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Comparison of sampling methods for description of floristic-structure in woody vegetation

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Abstract

The purpose of the present study was evaluation of the efficiency of the 'Fixed area', Strand, Prodan and Quadrat sampling methods to understand richness, diversity, floristic composition and horizontal structure of natural forest wood species. A census survey was carried out on a *cerradão* fragment, in which 27 fixed area plots were randomly established with dimensions of 20 × 20 meters. The center of each fixed area plot was considered a sampling point for the alternative methods of sampling, Prodan and Quadrat. For the Strand method, a line was established parallel to one side of the plot cutting it to the center. Richness and diversity of woody species in each method were evaluated by the rarefaction/extrapolation curves using the first three hill numbers. Finally, to characterize the horizontal structure, the Import Value Index percentage (IVI%) and the confidence interval of the basal area and number of individuals per hectare were calculated. The census survey registered a total of 82 species in the *cerradão* fragment, distributed among 59 genera and 33 botanical families. The study showed that the Fixed Area method was the best survey method regarding the richness, diversity and floristic composition. As for the horizontal structure of the forest, all methods differed, but the Fixed Area and Quadrat methods were the closest to the forestry survey census.

Keywords: Variable area, diversity, forestry census, sampling, *cerradão.*
Abbreviations: IVI%_Import Value Index Percentage, S_Strand method; P_Prodan method, PQ_Point Quadrant method; APA_environmental Protection area (*Área de Proteção Ambiental*), DBH_Diameter base hight, M_metres.

Introduction

The Cerrado is one of the biomes that are within the geographical limits of Brazil and represents about 23% of its territory (Sano et al., 2010). The phyto-physiognomies of Cerrado includes forest, savanna and pasture formations (Ribeiro and Walter, 2008). The forest formations represent 32% of the total area of the Cerrado Biome, in which the cerradão group is included (Sólorzano et al., 2012). Cerradão is a phytophysiognomy classified as a forest formation that develops on soils without the presence of water and interfluvial areas (Prado and Gibbs, 1993). The tree cover of *cerradão* forms a continuous canopy of 50% to 90%, which oscillates with the rainy season, whereas the canopy is at maximum in the rainy seasons. The average height of the trees can vary between 8 m and 15 m, where the light conditions favor the formation of very characteristic shrub and herbaceous strata (Ribeiro and Walter, 2008).

Obtaining qualitative and quantitative information of this vegetation is fundamentally important, especially for the evaluation of the forest community potential, whether for preservation, conservation or management purposes (Péllico Netto and Brena, 1997; Souza and Soares, 2013).

Forest inventory is the procedure adopted to obtain such information. It is usually carried out through sampling techniques, since performing it with a survey/census takes more time and faces greater costs. However, choosing the best technique or method of sampling to obtain quantitative and qualitative variables of vegetation with high precision and at the lowest possible cost and time has still been a great challenge for forestry science (Sanquetta et al., 2014; Campos and Leite, 2013), especially when the area to be inventoried (native or not) is extensive and there is not much time nor resources available, or when the area is difficult to access, hindering the use of traditional sampling methods.

Traditionally, the 'fixed area' method is the most used in forest inventories. It consists of the sampling of units of equal size and shape, performing the individuals testing according to the sample unit area (Péllico Netto and Brena, 1996). Although it presents numerous advantages, particularly in statistical validation, the employment of this method may be economically unattainable for some environmental agencies, companies and research centers. Thus, it is important to evaluate the efficiency of other sampling methods, aiming to reduce the time and cost of performing inventories without loss of precision (Santos et al., 2016).

Some less commonly used sampling methods in forest inventories such as Strand, Prodan and Point Quadrat, can be good alternatives to solve time and cost constraints when performing inventories, which ensure the statistical accuracy of the information generated (Moscovich et al., 1999; Farias et al., 2002; Téo et al., 2014; Oliveira et al., 2015). Nevertheless, few studies have considered the applicability of different sampling methods in relation to the forest census, the estimation of variables akin to floristic, and the phytosociological structure of wood vegetation in natural forest formations. Such information is essential to conduct the selection of sampling methods for forest inventories, which depend on the characteristics of the vegetation, the objectives to be achieved, the resources available, and the precision required in the sampling (Husch et al., 1982).

The purpose of this study was to evaluate the efficiency of the 'Fixed area', Strand, Prodan and Point Quadrat sampling methods to estimate the richness, diversity, floristic composition and horizontal structure of the vegetation in a *cerradão* fragment from the Lajeado State Park, located in Palmas, Tocantins. Two hypotheses were tested: (1) Richness, diversity and floristic composition are better represented by 'Fixed area' sampling than by variable area methods, which involve a smaller number of trees sampled; (2) Different sampling methods do not differ statistically from each other when used for the characterization of the horizontal structure of vegetation.

Results

Richness and diversity

The census registered a total of 82 species in the *cerradão* fragment, distributed among 59 genera and 33 botanical families. None of the sampling methods was able to represent the actual floristic richness present in the area, even applying the extrapolation of the bootstrap method (Table 1). From the four methods tested, the 'Fixed area' reached the closest values to the real ones.

Fig 1. shows the integrated rarefaction/extrapolation curves, representing the floristic richness (q=0), Shannon's floristic diversity (q=1) and Simpson's floristic diversity (q=2), from the *cerradão* wood vegetation inventoried through the census and the four sampling methods.

In Fig 1 (q=0), the richness recorded by the different sampling methods is equal to the one obtained by the census at the point where the sampling effort is met.

As for diversity, it is observed that in all the methods used, the curve of the 'Fixed area' represented the closest wood vegetation diversity to that of the census, followed by the Strand, Prodan and Point Quadrat methods. When q=1 (Shannon diversity), the census shows greater diversity, followed by Fixed area, Strand and Prodan, in which it presents no significant difference, and later Point Quadrat. When q=2 (Simpson diversity), there is a slight difference between the sampling methods; in decreasing order, census, Fixed area, Strand, Prodan and later Point Quadrat.

Table 2 shows the relation of families and species recorded in the census and in the inventories carried out by the different sampling methods. For each species, the number of trees per hectare was counted. The data presented in Table 2 also shows that, from the species recorded in the census, 13 were not sampled by any method and 23 species were submitted to the census and the four methods. It is possible to observe that all the species sampled by the variable area methods (S, P and PQ) are present in the fixed area sampling. As for families, only *Opiliaceae* was not sampled by the four sampling methods.

Compared to the census, the Fixed area method was the one that best described the order of importance of the species in the woody vegetation (Table 3). *Myrcia splendens* and *Emmotum nitens* were dominant in all types of surveys (census and sampling). Besides presenting higher density and basal area, these species presented a wide spatial distribution in the area, evaluated by the different sampling methods.

Floristic and structural characterization of the vegetation

The Fixed Area, Strand and Prodan methods were able to estimate the number of individuals per hectare more precisely, while the Fixed Area, Strand and Point Quadrat methods were able to better estimate the basal area per hctare (Table 4).

It is also observed that the Strand method presented the smallest equivalent area, and even with the smallest area sampled, the estimates of basal area and number of trees were higher than those found with the Prodan and Point Quadrat methods.

Discussion

In comparison to other methods, the Fixed Area presented better sampling of richness and floristic composition. However, when the sampling effort was met, the Fixed Area, Strand and Prodan methods did not differ in relation to the richness observed in the census. Even with the same number of sample units, the Fixed Area method has a greater sampling effort in relation to the number of individuals, and this has a close correlation with floristic richness (Dias, 2004). Therefore, to improve the floristic representation of an area, it is essential to sample a minimum amount of individuals or area (Magurran, 2004; Téo et al., 2014). Also, the Relevé method, described by Braun-Blanquet (Freitas and Magalhães, 2012), should be inventoried in approximately 1 ha.

The Fixed Area method presented a diversity of species (q=2) which was equal to the one obtained by the census, when the sampling effort was met by the number of individuals, statistically differing from the other methods. The methods of Strand, Prodan and Point Quadrat tend to sample fewer individuals and; thus, increase the number of low-density species; consequently, diversity indices that do not consider abundance (richness, q=0) nor present low weight (Shannon's diversity index, q=1). The difference in the species diversity between the methods is evidenced only in the indices that consider greater weight as the abundance of the species. Therefore, the methods of Strand, Prodan and Point Quadrat were not effective for sampling lower density species.

One of the characteristics of tropical forests is its high diversity due to the presence of many rare species, which result in less than 2 individuals per hectare (Magurran, 2004). In the Amazon biome, 1.4% of the estimated species represent half of the community's abundance, which are considered as the base of the wood vegetation and hyperdominant (Steege et al., 2013). For a more representative sampling of all the species located in the community, it is important to use methods with greater sample intensity, such as Fixed Area.

Operationally, the Fixed Area sampling method requires considerably more time for evaluation compared to the other evaluated variable area methods (Strand, Prodan and Point Quadrat). However, analysis of the sampling time of each method was not the object of this study. The increase of sampling effort is recommended when the Prodan and Point Quadrat sampling methods are chosen.

The alternative method is 'Strand' which presented accuracy to estimate parameters of the vegetation structure. However, the best methods that estimated the basal area and the number of individuals per hectare may vary according to vegetation type, sampling effort and sampling process. Santos et al. (2016) point out that it is critical to use alternative sampling methods in equine plantations, especially when there is an interest to study the horizontal structure of a forest. As an example, Moscovich et al., (1999) concluded that the best method to estimate these variables in an

Table 1. Number of species, genera and families recorded in the tree vegetation (DBH ≥ 5 cm) of a *cerradão* fragment located in the Lajeado State Park in Palmas, Tocantins obtained from the census survey and the sampling survey, considering four methods: Fixed Area, Strand, Prodan and Point Quadrat. The values in parentheses represent the richness estimated by the Bootstrap algorithm.

Richness	Census	Methods of Sampling			
		Fixed Area	Strand	Prodan	Point Quadrat
Species	82	69 (79)	45 (54)	35 (42)	27 (33)
Genera	59	51	35	28	22
Families	33	31	25	20	12

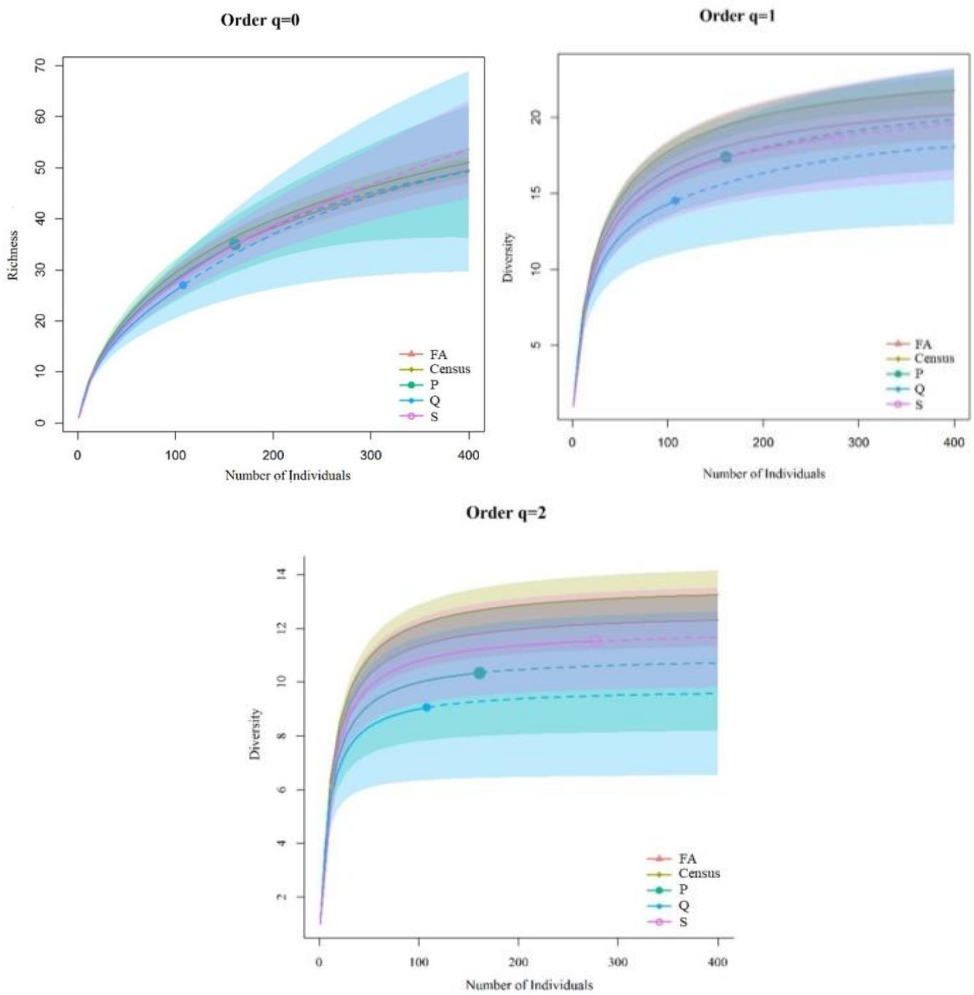

Fig 1. The continuous lines (rarefaction) and dotted lines (extrapolation) observed with 95% of confidence interval for three sampling curves (Hill numbers at q=0, 1 and 2), representing the sampling methods used in a *cerradão* area. The 95% of confidence intervals (the colored area near the lines) was obtained through the Bootstrap method. Fixed Area (FA), Strand (S), Prodan (P) and Point Quadrat (Q).

Table 2. Number of trees (DBH ≥ 5 cm) per hectare recorded by family and by species in a *cerradão* fragment located in the Lajeado State Park in Palmas, Tocantins, obtained from the census survey and the sampling survey, considering four methods: Fixed Area (FA), Strand (S), Prodan (P) and Point Quadrat (PQ).

Family	Species	Census	FA	S	P	PQ
Anacardiaceae	*Tapirira guianensis* Aubl.	78.3	42.6	15.3	7.0	4.7
	Tapirira obtusa (Benth.) J.D.Mitch.	14.9	5.6	-	-	0.5
	Thyrsodium spruceanum Benth.	0.5	-	-	-	-
Annonaceae	*Bocageopsis multiflora* (Mart.) R.E.Fr.	4.7	0.5	-	0.5	-
	Xylopia aromatica (Lam.) Mart.	95.0	51	10.7	3.3	2.4
Apocynaceae	*Aspidosperma macrocarpon* Mart.	2.8	1.4	-	-	-
	Aspidosperma subincanum Mart.	13.9	5.6	1.4	1.0	1.0
	Hancornia speciosa Gomes	2.8	1.9	0.5	0.5	0.5
	Himatanthus obovatus (Müll.Arg.) Woodson	0.5	-	-	-	-
	Himatanthus sucuubus (Spruce ex Müll.Arg.) Woodson	3.3	1.9	-	0.5	0.5
Araliaceae	*Schefflera vinosa* (Cham & Schltdl.) Frodin & Fiasch	0.5	-	-	-	-
Asteraceae	*Piptocarpha macropoda (DC.) Baker*	3.8	1.9	-	-	-
Burseraceae	*Protium heptaphyllum* (Aubl.) Marchand	6.1	3.8	1.0	-	-
	Tetragastris altissima (Aubl.) Swart	0.5	-	-	-	-
Caryocaraceae	*Caryocar coriaceum* Wittm.	23.7	12.5	1.9	2.4	2.4

Family	Species	Census	FA	S	P	PQ
Chrysobalanaceae	*Couepia grandiflora* (Mart. & Zucc.) Benth.	0.5	-	-	-	-
	Hirtella ciliata Mart. & Zucc.	1.0	0.5	0.5	-	-
	Hirtella glandulosa Spreng.	0.5	0.5	0.5	0.5	-
	Licania apetala (E. Mey.) Fritsch.	6.1	3.8	-	-	0.5
	Licania egleri Prance.	4.7	1.9	0.5	-	-
	Licania gardineri (Hook f.) Fritsch.	1.4	1.0	0.5	-	-
	Licania kunthiana Hook. f.	1.0	0.5	-	-	-
Clusiaceae	*Kielmeyera coriacea* Mart. & Zucc.	0.5	-	-	-	-
Connaraceae	*Connarus perrottetii* (DC.) Planch.	0.5	-	-	-	-
	Connarus suberosus Planch	5.6	1.4	-	-	-
	Rourea induta Planch	0.5	0.5	-	-	-
Dilleniaceae	*Davilla elliptica* A. St.-Hil.	2.8	1.0	0.5	-	-
Ebenaceae	*Diospyros hispida* Alph. D. C.	1.0	1.0	-	-	-
	Diospyros sericea Alph. D. C.	2.8	0.5	0.5	-	-
Erythroxylaceae	*Erythroxylum daphnites* Mart.	16.7	8.4	1.4	2.4	2.8
Euphorbiaceae	*Mabea fistulifera* Mart.	1.4	0.5	-	-	-
	Maprounea guianensis Aubl.	23.2	13.0	5.1	2.4	1
Fabaceae	*Bowdichia virgilioides* Kunth.	2.8	1.4	0.5	-	-
	Cenostigma macrophyllum Tul.	1.9	2.4	0.5	-	0.5
	Dalbergia densiflora Benth.	1.9	1.0	0.5	-	-
	Dalbergia miscolobium Benth.	1.9	0.5	0.5	-	-
	Dimorphandra gardineriana Tul.	1.9	1.0	0.5	0.5	-
	Hymenaea martiana Hayne.	0.5	-	-	-	-
	Hymenaea stigonocarpa Mart. ex Hayne.	1.4	1.0	0.5	1.0	0.5
	Hymenolobium petraeum Ducke.	0.5	0.5	-	-	-
	Inga alba (Sw.) Willd.	9.8	1.4	-	-	-
	Leptolobium dasycarpum Vogel.	1.0	-	-	-	-
	Parkia pendula (Willd.) Benth. ex Walp.	1.0	-	-	-	-
	Parkia platycephala Benth.	25	9.3	3.3	1.9	1.4
	Plathymenia reticulata Benth.	1.9	1.0	-	-	-
	Tachigali vulgaris L.G.Silva & H.C.Lima	33.4	20.4	7.9	1.4	0.5
	Vatairea macrocarpa (Benth.) Ducke.	1.9	0.5	-	-	-
Humiriaceae	*Sacoglottis guianensis* Benth.	12.1	4.7	0.5	-	-
Icacinaceae	*Emmotum nitens* (Benth.) Miers.	128.8	70.4	17.6	8.8	6.1
Lauraceae	*Mezilaurus itauba* (Meisn.) Taub. ex Mez.	33.8	13.0	3.3	0.5	0.5
	Ocotea pulchella (Nees & Mart.) Mez	0.5	-	-	-	-
Lythraceae	*Lafoensia pacari* A.St.-Hil.	0.5	0.5	-	-	-
	Physocalymma scaberrimum Pohl.	2.8	1.4	-	0.5	-
Malpighiaceae	*Byrsonima coccolobifolia* Kunth.	6.1	2.8	1.0	0.5	-
	Byrsonima laxiflora Griseb.	13.9	7.5	1.4	1.0	1.0
	Byrsonima pachyphylla A.Juss.	11.2	7.0	1.4	1.0	0.5
	Byrsonima sericea DC.	15.3	9.8	2.8	3.3	1.9
Malvaceae	*Eriotheca gracilipes* (K. Schum.) A. Rob.	2.8	1.4	-	0.5	-
	Eriotheca pubescens (Mart. & Zucc.) Schott. & Endl.	1.0	1.0	1.0	1.0	-
Melastomataceae	*Miconia albicans (Sw.) Triana*	106.1	52.4	4.7	4.7	3.3
	Miconia cuspidata Mart. ex Naudin.	19.5	8.4	1.4	1.0	0.5
	Miconia pepericarpa Mart. ex DC.	1.9	1.4	-	-	-
	Mouriri glazioviana Cogn.	0.5	0.5	-	0.5	-
	Mouriri gardneri Triana	1.0	-	-	-	-
Myristicaceae	*Virola sebifera* Aubl.	12.5	7.5	1.4	1.9	0.5
Myrtaceae	*Myrcia multiflora* (Lam.) DC.	1.4	1.0	0.5	0.5	0.5
	Myrcia splendens (Sw.) DC.	192.6	102.0	23.2	17.6	13.0
Ochnaceae	*Ouratea ovalis* (Pohl) Engl.	11.2	3.3	0.5	-	-
Opiliaceae	*Agonandra brasiliensis* Miers ex Benth. &. Hook. f.	0.5	-	-	-	-
Proteaceae	*Roupala montana* Aubl.	0.5	0.5	-	-	-
Rubiaceae	*Alibertia edulis* (Rich.) A. Rich. ex DC.	1.9	1.4	0.5	-	-
	Ferdinandusa elliptica Pohl. Pl. Bras.	6.5	2.8	1.4	0.5	-
Salicaceae	*Casearia arborea* (Rich.) Urb.	2.8	1.0	0.5	-	-
	Casearia grandiflora Camb.	1.0	1.0	0.5	-	-
Sapindaceae	*Matayba guianensis* Aubl.	2.4	1.0	-	-	-
Sapotaceae	*Pouteria ramiflora* (Mart.) Radlk.	13.5	5.1	0.5	0.5	0.5
Simaroubaceae	*Simarouba versicolor* A.St.-Hil.	4.2	1.0	1.0	-	-
Siparunaceae	*Siparuna guianensis* Aubl.	10.2	5.1	-	0.5	-
Vochysiaceae	*Qualea grandiflora* Mart.	12.5	7.9	0.5	0.5	-
	Qualea multiflora Mart.	1.0	0.5	-	-	-
	Qualea parviflora Mart.	97.7	49.1	8.4	5.1	3.3
	Vochysia gardneri Warm.	12.1	5.1	1.4	0.5	0.5

Table 3. Tree species (DBH ≥ 5 cm) with the highest IVI% recorded in a *cerradão* fragment located in the Lajeado State Park in Palmas, Tocantins, obtained from the census survey and sampling survey, considering four methods: Fixed Area, Strand, Prodan and Point Quadrat.

Species	Census	Fixed Area	Strand	Prodan	Point Quadrat
Myrcia splendens	12.39	(1º) 12.44	(2º) 13.39	(1º) 17.61	(1º)18.89
Emmotum nitens	10.14	(2º) 11.44	(1º) 16.09	(2º) 13.21	(2º) 16.04
Qualea parviflora	7.39	(3º) 7.59	(6º) 6.41	(5º) 5.91	(5º) 5.74
Xylopia aromatica	6.32	(4º) 6.81	(4º) 7.31	(7º) 3.98	(8º) 4.29
Tapirira guianensis	6.24	(5º) 6.46	(3º) 8.4	(3º) 8.38	(3º) 8.27
Miconia albicans	5.76	(6º) 5.74	(10º) 2.76	(6º) 4.82	(6º) 5.32
Parkia platycephala	4.28	(7º) 4.69	(7º) 5.48	(4º) 7.03	(4º) 7.087
Caryocar coriaceum	3.85	(9º) 3.92	(12º) 2.42	(8º) 3.79	(7º) 5.08
Tachigale vulgaris	3.71	(8º) 4.44	(5º) 6.58	(16º) 2.08	(18º) 1.21
Mezilaurus itauba	3.12	(10º) 2.47	(11º) 2.43	(11º) 2.63	(10º) 3.23
Total	63.20	66.00	71.27	69.44	75.15

Table 4. Values of basal area per hectare ($G.ha^{-1}$) and number of trees per hectare ($N.ha^{-1}$) and respective absolute sampling errors for each method according to the census.

Estimates	Census	Fixed Area	Strand	Prodan	Quadrantes
$N.ha^{-1}$	1147	1160	1240	1011	718
CI	-	108.21	192.21	252.90	339.51
$G.ha^{-1}$	16.12	16.44	14.70	10.68	17.82
CI	-	2.32	2.72	5.01	5.35
Área equivalente (ha)	2.16	1.08	0.14297	0.18602	0.15558

CI-Confidence Interval (95% of probability)

Araucaria Forest is the Strand method, while Druszcz et al. (2012) worked on *Pinus taeda* and verified that the Fixed Area and the Bitterlich method were far better in estimating the number of individuals per hectare and the basal area per hectare, respectively.

The Fixed Area method encompassed all the species sampled in the other methods. In addition, it sampled more individuals, despite the fact that the sampling points of the other variable area methods were located in the same locations, where the Fixed Area plots sampled.

Materials and methods

Description of the study area

The study was carried out on a 2.16-hectare *cerradão* fragment located between the South latitude parallels of 10º 10' 55'' and 10º 11' 20'' and between the West longitude meridians 48º 10' 50'' and 48º 10' 30'', which correspond to the Lajeado State Park, located in the central-west region of the State of Tocantins in the environmental protection area (APA) of *Serra do Lajeado*. The Park is situated at an altitude of 500 meters in flat and undulating relief. The climate is classified as *Aw*, markedly seasonal, with rains from December to February and dry winter from May to September. The average annual rainfall varies between 1,300 to 1,900 mm, and the average temperature is between 19ºC and 20ºC (Alvares et al., 2014).

The area under study is classified as dystrophic *cerradão* (Ratter et al., 1971), on well-drained soil. The predominant wood species in the areas are *Myrcia splendens*, *Emmotum nitens* and *Qualea parviflora*. The sub-forest is of the drained and open type. The height of the trees reaches about 22 meters, with top touching.

The maximum height found is higher than that of other dystrophic *cerradão* located in different regions of the country (Ratter et al., 1973; Ratter, 1987; Felfili et al., 2002; Silva, 2009; Camilotti et al., 2011), not exceeding 17 m.

Data collection

The census was performed on all trees with a DBH equal to or greater than 5 cm (measured at 1.30 m above the ground) from the *cerradão* fragment. Each tree was mapped (*X* and *Y* coordinates), and the DBH and total height variables were measured with the aid of a bevel gauge and hypsometric ruler, respectively.

The DBH of each tree was represented by the mean of diameters measured in two directions perpendicular to each other, since many *cerradão* tree trunks present irregularities. For trees with two or more trunks starting from a height of less than 1.30 m, and with DBH ≥ 5 cm, the DBH and the total height of each one were measured separately. All trees registered in the census were identified botanically, and at a family, genus and species level. The botanical material was collected in the field and was identified by specialists, based on the botanical classification system "Angiosperm Phylogeny Group IV - APG IV" (APG IV, 2016).

After the census, four sampling methods were tested in the area. These were the Fixed Area method and three of variable area: Prodan, Strand and Point Quadrat. Initially, the area of the *cerradão* was subdivided into plots of 20 m x 20 m. From the total plots, 27 of them (50% of the total) were randomly selected for sampling purposes. For the Fixed Area method, the data of all trees in each of the 27 plots (DBH, total height and botanical identification) were recorded. Subsequently, in the center of each plot, a sampling point was established for the application of the other variable area sampling methods: Prodan and Strand, as described in Péllico Netto and Brena (1997), and Point Quadrat, as described by Cottam et al. Curtis (1956). In the case of the Strand method, the center point was used to define the implantation site of the 15.7 metered sampling lines. Therefore, the sampling line was allocated in the center of the plot of 20 × 20 m, parallel to one side of the plot.

Data analysis

Cerradão tree flora was determined from the floristic and structural characterization of the vegetation. Regarding floristic, species richness and diversity were evaluated. Floristic richness, related to the number of species, genera and families, was counted both in the census survey and with each sampling method. During the implementation, the bootstrap algorithm (Santos, 2003) was also applied to the data, aiming to obtain the maximum species richness estimated in the area. The software used to process the algorithm data was the Estimates 5.0.

To determine the floristic diversity of the wood vegetation registered in the total area (census) and in the areas sampled through the different methods, the Diversity Profile was obtained using rarefaction according to Hill (1973). The comparison of floristic diversity recorded by each sampling method and in the census was done graphically. Considering that the sampling effort was different in each method, three integrated rarefaction/extrapolation curves were used, based on the first three Hill numbers as described by Chao et al. (2014): species richness (q=0), exponential of Shannon entropy or Shannon's diversity index (q=1), and the inverse Simpson concentration or Simpson's diversity index (q=2). The Diversity Profile obtained through rarefaction was calculated using program R, version 3.3.1 (R Development Core Team 2016) with the iNEXT package (Hsieh et al., 2015).

The horizontal structure of the vegetation registered in the census and in the sample surveys was evaluated considering the conventional phytosociological variables of the vegetation (Kent and Coker, 1992; Müeller-Dombois and Ellemberg, 1974): Import Value Index percentage (IVI%), sum of density, dominance and relative frequency for each species.

For the calculation of the density, any tree with more than one trunk with a DBH $\geq$ 5 cm at a height of less than 1.30 m was counted as a single individual. However, for the calculation of the basal area, the sectional areas of the respective trunks were summed to represent them as a whole. In order to evaluate the capacity of the different sampling methods to estimate the basal area and the number of trees per hectare, the sampling error for each of the four methods was calculated considering a significance level of 5%.

Conclusion

The 'Fixed area' sampling method can be efficiently used to estimate the richness and diversity, and to describes the floristic composition of the woody vegetation. Methods that present less sampling effort, such as Strand, Prodan and Point Quadrat, should introduce high density sampling points, or complement floristic sampling with other methods (e.g., random walk). Regarding the richness observed in the same number of individuals sampled, the methods of 'Fixed area', Strand, Prodan, and Point Quadrat are equal to the census. However, the use of the Strand, Prodan and Point Quadrat may not be efficient when the objective of the work is to sample low-density individuals. All methods interfere in the horizontal structure of the forest; however, the 'Fixed area' and Quadrants methods are the ones closest to the forest census. Therefore, these methods are recommended to conduct studies that evaluate these variables.

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