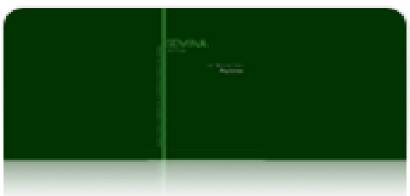


Semina: Ciências Agrárias

ISSN: 1676-546X

semina.agrarias@uel.br

Universidade Estadual de Londrina

Brasil

Pereira Miguel, Eder; Rezende, Alba Valéria; Assis Leal, Fabrício; Trondoli Matricardi, Eraldo Aparecido; Imana Ensinas, José Marcelo; Nunes Miranda, João Filipe

Floristic, structural, and allometric equations to estimate arboreal volume and biomass in a cerradão site

Semina: Ciências Agrárias, vol. 38, núm. 4, julio-agosto, 2017, pp. 1691-1702

Universidade Estadual de Londrina

Londrina, Brasil

DOI: 10.5433/1679-0359.2017v38n4p1691

Floristic, structural, and allometric equations to estimate arboreal volume and biomass in a cerradão site

Floristica, estrutura e equações alométricas na estimativa de volume e biomassa em uma área de cerradão

Eder Pereira Miguel[1*]; Alba Valéria Rezende[1];
Fabrício Assis Leal[2]; Eraldo Aparecido Trondoli Matricardi[1];
José Marcelo Imana Ensinas[1]; João Filipe Nunes Miranda[3]

Abstract

This objective of this study was to characterize the floristic, structural, and ecological groups and to estimate the arboreal volume and biomass of a *cerradão* site in Palmas, Tocantins, Brazil. A forest inventory was conducted on 10.15 ha of the study area. Plots of 400-m² were used for systematic sampling. All standing trees (dead or alive) with a breast-height diameter (DHB) greater than 5 cm were identified and measured. Floristic diversity and horizontal structure were assessed using the Shannon and importance value indices, respectively. Forest vertical structure was classified into three stratata and the tree species were categorized into ecological groups. Ninety tree volumes were rigorously cubed and weighed. Fresh- and dry biomass were sampled and estimated. Mathematical models were applied and adjusted to estimate tree volume and biomass. It was observed that the species *Myrcia splendens* and *Emmotum nitens* and the families Fabaceae and Chrysobalanaceae were dominant in our study site. The pioneer (613 individuals ha^{-1}) and climax (530 individuals ha^{-1}) tree species group predominated. The floristic diversity index was estimated as 3.35 nats ind^{-1}. The vertical structure analysis indicated fewer individuals in the superior stratum (13%) compared to the medium (63%) and inferior (24%) stratum. The Schumacher and Hall model showed better results with regard to estimated forest production. Forest volume and biomass estimates were 126.71 m³ ha^{-1} and 61.67 Mg ha^{-1}, respectively. The studied *cerradão* area had high floristic diversity and climax species predominated. Since this *cerradão* is in close proximity to the Amazon biome, its volume and biomass stocks were higher than those estimated for other *cerradão* and forest formations within the *Cerrado* biome.
Key words: Brazil. Cerrado Biome. Forestry inventory. Ecological group. Production.

Resumo

O objetivo do estudo foi caracterizar a florística, a estrutura, o grupo ecológico e estimar os estoques de volume e biomassa arbórea em uma área de 10, 15 hectares de cerradão, localizado no município de Palmas, Estado do Tocantins, utilizando a amostragem sistemática com parcelas de 400 m². Foram amostradas e identificadas todas as árvores vivas e mortas em pé, com diâmetro a 1,3 metros do solo ≥ 5 cm. A diversidade florística foi avaliada pelo o índice Shannon e a estrutura horizontal pelo o Índice de Valor de Importância. Quanto a estrutura vertical, a floresta foi classificada em três estratos. Sequencialmente as espécies foram classificadas em grupos ecológicos. Foram cubadas e pesadas 90 árvores. Obtida a massa verde, foram retiradas amostras para a obtenção da biomassa seca. Predominam

[1] Profs. Drs., Departamento de Engenharia Florestal, Universidade de Brasília, UnB, Campus Darcy Ribeiro, Brasília, DF, Brasil. E-mail: miguelederpereira@gmail.com; albavr@unb.br; ematricardi@gmail.com; jose.imana@gmail.com
[2] Dr. em Ciências Florestais, UnB, Campus Darcy Ribeiro, Brasília, DF, Brasil. E-mail: fabricioassisleall@gmail.com
[3] M.e em Ciências Florestais, UnB, Campus Darcy Ribeiro, Brasília, DF, Brasil. E-mail: joaofelipenm@gmail.com
[*] Author for correspondence

Received: May 19, 2016 - Approved: Jan. 12, 2017

na área as espécies *Myrcia splendens* e *Emmotum nitens* e, as famílias Fabaceae e Chrysobalanaceae. O grupo das espécies pioneiras (613 indivíduos ha^{-1}) e clímax (530 indivíduos ha^{-1}) se destacam. A diversidade florística foi de 3,35 $nats.ind^{-1}$. Quanto aos estratos verticais, a menor quantidade de indivíduos é encontrada no superior (13%), a maior no médio (63%) e no inferior 24%. Para estimar a produção o modelo de Schumacher e Hall se sobressaiu. A quantidade de volume e biomassa estocado foram: 126,71 m^3ha^{-1} e 61,67 $Mg.ha^{-1}$, respectivamente. A área de cerradão estudada apresentou alta diversidade florística, com predominância de espécies clímax. Em função da sua proximidade com o bioma Amazônico, os estoques de volume e biomassa estimados foram superiores em comparação com outros cerradões e outras formações florestais dentro do bioma Cerrado.
Palavras-chave: Brasil. Bioma Cerrado. Inventário florestal. Grupos ecológicos. Produção.

Introduction

The *Cerrado* biome has one of the richest and most diverse floras of all tropical forests and is characterized by a mosaic of physiognomic types, including savannah and campestral forestry formations (RIBEIRO; WALTER, 2008). The *cerradão* forestry formation is associated with interfluvial areas and has deep, well-drained soil (SOLÓRZANO et al., 2012). These are characteristics common to latosols with low- to average fertility, but also occur in dystrophic cambisols.

Over that past few decades, *cerradão* areas have been deforested and replaced by farmland (FELFILI et al., 2005; KLINK; MACHADO, 2005). A few fragments of *cerradão* can be found in all Brazilian states where the *Cerrado* biome predominates. It is necessary to characterize the floristic, structural, and production (volume, biomass, and carbon) aspects of these areas because this data can help evaluate the potential use of the forest. Inappropriate use of a forest can degrade the vegetation and soil, and lead to the loss of carbon from the soil to the atmosphere (GRACE et al., 2006).

Phytosociological studies are tools used in the characterization and structure of forest communities, it is a method of recognition and definition of plant communities (KUNZ et al., 2009; OLIVEIRA et al., 2012). The data are used to develop measures aimed at improving production and/or conservation of forests.

Most studies performed in the *cerradão* characterize the flora and structure; however, limited studies have focused on production. According to Rezende et al. (2006), the lack of this data is explained by species diversity, high intraspecies variability, and differences in crown and trunk shape within populations.

Thus, the aim of this study was to characterize the floristic- and ecological structures and to estimate the volume and biomass stocks in the aboveground part of the *cerradão* forest.

Material and Methods

This study was conducted in a 12.2 ha chaparral fragment located between 10°10′55″S and 10°11′20″S latitude, and 48°10′50″W and 48°10′30″W longitude, in Palmas, Tocantins, Brazil. According to Santos et al. (2013), most soils in this area are non-hydromorphic dark red latosols with medium texture. This soil type is usually deep to very deep, well drained, and has A, B, and C horizons. It has flat plain and wavy types of relief. According to the Köppen and Geiger classifications, the climate type in the region is C2wA’a’ and the average rainfall is ~1,700 mm/yr.

A *cerradão* logging vegetation inventory was conducted using the systematic sampling process recommended by Felfili et al. (2005). Plots 20 m × 20 m (400 m^2) were permanently demarcated. Fifty-four of them were established at the study site, encompassing a total area of 2.16 ha. All standing trees (dead or alive) were sampled and identified. Their height and DBH (diameter at breast height) were measured and they were counted if their DBH was ≥5 cm. DBH was measured using a caliper and the height was measured using a 15-m telescopic rule. Heights >15 m were indirectly measured using the telescopic rule as a reference.

Plant material was collected, pressed, and dried in a laboratory desiccator (MORI et al., 1989). Tree species were classified according to the system proposed by the *Angiosperm Phylogeny Group* (APG III, 2009). This step was performed *in loco* by botanists and by using the analytical botanical keys in the herbarium of the University of Brasilia.

To appropriately represent the floristic richness in the *cerradão*, the sample size was determined using the species-area curve (MUELLER-DOMBOIS; ELLEMBERG, 2002) and linear regression models with plateau response (REGRELRP). The model was adjusted with the Solver function of Microsoft Office Excel 2013. The REGRELRP model is estimated as follows:

$$Y_i = \beta_0 + \beta_1.X + \varepsilon$$

where Y = cumulative number of species in *i* sampled plots; X = number of plots sampled; i = 1,2,3, ..., n sampled plots; β_0, β_1 = parameters of the regression equation to be estimated; and ε = model error.

Sample sizes used to determine volume and biomass were estimated assuming a 10% sampling error at $\alpha = 5\%$.

The arboreal flora of the *cerradão* was characterized based on its composition, richness, and species diversity. The alpha diversity was estimated using the Shannon diversity index (H′), and the equability was approximated from the Pielou index (J). The vegetation structure was derived from the horizontal and vertical structures. The phytosociological and diametric distributions were calculated to elucidate the horizontal vegetation structure.

The phytosociological variables included the base area, density, frequency, and importance value indices (KENT; COKER, 1992; MUELLER-DOMBOIS; ELLEMBERG, 2002). They were estimated using Mata Nativa V. 3 (www.cientec.net) and the diameter distribution was established by setting class intervals at 5 cm (CAMILOTTI et al., 2011; COSTA; ARAÚJO, 2001; TOPPA et al., 2004).

As suggested by Souza et al. (2003), the vertical structure was estimated using the vegetation stratification in three total height (Ht) classes of total height. The inferior stratum (EI) was Ht < (Hm – 1σ), the medium stratum (EM) was (Hm – 1σ) < Ht < (Hm + 1σ), and the superior stratum (ES) was Ht > (Hm + 1σ), where Hm is the total average height, and σ is the deviation from the total height (Ht) pattern of the sampled trees.

The tree species were classified by ecological group (SWAINE; WITHMORE, 1988). Pioneer species are those whose seeds germinate only in clearings and totally open canopies and receive direct solar radiation, and thereby the seedlings grow rapidly. In climax species, the seeds germinate in shaded areas and the seedling show moderate and slow growth Secondary data reported by Abreu et al. (2014), Carvalho (2006), Lorenzi (2002), and Ressel et al. (2004) were also used in this classification process.

The ecologic importance of the families was estimated using the familiar importance value index (IVIF). The IVIF was approximated from the sum of the relative diversity values (number of species in the family/total number of species), the density, and the dominance (MORI; BOOM, 1983).

Volume and biomass were estimated for each tree, species, family, ecologic group, and area using equations developed and validated in the study. The trees measured in the inventory were segregated into diameter classes with 5-cm increments. There were eleven classes, which were cubed, weighed, and sampled (disks). The sample size was 3% of the total number of individuals per class using bole and crown and adding ninety trees from different species. Three hundred grams of leaf tissue was sampled from the crown of each tree.

To determine the total volume, cubing was performed in different length sections and Smalian's formula was applied (HUSCH et al., 1982). To obtain the biomass, the same trees were sectioned and its different compartments were weighed using an electronic scale with a maximum capacity of 300 kg and a precision of 0.05 kg.

Dry biomass was calculated from the ratio of dry weight to fresh weight. For the bole, wood disks of 5 cm thickness were sampled at the base, middle, and peak. Disks were also cut from thick (≥10 cm), medium (≥3 cm), and thin (<3 cm) branches. The bark was removed from all disks and the wood sampled from each compartment was weighed separately.

Three hundred grams of leaf tissue were sampled and dried in a laboratory desiccator then weighed using a balance with a 0.01-g precision. The samples were stored in a laboratory drier at 103 ± 2°C except for the leaves which were dried at 70 ± 2°C to a constant mass (SMITH, 1954). After drying, dry weights of samples were determined. The moisture coefficient was estimated using the ratio of fresh- to dry weight ($M_0\%/M_u$) of each sample. Fresh- and dry weights were estimated for each bole, branch, bark, and leaf sample. The total dry biomass was estimated from the product of the moisture coefficient and the fresh weight for each compartment (SOARES et al., 2006). The moisture coefficient was estimated as follows:

$$C_R = M_0\%/M_u.$$

where C_R= relation coefficient; M_U = fresh weight of the sample (g or kg); and $M_0\%$ = dry weight of the sample (g or kg).

The mathematical models were adjusted using the total volume and biomass values (Table 1). The independent variables were DBH, Ht, and combinations thereof.

Table 1. Curve representing the species-area relation accumulated and the plateau area of a *cerradão* area located in Palmas, in Tocantins, Brazil.

Author	Models
Spurr	$Y = \beta_0 + \beta_1 DBH^2 \cdot Ht + \varepsilon$
Schumacher-Hall	$Y = \beta_0 DBH^{\beta_1} \cdot Ht^{\beta_2} . \varepsilon$
Honner	$Y = \dfrac{DBH^2}{\beta_0 + \beta_1 \frac{1}{Ht}} + \varepsilon$
Ogaya	$Y = DBH^2(\beta_0 + \beta_1 Ht) . \varepsilon$
Takata	$Y = \dfrac{DBH^2 \cdot Ht}{\beta_0 + \beta_1 DBH} + \varepsilon$
Husch	$Y = \beta_0 DBH^{\beta_1} . \varepsilon$

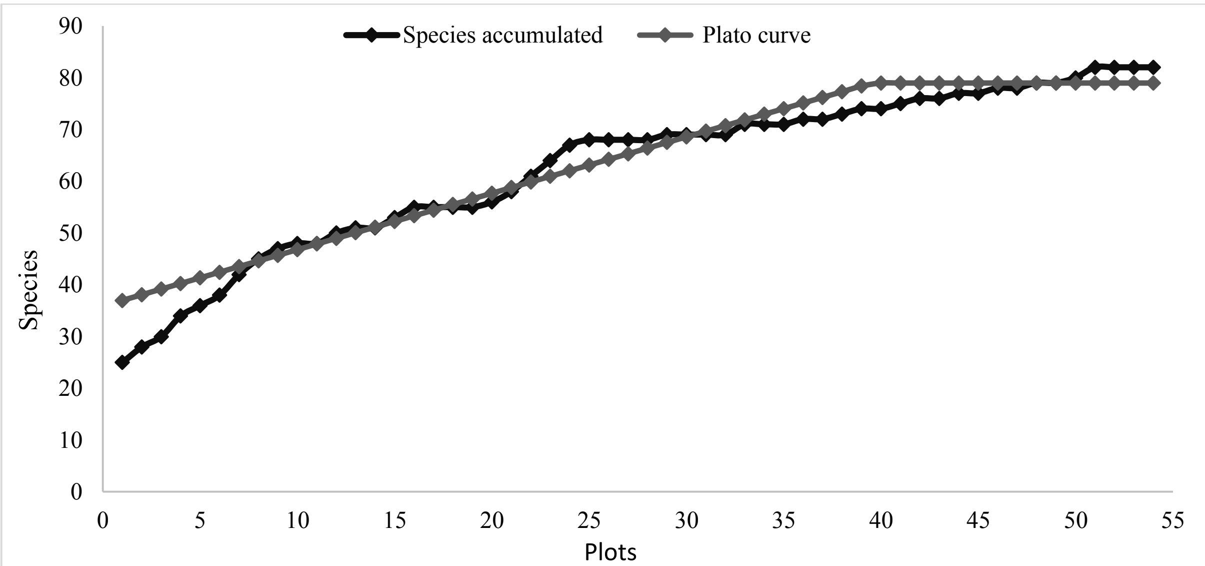
In which: Y = Volume or Biomass; Ht = Total Height (m); DBH = Diameter at Breast Height (cm); β*i*= Coefficient to be adjusted; ε = error associated to the model.

Model adjustment quality was verified using the following criteria: Adjusted Determination Coefficient (R^2 adjusted), Pattern Error of the Percentage Estimate (Syx%), and Graphic Analysis of the Residuals (DRAPER; SMITH, 1981). After selecting the equations for the relevant variable, the validation test was applied. Twenty trees were used to test the equation adjustments. The *t*-test for paired data was applied as suggested by Silveira et al. (2008).

Results and Discussion

The plateau response curve of the *cerradão* arboreal flora (Figure 1) was estimated by applying Y = 35.8951 + 1.090X (R^2 adjusted = 0.91 and S_{yx}% = 7). This equation was adjusted to represent the increase in floristic richness as a function of the sampled area. The target sampling size was reached using a 1.6 ha sampling area. At this point, the equation stabilized and attained a plateau curve, and more than 96% of the species had been sampled. These sampling results were superior to those reported by Pires-O'Brien and O'Brien (1995). These authors suggested that the tropical forest sampling area must include ≥90% of the tree species in the community.

Figure 1. Curve representing the species-area relation accumulated and the plateau area of *cerradão* area located in Palmas, in Tocantins, Brazil.



Assuming that tropical forests have high floristic richness, the tree species-area curve cannot completely stabilize even with a large sample size unless a census is used (SCHILLING; BATISTA, 2008). From 1–3 ha, the species-area curve tropical arboreal species richness reaches a stability asymptote (CONDIT et al., 1996; SCOLFORO et al., 2008). This finding was corroborated by the plateau response curve in this study when the sample size was stabilized at 1.6 ha.

In the *cerradão* area of this study, 1,228 trees ha^{-1} were counted. In other *cerradão* areas of the Brazilian *Cerrado*, the tree density was between 1,172 trees ha^{-1} and 1,251 trees ha^{-1} (SOUZA et al., 2010). Tree diameters varied from 5 cm to 65 cm, with an average of 11.55 cm (CV = 60%). tree height ranged from 3 m to 21 m, with a 9-m average (CV = 28%). The base area (17.34 m^2 ha^{-1}) determined in this study lies within the limit previously registered in *cerradão* areas (17.05–24.90 m^2 ha^{-1}). Approximately 7% of these measurements were obtained from standing dead trees. This proportion also resembles those observed in others *cerradão* areas (MARIMON JUNIOR; HARIDASAN, 2005). Therefore, they have an important ecological role in the *cerradão* community.

A total of 34 botanical families were identified, of which 16 occurred in only one plot. The most representative families were Fabaceae (15), Chrysobalanaceae (7), Apocynaceae and Melastomataceae (5), Malpighiaceae and Vochysiaceae (4), and Anacardiaceae and

Connaraceae (3). These families accounted for 56% of all species sampled in the area. The most representative species were *Myrcia splendens*, *Emmotum nitens*, *Miconia albicans*, *Qualea parviflora*, *Xylopia aromatica*, and *Tapirira guianensis*. Together, they constituted 60% of all individual trees sampled.

The family Fabaceae has been focused in several studies conducted in *Cerrado* areas (FELFILI; SILVA JÚNIOR, 1993); LOPES et al., 2011; SANTOS et al., 2007). Their predominance was attributed to their biological nitrogen fixation capacity and their ability to recover degraded soils and low fertility areas in the studied biomes (SOUZA et al., 2010). There was also a high density of one species (*Myrcia splendens)* of the Myrtaceae.

It was observed that among the 82 species found in the study area, 12% accounted for 63% of the total IVI: *Myrcia splendens* (12%), *Emmotum nitens* (10%), *Qualea parviflora* (7%), *Xylopia aromatica* (6%), *Tapirira guianensis* (6%), *Miconia albicans* (7%), *Parkia platycephala* (4%), *Caryocar coriaceum* (4%), *Tachigale vulgaris* (4%), and *Mezilaurus itauba* (3%). Our results are consistent with those reported by Bridgewater et al. (2004). They confirmed that only a few dominant species constituted the majority of the logging flora in the various *cerrado* phytophysiognomies.

Souza et al. (2008) studied the *cerradão* areas in Paraopeba, Minas Gerais, Brazil. They found strong dominances of *Myracrodruon urundeuva*, *Callisthene major*, *Cassia apoucouita,* and *Rollinia sylvatica*, none of which was found at our study site. Haidar et al. (2013), however, identified *Caryocar coriaceum, Emmotum nitens*, and *Lafoensia pacari,* all of which were also found in the present study. Therefore, as Ratter et al. (1973) and Solórzano et al. (2012) previously indicated, two types of *cerradão* occur in the Cerrado biome.

Based on the species with the highest IVI% in the community, only *Mezilaurus itauba* is rare in the savannah environment. All other species are found in the savannah and dry forest areas. These two phytophysiognomies have species commonly found in the *Cerrado* Biome (FELFILI et al., 2004; FELFILI; FAGG, 2007). *Mezilaurus itauba* is in the Amazon phytogeographical domain but it also occurs in the forest-savannah areas of Mato Grosso and Amazon (Brazil) (ARAÚJO et al., 2009).

Myrcia splendens had the highest IVI in the area. Its density was also very high. Nevertheless, in the forest-savannah areas of São Paulo, Mato Grosso do Sul, Minas Gerais, Goias, and Distrito Federal, this species does not have the highest IVI (COSTA; ARAÚJO, 2001; GUILHERME; NAKAJIMA, 2007; MARIMON JUNIOR; HARIDASAN, 2005). On the other hand, the floristic inventory performed by Solórzano et al. (2012) indicated that, in the *cerradão* area of Tocantins, this species was among the most important species and commonly occurred in the region's *cerradão*.

The alpha diversity of the forest-savannah (3.35 nats ind^{-1}) in this study was similar to those recorded for other *cerradão* areas previously evaluated (2.92–3.54 nats ind^{-1}) (SOLÓRZANO et al., 2012). The Pielou evenness determined in this present study (0.76) corroborated the values reported elsewhere (0.73–0.91; SALIS et al., 2006; GUILHERME; NAKAJIMA, 2007). The evenness score for the *cerradão* indicated moderate diversity and surpassed 76% of the maximum possible value (*Hmax*) because of the dominance of some species in the area (MAGURRAN, 2004).

Three vertical structure strata were defined for the community under study: inferior (HT < 6.41 m), medium (6.41 m $\leq$ HT < 11.54 m), and superior (HT $\geq$ 11.54 m). The fewest trees were found in the superior stratum (ES). Only 325 individuals (13%) there could reach the upper canopy. In the medium stratum (EM), 1,565 trees (63%) grew to that height, and 591 individuals (24%) reached that level in the inferior stratum (EI).

The density of the pioneer trees was 613 individuals ha^{-1}, whereas that of the climax species was 530 individuals ha^{-1}. On the other hand, there were 57 climax species and only 25 pioneer species.

The climax species represented 60% of the upper stratum. Therefore, the forest-savannah of this present study was mature and consisted of a heterogeneous mixture of species (CONDÉ; TONINI, 2013). There were relatively few long-living pioneer species in the upper stratum because the climax species with high longevity there outgrow and crowd out the pioneer trees when the forest is at the advanced stage of succession.

All volume- and biomass models were statistically significant ($p < 0.05$), but the Schumacher and Hall model was the best fit (in terms of R^2 and Syx%) for =estimating volume (0.99 and 15%) and biomass (0.97 and 28%). These values fall within the ranges of those previously established for other regions. In those cases, the determination coefficient and the estimate pattern error ranged from 0.85–0.99 and from 15–128%, respectively. For the biomass, these metrics varied between 0.81 and 0.97 and between 28% and 65%, respectively (SCOLFORO et al., 2008; VIEIRA et al., 2008).

Further research is necessary to develop predictive allometric models for aerial distances. Lehmann et al. (2014) stated that the arboreal community and its intra- and interspecific relationships vary significantly and one model alone cannot adequately account for the productivity in different regions.

A validation test was applied and no significant statistical differences were found between the estimated and observed values for volume and biomass. The following equations were used:

$$VTcc = 0.000085 \times DHB^{2.122270} \times Ht^{0.666217}$$

and

$$BT = 0.0123307 \times DHB^{1.79593} \times Ht^{1.54701}$$

where VTcc = total volume with bark (m^3); BT = total biomass (Mg); Ht = total height (m); and DHB = diameter at breast height (cm).

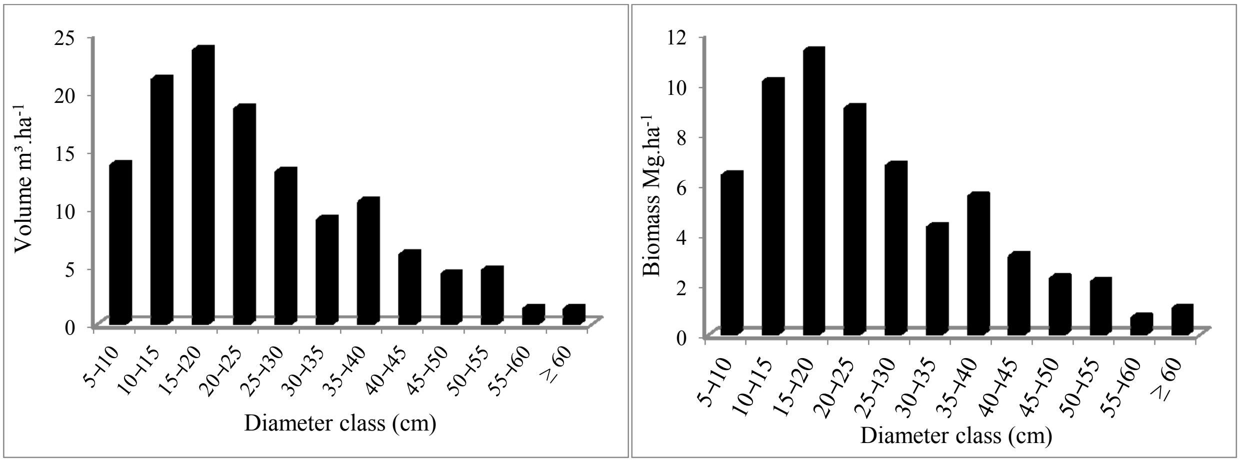
Volume and biomass estimates were obtained for all standing trees, alive or dead, with DHB ≥5 cm. The volume was 126.714 m^3 ha^{-1} (± 9.820 m^3 or 8%) and the biomass was 61.67 Mg ha^{-1} (± 5.43 Mg or 9%). These results are slightly greater than those reported by Scolforo et al. (2008) and Morais et al. (2013) (117 m^3 and 56.10 Mg, respectively). A possible explanation for this discrepancy is that in Tocantins, the forested areas are better protected and denser because they are close to the Amazon Biome.

The dead trees contributed significantly to the total volume and biomass production at 7%. It was determined that dead trees constituted the third largest dry volume and biomass production of all the populations registered in the arboreal community. The first- and second most productive living species in the forest-savannah were *Emmotum nitens* and *Tapirira guianensis*, respectively. *Emmotum nitens* belongs to Icacinaceae, which contributed to the highest biomass in the *cerradão*, followed by Fabaceae and Anacardiaceae. In terms of volume, however, Fabaceae is slightly more productive than Icacinaceae and it underscores the effect of density on biomass production.

Sanquetta (2002) studied a forestry reservation in Chile and estimated that its biomass was 558.3 Mg ha^{-1}. According to these authors, dead trees accounted for 5% of the total biomass. Amaro et al. (2013) estimated 227 Mg ha^{-1} biomass production for a seasonal deciduous forest in Minas Gerais, Brazil and reported that dead trees contributed to 4% of the total. Under natural conditions, the proportion of dead trees in a tropical forest can be as high as 20% (in terms of volume, biomass, and carbon) (OSWALT; BRANDEIS, 2008).

The greatest volume and biomass productivity were found in the tree population with diameters ranging from 10–25 cm (Figure 2) despite the fact that this size class represented only 13% of the total number of trees per hectare in the *cerradão* community.

Figure 2. Distribution of production in volume (m³ ha⁻¹) and biomass (Mg ha⁻¹), per diameter class, of the arboreal community in a *cerradão* community, located in Palmas, Tocantins, Brazil.



Even at lower tree densities, the larger diameter classes produce the most volume and biomass. Nevertheless, the first diameter class (5–10 cm) represented half of the trees sampled but produced only 12% of the total volume and biomass.

Volume and biomass distributions were analyzed based on the highest IVI% (Table 2). All species except for *Miconia albicans* had high volumes and biomass stocks because they had relatively elevated densities (numbers of trees per hectare) and larger trees. Although the density of *Miconia albicans* was high in the *cerradão*, its total base area was low (0.38 m^2 ha^{-1}). As a result, it produces relatively less volume and biomass, particularly for the bole.

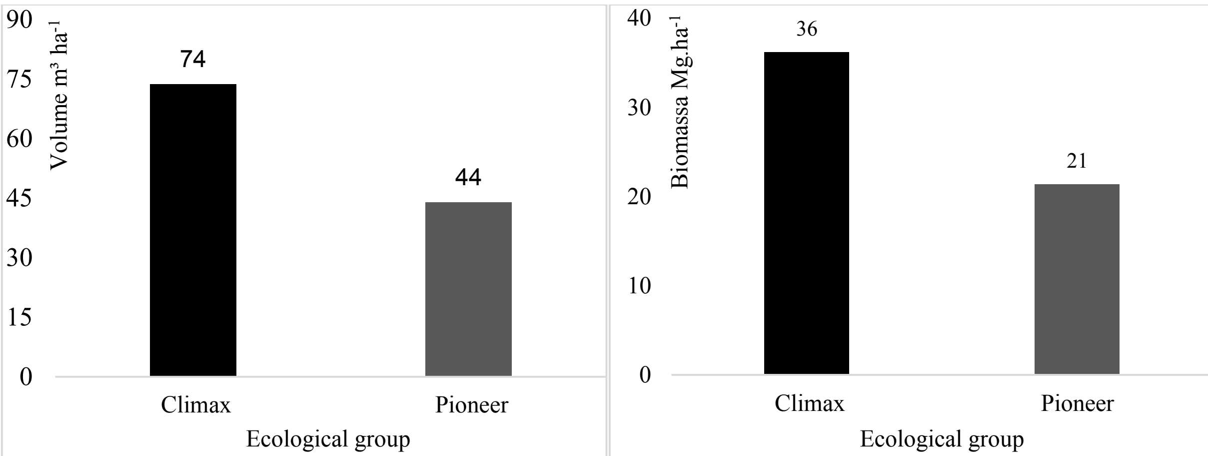
Table 2. Productivity in terms of volume (m^3 ha^{-1}) and dry biomass (Mg ha^{-1}) of the ten species with the highest IVI (species classified in decreasing order of IVI) in Palmas, Tocantins, Brazil.

Scientific name	Order of IVI (%)	Value of IVI (%)	Volume ($m^3.ha^{-1}$)	Biomass ($Mg.ha^{-1}$)
Myrcia splendens	1	12.43	13.3105	5.28
Emmotum nitens	2	10.12	18.2145	9.44
Qualea parviflora	3	7.42	8.5751	3.72
Xylopia aromatica	4	6.34	5.5391	2.88
Tapirira guianensis	5	6.24	10.8002	5.71
Miconia albicans	6	5.69	1.6884	0.64
Parkia platycephala	7	4.28	8.8243	3.95
Caryocar coriaceum	8	3.85	7.7692	3.35
Tachigale vulgaris	9	3.72	6.0817	3.44
Mezilaurus itauba	10	3.12	5.9436	3.21
Total		63.21	86.7466	41.62

The trees with highest IVI accounted for 68% and 67% of the volume and biomass in the area, respectively. Therefore, half of the volume and biomass in the *cerradão* community is explained by the species with the highest density (individuals ha^{-1}), dominance (m^2 ha^{-1}), and homogeneous distribution in the area. Most of the productivity in tropical forests formations is attributed to a few species each of which has low productivity and density and small base area.

In the arboreal community under study, the proportion of species in the pioneer group was highest (54% of the living species in the community). Their total volume was 43.93 m^3 ha^{-1} (37%) and their total biomass was 21.35 Mg ha^{-1} (37%). On the other hand, the climax group represented 46% of the species in the community; however, its volume and biomass were 73.63 m^3 ha^{-1} (63%) and 36 15 Mg ha^{-1} (63%), respectively (Figure 3). Taken together, the results indicate that the larger species belong to the climax group in this study area, and this arboreal community is well conserved and at an advanced stage of succession.

Figure 3. Distribution of volume and biomass in the different species in ecologic groups, located in Palmas, Tocantins state, in Brazil.



Conclusions

The area studied had rich floristic diversity with a dominance of climax tree species. Biomass and tree volume increased with decreasing distance from the Amazon biome. This observation contrasts those reported for several studies of the Cerrado biome.

The best allometric equations were derived from the Schumacher & Hall model. Therefore, this model is recommended for predicting volume and biomass in *cerradão* sites where floristic and structural characteristics resemble those of the present study.

The pioneer species group had the largest number of individuals but the climax species had the greatest volume and biomass. Therefore, larger species in the arboreal *cerradão* belong to the climax group, and the community in this study site was at an advanced stage of succession.

The findings of this study may facilitate decision makers to establish and enforce management and conservation measures in the Cerrado biome.

Acknowledgment

Financial support for this study was provided by the Brazilian National Council of Science and Technology (CNPQ). Field work support and help were provided by the Tocantins Environmental Institute (Naturatins).

References

ABREU, T. A. L.; PINTO, J. R. R.; MWES, H. A. Variações na riqueza e na diversidade de espécies arbustivas e arbóreas no período de 14 anos em uma Floresta de Vale, Mato Grosso, Brasil. *Rodriguésia*, Rio de Janeiro, v. 65, n. 1, p. 13-88, 2014.

AMARO, M. A.; SOARES, C. P. B.; SOUZA, A. L.; LEITE, H. G.; SILVA, G. F. Estoque volumétrico, de biomassa e de carbono em uma floresta estacional semidecidual em Viçosa, Minas Gerais. *Revista* Árvore, Viçosa, MG, v. 37, n. 55, p. 849-857, 2013.

ANGIOSPERM PHYLOGENY GROUP III – APG III. An update of the angiosperm phylogeny group classification for the orders and families of flowering plants. *Botanical Journal of the Linnaean Society*, London, v. 161, n. 4, p. 105-121, 2009.

ARAÚJO, R. A.; COSTA, R. B.; FELFILI, J. M.; GONÇALVEZ, I. K.; SOUSA, R. A. T. V.; DORVAL, A. Florística e estrutura de fragmento florestal em área de transição na Amazônia Matogrossense no município de Sinop. *Acta Amazônica*, Manaus, v. 39, n. 4, p. 865-877, 2009.

BRIDGEWATER, S.; RATTER, J. A.; RIBEIRO, J. F. Biogeographic patterns, B-diversity and dominance in the cerrado biome of Brazil. *Biodiversity Conservation*, Berlin, v. 13, n. 12, p. 2295-2318, 2004.

CAMILOTTI, D. C.; PAGOTTO, T. C. S.; ARAUJO, A. C. Análise da vegetação arbórea de um remanescente de Cerradão em Bandeirantes, Mato Grosso do Sul, Brasil. *Iheringia, Série Botânica,* Porto Alegre, v. 66, n. 1, p. 31-46, 2011.

CARVALHO, P. E. R. *Espécies arbóreas brasileiras*. Brasília: Embrapa informação tecnológica; Embrapa Florestas, Colombo, 2006. 548 p.

CONDÉ, T. M.; TONINI, H. Fitossociologia de uma floresta ombrófila densa na Amazônia Setentrional, Roraima, Brasil. *Acta Amazonica*, Manaus, v. 43, n. 3, p. 247-260, 2013.

CONDIT, R.; HUBBELL, S. P.; LAFRANKIE, J. V.; SUKUMAR, R.; MANOKARAN, N.; FOSTER, R. B.; ASTHON, P. S. Species-area and species individual relationships for tropical trees: a comparison of three 50-ha plots. *Journal of Ecology*, London, v. 84, n. 1, p. 549-562, 1996.

COSTA, A. A.; ARAÚJO, G. M. Comparação da vegetação arbórea de cerradão e de cerrado na Reserva do Panga, Uberlândia, Minas Gerais. *Acta Botânica Brasílica*, São Paulo, v. 15, n. 1, p. 63-72, 2001.

DRAPER, N. R.; SMITH, H. *Applied regression analysis*. New York: J. Wiley, 1981. 736 p.

FELFILI, J. M.; CARVALHO, F. A.; HAIDAR, R. F. *Manual para o monitoramento de parcelas permanentes nos biomas Cerrado e Pantanal*. Brasília: Universidade de Brasília, Departamento de Engenharia Florestal, 2005. 51 p.

FELFILI, J. M.; FAGG, C. W. Floristic composition, diversity and structure of the cerrado sensu stricto on rocky soils in northern Goiás and southern Tocantins, Brazil. *Revista Brasileira de Botânica*, São Paulo, v. 30, n. 3, p. 375-385, 2007.

FELFILI, J. M.; SILVA JÚNIOR, M. C. A comparative study of cerrado (sensu stricto) vegetation in Central Brazil. *Journal of Tropical Ecology*, Cambridge, v. 9, n. 3, p. 277-289, 1993.

FELFILI, J. M.; SILVA JUNIOR, M. C.; SEVILHA, A. C.; FAGG, C. W.; WALTER, B. M. T.; NOGUEIRA, P. E.; REZENDE, A. L. Diversity, floristic and structural patterns of cerrado vegetation in Central Brasil. *Plant Ecology,* Dordrecht, v. 175, n. 1, p. 37-46, 2004.

GRACE, J.; SAN JOSE, J.; MEIR, P.; MIRANDA, H.; MONTES, R. Productivity and carbon fluxes of tropical savannas. *Journal of Biogeography*, Oxford, v. 33, n. 1, p. 387-400, 2006.

GUILHERME, F. A. G.; NAKAJIMA, J. N. Estrutura da vegetação arbórea de um remanescente ecotonal urbano floresta-savana no Parque do Sabiá, em Uberlândia, MG. *Revista* Árvore, Viçosa, MG, v. 31, n. 2, p. 329-338, 2007.

HAIDAR, R. F.; FELFILI, J. M.; PINTO, J. R. R.; DIAS, R. R.; DAMASCO, G.; SILVA, L. C. R.; FAGG, C. W. Florestas estacionais e áreas de ecótono no estado do Tocantins, Brasil: parâmetros estruturais, classificação das fitofisionomias florestais e subsídios para conservação. *Acta Amazonica*, Manaus, v. 43, n. 3, p. 261-290, 2013.

HUSCH, B.; MILLER, C. L.; BEERS, T. E. *Forest mensuration*. 3th ed. New York: J. Willey and Sons, 1982. 402 p.

KENT, M.; COKER, P. *Vegetation description and analysis*. A practical approach. Chichester: Wiley-Blackwell, 1992. 428 p.

KLINK, C. A.; MACHADO, R. B. Conservation of the brazilian Cerrado. *Conservation Biology*, Berlin, v. 19, n. 3, p. 707-713, 2005.

KUNZ, S. H.; IVANAUSKAS, N. M.; MARTINS, S. V. Estrutura fitossociologica de uma área de cerradão em Canarana, Estado de Mato Grosso, Brasil. *Acta Scientiarum. Biological Sciences*, Maringá, v. 31, n. 3, p. 255-261, 2009.

LEHMANN, C. E. R.; ANDERSON, T. M.; SANKARAN, M.; HIGGINS, S. I.; ARCHIBALD, S.; HOFFMANN, W. A.; HANAN, N. P.; WILLIAMS, R. J.; FENSHAM, R. J.; FELFILI, J. M.; HUTLEY, L. B.; RATNAM, J.; SAN JOSE, J.; MONTES, R.; FRANKLIN, D.; SMITH, J. R.; RYAN, C. M.; DURIGAN, G.; HIERNAUX, P.;

HAIDAR, R.; BOWMAN, D. M. J. S.; BOND. W. J. Savanna vegetation-fire-climate relationships differ among continents. *Science*, Washington, v. 343, n. 6170, p. 547-552, 2014.

LOPES, S. F.; VALE, V. S.; OLIVEIRA, A. P.; SCHIAVINE, I. Análise comparativa da estrutura e composição florística de cerrado no Brasil central. *Interciencia*, Caracas, v. 36, n. 1, p. 8-15, 2011.

LORENZI, H. Árvores *brasileiras:* manual de identificação e cultivo de plantas árboreas nativas do Brasil. 2. ed. Nova Odessa: Institute Plantarum, 2002. 368 p.

MAGURRAN, A. E. *Measuring biological diversity*. Oxford: Blackwell Publishing, 2004. 215 p.

MARIMON JUNIOR, B. H.; HARIDASAN, M. Comparação da vegetação arbórea e características edáficas de um cerradão e um cerrado sensu stricto em áreas adjacentes sobre solo distrófico no leste de Mato Grosso, Brasil. *Acta Botanica Brasilica*, São Paulo v. 19, n. 4, p. 913-926, 2005.

MORAIS, V. A.; SCOLFORO, J. R. S.; SILVA, C. A.; MELLO, J. M.; GOMIDE, L. R.; OLIVEIRA, A. D. Carbon and biomass stocks in a fragment of cerradão in Minas Gerais state, Brazil. *Cerne*, Lavras, v. 19, n. 2, p. 237-245, 2013.

MORI, S. A.; BOOM, B. M. Ecological importance of myrtaceae in an eastern brazilian wet forest. *Biotropica*, Malden, v. 15, n. 1, p. 68-70, 1983.

MORI, S. A.; SILVA, L. A. M.; LISBOA, G.; CORADIN, L. *Manual de manejo do herbário fanerogâmico*. Ilhéus: CEPAAC, 1989. 103 p.

MUELLER-DOMBOIS, D.; ELLENBERG, H. *Aims and methods of vegetation ecology*. 2th ed. Princeton: The Blackburn Press, 2002. 547 p.

OLIVEIRA, L. S. B.; MARANGON, L. C.; FELICIANO, A. L. P.; CARDOSO, M. O.; LIMA, A. S.; SANTOS, W. B.; SILVA. V. F. Structure of the woody component of an Atlantic forest Fragment, Moreno – PE. *Semina: Ciências Agrárias*, Londrina, v. 33, n. 1, p. 203-212, 2012.

OSWALT, S. N.; BRANDEIS, T. J. Contribution of dead wood to biomass and carbon stocks in the caribbean: St. John, U. S. Virgin Islands. *Biotropica*, Malden, v. 40, n. 1, p. 20-27, 2008.

PIRES-O'BRIEN, M. J.; O'BRIEN, C. M. *Ecologia e modelamento de* florestas *tropicais*. Belém: Fcap, 1995. 400 p.

RATTER, J. A.; RICHARDS, P. W.; ARGENT, G.; GIFFORD, D. R. Observations on the vegetation of north eastern Mato Grosso I: the woody vegetation types of the Xavantina-Cachimbo expedition area. *Philosophical Transactions of the Royal Society of London*, London, v. 226, n. 880, p. 449-492, 1973.

RESSEL, K.; GUILHERME, F. A. G.; SCHIAVINI, I.; OLIVEIRA, P. E. Ecologia morfofuncional de plântulas de espécies arbóreas da Estação Ecológica do Panga, Uberlândia, Minas Gerais. *Brazilian Journal of Botany,* São Paulo, v. 27, n. 2, p. 311- 323, 2004.

REZENDE, A. V.; VALE, A. T.; SANQUETTA, C. R.; FIGUEIREDO FILHO, A.; FELFILI, J. M. Comparação de modelos matemáticos para estimativa do volume, biomassa e estoque de carbono da vegetação lenhosa de um cerrado *sensu stricto* em Brasília, DF. *Scientia Forestalis*, Piracicaba, v. 71, n. 1, p. 65-76, 2006.

RIBEIRO, J. F.; WALTER, B. M. T. As principais fitofisionomias do Bioma Cerrado. In: SANO, S. M.; ALMEIDA, S. P.; RIBEIRO, J. F. (Ed.). *Cerrado*: ecologia e flora. Brasília: EMBRAPA-CPAC, 2008. p. 151-212.

SALIS, S. M.; ASSIS, M. A.; CRISPIN, S. M. A.; CASAGRANDE, J. C. Distribuição e abundância de espécies arbóreas em cerradões no Pantanal, Estado do Mato Grosso do Sul, Brasil. *Revista Brasileira de Botânica*, São Paulo, v. 29, n. 3, p. 339-352, 2006.

SANQUETTA, C. R. Métodos de determinação de biomassa florestal. In: SANQUETTA, C. R.; WATZLAWICK, L. F.; BALBINOT, R.; ZILIOTTO, M. A. B.; GOMES, F. S. (Ed.). *As florestas e o carbono*. Curitiba: Ed. dos Autores, 2002. p. 119-140.

SANTOS, H. G.; JACOMINE, P. K. T.; ANJOS, L. H. C.; OLIVEIRA, V. A.; LUMBRERAS, J. F.; COELHO, M. R.; ALMEIDA, J. A.; CUNHA, T. J. F.; OLIVEIRA, J. B. (Ed.). *Sistema brasileiro de classificação de solos*. 3. ed. Brasília: Embrapa, 2013. 353 p.

SANTOS, R. M.; VIEIRA, F. A.; FAGUNDES, M.; NUNES, Y. R. F.; GUSMÃO, E. Riqueza e similaridade florística de oito remanescentes florestais no norte de Minas Gerais, Brasil, Brazil. *Revista* Árvore, Viçosa, MG, v. 31, n. 3, p. 135-144, 2007.

SCHILLING, A. C.; BATISTA, J. L. F. Curva de acumulação de espécies e suficiência amostral em florestas tropicais. *Revista Brasileira de Botânica*, São Paulo, v. 31, n. 1, p. 179-187, 2008.

SCOLFORO, J. R. S.; CARVALHO, L. M. T.; OLIVEIRA, A. D. *Projeto:* inventário florestal de Minas Gerais: monitoramento dos reflorestamentos e tendências da produção em volume, peso de matéria seca e carbono. Lavras: Editora UFLA, 2008. 345 p.

SILVEIRA, P.; KOEHLER, H. S.; SANQUETTA, C. R.; ARCE, J. E. O estado da arte na estimativa de biomassa e carbono em formações florestais. *Revista Floresta*, Curitiba, v. 38, n. 1, p. 185-206, 2008.

SMITH, D. M. *Maximum moisture content method for determining specific gravity of small wood samples*. Madison: United States Forest Products Laboratory Report, nº 2014, Agriculture, dec. 1954. 8 p.

SOARES, C. P. B.; PAULA NETO, F.; SOUZA, A. L. *Dendrometria e inventário florestal*. Viçosa, MG: Editora UFV, 2006. 272 p.

SOLÓRZANO, A.; PINTO, J. R. R.; FELFILI, M. J.; HAY, J. D. V. Perfil florístico e estrutural do componente lenhoso em seis áreas de cerradão ao longo do bioma Cerrado. *Acta Botanica Brasilica*, Feira de Santana, v. 26, n. 2, p. 328-341, 2012.

SOUZA, D. R.; SOUZA, A. L.; GAMA, J. R. V.; LEITE, H. G. Emprego de análise multivariada para estratificação vertical de florestas inequiâneas. *Revista* Árvore, Viçosa, MG, v. 27, n. 1, p. 59-63, 2003.

SOUZA, P. B.; MEIRA NETO, J. A. A.; SILVA, A. F.; SOUZA, A. L. Composição florística da vegetação arbórea de um remanescente de cerração, Paraopeba, MG. *Revista* Árvore, Viçosa, MG, v. 32, n. 4, p. 771-780, 2008.

SOUZA, P. B.; SAPORETTI JUNIOR, A. W.; SOARES, M. P.; VIANA, R. H. O.; CAMARGOS, V. L.; MEIRA NETO, J. A. A. Florística de uma área de cerradão na floresta nacional de Paraopeba – Minas Gerais. *Revista Cerne*, Lavras, v. 16, n. 1, p. 86-93, 2010.

SWAINE, M. D.; WHITMORE, T. C. On the definition of ecological species groups in tropical rainforests. *Vegetatio*, Dordrecht, v. 75, n. 1, p. 81-86, 1988.

TOPPA, R. H.; PIRES, J. S. R.; DURIGAN, G. Flora lenhosa e síndromes de dispersão nas diferentes fisionomias da vegetação da Estação Ecológica de Jataí, Luiz Antonio, São Paulo. *Hoehnea*, São Paulo, v. 32, n. 1, p. 67-76, 2004.

VIEIRA, S. A.; ALVES, L. F.; AIDAR, M.; ARAÚJO, L. S.; BAKER, T.; BATISTA, J. L. F.; CAMPOS, M. C.; CAMARGO, P. B.; DELITTI, W. B. C.; HIGUCHI, N.; HONÓRIO, E.; KELLER, M.; MATTOS, E. A.; PHILLIPS, O.; SANTOS, F. A. M.; SHIMABUKURO, M. T.; SILVEIRA, M.; TRUMBORE, S. E**.** Estimation of biomass and carbon stocks: the case of the Atlantic Forest. *Biota Neotropica*, Campinas, v. 8, n. 2, p. 21-29, 2008.