MODELING AND PREDICTION OF VOLUME AND AEREAL BIOMASS OF THE TREE VEGETATION IN A *CERRADÃO* AREA OF CENTRAL BRAZIL

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SUMMARY

This research aims to adjust and select models to quantify the volume of the tree vegetation and its total and compartmental biomass, in a 'cerradão' (forest savanna), in the municipality of Palmas, Tocantins, Brazil. A forestry inventory was performed in an area of 10.15ha, divided in sampling plots measuring 400m^2, in which all living and dead standing trees ≥5cm DBH were sampled and identified, with a 20% error margin. The trees were cubed using the Smalian method and 84 of them were weighted. After obtaining the green mass by compartment, samples were removed in order to estimate the dry biomass. Mathematical models were adjusted to estimate total volume/biomass per unit area as well as by compartment. The Schumacher and Hall model was chosen. After processing, the inventory error was within the admissible margin. Volume and total stoked biomass by hectare were 126.71m^3·ha^{-1} and 61.67Mg·ha^{-1}. For the bole and crown compartments the values were 79.23 and 47.17m^3·ha^{-1} for volume and 29.70 and 31.98Mg·ha^{-1} for biomass. Dead trees summed 6.70% of the volume and 7.00% of the biomass, while leaves contributed with 7.3% of the total biomass. Bark summed 11.50% of the volume and 21.00% of the biomass. Volume and biomass stocks on the studied biome, when compared to others types of 'cerradões', are higher than those found on savannan formations.

Introduction

The loss of vegetal cover in most tropical ecosystems has been one of the major global concerns in the past decades, particularly due to the important role they play in the global carbon cycle (Djomo *et al*., 2011). One of these ecosystems is the brazilian savanna, which is still considered one of the richest and most diverse savannas (Mendonça *et al*., 2008).

Among the forest formations of the savanna, there is the 'cerradão' (forest savanna), that is usually associated with areas of interfluve, well-drained land and deep soils (Ribeiro and Walter, 2008). In Brazil, the vast majority of the studies carried out in areas of 'cerradão' focus on the characterization of its flora (composition, richness and diversity) and vegetation structure. Studies related to the production of this phytophysiognomy ('cerradão'), in terms of wood volume, biomass and carbon stocks, are rare. Information regarding stocks of volume, biomass and carbon on native vegetation of different characteristics of the savanna biome is still scant, considering the importance of such data to support vegetation management aiming to its sustainable use and conservation, as well as for damaged environments restoration.

According to Rezende *et al.* (2006), such lack information relates to the diversity and variety among trees of the same species, and the variations on stem and crown shapes of the trees of said biome. In general, such vegetation characteristics meke necessary a large amount of tree samples in order to estimate biome's vegetation stocks in volume and biomass and, consequently, the costs and time to obtain the data are high.

The stock in logging volume of a forest can the determined or estimated from the real volume of trees individually. Determining tree's volume can be done by cubing, which consists in measuring diameters, equidistant or not, through the trunk. The measurement can be carried out in analytical (formulas) or graphic (outlining trunk's longitudinal profile) form; by water displacement, using the xylometer method; or by tree weighting (Machado e Figueiredo Filho, 2006; Soares *et al*., 2006). Of all proceedings used to determine volume, cubing is the most commonly used on forestry inventories.

Another important variable is the biomass, defined by Soares *et al*. (2006) as the

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MODELAJE Y PREDICCIÓN DEL VOLUMEN Y BIOMASA AÉREA DE LA VEGETACIÓN ARBÓREA EN UN ÁREA DE *CERRADÃO* DEL CENTRO DE BRASIL

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RESUMEN

El objetivo de la investigación fue ajustar y seleccionar modelos para cuantificar el volumen y la biomasa total y por compartimientos, en la vegetación arbórea en 'cerradão' (sabana forestal) en el municipio de Palmas, Tocantins, Brasil. Se realizó un inventario forestal en un área de 10,15ha, mediante un muestreo sistemático con parcelas de 400m², donde fueron muestreados e identificados todos los árboles en pie vivos y muertos con DAP≥5cm, con un error admisible del 20%. Fueron cubicados 84 árboles por el método Smalian y luego pesados. Después de obtener la masa verde por compartimientos se tomaron muestras del material a fin de obtener la biomasa seca. Para estimar el total de volumen/biomasa por unidad de área y por compartimientos, se realizó un ajuste de los modelos matemáticos. Se seleccionó el modelo de Schumacher y Hall. Después de realizar el inventario, el error estuvo dentro del valor admitido. El volumen y la biomasa total aérea almacenados por hectárea fueron 126,71m³·ha^{-1} y 61,67Mg·ha^{-1}, respectivamente. Para los compartimientos fuste y copa, los valores para el volumen fueron 79,23 y 47,17m³·ha^{-1} y para la biomasa 29,7 y 31,98Mg·ha^{-1}. Los árboles muertos contribuyeron con 6,70% del volumen y 7% de la biomasa; las hojas con el 7,30% de la biomasa total. La corteza contribuyó con 11,5% del volumen y 21% de la biomasa. El stock de volumen y biomasa encontrado en el área de estudio, comparado con otros 'cerradões' y diferentes tipos de vegetación de cerrado, es más alto que los encontrados en las formaciones de sabana.

MODELAGEM E PREDIÇÃO DO VOLUME E BIOMASSA AÉREA DA VEGETAÇÃO ARBÓREA EM ÁREA DE CERRADÃO NO BRASIL CENTRAL

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RESUMO

Objetivou-se ajustar e selecionar modelos para quantificar o volume e a biomassa total e por compartimento na vegetação arbórea em um cerradão, no Município de Palmas, Tocantins, Brasil. Foi realizado um inventário florestal em área de 10,15ha, utilizando amostragem sistemática com parcelas de 400m², onde foram amostradas e identificadas todas as árvores vivas e mortas em pé, com DAP≥5cm para um erro admissível de 20%. Foram cubadas pelo método de Smalian e posteriormente pesadas 84 árvores. Obtido a massa verde por compartimentos, foram retiradas amostras do material visando à obtenção da biomassa seca. Para a estimativa do volume/biomassa total, e por compartimento por unidade de área ajustou modelos matemáticos. O modelo de Schumacher e Hall foi o selecionado. Quando processado o erro do inventário ficou dentro do admitido. A quantidade de volume e biomassa total aéreo estocado por hectares foram 126,71m³·ha^{-1} e 61,67Mg·ha^{-1}. Quando analisados pelos compartimentos fuste e copa, estes valores para o volume foi 79,23 e 47,17m³·ha^{-1} e 29,70 e 31,98Mg·ha^{-1} para a biomassa. As árvores mortas contribuíram com 6,7% do volume e 7% da biomassa, as folhas com 7,30% da biomassa total. As cascas contribuem com 11,50% do volume e 21,00 % da biomassa. O estoque em volume e biomassa no cerradão estudado, quando comparado a outros cerradões e distintos tipos de vegetação do cerrado, encontra-se superior ao encontrado nas formações savânicas.

organic matter produced by area unit, and might be expressed as dry matter mass. According to Sanquetta and Balbinot (2004), forest biomass might be the total mass existing in the forest or its tree fraction.

The biomass stock and the volume can be determined or estimated. The volume determination is done by weighting the tree, and the estimation can be obtained from a mathematical relation, such as ratio or regression of data from forest inventories or remote sensing. The methods applied to obtain biomass estimates in forest areas are mostly based, on data from forest inventories, applying regression equations that permit to estimate biomass from diameter and height data (Silveira, 2010).

Once the equations are determined to predict volume and biomass of a forest, the relative improbabilities regarding the estimates are analyzed only on the forest inventory sampling. However, the main error source on volume and biomass estimates in tropical forests is due to equation selection (Vieira *et al.*, 2008).

The goal of the present study is to adjust and select models to quantify true volume and biomass by compartment and to estimate them on a 'cerradão' fragment.

Material and Methods

The study was carried out in a 'cerradão' covering 12.15ha in the municipality of Palmas, Tocantins State, Brazil, located between 10º10'55'' and 10º11' 20''S and between 48º10'50'' and 48º10'30''W. According to Embrapa (2011), the local soil is classified as Dark Red Oxisoil, non-hydromorphic with an oxisoil B-horizon. It presents plain and wavy relief, and the climate, according to the Koppen and Geiger (1928) classification is C2wA'a, with annual rainfall of 1700mm.

The studied dry soil is characterized as distrophic (Ratter *et al.*, 1973). There are 1.228 árvores/ha, including standing trees, dead or alive, with DBH≥5cm, and the base area measures 17,34m²·ha^{-1}. The trees are distributed in 82 species, 60 genders and 34 families. The predominating families are Fabaceae, Chrysobalanaceae and Vochysiaceae, and species are *Myrcia splendens*, *Emmotum nitens* and *Qualea parviflora* in an open and drained lower story, characteristics found in other 'cerradões' in Brazil (Ratter *et al*.,1973; Camilotti *et al*., 2011).

To develop the inventory, the fixed area method, and the sampling process adopted to estimate volume and biomass was systemic (Péllico Netto e Brena, 1997). Using GPSMAP 62S, 54 plots measuring 400m² (20x20m) each, 40m distant from each other and summing 2.16ha were sampled. In each plot, standing living or dead trees were sampled and identified, with DBH (at 1,30m height) ≥5cm. The diameters were measured using a caliper and total height (Ht) and bole (Hf) measuring was performed using a telescopic rule.

To develop the equations, the trees measured on the forest inventory were distributed in diameter classes, with a 5cm amplitude, as suggested in other studies (Marimon-Junior and Haridasan, 2005; Camilotti *et al*., 2011). Summing 11 classes, they were cubed, weighted and sampled, representing 3% of the specimens per class on each of the different compartments (bole and crown), and totalizing 84 trees of distinct species. The trees were cut down and bole, branches and leaves were separated.

To determine the volume, the cubing was performed on compartment sections, due to the naturally uneven form of the stems, and the Smalian formula was adopted (Machado and Figueiredo Filho, 2006). The total volume of trees was obtained from summing bole and branches sections, and crown volume.

In order to obtain the biomass, after the rigorous cubing, the trees were selected and its different compartments (foliage, branches, bole and bark) weighted. The fresh weight of each compartment for each tree was obtained with an electronic balance with a maximum capacity of 300kg and 0,05kg sensibility. Sequentially, samples from different compartments samples were separates, aiming to obtain dry biomass from the dry mass/humid mass relation. For the bole, tree logging samples of 5cm thickness were collected fromthe base, the middle and the top of the bole. The same procedure was followed with the branches, but the samples were taken from each three selected branches: thick (≥10cm), medium (≥3cm) and thin (<3cm).

As for the leaf compartments, samples weighting 300g were composed of leaves from the bottom, medium and top of the crown, and were dried in a greenhouse. After sample separation, leaves were placed in plastic bags to avoid water loss. The samples were weighted using an analytic balance with a 0.01g sensibility, and then they were stocked for dry weight determination.

The samples were taken to the Logging Technology Laboratory, Universdade de Brasília, and placed in a greenhouse to dry at 103 ±2ºC, while leaves were dried at 70 ±2ºC, until obtaining the constant mass (1% variation) (Smith, 1954; Rufini *et al*., 2010). After drying was completed, the samples were weighted again to obtain their respective dry weights. With the dry and humid mass values of each sample, a relation coefficient C_R was obtained for every sampled specie, and it was possible to estimate the dry biomass from the product of this coefficient and the green biomass obtained (Soares *et al*., 2006). The relation coefficient is given by $C_R = M_0\%/M_u$, where M_U: weight of fresh sample (g or kg) and $M_0\%$: weight of dry sample (g or kg).

The mathematical models The mathematical models, linear or non-linear (Scolforo *et al*., 2008), are shown in Table I. They were adjusted in order to estimate stocks in volume and biomass of the trees, as suggested by Scolforo and Thiersch (2004). To choose the best equation, the criteria adopted was based on traditional patterns for verifying adjustment quality: the adjusted determination coefficient ($R^2_{adjusted}$), the percentage estimate error pattern ($S_{yx\%}$) and the residual graphic analysis (Drapper and Smith, 1981).

After selecting the equations, a validation test was performed; to do it, 19 trees that were not considered on the equation adjustment were used and the t test for paired data was selected (Silveira *et al*., 2009). With the equations selected and validated, the stocks were estimated in volume and biomass, sampled in the 54 plots of the forest inventory, as well as the stocks for each variable per hectare.

Results and Discussion

Table II presents results from models adjusted for volume, total biomass and bole variables, and their respective precision measurement. All model adjustements led to significance (p<0.05). It is observed that the determination coefficient ($R^2_{adjusted}$) for the total volume variable and the bole variable varied from 0.85 to 0.99. Authors like Scolforo *et al*. (2008), Colpini *et al*.

TABLE I
MATHEMATICAL MODELS TO BE ADJUSTED FOR VOLUME AND BIOMASS ESTIMATES

Author	Model
Spurr (1952)	$Y= \beta_0 + \beta_1 Dhb^2 \cdot Ht + \varepsilon$
Schumacher and Hall (1933)	$Y= \beta_0 Dhb^{\beta 1} \cdot Ht^{\beta 2} \cdot \varepsilon$
Husch (1963)	$Y= \beta_0 Dhb^{\beta 1} \cdot \varepsilon$

Y: volume or biomass, Ht: total height (m), Dhb: diameter at breast height (cm), β': coefficient to be adjusted, ε: error associated to the model.

TABLE II
PARAMETERS AND PRECISION MEASURING ESTIMATES FOR TOTAL VOLUME AND BIOMASS, AND BOLE, FOR TREES WITH Dhb≥5cm, IN A 'CERRADÃO' AREA

Author	Model	$R^2_{adjusted}$	$S_{yxm}{}^3$	$S_{yx\%}$
Spurr (1952)	$VTcc= 0.000609 + 0.00005121 \cdot Dhb^2 \cdot Ht$	0.98	0.035	23.15
	$Vfcc= 0.012289 + 0.0000273 \cdot Dhb \cdot Ht$	0.93	0.047	50.28
Schumacher and Hall (1933)	$VTcc= 0.000085 \cdot Dhb^{2.122270} \cdot Ht^{0.666217}$	0.99	0.023	15.01
	$Vfcc= 0.0001063 \cdot Dhb^{1.79116} \cdot Ht^{0.792509}$	0.96	0.020	21.45
Husch (1963)	$VTcc= 0.00029167 \cdot Dbh^{2.30125}$	0.97	0.051	33.13
	$VFcc= 0.00038316 \cdot Dhb^{2.05326}$	0.90	0.054	57.88
	Biomass			
Spurr (1952)	$BTs= 0.949568605 + 0.02777641 \cdot Dbh^2 \cdot Ht$	0.97	32.74	37.74
	$BFs= 8.092816617 + 0.00921173 \cdot Dhb \cdot Ht$	0.90	21.11	57.88
Schumacher and Hall (1933)	$BTs= 0.0123307 \cdot Dhb^{1.79393} \cdot Ht^{1.54701}$	0.97	25.52	27.96
	$Bfsd= 0.0208857 \cdot Dbh^{1.17985} \cdot Ht^{1.39106}$	0.96	18.55	44.96
Husch (1963)	$BTs= 0.215502 \times Dhb^{2.20774}$	0.88	48.25	52.60
	$Bfs= 0.212952 + Dhb^{1.9193}$	0.81	26.55	64.05

VTcc: total volume considering the bark; VFcc: bole volume considering the bark; BTs: total dry biomass; BFs: bole dry biomass; Ht: total height; Dhb: diameter at breast height

(2009) and Rufini *et al.* (2010) also found similar results while working with native vegetation involving volumetric equations, and found elevated values for the $R^2_{adjusted}$ as well.

Regarding the error margin of the estimate ($S_{yx\%}$), it was observed that the values vary from 15,01% to 65,01%. Scolforo *et al.* (2008), while studding the 'cerradão' area in different regions of Minas Gerais. Brazil. found values varying between 18% and 128%, and Rocha (2011), working in a seasonal deciduous forest in Goias, Brazil, where vegetation has similar characteristics to the 'cerradão', found values of 28% and 272%. It was verified that in order to estimate total volume and bole volume, the models presented satisfactory characteristics, except the Husch model in the case of the bole volume. However, the best statistics to obtain total volume and bole are from the Schumacher and Hall model.

Regarding the biomass characteristics, it is noted that the determination coefficient (R^2) varied from 81.91% to 97.20%. Other works also found similar R^2 values (Vieira *et al.*, 2008; Rocha, 2011). The $S_{yx\%}$ varied from 27.96% to 64.05%, and the error was larger than that registered in the volume equations, probably due to trees variety. Scolforo *et al.*, (2008), studying distinct 'cerradão' areas in Minas Gerais, found $S_{yx\%}$ values varying from 16 to 49% for total biomass equations. However, the adjusted equations for total biomass and bole biomass estimates have the same volume and the best statistics were obtained using the Schumacher and Hall model.

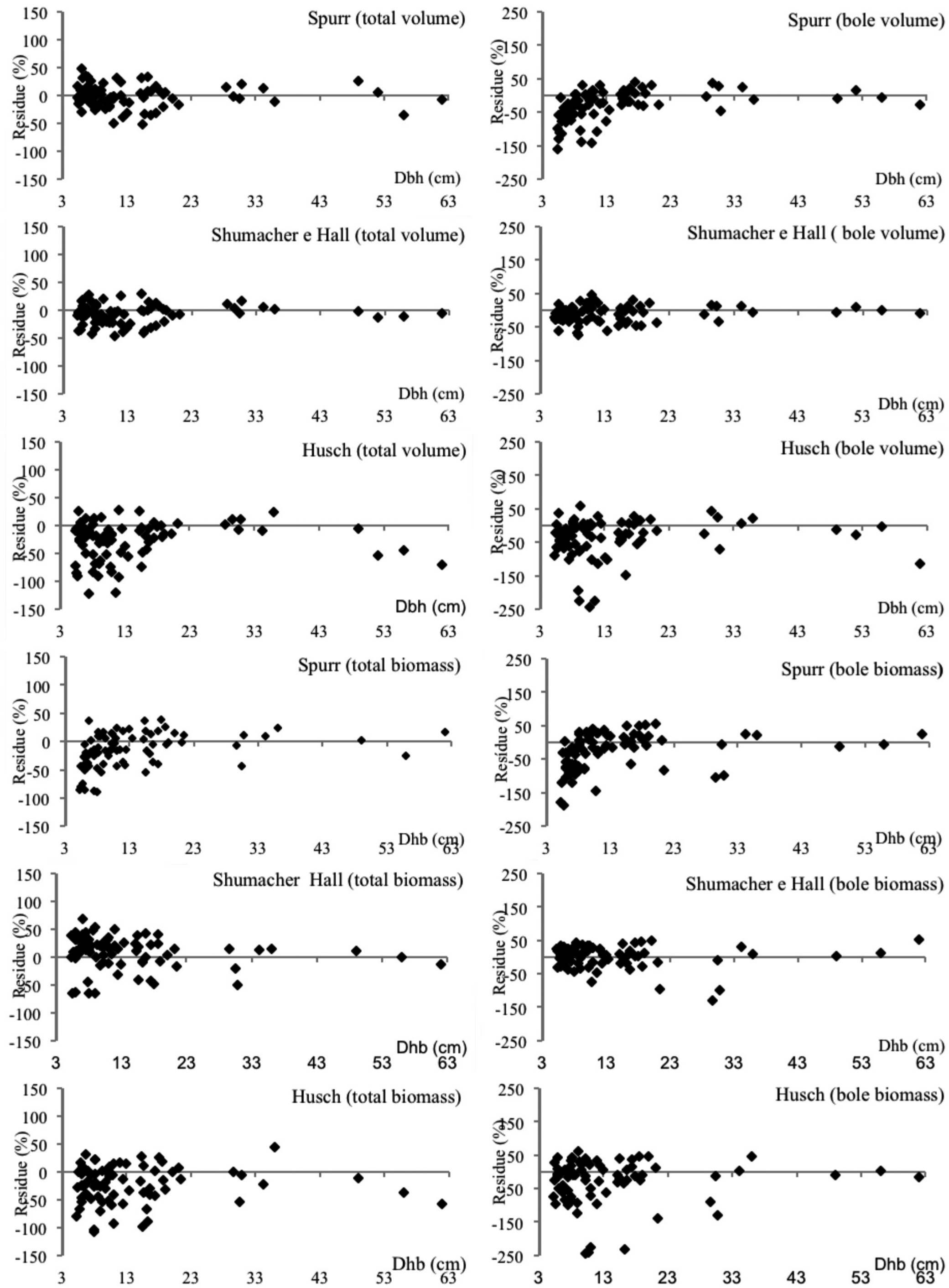

Figure 1. Total volume, total biomass and bole biomass resulting from the equations adjusted for trees with Dhb≥5cm, in a 'cerradão' area.

The residual distribution pattern also varied between the models tested (Figure 1), following the same behavior of the previous statistics. It can be seen that the worse residual distribution are found on the Husch and Spurr model, while the Schumacher and Hall model presented better results for residual distribution, without any tendency in the estimates for the volume and biomass variables (total and bole).

By comparing the precision of the models it is evident that the Schumacher and Hall model exceled the others in estimating the volume and biomass variables. The model superiority had been found previously in other studies performed on the 'cerradão' region (Scolforo *et al.* 2008) and in different native forests (Colpini *et al.* 2009). The validation test was applied and statistic differences between volume and biomass were not significant regarding what was observed and the adjusted equations, at a 95% probability level, which proves the reliability of the estimates generated by the equations.

Tree crown volume and biomass were obtained from the difference between the estimated values for volume, total biomass and bole biomass. This strategy avoids inconsistence on the results. Sequentially, values for volume and biomass (total and bole) per plot were obtained individually for every tree by the use of the selected equations.

Logging volume analysis

It is observed on Table III that the bole volume of smaller trees was higher than the crown volume. When the tree grows and enters the larger diameter classes, such relation reverses; therefore, trees with greater diameter present greater crown volume. The logging volume percentage on 'cerradão' trees is greater on the bole (56%) than on the crown (44%). Such result corroborates what was observed by Scolforo *et al.* (2008), who stated that the bole volume varied from 55 to 65%, upon studying 'cerradãos' in Minas Gerais.

Dry biomass analysis

Table IV shows the values estimated for total, bole and crown biomass according to diameter class. It can be observed that the greater percentage (>50%) is found in boles from trees of the lower diameter class, and the greater the diameter class, this percentage is reduced, becoming stable between 40 and 43%. However, the average 'cerradão' tree concentrated more biomass on the crown (52%) than on the bole (48%). The greater concentration of biomass might be explained by the inclusion of leaves, which represented during the studied period 7.3% of the total biomass. The leaves percentage changes, depending on the season, since the 'cerradão' presents deciduous characteristics.

From the biomass values by diameter class, it was possible to state that in the studied 'cerradão', trees beloging to smaller diameter classes tend to present a greater biomass amount on the bark than trees on higher classes. This elevated bark proportion, especially on trees with smaller diameter could be due a survival strategy. Besides the hydric deficit and high temperatures, the 'cerradão' plants suffer disturbances caused by fire, whether caused by human action or not, and the thick layers of barks that can resist or minimize the damage caused by the flames, mostly during the initial years of life or on smaller species.

Stocks estimates in volume and biomass per unit area

The stocked volumes and biomass, for standing trees with Dhb ≥ 5 cm, dead or alive, is shown on Table V. It is noted that the 'cerradão' presents an average total volume, considering the bark, estimated in 126.71 ±9.82$m^3 \cdot ha^{-1}$. Around 62% of this volume is in the bole and 38% in the crown, and ~11,5% of this volume belongs to the bark.

Studies regarding the volume stoked in the crown and bole of trees and about bark percentage of the total volume indicate differences among the biomes, between different regions on the same biome and among individuals of the same specie (Vieilledent *et al.*, 2010). On the chaparral biome, for example, Paula *et al.* (1993), while studying a riparian forest, estimated the volume of specimens with Dbh≥5cm to be 170.44$m^3 \cdot ha^{-1}$, where tree trunks represented 87% of the volume, and the branches 13%. Another study performed by

TABLE III
AVERAGE VOLUME BY DIAMETER CLASS WITH Dhb≥5cm, IN 'CERRADÃO' AREA

Class Dhb (cm)	Total volume (m^3)	Bole volume (m^3)	% Bole	Crown volume	% Crown
5⊣10	0.0233	0.0184	79	0.0053	21
10⊣15	0.0602	0.0395	66	0.0206	34
15⊣20	0.1780	0.1163	65	0.0617	35
20⊣25	0.3148	0.1920	61	0.1227	39
25⊣30	0.8001	0.4800	60	0.3200	40
30⊣35	0.8254	0.4682	57	0.3571	43
35⊣40	1.4708	0.7680	52	0.7028	48
40⊣45	1.6889	0.8444	50	0.8444	50
45⊣50	2.0250	0.9517	47	1.0730	53
50⊣55	2.1252	0.9563	45	1.1688	55
55⊣60	2.1355	0.9609	45	1.1745	55
≥ 60	2.1487	0.9669	45	1.1818	55
Average	-	-	56		44

TABLA IV
AVERAGE STOCK AND DRY BIOMASS PERCENTAGE PER TREE DIAMETER CLASS WITH Dhb≥5cm, IN 'CERRADÃO' AREA

Class Dhb (cm)	Total biomass (kg)	Bole biomass (kg)	% Bole	Crown biomass (kg)	% Crown
5⊣10	15.80	9.10	58	6.70	42
10⊣15	41.68	24.03	58	17.65	42
15⊣20	103.45	58.10	56	45.35	44
20⊣25	181.44	88.05	49	93.39	51
25⊣30	362.47	175.92	49	186.55	51
30⊣35	378.56	179.68	47	98.88	53
35⊣40	1071.65	461.33	43	610.32	57
40⊣45	1046.69	450.75	43	595.94	57
45⊣50	1075.12	449.25	42	625.87	58
50⊣55	1082.01	471.25	44	610.76	56
55⊣60	1080.10	466.23	43	613.87	57
≥ 60	1070.12	462.23	43	607.89	57
Average	-	-	48		52

TABLE V
PARAMETER ESTIMATORS FOR THE VARIABLES VOLUME ($m^3 \cdot ha^{-1}$) AND DRY BIOMASS ($Mg \cdot ha^{-1}$) OF TREES (Dhb≥5cm) SAMPLED ON A 'CERRADÃO' AREA

Variable	Area	Average	Error %	Confidence interval*
Total volume	hectare	126.7147	7.75	$116.8943 \leq \overline{X} \leq 136.5351$
Bole volume	hectare	79.2348	8.20	$72.7375 \leq \overline{X} \leq 85.7320$
Crown volume	hectare	47.1464	10.05	$42.5916 \leq \overline{X} \leq 52.0957$
Total biomass	hectare	61.67	8.80	$56.73 \leq \overline{X} \leq 66.60$
Bole biomass	hectare	29.29	8.20	$27.53 \leq \overline{X} \leq 32.13$
Crown biomass	hectare	31.98	12.20	$28.08 \leq \overline{X} \leq 35.88$

* Probability level 95%.

Paula *et al.* (1998), in a chaparral area in Maranhao, Brazil, estimated a total volume of 40.50m^3·ha^{-1} for specimens with Dbh≥5cm; of this volume, ~66% was stocked in trunks and 34% in branches. In a study performed in 'cerradão' areas in Minas Gerais (Morais *et al.*, 2013) the proportion obtained was that ~40% of the logging material could be found in the bole and 60% in the crown. The authors reported an average volume of 117.00m^3·ha^{-1} for the region. It is observed that the relations between bole and crown volumes found by these researchers corroborate the results presented on this study.

Rufini *et al.* (2010), while studying 'cerradão' vegetation in Minas Gerais, in tree regions on the São Francisco River, verified that from 48.3 to 54.9% of the tree total volume is stocked on the bole. Besides, the bark percentage relation to the total tree volume varied from 10% to 21.9%.

The average total biomass stoked per hectare, considering standing trees, dead or alive, with Dbh≥5cm, was estimated in 61.67 ±5.43Mg. However, 7.30% of this biomass is from the leaves and, therefore, the total biomass value can increase or decrease according to some species conditions in the 'cerradão'. Besides, the average contribution of the bark on the total production of dry biomass is around 21%, but when analyzing each compartment separately, it was found that 24% of the crown biomass corresponds to bark and the bole is 17%; in other words, the greater percentage is stoked on the crown.

It is important to emphasize that dead trees are important part of the volume production (6,70%) and biomass (7.00%) of the 'cerradão'. Sanquetta *et al.* (2002) performed a study in a Chilean forest and estimated the biomass stock in 558.30Mg·ha^{-1}. According to these authors, the dead trees contributed to 5% of the total biomass. Amaro *et al.* (2013) estimated as 227Mg·ha^{-1} the logging biomass stock in a seasonal forest located in Minas Gerais and verified that the dead trees contributed to 3.50% of the biomass total value.

Figure 2 presents the distribution of the total volume (m^3·ha^{-1}) and total biomass (kg·ha^{-1}), per diameter class, of the 'cerradão' tree community, considering the contribution of each tree compartment, the bole and the crown. It can be observed that the greater productions in volume and biomass are concentrated on the tree population with diameter from 10 to 25cm, equal to what was observed for the entire tree community of the 'cerradão'. The greater stocks in volume and dry biomass of the trees that belong to different diameter classes are concentrated, in great part, respectively, on the bole and on the crown.

Figure 3 shows the relation of the variables volume, dry biomass and number of trees per hectare to the diameter classes. It can be noted that the first diameter class (5-10cm) more than 50% is concentrated on the tree amount on the 'cerradão', while there is no correspondence with production, either in volume and dry biomass. The results show that the stocked production in volume and dry biomass stocked in the first diameter class represents ~12% of the stocked total.

It is highlighted that, the third diameter class (Figure 3) represents less than 13% of the number of trees per per hectare, but its population is responsible for the largest stocks in volume and biomass. Therefore, is can be asserted that, even with lower densities, the greater diameter classes concentrate, proportionally, greater productions in volume and biomass.

Conclusions

The equations obtained with the Schumacher and Hall model to estimate volume and biomass (total and bole) presented better statistics, which makes it the most appropriate model to estimate volume and biomass in 'cerradão' areas in Tocantins, Brazil.

The volume and total stoked biomass by hectare were 126.71m^3·ha^{-1} and 61.67Mg·ha^{-1}. When analyzed by bole and crown the values were 79.23 and 47.17m^3·ha^{-1} for volume, and 29.70 and 31.98Mg·ha^{-1} for biomass.

The standing dead trees contribute 6.70% of the volume and 7.00% of the dry biomass. From the total volume stocked per hectare, ~60% is in the bole and 40% in the crown, while ~48% of the total dry biomass stocks are concentrated in the

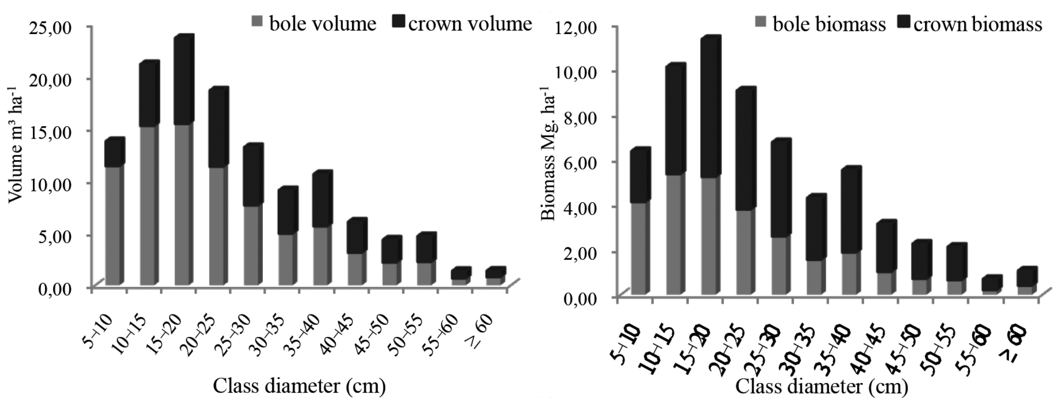

Figure 2. Tree community production regarding volume (m^3·ha^{-1}) and dry biomass (Mg·ha^{-1}) per diameter class, in a 'cerradão' area.

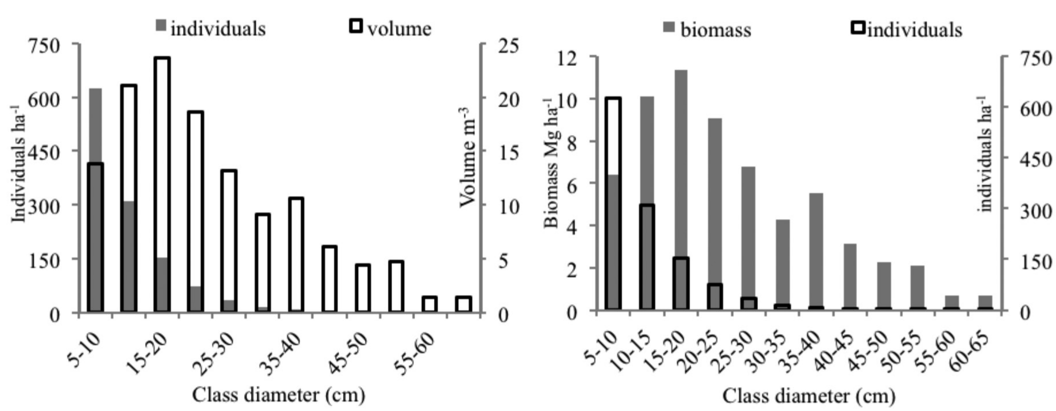

Figure 3. Distribution of volume (m^3·ha^{-1}), dry biomass (Mg·ha^{-1}) and number of trees per Dhb class, in a 'cerradão' area.

bole and 52% in the crown. The leaves sum ~7,3% of the area total biomass. Barks contributes 11.5% of the total volume and 21% of the total biomass. In addition, the biomass percentage is greater in the crown (24%) than in the bole (17%).

The volume and biomass stock in the studied 'cerradão' area, when compared to other areas with different types of vegetation, is superior to what is found on savanna formations.

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