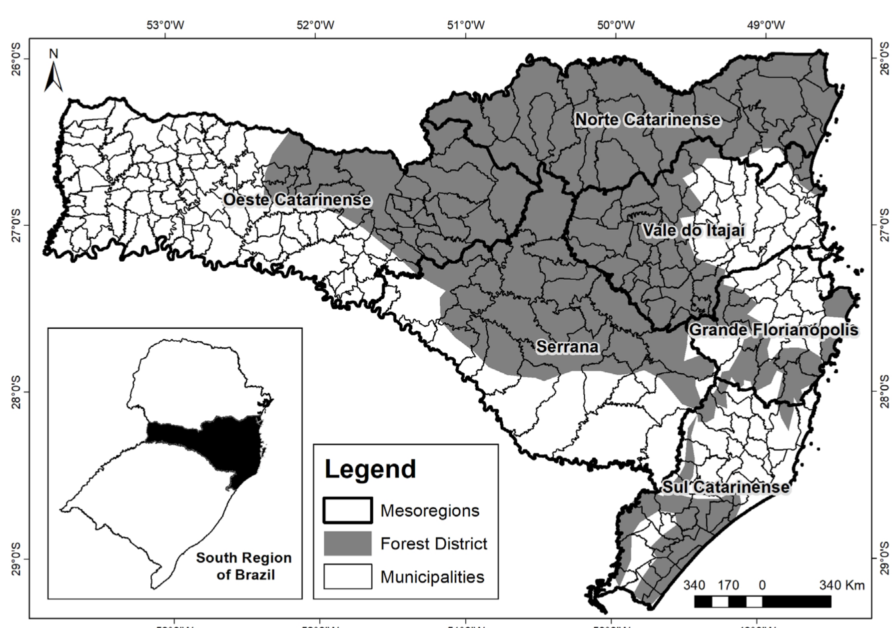

Figure 1. State of Santa Catarina, mesoregions, municipalities, and delimitation of Forest District
Source: adapted from IBDF (1984).
Figura 1. Estado de Santa Catarina, mesorregiões, municípios e delimitação do distrito florestal
Fonte: adaptado de IBDF (1984).

Table 1. Characteristics of recent studies of planted forests in Santa Catarina, Brazil
Tabela 1. Estudos recentes sobre florestas plantadas em Santa Catarina, Brasil

Study	ACR	PEVS	Transparent World
Base Year	2015	2014	2014
Method for data collection	Data of associated companies	Forms from the municipal organ, cooperatives, etc.	Semi-automatic classification of orbital images
Information extent	State of Santa Catarina	Brazilian municipalities	Peru, Liberia, Colombia, Cambodia, Brazil, Malaysia, Indonesia
Release format	Technical report	Electronic data sheet	Map in shapefile format

The work was divided into three main steps: (1) data preparation; (2) data collection; and (3) information analysis. The PEVS data preparation consisted of reorganizing the spreadsheet in the Microsoft MS-Excel application, selecting the municipalities of Santa Catarina containing the data of the planted forest area. The Transparent World study was processed by using ArcGIS 10.1, selecting only the polygons of planted forests in Santa Catarina. The analysis of the attribute table made it possible to extract the planted forest area by the municipality of Santa Catarina identified in this study.

The data were collected by allocating 200 random sampling points for each municipality of Santa Catarina and interpreting land use/cover at each point using Google Earth images. Two classes of land use/cover were used: “planted forest” and “not planted forest” (UCAR et al., 2016) (Figure 2). The “planted forest” class considered areas covered with forest plantations of the genera *Pinus*, *Eucalyptus* and *Araucaria*, including the areas of forest planting and harvesting stage of replanting. At the same time, the dates of the images were controlled.

After sampling each of the 295 municipalities, data were analyzed in a spreadsheet to calculate the proportion of planted forests by municipality, the standard error, and the confidence interval, and, with the land area of each municipality, the area of forest planted by municipality could be estimated. The 200 sampling points per municipality served as preliminary sampling, to calculate sampling sufficiency. The acceptable standard error was set to 2% and, thus, for the municipalities that did not reach the standard acceptable error, new sampling points were deployed, until reaching the acceptable standard error. Thus, the sampling intensity varied between municipalities. Figure 3 shows the relationship between the number of samples and the decrease in the confidence interval. Most municipalities had average stabilization and confidence intervals achieved with the 200 sampling points.

To estimate the total area of planted forests for Santa Catarina and the mesoregions, the complete set of sample randomized points was used by municipality.

To calculate the percentage of planted forests (p), Equation 1 was used.

$p = n/N$ (Eq. 1)

Where:

N = total number of sampled points;

n = number of items classified as planted forest;

To calculate the standard error (SE) Equation 2 was used.

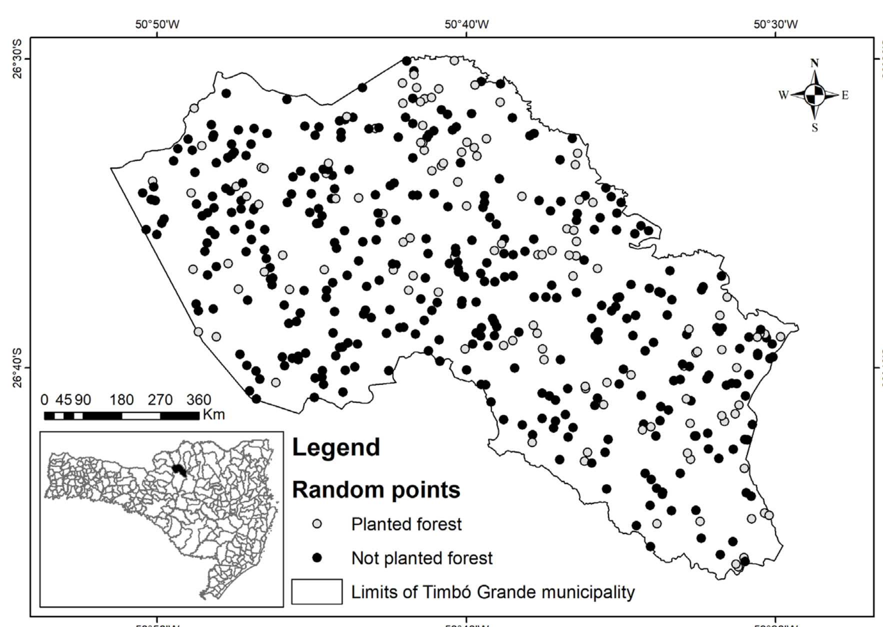

Figure 2. Municipality of Timbó Grande with randomized sampling points in the state of Santa Catarina, Brazil
Figura 2. Município de Timbó Grande e pontos de amostragem aleatória em Santa Catarina, Brasil

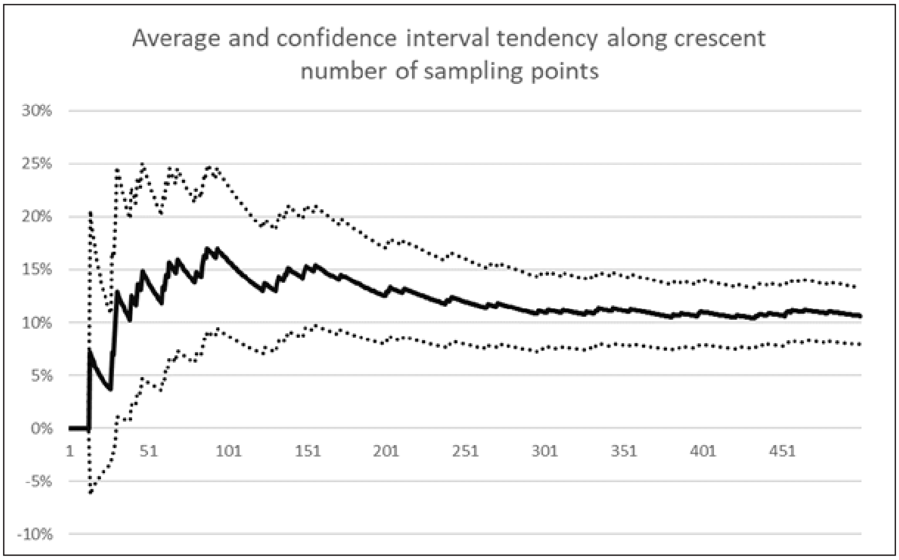

Figure 3. Proportion of planted forests and variance of the confidence interval related to the number of sampling points in the municipality of Lages (SC) in the state of Santa Catarina, Brazil

Figura 3. Proporção de florestas plantadas e variância do intervalo de confiança em relação ao número de pontos amostrais no município de Lages (SC) em Santa Catarina, Brasil

SE = √ (p x q / N) (Eq. 2)

Where:

p (percentage of planted forest) = n/N;

q (percentage of not planted forest) = 1−p;

N = total number of sampled points

When the number of items classified as planted forest (n) was less than 10, a different equation for standard error (SE) was used (Equation 3).

SE = (√ n) / N (Eq. 3)

Where:

n = number of items classified as planted forest;

N = total number of points sampled.

To calculate the confidence interval (CI), Equation 4 was used, whereas Equation 5 was used for Sampling Sufficiency (Sn) (GREGORY, 2014).

CI (95%) = SE × t (Eq. 4)

Where:

SE = standard error;

t = (Student's t-distribution)

Sn = p% x q% / SE² (Eq. 5)Where:

p% = percentage of the planted forest;

q% = 100% of p%;

SE = acceptable standard error.

When the value of planted forests area identified in other studies was within the confidence EPA interval, no significant difference was considered between the values of the sampling and of the study to a 95% probability (NOWAK & GREENFIELD, 2010).

Results and discussion

The results showed an expected chronological diversity between the dates of the satellite images used in the study. This is primarily due to the variety of sensors, such as TM, ETM and OLI Landsat, Digital Globe, GeoEye-1, Ikonos, MODIS\Terra, SPOT, among others. However, approximately 70% of the images were from 2013 and 2014 years, thus, compatible with the period of the most recent studies adopted in this work (Table 1).

Area of planted forest for the State of Santa Catarina

Considering the state of Santa Catarina, the study analyzed 76,146 sampling points, and of these, 9,034 (11.9%) were classified as "planted forest" and 67,112 (88.1%) classified as "not planted forest." Thus, considering the total area of Santa Catarina, the estimated planted forest area in the state is 1,135,481ha, with a standard error of 0.12%. Assuming a 95% confidence interval, this value is between 1,113,499ha and 1,157,464ha, as shown in Table 2.

Comparing the values obtained in this study with those of ACR (2016), IBGE (2014) and Transparent World (2016) found relatively disparate values (Table 2), which, in a first view, could be related to the different survey methods of each study.

The ACR study (2016) has focused on extensive forest plantations, conducted by medium or big companies. In other words, independent plantations and those out of industrial areas will most likely not be considered. This study reports an area of 660,700ha of planted forests in Santa Catarina.

The IBGE (2014) presents an area of 1,033,624ha, which is lower and outside this study's confidence interval, whereas Transparent World (2016) presents an area of 1,188,953ha, greater and outside the confidence interval.

The sampling standard error was 0.12% which generated a relatively reduced confidence interval, indicating that the estimation of the planted forest area has reached great accuracy. Other studies that used RSP to estimate the land cover have obtained higher standard errors. Vibrans et al. (2013) obtained 1.4% standard error in estimating forest area in Santa Catarina by using IFFSC field samples, using simple random sampling. Jacobs et al. (2014) have reached the maximum standard error of 3% in the estimated coverage of urban and semi-urban areas in 139 Australian municipalities. Richardson & Moskal (2014) had 1.4% of standard error in estimating the urban tree canopy coverage in Seattle by using RSP.

An analysis of the planted forest area by region allows to evaluate the differences regarding the context of each, their natural, social, and economic

Table 2. Planted forest area in Santa Catarina and comparison with other studies

Tabela 2. Área de florestas plantadas em Santa Catarina e comparação com outros estudos

Class	Planted Forest (ha)	Planted Forest (%)
This study	1,135,481	11.9
ACR	660,700	6.9
IBGE	1,033,624	10.8
Transparent World	1,188,953	12.5

Table 3. Planted forest area by mesoregion in the state of Santa Catarina, Brazil

Tabela 3. Área de florestas plantadas por mesorregião em Santa Catarina, Brasil

Mesoregion	PF	%	SE	CI
Serrana	438.0	35.6	0.39	420.9-455.0
Oeste Catarinense	284.6	23.1	0.18	274.9-294.3
Norte Catarinense	207.4	16.8	0.40	194.9-219.9
Vale do Itajaí	149.4	12.1	0.27	142.5-156.3
Sul Catarinense	98.0	8.0	0.28	92.6-103.4
Grande Florianópolis	54.3	4.4	0.38	48.8-59.8

FP = Estimated planted forest area (1000 hectares); % = Percentage of estimated planted forest area; SE = standard error in percentage; CI = confidence interval (95%)

Table 4. Municipalities with the highest estimated planted forest areas (area in 1000ha) in the state of Santa Catarina, Brazil

Tabela 4. Municípios com maiores estimativas de áreas de florestas plantadas (área in 1000ha) em Santa Catarina, Brasil

Municipality	N	n	p%	SE	PF	CI	IBGE	TW
Santa Cecilia	600	243	40.5	2.00	46.4	4.5	55.5	54.1
Otacilio Costa	616	233	37.8	1.95	31.9	3.2	34.0 *	42.5
Lages	500	53	10.6	1.38	27.9	7.1	34.7 *	45.1
Caçador	520	140	26.9	1.95	26.5	3.8	* 24.4	30.0 *
Rio Negrinho	504	132	26.2	1.96	23.8	3.5	24.0 *	35.6
Mafra	325	47	14.5	1.95	20.3	5.4	10.7	27.4
Capão Alto	319	41	12.9	1.87	17.2	4.9	14.0 *	22.0 *
Campo Belo do Sul	450	73	16.2	1.74	16.7	3.5	15.3 *	19.7 *
Timbó Grande	479	125	26.1	2.01	15.6	2.4	7.8	19.9
Lebon Régis	353	58	16.4	1.97	15.5	3.6	4.4	24.2
Correia Pinto	450	105	23.3	1.99	15.2	2.5	* 15.8	22.7
Itaiópolis	260	30	11.5	1.98	14.9	5.1	12.0 *	19.7 *
Bom Retiro	310	41	13.2	1.92	14.0	4.0	21.6	19.3
Água doce	245	26	10.6	1.97	13.9	5.1	16.1 *	23.5
São José do Cerrito	309	45	14.6	2.01	13.8	3.7	5.2	* 15.8
Curitibanos	325	47	14.5	1.95	13.7	3.6	33.0	15.0 *
Canoinhas	292	35	12.0	1.90	13.7	4.3	12.1 *	16.6 *
Ponte Alta do Norte	561	192	34.2	2.00	13.7	1.6	28.7	21.1
Calmon	450	95	21.1	1.92	13.5	2.4	15.7 *	21.6
Bocaina do Sul	500	130	26.0	1.96	13.3	2.0	11.0	15.4

N = number of randomized points; n = number of items classified as planted forest; p = proportion of planted forest related to municipality area in percentage; SE = standard error in percentage; PF = estimated planted forest area in 1000ha; CI = confidence interval (95%) in 1000ha; IBGE = PEVS 2014 data in 1000ha; TW = Transparent Data World in 1000ha. * = no significant difference IC (95%).

characteristics. Using the division into meso-regions (IBGE, 2013) (Figure 5) the planted forest varies between the meso-regions. The largest planted forest area is in the Serrana region, with 437,968.06ha, followed by the Oeste with 284,580.17ha, with 207,405.40ha, the Vale do Itajaí with 149,368.62ha, the Sul with 97,999.11ha, and Grande Florianópolis with 54,254.01ha (Table 3; Figure 4).

Area of planted forests by municipality of Santa Catarina

The estimation of the planted forest area to the municipal unit presented 2% maximum standard error. Table 4 shows a list of 20 cities with the most planted forests.

The study shows that 82 of the 295 municipalities of Santa Catarina presented a low proportion of planted forest (number of items classified as planted forest (n) < 10) (Figure 5). Three municipalities had no samples classified as planted forests, showing no planted forest area: Bombinhas, Florianópolis, and Palhoça. In these municipalities with a small area of planted forest and, consequently, zero or few points sorted in the "planted forest" class, this class of land coverage can be underestimated or not even be sampled (HAMILTON & MEGOWN, 2016).

The results show that the cities with the largest planted forest areas are currently concentrated in the Forest District established by the Secretary of Agriculture of the state of Santa Catarina in 1975 (IBDF, 1984). That is, in the wood pole of Santa Catarina, where the biggest industries consumers of raw materials from planted forests are installed. The municipalities that already presented small planted forest area are mostly out of the Forest District and probably have this activity related to small rural properties, where the use of the raw materials intended for their own use, "green savings," or small sawmills.

The PEVS study (IBGE, 2014) differs from the EPA results. From the 295 municipalities, only 151 did not differ. The PEVS data are based on structured research applied in each municipality. Consequently, the PEVS data are not

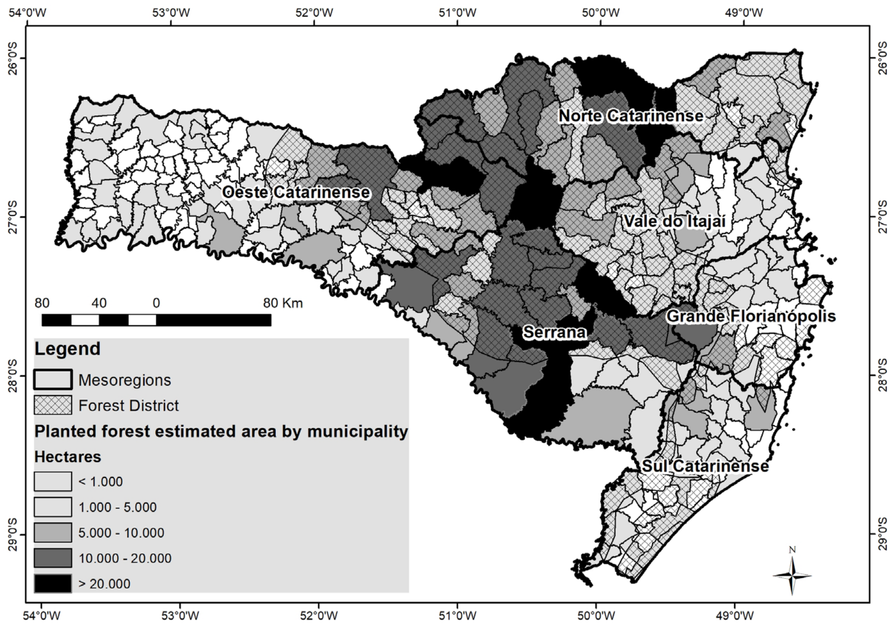

Figure 5. Municipalities of Santa Catarina by class of estimated planted forest area, mesoregions, and forest district

Figura 5. Municípios de Santa Catarina por classe de área estimada de florestas plantadas, mesorregiões e distrito florestal

based on estimation by sampling or measured by remote sensing, but on personal information from technicians and managers. This may explain the difference from the results of this study.

The Transparent World (TRANSPARENT WORLD, 2016) results are closer to this study. A comparison shows that 196 of the 295 municipalities do not differ from this study results and are within the confidence interval (95%). This is probably due to the methodology used, consisting of automated classification of satellite images from dates like those of this study. This mapping has been done in seven countries including Brazil. However, the accuracy test was only performed for Malaysia until now (PETERSEN et al., 2016), thus lacking a complete accuracy measurement.

As potential perspectives for new studies, it is crucial to consider comparisons with land use surveys such as MonitoraSC (VIBRANS, 2021) and Mapbiomas (SOUZA et al., 2020), instead of solely focusing on specific planted forest surveys. This approach will offer broader understanding of the landscape and facilitate the mapping of various land classes. Additionally, exploring the use of systematic sampling points, in contrast to random sampling points, could be an intriguing method. By adopting systematic sampling, researchers may achieve more structured and comprehensive data for mapping the designated classes.

Conclusions

-The random sampling points methodology showed a promising result for the state of Santa Catarina.

-Results by municipality were satisfactory, despite the relatively small number of points collected per municipality. Consequently, increasing sampling intensity will reduce the standard error and confidence interval and reach even more accurate estimations.

-The random sampling points selected over aerial and orbital images was a simple and objective methodology and shows that simple, low-cost, and accessible tools can effectively give information to decision-makers on planning.

-Monitoring the area of planted forests by municipality is possible, since the randomized sampling points can be controlled and reclassified over time.

-Finally, using the random sampling points of this study is suggested to verify the accuracy and validate the mapping of the Transparent World survey (2016), as well as MonitoraSC (VIBRANS, 2021), and Mapbiomas (SOUZA et al, 2020).

References

ADAMI, M.; RIZZI, R.; MOREIRA, M. A.; RUDORFF, B. F. T.; FERREIRA, C. C. Amostragem probabilística estratificada por pontos para estimar a área cultivada com soja. **Pesquisa agropecuária brasileira**, v.45, n.6, p.585-592, 2010. DOI: https://doi.org/10.1590/S0100-204X2010000600008.

ASSOCIAÇÃO CATARINENSE DE EMPRESAS FLORESTAIS (ACR). **Anuário estatístico de base florestal para o Estado de Santa Catarina 2016 (ano base 2015).** Lages, 2016.

AUNE-LUNDBERG, L.; STRAND, G. Comparison of variance estimation methods for use with two-dimensional systematic sampling of land use/land cover data. **Environmental Modelling & Software**, n.61, pg. 87-97, 2014. DOI: https://doi.org/10.1016/j.envsoft.2014.07.001.

BRASIL. **Decreto nº 8.375, de 11 de dezembro de 2014. Define a Política Agrícola para Florestas Plantadas.** Brasília, DF, 2014. Available from: https://www.planalto.gov.br/ccivil_03/_ato2011-2014/2014/decreto/d8375.htm. Accessed on: 19 jul. 2016.

BANCO REGIONAL DE DESENVOLVIMENTO DO EXTREMO SUL (BRDE). **Florestamento na Região Sul do Brasil: uma análise econômica**. Porto Alegre, RS, 2003. 65p, il.

EPIPHANIO, J.C.N.; LUIZ, A.J.B.; FORMAGGIO, A.R. Estimativa de áreas agrícolas municipais, utilizando sistema de amostragem simples sobre imagens de satélite. **Bragantia**, v.61, n.2, p.187-197, 2002. Doi: https://doi.org/10.1590/S0006-87052002000200012.

GONÇALVES, J.L.M.; ALVARES, C.A.; HÜBNER, A.; ARTHUR Jr., J.C. Caracterização edafoclimática e manejo de solos das áreas com plantações de Eucalipto. p.113-155. In: SCHUMACHER, M.V.; VIEIRA, M. (Orgs.). **Silvicultura do eucalipto no Brasil**. Santa Maria: UFSM, 2015. 308 p.

GREGORY, S. **Statistical Methods and the Geographer**. Routledge, London, 2014 - 256p. Doi: https://doi.org/10.4324/9781315837185.

HAMILTON, R.; MEGOWN, K. **Monitoring and quantifying weed cover using a dot-grid sampling technique**. A Weed Manager's Guide to Remote Sensing and GIS – Mapping and Monitoring. USDA – Remote Sensing Application Center. Available from: https://www.researchgate.net/publication/237774046_Monitoring_and_Quantifying_Weed_Cover_Using_a_Dot-Grid_Sampling_Technique. Accessed on: Mar. 24, 2023.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE). Departamento de Agropecuária. **Pesquisas agropecuárias**. 2. ed. – Rio de Janeiro, RJ, 2002. 92p (IBGE. Boletim Técnico).

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE). **Malhas municipais**: **Estado de Santa Catarina. Ano: 2013**. Available from: ftp://geoftp.ibge.gov.br/organizacao_do_territorio/malhas_territoriais/malhas_municipais/municipio_2013/SC/. Accessed on: Nov 17, 2016.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE). **Produção da extração vegetal e silvicultura.** Rio de Janeiro, v. 29, p.1-56, 2014.

INSTITUTO BRASILEIRO DE DESENVOLVIMENTO FLORESTAL (IBDF). Departamento de Economia Florestal. **Inventário florestal nacional: florestas plantadas: Paraná-Santa Catarina**. Brasília, DF, 1984. 283 p, il., mapas.

JACOBS, B.; MIKHAILOVICH, N.; DELANEY, C. **Benchmarking Australia's Urban Tree Canopy: An i-Tree Assessment**. Institute for Sustainable Futures, University of Technology Sydney, 2014. 44p.

JINGUJI, I. **Dot sampling method for area estimation**. Expert meeting on 'Crop Monitoring for Improved Food Security' in Vientiane, LAO. FAO Regional Office for Asia and the Pacific. 2014. Available from: https://www.fao.org/fileadmin/templates/rap/files/meetings/2014/140217_EM_1-1_Dot_Sampling_Method_for_Area_Estimation.pdf. Accessed on: Jul. 19,2016.

JUNIOR, M.D. **Impacto do manejo de povoamentos na produtividade e qualidade da madeira de Pinus taeda**. 2014. 276p. Tese (Doutorado em Engenharia Florestal. Programa de Pós-Graduação em Engenharia Florestal. Setor de Ciências Agrárias) Universidade Federal do Paraná. Curitiba, PR. 2014. Available from: https://acervodigital.ufpr.br/handle/1884/35819. Accessed on Jul. 19, 2016.

LUIZ, A.J.B. **Estatísticas agrícolas por amostragem auxiliadas pelo sensoriamento remoto**. 2003. 114p. Tese (Doutorado em Sensoriamento Remoto. Instituto Nacional de Pesquisas Espaciais), São José dos Campos, 2003. Available from: http://urlib.net/ibi/6qtX3pFwXQZ3P8SECKy/B4Dar. Accessed on: Jul. 19,2016.

MEDEIROS, J.D. Mata Atlântica em Santa Catarina: Situação atual e perspectivas futuras. In: SCHÄFFER, W.B.; PROCHNOW, M. (Eds.) **A Mata Atlântica e você: como preservar, recuperar e se beneficiar da mais ameaçada floresta brasileira**. Brasília: APREMAVI, 2002. 156p. Available from: https://apremavi.org.br/wp-content/uploads/2021/08/a-mata-atlantica-e-voce-baixa-20mb.pdf. Accessed on: Jul. 19,2016.

NOWAK, D. J.; GREENFIELD, E. J. Evaluating the national land cover database tree canopy and impervious cover estimates across the conterminous United States: A comparison with photo-interpreted estimates. **Environmental Management.,** v.46, p.378-390, 2010. Doi: https://doi.org/10.1007/s00267-010-9536-9.

PAIVA, H.N.; LEITE, H.G. Desbastes e desramas em povoamentos de Eucalyptus.. In.: SCHUMACHER, MAURO V; VIEIRA, M. (Orgs.). **Silvicultura do eucalipto no Brasil**. Santa Maria: UFSM, 2015. p.83-112

PETERSEN, R.; GOLDMAN, E.; HARRIS, N.; SARGENT, S.; AKSENOV, D. **Mapping Tree Plantations with Multispectral Imagery: Preliminary Results for Seven Tropical Countries**. Technical Note. Washington, DC: World Resources Institute, 2016. Available from: https://www.wri.org/research/mapping-tree-plantations-multispectral-imagery-preliminary-results-seven-tropical. Accessed on Jul. 19,2016.

RICHARDSON, J.J., MOSKAL, L.M. Uncertainty in urban forest canopy assessment: Lessons from Seattle, WA, USA. **Urban Forestry & Urban Greening**, vol. 13, pg. 152-157, 2014. Doi: https://doi.org/10.1016/j.ufug.2013.07.003.

SOUZA, C.M., Jr.; Z. SHIMBO, J.; ROSA, M.R.; PARENTE, L.L.; A. ALENCAR, A.; RUDORFF, B.F.T.; HASENACK, H.; MATSUMOTO, M.; G. FERREIRA, L.; SOUZA-FILHO, P.W.M. et al. Reconstructing Three Decades of Land Use and Land Cover Changes in Brazilian Biomes with Landsat Archive and Earth Engine. **Remote Sens**. 2020, v.12, 2735. DOI: https://doi.org/10.3390/rs12172735.

TRANSPARENT WORLD. **"Tree Plantations"**. Available from: http://data.globalforestwatch.org/datasets/

UCAR, Z.; BETTINGER, P.; MERRY, K.; SIRY, J.; BOWKER, J.M.; AKBULUT, R. A comparison of two sampling approaches for assessing the urban forest canopy cover from aerial photography. **Urban Forestry & Urban Greening**, v.16, p.221-230, 2016. Doi: https://doi.org/10.1016/j.ufug.2016.03.001.

USDA FOREST SERVICE. **I-Tree Canopy Technical Notes**. Available from: http://www.itreetools.org/canopy/resources/iTree_Canopy_Methodology.pdf>. Accessed on: Feb. 08, 2016.

VIBRANS, A.; MCROBERTS, R.E.; MOSER, P.; NICOLETTI, A.L. Using satellite image-based maps and ground inventory data to estimate the area of the remaining Atlantic Forest in the Brazilian state of Santa Catarina. **Remote Sensing of Environment**, v.130, p.87-95, 2013. Doi: https://doi.org/10.1016/j.rse.2012.10.023.

VIBRANS, A. **Inventário Florístico Florestal de Santa Catarina**: o que você deve saber sobre as florestas de Santa Catarina. Blumenau. FURB, 2015. 20 f.

VIBRANS, A.C.; NICOLETTI, A.L.; LIESENBERG, V.; REFOSCO, J.C.; KOHLER, L. P. de A.; BIZON, A.R.; LINGNER, D.V.; DAL BOSCO, F.; BUENO, M.M.; DA SILVA, M.S.; PESSATTI, T.B. MonitoraSC: um novo mapa de cobertura florestal e uso da terra de Santa Catarina. **Agropecuária Catarinense**, v.34, n.2, p.4248, 2021. DOI: https://doi.org/10.52945/rac.v34i2.1086.