# Community structure and comparative analysis of the woody component of a cerrado remnant in Southeastern Brazil

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ABSTRACT - (Community structure and comparative analysis of the woody component of a cerrado remnant in Southeastern Brazil). The aims of the present work were to carry out a floristic-structural study of the shrubby-arboreal component of a savanna fragment (cerrado *sensu stricto*) in São Paulo State, Southeastern Brazil, and to compare with other areas. Twenty-one plots of 250 m² each were delimited and plants with stem basal diameter equal or superior to 3 cm were included in the sampling. The recorded individuals corresponded to 3,062 and 58 species belonging to 34 families were registered. Asteraceae had the largest number of species (seven), followed by Fabaceae and Myrtaceae (five each). The most important species were *Tibouchina stenocarpa* and *Anadenanthera falcata*. The floristic composition of the study area indicates that it might be considered a transition from cerrado to seasonal semi-deciduous forest. The comparison with other surveys indicates floristic-structural heterogeneity of these cerrado areas and the multivariate analysis showed that areas grouped according to their geographical position and soil type.
Key words: phytosociology, savanna, similarity

RESUMO - (Estrutura da comunidade e análises comparativas do componente lenhoso de um remanescente de cerrado na região Sudeste do Brasil). O presente estudo teve como objetivo realizar um levantamento florístico-estrutural da comunidade arbustivo-arbórea de um fragmento de cerrado *sensu stricto* no Estado de São Paulo e compará-lo com outras áreas de cerrado. Foram delimitadas 21 parcelas de 250 m² cada onde as plantas com diâmetro basal do caule igual ou superior a 3 cm foram incluídas na amostragem. Foram registrados 3062 indivíduos pertencentes a 58 espécies e 34 famílias. Asteraceae apresentou o maior número de espécies (sete), seguida por Fabaceae e Myrtaceae (cinco cada). As espécies mais importantes foram *Tibouchina stenocarpa* e *Anadenanthera falcata*. A composição florística da área de estudo indica que esta pode ser considerada como uma transição entre cerrado e floresta estacional semidecídua. A comparação com outras áreas indicou que há considerável heterogeneidade florístico-estrutural nas áreas de cerrado e as análises multivariadas mostraram que as áreas comparadas se agruparam de acordo com sua posição geográfica e tipo de solo.
Palavras-chave: fitossociologia, savana, similaridade

## Introduction

The Neotropics have the world's second largest area of savannas and open woodlands, and Brazil constitutes the south limit of the savannas distribution in the American continent (Furley 1999). The Brazilian savanna, called cerrado, originally occupied around two million km² of the national territory, including continuous and disjunct areas (Coutinho 2002). Today, it is estimated to be reduced to about 1.05 millions km² (MMA 2009).

The so called cerrado is formed by a vegetation complex which encompasses a series of physiognomies from open grasslands (*campo limpo*) to dense woodlands (*cerradão*), with three intermediate physiognomies: *campo sujo*, grassland with a scattering of shrubs and small trees; *campo cerrado*, where there are some more shrubs and trees but still a larger proportion of grassland; and *cerrado* (*sensu stricto*), where trees and shrubs dominate but with a fair amount of herbaceous vegetation (Coutinho 2002). Such diversity of physiognomies contributes

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to the great richness of cerrado biome: more than 11,000 plant species have already been catalogued (Mendonça *et al.* 2008), and about half of them are endemic (Myers *et al.* 2000). Although it has been considered one of the 25 hotspots for global-scale conservation (Myers *et al.* 2000), cerrado still does not have legal instruments directed to its preservation (Durigan *et al.* 2004), and only 2.2% of its area are under legal protection (Klink & Machado 2005).

The cerrado areas in São Paulo State, Southeastern Brazil, are included in the south limit of distribution of the cerrado biome, and its remnants are fragmented in this area, undergoing a rapid destruction process (Durigan *et al.* 2004). Approximately 1,625,225 ha of cerrado (around 88.5% of the original area) are estimated to have been destructed in a 40-year period at this region (Kronka *et al.* 2005). In spite of their distance from the core area, São Paulo cerrados are notably rich in species and, therefore, highly representative (Ratter *et al.* 2003). As cerrado plants are hardly conserved out of their natural habitat because cultivation techniques are unknown for most species, preservation of samples from this vegetation is probably the only way to assure its survival (Durigan *et al.* 2004).

In this context, floristic and structural inventories have been carried out in cerrado remnants at a higher frequency because they are fundamental to any action which aims at more effective management, recovering and conservation. In the region of Botucatu municipality, São Paulo State, there are some cerrado fragments of still unknown structure; an inventory of these fragments is thus needed before they suffer more drastic interference.

The present study aimed at carrying out a floristic-structural analysis of the shrubby-arboreal component of a cerrado *sensu stricto* fragment in Botucatu municipality, São Paulo State, Brazil, and also to compare the studied fragment with some other cerrado areas, in order to answer the following questions: 1) Are the flora and structure of these woody communities similar? 2) Are the inventoried species in Botucatu area peculiar to cerrado formations? 3) In the negative cases, are the floristic elements originated from the surrounding vegetation formations? Results can help select areas for the establishment of future conservation units and recovering projects of degraded cerrado areas in Botucatu region.

## Material and methods

The present study was carried out in Botucatu municipality, located in the west-central region of São Paulo State, Southeastern Brazil. The area corresponds to a cerrado *sensu stricto* fragment, at 830 m altitude (22º57'34"S and 48º31'20"W). The climate of the region is Cfa according to Koeppen classification (Cunha & Martins 2009), and the soil in the area is Red-Yellow Latosol, according to the Brazilian System of Soil Classification (EMBRAPA 1999).

Structural analysis was carried out from January 2004 to April 2005, and 21 contiguous plots of 25 m × 10 m each were laid out. In each plot, plants with stem basal diameter (SBD) equal or superior to 3 cm were marked and identified, followed by diameter measurement and height assessment. Dead individuals were considered as a single group, independent of their identification.

For the structural analysis, density, dominance and frequency (in relative terms) and importance value index (IV) were calculated for each species (Mueller-Dombois & Ellenberg 1974). Biological diversity was assessed through Shannon-Wiener (H') and Equitability (J) indexes (Krebs 1989). All calculations were done by using the FITOPAC 1 software (Shepherd 1995). The spatial patterning in populations with two or more individuals was calculated by using the standardized Morisita Index of dispersion (Ip) which ranges from -1.0 to +1.0, with 95% confidence limits at +0.5 and -0.5 (Krebs 1989). Random patterns give Ip of zero, clumped patterns above zero and uniform patterns below zero. However, we assumed that values very close to zero express random pattern.

All the identified species were also characterized in relation to their ability to occupy different phytocenoses. The species database was the lists found in Mendonça *et al.* (1998), Durigan *et al.* (2004) and Barbosa & Martins (2008). The species were arranged according to the APG II taxonomic system as presented in Souza & Lorenzi (2008). Voucher specimens were deposited in the Herbarium BOTU (Herbário Irina Delanova Gemtchujnicov, Instituto de Biociências de Botucatu, UNESP).

Data from ten previously published quantitative surveys on cerrado *sensu stricto* vegetation (table 1, figure 1) were joined to our data and used to elaborate matrixes for multivariate analysis, in which the woody species were considered variables and

Table 1. Details of the cerrado *sensu stricto* surveys used for similarity analysis with the present study. LA: Yellow Latosol, LV: Red Latosol, LVA: Red-Yellow Latosol, RQ: Quartzarenic Neosol, SBD: stem basal diameter, DKH: stem diameter at knee height, DBH: stem diameter at breast height, DS: stem diameter at 30 cm of soil, H: height, N: number of individuals, F: number of families, S: number of species, H' : Shannon-Wiener Index.

| | Study site/State | Latitude, Longitude | Altitude (m) | Soil type[a] | Climate type[b] | Area (m²) | Criterion for inclusion | N | F | S | H' | References |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | Botucatu/SP | 22º57'34"S, 48º31'20"W | 830 | LVA | Cfa | 5250 | SBD ≥ 3 cm | 3062 | 34 | 58 | 3.18 | Present study |
| B | Águas de Santa Bárbara/SP | 22º53'S, 49º14'W | 600-680 | LV, LVA | Cwa | 4400 | SBD ≥ 3 cm | 2447 | 44 | 83 | 3.37 | Meira Neto (1991) |
| C | Agudos/SP | 22º-23ºS, 49º30'-48º30'W | 550 | LV | Cwa | 2250 | SBD ≥ 3 cm | 1513 | 31 | 71 | 3.28 | Bertoncini (1996) |
| D | Brotas/SP | 22º11'S, 47º54'W | 710 | RQ | Cwa | 5000 | DKH ≥ 5 cm | - | 27 | 44 | 3.02 | Durigan *et al.* (2002) |
| E | Corumbataí/SP | 22º15'S, 47º00'W | 604[c] | LA | Aw | 3400 | H ≥ 1,5 m | 5243 | 41 | 86 | 3.15 | Pinheiro (2006) |
| F | Itirapina/SP | 22º08'S, 47º47'W | 800 | RQ | Cwa | 5200 | SBD ≥ 5 cm | 1281 | 24 | 44 | 3.08 | Durigan *et al.* (1994) |
| G | Luiz Antônio/SP | 21º57-63'S, 47º82-67'W | 638[c] | RQ | Cwa[c] | 10000 | DKH ≥ 3 cm | 642 | 25 | 50 | 2.99 | Toppa (2004) |
| H | Patrocínio Paulista/SP | 20º46'12"S, 47º14'24"W | 775-836 | RQ | Cwa/Cwb | 3000 | DBH ≥ 5 cm | 511 | 30 | 53 | 3.05 | Teixeira *et al.* (2004) |
| I | Santa Rita do Passa Quatro/SP | 21º36-38'S, 47º36-39'W | 590-740 | LV, LVA,RQ | Cwa | 1250 | SBD ≥ 1 cm | 1747 | 31 | 75 | 3.62 | Fidelis & Godoy |
| J | Brasília/DF | 15º46-45'S, 47º50-51'W | 1000-1050 | LV | Cwa | 10000 | DS ≥ 5 cm | 882 | 30 | 54 | 3.41 | Assunção & Felfili (2004) |
| K | Paraopeba/MG | 19º20'S, 44º20'W | 734-750 | LV, LVA,LA | Aw | 10000 | DS ≥ 5 cm | 1990 | 38 | 73 | 3.57 | Balduino *et al.* (2005) |

[a] According to the Brazilian System of Soil Classification (EMBRAPA 1999), [b] According to the Koeppen Classification, [c] Source: CEPAGRI (2008)

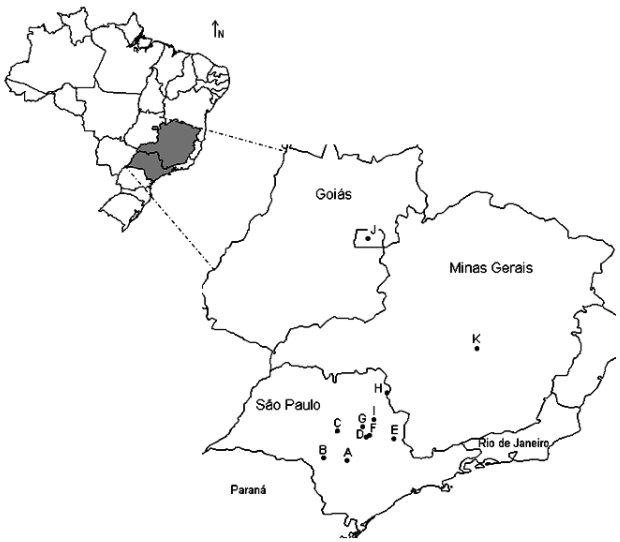


Figure 1. Map showing the locations of the present and previous study in areas of cerrado *sensu stricto*. The letters on the map correspond to those used in table 1.

the surveys were considered samples. Two of these surveys were performed in nuclear areas of cerrado, one located in the Federal District (Brasília) and other in Minas Gerais State. The other selected surveys were performed in São Paulo State and are marginal or disjunct cerrado areas (Ratter *et al.* 2003). These areas were selected in order to compare the floristic composition and structure of the studied cerrado aiming to investigate if there are peculiarities in that particular area, as pointed out initially.

The species in all study-sites and their importance value (IV) were used for the construction of the matrix in order to performed the Principal Components Analysis (PCA) and TWINSPAN classification (Two-Way Indicator Species Analysis) aiming to test the floristic and structural similarity among the surveys. The IV was used in these analyses since it gives good indications of the population structure of each species at each site (Felfili & Silva Junior 1993). The species with incomplete identification (only genera, aff. or cf.) were not counted and the species present only in one area were also excluded, in accordance with methodology adopted by Ratter *et al.* (2003).

## Results

A total of 3,062 individuals were sampled, including dead and undetermined ones. Fifty-eight species belonging to 34 families were registered but only 52 were identified to species level (table 2). The richest family was Asteraceae (seven species), followed by Fabaceae (five), Myrtaceae (five), Melastomataceae (four), and Erythroxylaceae (three). Together, they account for 41.38% of the surveyed species. Among the remaining families, seven were represented by two species each, and 22 were

Table 2. Structural parameters of species in cerrado *sensu stricto* area, Botucatu, São Paulo State, Brazil, orderly decreasing of IV (Importance Value). N: Number of Individuals, FR: Relative Frequency (%), DR: Relative Density (%), DoR: Relative Dominance (%), Ip: Standardized Morisita Index of Dispersion, FT: Phytocenoses (C: cerrado, F: forest, C/F: cerrado and forest).

| | Species | Family | N | FR | DR | DoR | IV | Ip | Spatial Pattern | FT |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | *Tibouchina stenocarpa* (DC.) Cogn. | Melastomataceae | 375 | 3.66 | 12.25 | 18.05 | 33.96 | 0.504 | clumped | C/F |
| 2 | *Anadenanthera falcata* (Benth.) Speg. | Fabaceae | 202 | 3.66 | 6.60 | 19.96 | 30.21 | 0.504 | clumped | C/F |
| 3 | *Ouratea spectabilis* (Mart. *ex* Engl.) Engl. | Ochnaceae | 279 | 3.66 | 9.11 | 6.74 | 19.51 | 0.500 | clumped | C/F |
| 4 | *Rapanea umbellata* (Mart.) Mez | Myrsinaceae | 288 | 3.48 | 9.41 | 5.61 | 18.50 | 0.566 | clumped | C/F |
| 5 | Dead individuals | - | 192 | 3.66 | 6.27 | 6.31 | 16.24 | 0.500 | clumped | - |
| 6 | *Myrcia guianensis* (Aubl.) DC. | Myrtaceae | 230 | 3.66 | 7.51 | 3.59 | 14.76 | 0.502 | clumped | C/F |
| 7 | *Dalbergia miscolobium* Benth. | Fabaceae | 110 | 3.66 | 3.59 | 4.86 | 12.11 | 0.505 | clumped | C |
| 8 | *Eupatorium vauthierianum* DC. | Asteraceae | 161 | 3.31 | 5.26 | 2.66 | 11.23 | 0.505 | clumped | C/F |
| 9 | *Erythroxylum suberosum* A. St.-Hil. | Erythroxylaceae | 137 | 3.48 | 4.47 | 1.66 | 9.62 | 0.509 | clumped | C/F |
| 10 | *Acosmium subelegans* (Mohlenbr.) Yakovlev | Fabaceae | 122 | 2.79 | 3.98 | 2.54 | 9.31 | 0.516 | clumped | C |
| 11 | *Myrcia lingua* (O. Berg.) Mattos & D. Legrand | Myrtaceae | 114 | 3.48 | 3.72 | 1.85 | 9.06 | 0.500 | clumped | C |
| 12 | *Schefflera vinosa* (Cham. & Schltdl.) Frodin & Fiaschi | Araliaceae | 84 | 3.31 | 2.74 | 2.77 | 8.82 | 0.504 | clumped | C |
| 13 | *Piptocarpha rotundifolia* (Less.) Baker | Asteraceae | 64 | 3.14 | 2.09 | 2.56 | 7.79 | 0.393 | clumped | C |
| 14 | *Rapanea guianensis* Aubl. | Myrsinaceae | 67 | 3.31 | 2.19 | 1.23 | 6.73 | 0.568 | clumped | C/F |
| 15 | *Guapira noxia* (Netto) Lundell | Nyctaginaceae | 43 | 2.79 | 1.40 | 2.39 | 6.59 | 0.344 | clumped | C/F |

| | Species | Family | N | FR | DR | DoR | IV | Ip | Spatial Pattern | FT |
|---|---|---|---|---|---|---|---|---|---|---|
| 16 | *Erythroxylum tortuosum* Mart. | Erythroxylaceae | 71 | 3.14 | 2.32 | 0.88 | 6.33 | 0.505 | clumped | C |
| 17 | *Gochnatia pulchra* Cabrera | Asteraceae | 53 | 2.96 | 1.73 | 1.22 | 5.91 | 0.500 | clumped | C/F |
| 18 | *Miconia albicans* (Sw.) Triana | Melastomataceae | 36 | 2.44 | 1.18 | 1.27 | 4.88 | 0.205 | clumped | C/F |
| 19 | *Stryphnodendron adstringens* (Mart.) Coville | Fabaceae | 28 | 2.09 | 0.91 | 1.76 | 4.77 | 0.528 | clumped | C/F |
| 20 | *Ocotea pulchella* (Nees) Mez | Lauraceae | 39 | 2.61 | 1.27 | 0.70 | 4.59 | 0.179 | clumped | C/F |
| 21 | *Miconia ligustroides* (DC.) Naudin | Melastomataceae | 34 | 2.79 | 1.11 | 0.60 | 4.50 | 0.143 | clumped | C/F |
| 22 | *Psidium pohlianum* O. Berg | Myrtaceae | 24 | 2.61 | 0.78 | 0.58 | 3.98 | -0.349 | uniform | C |
| 23 | *Campomanesia pubescens* (DC.) O. Berg. | Myrtaceae | 35 | 2.44 | 1.14 | 0.34 | 3.93 | 0.451 | clumped | C/F |
| 24 | *Zanthoxylum rhoifolium* Lam. | Rutaceae | 26 | 2.44 | 0.85 | 0.59 | 3.88 | 0.087 | random | C/F |
| 25 | *Psychotria sessilis* Vell. | Rubiaceae | 23 | 2.61 | 0.75 | 0.34 | 3.70 | 0.061 | random | C/F |
| 26 | *Byrsonima coccolobifolia* Kunth | Malpighiaceae | 27 | 1.92 | 0.88 | 0.42 | 3.22 | 0.506 | clumped | C |
| 27 | *Styrax ferrugineus* Nees & Mart. | Styracaceae | 16 | 1.39 | 0.52 | 1.19 | 3.10 | 0.527 | clumped | C/F |
| 28 | *Pouteria torta* (Mart.) Radlk. | Sapotaceae | 23 | 0.70 | 0.75 | 1.56 | 3.01 | 0.865 | clumped | C/F |
| 29 | *Pera glabrata* (Schott) Poepp. *ex* Baill. | Peraceae | 14 | 1.74 | 0.46 | 0.71 | 2.91 | 0.070 | random | C/F |
| 30 | *Qualea grandiflora* Mart. | Vochysiaceae | 12 | 1.05 | 0.39 | 0.88 | 2.32 | 0.541 | clumped | C |
| 31 | *Aegiphila lhotszkyana* Cham. | Lamiaceae | 12 | 1.74 | 0.39 | 0.17 | 2.30 | -0.192 | uniform | C |
| 32 | *Tabebuia ochracea* (Cham.) Standl. | Bignoniaceae | 12 | 1.57 | 0.39 | 0.20 | 2.16 | -0.024 | random | C/F |
| 33 | *Symplocos lanceolata* A. DC. | Symplocaceae | 9 | 1.22 | 0.29 | 0.52 | 2.03 | 0.211 | clumped | C/F |
| 34 | *Eriotheca gracilipes* (K. Schum.) A. Robyns | Malvaceae | 6 | 0.70 | 0.20 | 0.58 | 1.48 | 0.510 | clumped | C/F |
| 35 | *Lafoensia pacari* A. St.-Hil. | Lythraceae | 7 | 1.05 | 0.23 | 0.15 | 1.43 | 0.000 | random | C/F |
| 36 | *Gochnatia barrosii* Cabrera | Asteraceae | 8 | 1.05 | 0.26 | 0.12 | 1.42 | 0.308 | clumped | C |
| 37 | *Erythroxylum cuneifolium* (Mart.) O.E. Schulz. | Erythroxylaceae | 11 | 0.70 | 0.36 | 0.21 | 1.27 | 0.548 | clumped | C/F |
| 38 | *Aspidosperma tomentosum* Mart. | Apocynaceae | 11 | 0.70 | 0.36 | 0.20 | 1.25 | 0.723 | clumped | C/F |
| 39 | *Caryocar brasiliense* Cambess. | Caryocaraceae | 8 | 0.87 | 0.26 | 0.11 | 1.25 | 0.493 | clumped | C |
| 40 | *Piptocarpha axillaris* (Less.) Baker | Asteraceae | 7 | 0.87 | 0.23 | 0.09 | 1.19 | 0.423 | clumped | C/F |
| 41 | *Alibertia concolor* (Cham.) K. Schum. | Rubiaceae | 6 | 0.70 | 0.20 | 0.25 | 1.15 | 0.317 | clumped | C/F |
| 42 | *Leandra aurea* (Cham.) Cogn. | Melastomataceae | 6 | 0.70 | 0.20 | 0.17 | 1.06 | 0.510 | clumped | F |
| 43 | *Vochysia tucanorum* Mart. | Vochysiaceae | 7 | 0.70 | 0.23 | 0.11 | 1.03 | 0.518 | clumped | C/F |
| 44 | *Plenckia populnea* Reissek | Celastraceae | 4 | 0.70 | 0.13 | 0.16 | 0.98 | -0.144 | uniform | C/F |
| 45 | Arecaceae 1 | Arecaceae | 1 | 0.17 | 0.03 | 0.69 | 0.90 | - | - | - |
| 46 | *Piptocarpha macropoda* (DC.) Baker | Asteraceae | 3 | 0.35 | 0.10 | 0.02 | 0.47 | 0.423 | clumped | F |
| 47 | *Jacaranda oxyphylla* Cham. | Bignoniaceae | 2 | 0.35 | 0.07 | 0.01 | 0.42 | -0.048 | random | C/F |
| 48 | *Vernonia polyanthes* Less. | Asteraceae | 2 | 0.17 | 0.07 | 0.07 | 0.31 | 1.000 | clumped | C/F |
| 49 | Faboideae 1 | Fabaceae | 1 | 0.17 | 0.03 | 0.09 | 0.30 | - | - | - |
| 50 | *Daphnopsis utilis* Warm. | Thymelaeaceae | 2 | 0.17 | 0.07 | 0.04 | 0.28 | 1.000 | clumped | C/F |
| 51 | *Couepia grandiflora* (Mart. & Zucc.) Benth. *ex* Hook. f. | Chrysobalanaceae | 1 | 0.17 | 0.03 | 0.07 | 0.28 | - | - | C/F |
| 52 | *Ocotea corymbosa* (Meisn.) Mez | Lauraceae | 1 | 0.17 | 0.03 | 0.05 | 0.26 | - | - | C/F |
| 53 | *Helietta* sp. | Rutaceae | 1 | 0.17 | 0.03 | 0.02 | 0.23 | - | - | - |
| 54 | *Eugenia bimarginata* DC. | Myrtaceae | 1 | 0.17 | 0.03 | 0.01 | 0.22 | - | - | C/F |
| 55 | *Tournefortia paniculata* Vent. | Boraginaceae | 1 | 0.17 | 0.03 | 0.01 | 0.22 | - | - | C/F |
| 56 | Unknown 1 | - | 1 | 0.17 | 0.03 | 0.01 | 0.22 | - | - | - |
| 57 | *Davilla elliptica* A. St.Hil. | Dilleniaceae | 1 | 0.17 | 0.03 | 0.01 | 0.21 | - | - | C |
| 58 | Unknown 2 | - | 1 | 0.17 | 0.03 | 0.00 | 0.21 | - | - | - |

monospecific. The Diversity and Equitability Indexes in the community were 3.176 and 0.782, respectively.

The community total density was 5832.38 ind $ha^{-1}$ (table 2). The species with the highest relative density was *Tibouchina stenocarpa* (12.25%), followed by *Rapanea umbellata* (9.41%), *Ouratea spectabilis* (9.11%), *Myrcia guianensis* (7.51%) and *Anadenanthera falcata* (6.60%). Together, they account for 44.9% of the sampled individuals. The total basal area was 37.07 $m^2.ha^{-1}$, and the highest values per species were observed for *Anadenanthera falcata* (3.9 $m^2$ $ha^{-1}$) and *Tibouchina*

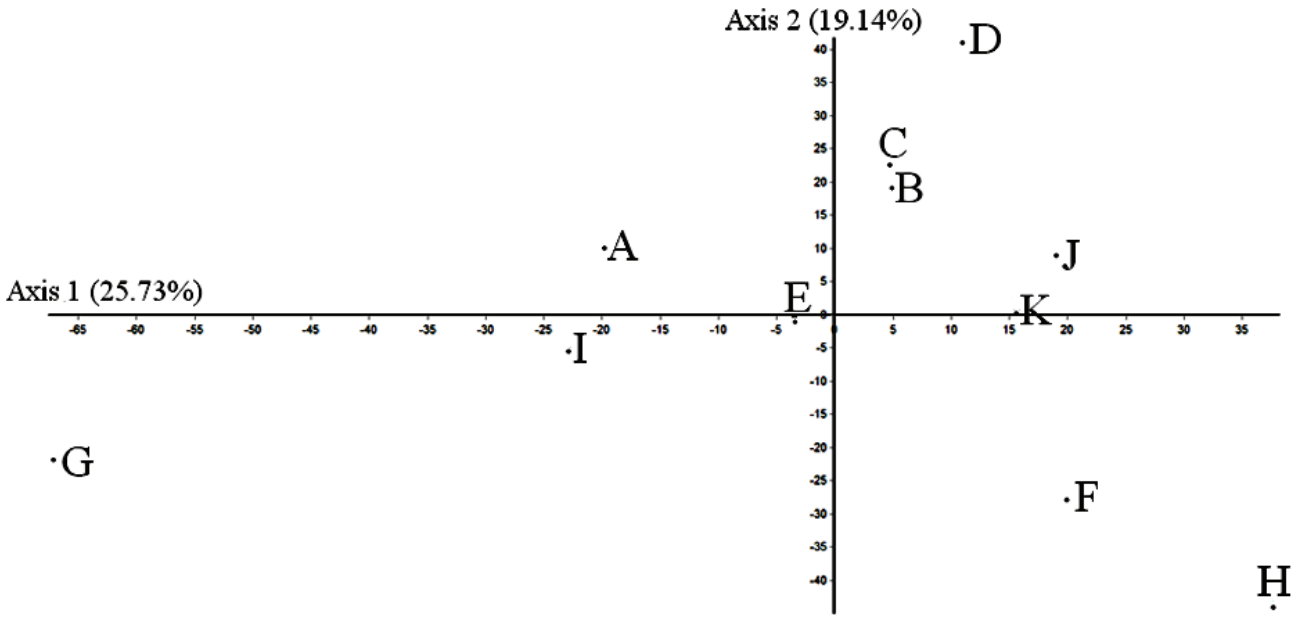


Figure 2. Principal Component Analysis (PCA) ordination diagram applied to species found in 11 surveys in cerrado *sensu stricto*. The letters correspond to those used in the map and in table 1.

*stenocarpa* (3.5 m² ha$^{-1}$), the dominant species in the studied area.

The species with the highest IV, in decreasing order, were: *Tibouchina stenocarpa*, *Anadenanthera falcata*, *Ouratea spectabilis*, *Rapanea umbellata*, *Myrcia guianensis*, *Dalbergia miscolobium*, *Eupatorium vauthierianum*, *Erythroxylum suberosum*, *Acosmium subelegans* and *Myrcia lingua*. Together they are responsible for 56.09% of the total IV. If dead individuals were included, this value would increase to 61.50%.

A larger concentration of individuals (45.75%) was encountered in the smallest classes of diameters (3-6 cm), and the number of individuals decreased as diameter classes increased. Concerning the vertical structure, the largest concentration of individuals was registered in the 1-3 m height class (63%), 20% of them belong to 3-4 m class, and only 12.3% were higher than this value, characterizing a discontinuous arboreal stratum, typical of cerrado *sensu stricto*. Few species reached the higher heights, especially *Anadenanthera falcata* (8.5 m), *Pera glabrata* (8 m), *Ocotea corymbosa* (7 m) and *Pouteria torta* (7 m).

The largest number of species (n = 39) had clumped spatial distribution, and the highest clump values were observed for *Daphnopsis utilis*, *Vernonia polyanthes*, *Pouteria torta*, *Aspidosperma tomentosum*, *Rapanea guianensis* and *Rapanea umbellata*. Random (n = 6) and uniform (n = 3) distribution were also registered but for few species (table 2).

Of the total of 52 identified species, 71.1% (n = 37) can be found in cerrado and forest (semi-deciduous and/or riparian) areas, 25% (n = 13) are exclusively found in cerrado areas and 3.9% (n = 2) are reported as exclusively found in forests (table 2).

The overall number of species sampled in all surveys compared was 238, excluding taxa not identified to species level. Of these identified species a total of 113 taxa were excluded because they occurred in only one survey, as recommended by methodology adopted. So, the final matrix included 125 species. Some of them had wide distribution and were registered in 10 of the 11 sites compared: *Aspidosperma tomentosum*, *Erythroxylum suberosum*, *Ouratea spectabilis* and *Qualea grandiflora*. These species had different importance value among the areas. For example, *Ouratea spectabilis* which occurs in all areas of São Paulo presented a range of IV between 5.30 and 25.32.

Some species were important in some areas and rare in others as *Myrcia lingua* that was one of the main species in Luiz Antônio (Toppa 2004), but rare in Brotas (Durigan *et al.* 2002). *Acosmium subelegans* was the most important species in Brotas (Durigan *et al.* 2002) and rare in Corumbataí (Pinheiro 2006).

*Daphnopsis fasciculata*, *Tibouchina stenocarpa* and *Vochysia parviflora* were the most important species in Corumbataí (Pinheiro 2006), Botucatu (this study) and Minas Gerais (Balduino *et al.* 2005), respectively, and absent in all other areas.

In the PCA (figure 2), axis 1 was responsible for 25.73% of the information contained in all the variables and the axis 2 by 19.14%, so the information accumulated by the first two principal components was 44.87%. The variables with greater discriminatory value were *Anadenanthera falcata* (- 0.6868) in the first axis, leading to greater proximity of Botucatu, Luiz Antônio and Santa Rita do Passa Quatro surveys in the ordination space. *Qualea grandiflora* (- 0.6246) in the second axis influenced the location of Itirapina, Patrocínio Paulista, Luiz Antônio and Santa Rita do Passa Quatro. *Acosmium subelegans* showed high discriminatory value in the second axis (0.3486), defining the position of Brotas, Agudos, Águas de Santa Bárbara and Botucatu in the ordination space. The other areas showed an intermediary position.

The TWINSPAN analysis (figure 3) defined two major groups and showed a more coherent segregation pattern, considering the geographical position of the surveys. In the first division level, two groups were segregated, one composed of São Paulo cerrados and other formed by nuclear areas (Minas Gerais and Federal District). The divisions were strong with eigenvalues above 0.30 (Gauch 1982 *apud* Felfili *et al.* 2004). The preferential species to the nuclear areas were *Agonandra brasiliensis*, *Enterolobium gummiferum*, *Erythroxylum deciduum*, *Eugenia dysenterica*, *Machaerium opacum*, *Schefflera macrocarpa*, *Sclerolobium paniculatum*, species that were not found in the surveys in São Paulo. The São Paulo surveys were finally divided into groups more similar to the spatial arrangement produced in the PCA analysis.

## Discussion

The number of species observed in the studied cerrado is within the interval from 44 to 86 species reported in other cerrado at neighboring sites (table 1). This range may be due to different inclusion criterion adopted by the authors or to local variations related to environmental peculiarities or the degree of disturbance that the areas had undergone. However, the studied area showed to be highly distinct as Asteraceae is its richest family, a fact that was not observed in previous inventories performed in cerrados of Botucatu region (Silberbauer-Gottsberger & Eiten 1987, Bicudo *et al.* 1996), which present Fabaceae, Myrtaceae in such position. This feature may be related to the conservation state of the studied cerrado considering that among the inventoried Asteraceae species *Eupatorium vauthierianum* (Maluf & Wizentier 1998) and *Vernonia polyanthes* (Lorenzi 2008) are reported as colonizer species and *Piptocarpha axilaris* (Lorenzi 2009) and *P. rotundifolia* (Lorenzi 1998) are reported as pioneers in cerrado and forest areas.

The obtained diversity value (H' = 3.18) is similar to others found in some areas of cerrado *sensu stricto*, in São Paulo State (table 1), within the same range as that of Federal District cerrados (Assunção & Felfili 2004).

Density and basal area per hectare were among the highest values recorded in the region. The basal area value (37.07 $m^2 ha^{-1}$) was similar to those obtained in other neighboring cerrado areas like 42.72 $m^2 ha^{-1}$

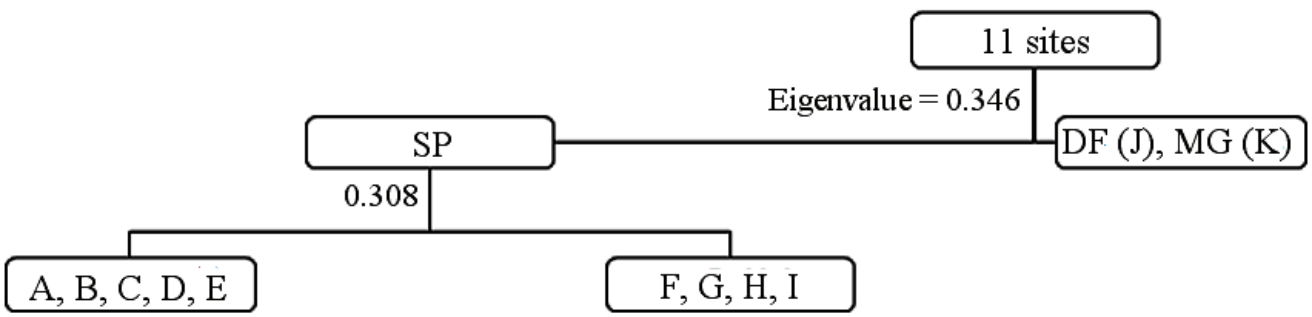


Figure 3. Classification by TWINSPAN applied to species found in 11 surveys in cerrado *sensu stricto*. The letters correspond to those used in the map and in table 1.

found by Cavassan *et al.* (1993) in cerradão, 42.83 $m^2/ha^{-1}$ found by Bertoncini (1996) in cerrado *sensu stricto* and 48.27 $m^2$ $ha^{-1}$ found by Faraco (2007) in cerradão. The basal area obtained for some other inventories was inferior to these values (see Cesar *et al.* 1988, Fidelis & Godoy 2003, Assunção & Felfili 2004, Balduino *et al.* 2005, all related to cerrado *sensu stricto* areas). These results may be related to the fact that the cerrados with higher values of basal area are frequently close or transitions to forest or cerradão areas, which generally show greater values to this parameter (see discussion in Cavassan *et al.* 1993, Bertoncini 1996, Faraco 2007).

The community diametric distribution showed a higher concentration of plants in the lowest classes, which can indicate that there is a great quantity of new individuals and that the community is probably undergoing an auto-regeneration phase (Assunção & Felfili 2004). However, in the case of cerrado, it must also be considered that some species present short adults, which is their maximum genetic potential expression (Silva Junior & Silva 1988).

The highest IV was observed for *Tibouchina stenocarpa* due to its high dominance value resultant from the large number of its individuals. Such feature is uncommon as this species rarely appears in other structural studies. It was recorded by Pereira-Silva *et al.* (2004) in Luiz Antônio (São Paulo State), with low importance value (0.61). This species is considered a pioneer in Botucatu region, present in areas with different degradation degrees (Sartor 1994). According to Durigan *et al.* (2004), it occurs in different cerrado physiognomies and in riparian forests. Besides, *T. stenocarpa* can be associated not only with disturbed vegetation but also with higher water availability in the soil, as its presence in more humid areas was reported by Pinto *et al.* (2005).

The second most important species in the community was *Anadenanthera falcata*, more frequently reported among those of high IV in cerrado areas (Fidelis & Godoy 2003, Toppa 2004, Pinheiro 2006). Although this species was less abundant than *Tibouchina stenocarpa*, its representatives had larger basal area, leading therefore to high dominance.

Among the ten species with the highest IV, only the bush *Eupatorium vauthierianum* is not commonly reported in cerrado structural studies. This species had an IV of 0.65 in a *cerradão* area in Corumbataí, São Paulo State (Cesar *et al.* 1988). However, it was abundant in a region of poor and acid soil, in Santo André (São Paulo State), which underwent anthropic interferences, and was considered an r-strategist colonizer species (Maluf & Wizentier 1998). Thus, its occurrence may evidence the regeneration phase now experienced by the studied area which, although preserved since year 2001, might have suffered anthropic interferences in the past since it is located beside a highway and an abandoned reforestation area. This may have contributed to some changes in the vegetation, favoring the establishment of pioneer species.

The particular feature of the studied cerrado where predominate species that are encountered both in cerrado and forest areas may indicate the occurrence of past immigration of forest species, since the area has being protected from fire for several years. Species like *Alibertia concolor*, *Guapira opposita*, *Lafoensia pacari*, *Miconia ligustroides*, *Ocotea corymbosa*, *Ocotea pulchella, Pera glabrata*, *Platypodium elegans*, *Qualea multiflora*, *Rapanea umbellata*, *Solanum variabile*, *Tibouchina stenocarpa* and *Vochysia tucanorum* have been previously reported in seasonal semi-deciduous forest in Botucatu region (Grombone-Guaratini & Maimoni-Rodella 1995). Although the studied cerrado may be easily distinguished from forest formations by its physiognomy, its floristic composition indicates that the area might be considered a transition from cerrado to seasonal semi-deciduous forest. This situation was demonstrated by Pinheiro & Monteiro (2006) who had pointed out that in absence of periodical fire some cerrado formations undergo secondary succession, leading to the establishment of forest ecosystems in ecotone areas. Considering that a seasonal semi-deciduous forest is located in the neighborhood, this hypothesis seems plausible. Besides, cerrados in marginal or disjunct areas are known to gradually grade to other formations and, as a consequence, show considerable floristic richness (Castro *et al.* 1999, Durigan & Ratter 2006).

The most abundant species showed clumped spatial distribution, which could be a reflex of the existence of spots more favorable to their development, leading to higher concentration of individuals in these sites (Ludwig & Reynolds 1988). According to Durigan *et al.* (2002), the high clumping rate of some species may also be associated with their regeneration form, and many cerrado species can regenerate by sprouting from subterranean structures. However, there is no available information on the species present in the studied area, except for *Stryphnodendron adstringens* and *Aegiphla*

*lhotszkyana*, which can propagate from subterranean systems (Rizzini & Heringer 1966). In São Paulo State cerrados, clumped spatial distribution seems to be the most common pattern, followed by uniform and random patterns, which normally occur at lower proportions (Durigan *et al.* 2002).

The ordination of the compared sites obtained by PCA analysis produced results that show greater proximity among areas with some degree of disturbance as Itirapina, Brasília and Paraopeba. The cerrado of Patrocínio Paulista, which is a reserve, was close to these areas probably due to the inclusion criterion adopted, resulting in a more reduced inventory. The ordination of the other areas may be related to soil characteristics, considering that the soil type is Quartzarenic Neosol in all sites with negative ordination in Axis 2. The remaining São Paulo areas, which are distributed in the positive region of Axis 2 present Red or Yellow Latosol (except Brotas).

The TWINSPAN classification was more related to geographical distribution, since the São Paulo areas were separated from the Minas Gerais and Federal District areas, forming two different groups. Similar results were obtained by Ratter *et al.* (2003). This analysis seems to be more reliable than others in the comparison of plant communities (Scudeller *et al.* 2001) and corroborates the statement that São Paulo State holds one of the cerrado centers of diversity whose floristic composition is different from the other cerrado diversity centers in Brazil (Ratter *et al.* 1996, Durigan *et al.* 2003, Gomes *et al.* 2004). Additionally, this analysis produced the same classification for São Paulo areas as observed in PCA analysis, segregating sites with Quartzarenic Neosol from areas with Latosol.

The peculiarities of the cerrado structure in Botucatu confirm the extreme variability of this vegetation even in restrict geographic areas, indicating the formation of regional vegetation mosaics, as previously reported for other cerrado biome areas (Bridgewater *et al.* 2004). The high diversity observed in that small sampled area reveals the importance of such fragments which, although altered, can be considered a remnant of the original vegetation, serving as floristic-structural reference for future conservation actions in the region. As stated by Assunção & Felfili (2004), its maintenance is essential, mainly if we consider its role in the connection with other fragments, allowing pollen flow and seed dispersion among close areas. In addition, data obtained until the present moment can be useful for a better understanding of the structure and dynamics of the community, contributing therefore to future actions of conservation and rational sustainable exploitation.

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