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# STRUCTURE AND FLORISTICS OF THE ARBOREAL COMPONENT OF A DYSTROPHIC CERRADÃO AND COMPARISON WITH OTHER CERRADÕES IN CENTRAL BRAZIL

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This study describes the structure of the arboreal plant community in a cerradão fragment located at the Serra de Caldas Novas State Park, Goiás, central Brazil. It also compares the collected data with information from 10 other cerradão sites on dystrophic and mesotrophic soils. All trees of 4.77 cm or more diameter at breast height, in twenty-five 20 m × 20 m plots, were surveyed. Soil samples were analysed to determine the availability of nutrients. The vegetation had a discontinuous canopy, with a high density of small and medium-sized trees, and the soil was classified as dystrophic according to nutrient availability. Under ordination using Detrended Correspondence Analysis, species characteristic of the study site, such as *Sclerolobium paniculatum* and *Emmotum nitens*, were positioned in the central portion, while cosmopolitan species formed distinct groups, separated along the two axes. The community showed a low level of similarity in comparison to cerradões reported in the literature in other parts of Brazil, having more than 50% similarity only with three geographically close sites.

*Keywords.* Dystrophic cerradão, floristic survey, mesotrophic cerradão, multivariate analysis.

## Introduction

The cerrado is the second largest vegetation type in Brazil, occupying about 2 million km$^2$, and is exceeded only by the Amazonian forest with 3.5 million km$^2$ (Furley & Ratter, 1988; Ratter *et al.*, 1997). It occupies the central part of the country and is usually located on crystalline or sedimentary plateaus (Brasil & Alvarenga, 1989; Silva & Bates, 2002). This extensive biome is a biodiversity 'hotspot' and is a conservation priority area because 70% of it has already been altered by intensive human activity and only 6.2% is protected in reservations or conservation units (Myers *et al.*, 2000). The natural vegetation of cerrado varies

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from open, dry grassland (termed campo limpo) to savanna parkland containing scattered low contorted trees of 4–8 m in a grassland matrix (termed cerrado *sensu stricto*, *s.s.*) to forest physiognomies of characteristic species called cerradão (the augmentative of cerrado in Portuguese) (Eiten, 1972; Coutinho, 1978; Ratter *et al.*, 1997).

The cerradão is essentially a sclerophyllous forest (Rizzini, 1979), that occupies around 1% of the cerrado biome (Borlaug, 2002) and is associated with well-drained deep soils (Ribeiro & Walter, 2008). Its flora consists of typical cerrado species mixed with those of forest; however, there is a group that has cerradão as their most characteristic habitat. Cerradões (plural of cerradão) show great variation in vegetation structure, ranging from those with 6–7 m tall emergent trees and partially closed canopies to true forests with up to 15 m tall trees and more than 90% canopy cover (Ratter *et al.*, 1977).

Although cerradão now covers perhaps only c.1% of the cerrado biome, there is evidence that in the past, before massive human influence, it formed a major – or possibly the dominant – component of cerrado vegetation (see Ratter *et al.*, 2006). Many of the 19th-century botanical explorers comment on its prevalence across central Brazil and it was even abundant at the time of the cutting of the Belo Horizonte–Brasília highway in the 1960s and of the roads in eastern Mato Grosso at the same time (Rizzini, 1979; Ratter *et al.*, 2006). Rizzini (1963) and Rizzini & Heringer (1962) used the term *floresta xeromorfa* for cerradão and Warming (1892) equated it to the Indian name *Catanduva*. The latter author had not seen great landscapes of this vegetation but had heard of them from travellers and deduced from the frequent use of the term *Catanduva* as a place name that it was once widespread. Durigan has demonstrated the regeneration of cerradão on reserves in São Paulo State that have been protected, particularly against fire, for a considerable period (Durigan *et al.*, 2003; Durigan, 2006). There seems little doubt that it would represent the climax vegetation of a very great area of the cerrado biome in the absence of human disturbance.

Studies on vegetation (Ratter, 1971; Ratter *et al.*, 1973) and soil properties (Askew *et al.*, 1971) were published as a result of the 1967–69 British expedition in the Xavantina-Cachimbo area of Mato Grosso State in the central Brazilian plateau (Ratter *et al.*, 1973). These and subsequent studies in several areas have shown the existence of two types of cerradão, one type, called mesotrophic, occurring in soils with pH greater than 5.1 and availability of Ca greater than 2 cmol $dm^{-3}$, and the other, called dystrophic, occurring in soils with pH from 4.0 to 4.8 and Ca contents lower than 0.5 cmol $dm^{-3}$ (Ratter, 1971; Ratter *et al.*, 1973, 1977; Araújo & Haridasan, 1988; Furley & Ratter, 1988). The number of species found in these cerradão types varied from 25 to 125, with a Shannon diversity index from 2.92 to 3.56 (Felfili *et al.*, 1994; Guilherme & Nakajima, 2007). Another important aspect is that, unsurprisingly, cerradões often occur on soils of intermediate character in transition zones between more open cerrado formations and deciduous and semi-deciduous forests (Ratter, 1971; Ratter *et al.*, 1977; Marimon-Júnior & Haridasan, 2005). The most common characteristic species are *Callisthene fasciculata* Mart. and *Magonia pubescens* in mesotrophic cerradão, and *Emmotum nitens* and *Hirtella glandulosa* in dystrophic cerradão (Ratter, 1971; Ratter *et al.*, 1973, 1977; Araújo & Haridasan, 1988). (See Table 2 for authors for species recorded in the present study.)

There are few reports in the literature on cerradão due to its small area compared with the other cerrado physiognomies and also because of its widespread destruction for agricultural and other uses. Thus, there is an urgent need to generate information for the conservation and management of the remaining areas of this interesting and important vegetation.

The objective of the present study was to characterise the vegetation and the soil of a fragment of cerradão located in the Serra de Caldas Novas State Park and compare it with other cerradão areas in central Brazil.

## Material and Methods

The study was carried out in a cerradão located along the eastern boundary of the Serra de Caldas Novas State Park (Parque Estadual de Caldas Novas, PESCAN) (see Fig. 1) at 17°46′S, 48°39′W and an altitude of 780 m in an area with outcrops of metasiltite rocks (Embrapa, 1983). The region has well-defined dry and rainy seasons and the climate is Aw (savanna subtype of the tropical rain climate) according to Köppen's classification (1948). The mean annual temperature is 22°C and the annual precipitation is 1550 mm (Reatto & Martins, 2005). Red and yellow latosols occur along the top of the PESCAN plateau and lithosols along the borders (Embrapa, 1983). The park is a conservation unit with an area of 12,315 ha, created in 1970 to protect the recharging of the hydrothermal aquifer in the area and maintain the regional flora and fauna. The cerradão area sampled is of about 45 ha, surrounded by areas of lower and more open cerrado and riverine and semideciduous forests.

In order to characterise the soil of cerradão, six plots were randomly selected among the 25 plots where vegetation was sampled. Soil samples of 0–20 cm depth were collected from three random points in each plot and made into a composite sample. These were air-dried and passed through a 2 mm mesh sieve. Soil pH was measured in 1:2.5 soil–water suspensions. Exchangeable $Ca^{2+}$, $Mg^{2+}$ and $Al^{3+}$ were determined in 1*N* KCl. Mellich extract (0.0125*N* $H_2SO_4$ + 0.05*N* HCl) was used for the determination of P, $K^+$ and base saturation. Diethylenetriaminepentaacetic acid (DTPA) (pH 7.3) was used for the extraction of $Fe^{3+}$ and $Mn^{2+}$. Aluminium was obtained by titration with 0.025*N* NaOH (Allen, 1974). The P content was determined by colorimetry and K by flame photometry. The organic matter was estimated by titration with 0.5*N* $Fe_2SO_4$ (Walkley & Black, 1934) and levels of other elements were obtained by atomic absorption spectrophotometry. The analyses were carried out at the Soils Laboratory of the Federal University of Uberlândia.

Twenty-five contiguous 20 m × 20 m plots were surveyed to register all trees of 4.77 cm or more diameter at breast height (dbh), giving a total sample area of 1 ha. Phytosociological parameters (density, dominance, frequency, and importance

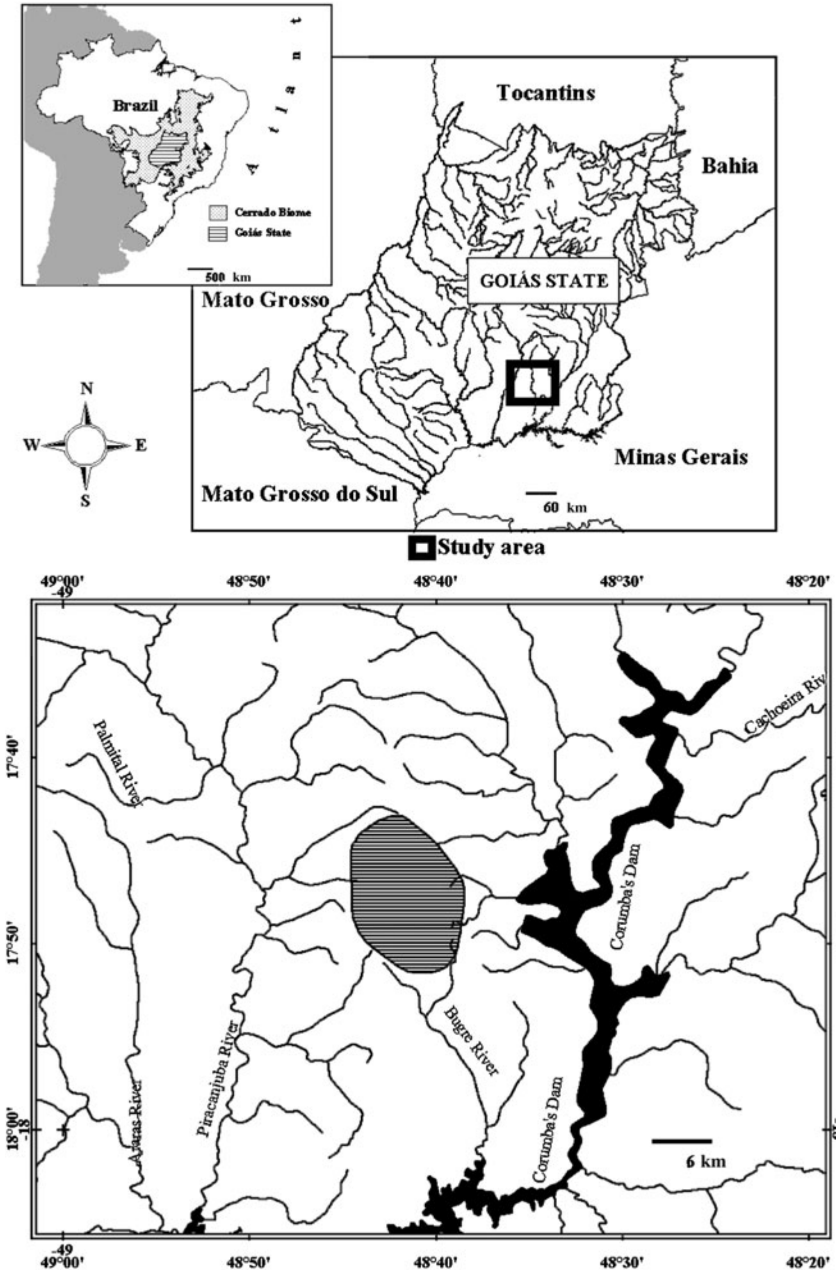


FIG. 1. Location of the Serra de Caldas Novas State Park, Goiás, Brazil (with transversal lines). Drawing by Borges Filho, H.C.

value) were calculated using FITOPAC software (Shepherd, 2006). The classification system adopted for the plant families was APG II (Angiosperm Phylogeny Group, 2003).

Sturge's formula ($k = \log_2 n + 1$, where $n$ is the number of samples and $k$ is the number of bins) was used to calculate the optimal number of bins for a histogram of the diameter distribution of the tree species in the community with dbh $\geq$ 4.77 cm. The frequency distribution of diameters was well fitted by a gamma distribution.

The allometric relationship (H/D) between tree height and dbh was evaluated using simple regression analysis. According to Thornley (1999), the H/D ratio provides an adequate description of this allometric relationship in plants.

Ordination of tree species was performed using Detrended Correspondence Analysis (DCA – Hill, 1979; Hill & Gauch, 1980). This method is based on Reciprocal Averaging (RA) and is geared towards ecological analyses as it has the potential to uncover modal as well as linear gradients. Reciprocal Averaging is also referred to as correspondence analysis. Detrended Correspondence Analysis is an extension of correspondence analysis, whereby as an extra step the axes are detrended and rescaled in order to overcome the tendency of the correspondence analysis to distort one-dimensional gradients into an arch along the second axis and to unevenly space samples along the first axis (Holland, 2008).

Floristic similarity between our site and 10 other areas of Brazilian cerradão was compared by the Sørensen similarity index and the UPGMA (Unweighted Pair-Group Method Using Arithmetic Average) clustering method, based on species lists for each area (Kent & Coker, 1992; Afifi & Clark, 1997). For this analysis two worksheets were constructed: one with a quantitative data analysis for tree community ordination (DECORANA), and the other qualitative (with data of presence and absence) for analysis of the similarity (cluster) among the 11 areas of cerradão. Only areas sampled by the plot method were used in comparisons.

A classification of the 11 areas of cerradão was carried out using the Two-Way Indicator Species Analysis (TWINSPAN) method. The method is divisive and polythetic and builds a dichotomous table for the identification of preferential species and plots. The samples are first sorted by successive divisions. Then, the species are also classified in the same way, using the divisions of the samples as a base. The two classifications are made simultaneously and the dichotomies are obtained by dividing the ordinations in half (Kent & Coker, 1992).

Software PC-ORD for Windows, version 5.10 (McCune & Mefford, 2006) was used for multivariate analysis of ordination (DECORANA), clustering (UPGMA) and the TWINSPAN classification method.

## Results

The soil in the PESCAN cerradão area has low availability of P, Ca and Mg, with a base saturation of 8.3 and soil pH of 5 (Table 1).

TABLE 1. Characteristics of the soil in the cerradão in the Serra de Caldas Novas State Park, Goiás, Brazil, collected from 0–20 cm depth

| Characteristic | Value | SD |
|---|---|---|
| pH ($H_2O$) | 5.0 | 0.2 |
| Available nutrients (mg $dm^{-3}$): | | |
| – P | 2.2 | 1.1 |
| – K | 86.3 | 22.9 |
| – Fe | 69.8 | 16.1 |
| – Mn | 255.0 | 62.0 |
| Available nutrients ($cmol_c$ $dm^{-3}$): | | |
| – Ca | 0.1 | 0.1 |
| – Mg | 0.1 | 0.0 |
| – Al | 0.8 | 0.2 |
| Base saturation (%) | 8.3 | 0.8 |
| Organic matter (%) | 6.4 | 0.5 |

$n = 6$, SD = standard deviation.

A total of 1051 individuals belonging to 99 species were sampled in the 1 ha area of cerradão (Table 2). The families with the greatest number of species were Leguminosae (19), followed by Vochysiaceae (7), Apocynaceae (6) and Myrtaceae (6), while the genera with the greatest number of species were *Aspidosperma* (4), *Alibertia* (3), *Myrcia* (3), *Qualea* (3) and *Vochysia* (3).

*Sclerolobium paniculatum*, *Emmotum nitens*, *Xylopia aromatica*, *Bowdichia virgilioides* and *Qualea grandiflora* were the most important species, giving 34.2% of the importance value and 35.6% of the total number of individuals. Forty-four species (44.4% of the total) had only one or two individuals and were classified as rare species in the community (Table 2). The basal area was calculated as 14.34 $m^2$ $ha^{-1}$ and the Shannon diversity index (H′) as 3.7 (Table 3).

Diameter distribution (Fig. 2) and the relationship between height and diameter (Fig. 3) show that most of the trees had diameters from 5 to 20 cm and heights between 2 and 10 m. The H/D ratio is greater for small diameters (Fig. 3). Very few individuals showed heights greater than 14 m and diameters above 40 cm. An increase in diameter usually leads to a greater variation in observed plant heights (Fig. 3), which reflects a larger H/D ratio and reduces its accuracy.

Ordination of species (Fig. 4) resulted in a dispersed cloud of points along the two axes, with a greater variation for axis II. Typical cerradão species such as *Sclerolobium paniculatum* and *Emmotum nitens* were positioned in the central part, with average values for the two axes. On the other hand, species that also occur in seasonal semideciduous forests, such as *Styrax camporum*, *Alibertia edulis*, *Cardiopetalum calophyllum* and *Dipteryx alata*, presented greater values for axis II and were positioned away from the rest of the species. For the first axis, the eigenvalue was large (0.34) and species of the cerrado (*s.s.*) such as *Connarus suberosus*, *Caryocar*

TABLE 2. Phytosociological parameters of the arboreal species of the dystrophic cerradão in the Serra de Caldas Novas State Park, Goiás, Brazil

| Species | *N* | RD | RF | RDo | IV |
|---|---|---|---|---|---|
| *Sclerolobium paniculatum* Vogel | 147 | 13.99 | 4.95 | 20.00 | 38.93 |
| *Emmotum nitens* (Benth.) Miers | 80 | 7.61 | 4.36 | 11.83 | 23.80 |
| *Xylopia aromatica* (Lam.) Mart. | 74 | 7.04 | 4.36 | 3.12 | 14.52 |
| *Bowdichia virgilioides* Kunth | 34 | 3.24 | 3.96 | 6.09 | 13.29 |
| *Qualea grandiflora* Mart. | 40 | 3.81 | 3.17 | 5.07 | 12.04 |
| *Dipteryx alata* Vogel* | 20 | 1.90 | 1.98 | 6.49 | 10.37 |
| *Vatairea macrocarpa* (Benth.) Ducke | 27 | 2.57 | 3.17 | 3.76 | 9.50 |
| *Caryocar brasiliense* Cambess. | 29 | 2.76 | 1.58 | 4.91 | 9.26 |
| *Lippia salviifolia* Cham. | 44 | 4.19 | 2.38 | 1.96 | 8.52 |
| *Byrsonima crassa* Nied. | 33 | 3.14 | 2.38 | 1.35 | 6.87 |
| *Magonia pubescens* A.St.-Hil.* | 26 | 2.47 | 2.57 | 1.69 | 6.74 |
| *Styrax ferrugineus* Nees & Mart. | 32 | 3.04 | 1.78 | 1.67 | 6.49 |
| *Curatella americana* L. | 21 | 2.00 | 2.38 | 1.76 | 6.14 |
| *Kielmeyera coriacea* Mart. & Zucc. | 22 | 2.09 | 2.18 | 1.35 | 5.62 |
| *Erythroxylum daphnites* Mart. | 17 | 1.62 | 2.18 | 1.35 | 5.15 |
| *Hymenaea stigonocarpa* Mart. ex Hayne | 12 | 1.14 | 1.98 | 2.01 | 5.13 |
| *Qualea parviflora* Mart. | 13 | 1.24 | 1.19 | 2.67 | 5.09 |
| *Qualea multiflora* Mart. | 20 | 1.90 | 1.98 | 1.01 | 4.89 |
| *Astronium fraxinifolium* Schott ex Spreng.* | 15 | 1.43 | 1.98 | 1.41 | 4.81 |
| *Hirtella glandulosa* Spreng. | 11 | 1.05 | 1.58 | 2.05 | 4.68 |
| *Aspidosperma macrocarpon* Mart. | 17 | 1.62 | 2.38 | 0.68 | 4.67 |
| *Maprounea guianensis* Aubl. | 19 | 1.81 | 2.38 | 0.46 | 4.64 |
| *Stryphnodendron polyphyllum* Mart. | 15 | 1.43 | 1.58 | 0.65 | 3.66 |
| *Pterodon pubescens* (Benth.) Benth. | 9 | 0.86 | 1.39 | 1.37 | 3.61 |
| *Matayba guianensis* Aubl. | 14 | 1.33 | 1.39 | 0.84 | 3.56 |
| *Simarouba versicolor* A.St.-Hil. | 12 | 1.14 | 1.39 | 0.80 | 3.33 |
| *Vochysia haenkeana* Pohl | 10 | 0.95 | 1.39 | 0.82 | 3.16 |
| *Plathymenia reticulata* Benth. | 14 | 1.33 | 1.19 | 0.57 | 3.09 |
| *Davilla elliptica* A.St.-Hil. | 11 | 1.05 | 1.39 | 0.34 | 2.77 |
| *Sclerolobium aureum* (Tul.) Baill. | 10 | 0.95 | 1.39 | 0.41 | 2.75 |
| *Acosmium dasycarpum* (Vogel) Yakovlev | 9 | 0.86 | 1.58 | 0.27 | 2.71 |
| *Miconia albicans* (Sw.) Triana | 8 | 0.76 | 1.39 | 0.24 | 2.39 |
| *Alibertia edulis* (Rich.) A.Rich. ex DC. | 8 | 0.76 | 1.19 | 0.38 | 2.33 |
| *Schefflera macrocarpa* (Cham. & Schltdl.) Frodin | 8 | 0.76 | 1.19 | 0.31 | 2.26 |
| *Myrcia* sp. | 8 | 0.76 | 1.19 | 0.21 | 2.16 |
| *Cardiopetalum calophyllum* Schltdl. | 8 | 0.76 | 1.19 | 0.19 | 2.14 |
| *Protium heptaphyllum* (Aubl.) Marchand | 6 | 0.57 | 0.59 | 0.85 | 2.02 |
| *Alibertia myrciifolia* Spruce ex K.Schum. | 7 | 0.67 | 0.99 | 0.24 | 1.90 |
| *Miconia ferruginea* (Desr.) DC. | 6 | 0.58 | 0.99 | 0.29 | 1.86 |
| *Salvertia convallariodora* A.St.-Hil. | 4 | 0.38 | 0.79 | 0.65 | 1.82 |
| *Aspidosperma tomentosum* Mart. | 6 | 0.57 | 0.99 | 0.23 | 1.79 |
| *Diospyros hispida* A.DC. | 5 | 0.48 | 0.59 | 0.65 | 1.72 |
| *Styrax camporum* Pohl | 7 | 0.67 | 0.59 | 0.45 | 1.71 |
| *Byrsonima coccolobifolia* Kunth | 7 | 0.67 | 0.79 | 0.19 | 1.65 |
| *Eriotheca gracilipes* (K.Schum.) A.Robyns | 5 | 0.48 | 0.79 | 0.38 | 1.64 |

TABLE 2. (*Cont'd*)

| Species | *N* | RD | RF | RDo | IV |
|---|---|---|---|---|---|
| *Vochysia rufa* Mart. | 6 | 0.57 | 0.79 | 0.24 | 1.60 |
| *Dilodendron bipinnatum* Radlk.* | 2 | 0.19 | 0.40 | 0.85 | 1.44 |
| *Guapira noxia* (Netto) Lundell | 4 | 0.38 | 0.59 | 0.41 | 1.38 |
| *Annona crassiflora* Mart. | 5 | 0.48 | 0.59 | 0.25 | 1.32 |
| *Salacia crassifolia* (Mart. ex Schult.) G.Don | 4 | 0.38 | 0.79 | 0.14 | 1.31 |
| *Annona coriacea* Mart. | 5 | 0.48 | 0.59 | 0.14 | 1.21 |
| *Machaerium acutifolium* Vogel | 3 | 0.29 | 0.59 | 0.17 | 1.05 |
| *Dimorphandra mollis* Benth. | 3 | 0.29 | 0.59 | 0.14 | 1.02 |
| *Heteropterys byrsonimifolia* A.Juss. | 3 | 0.29 | 0.59 | 0.13 | 1.01 |
| *Cybistax antisyphilitica* (Mart.) Mart. | 3 | 0.29 | 0.59 | 0.07 | 0.95 |
| *Psidium* sp. 2 | 3 | 0.29 | 0.40 | 0.23 | 0.92 |
| *Eriotheca pubescens* (Mart. & Zucc.) Schott & Endl. | 2 | 0.19 | 0.40 | 0.20 | 0.78 |
| *Neea theifera* Oerst. | 3 | 0.29 | 0.40 | 0.09 | 0.78 |
| *Piptocarpha rotundifolia* (Less.) Baker | 2 | 0.19 | 0.40 | 0.18 | 0.76 |
| *Handroanthus serratifolius* (Vahl) S.O.Grose* | 2 | 0.19 | 0.40 | 0.11 | 0.70 |
| *Licania humilis* Cham. & Schltdl. | 2 | 0.19 | 0.40 | 0.11 | 0.70 |
| *Aspidosperma subincanum* Mart.* | 2 | 0.19 | 0.20 | 0.28 | 0.67 |
| *Antonia ovata* Pohl* | 2 | 0.19 | 0.40 | 0.06 | 0.64 |
| *Connarus suberosus* Planch. | 2 | 0.19 | 0.40 | 0.04 | 0.63 |
| *Eremanthus glomerulatus* Less. | 2 | 0.19 | 0.40 | 0.04 | 0.63 |
| *Ficus enormis* (Mart. ex Miq.) Mart. | 2 | 0.19 | 0.40 | 0.04 | 0.63 |
| *Cecropia pachystachya* Trécul | 2 | 0.19 | 0.40 | 0.04 | 0.62 |
| *Myrcia tomentosa* (Aubl.) DC. | 2 | 0.19 | 0.40 | 0.03 | 0.62 |
| *Machaerium opacum* Vogel | 1 | 0.10 | 0.20 | 0.26 | 0.55 |
| *Plenckia populnea* Reissek | 1 | 0.10 | 0.20 | 0.25 | 0.54 |
| *Alibertia sessilis* (Vell.) K.Schum. | 2 | 0.19 | 0.20 | 0.12 | 0.51 |
| *Ouratea spectabilis* (Mart. ex Engl.) Engl. | 2 | 0.19 | 0.20 | 0.08 | 0.47 |
| *Guapira* sp. | 1 | 0.10 | 0.20 | 0.15 | 0.44 |
| *Ocotea spixiana* (Nees) Mez | 2 | 0.19 | 0.20 | 0.05 | 0.44 |
| *Lafoensia pacari* A.St.-Hil. | 1 | 0.10 | 0.20 | 0.13 | 0.43 |
| *Dalbergia violacea* (Jacq.) Hoffmanns. | 1 | 0.10 | 0.20 | 0.12 | 0.42 |
| *Inga* sp. | 2 | 0.19 | 0.20 | 0.03 | 0.42 |
| *Himatanthus obovatus* (Müll.Arg.) Woodson | 1 | 0.10 | 0.20 | 0.11 | 0.40 |
| *Pouteria torta* (Mart.) Radlk. | 1 | 0.10 | 0.20 | 0.09 | 0.38 |
| *Hancornia speciosa* B.A.Gomes | 1 | 0.10 | 0.20 | 0.07 | 0.36 |
| *Bauhinia* sp. | 1 | 0.10 | 0.20 | 0.06 | 0.35 |
| *Virola sebifera* Aubl. | 1 | 0.10 | 0.20 | 0.06 | 0.35 |
| *Diospyros burchellii* Hiern | 1 | 0.10 | 0.20 | 0.05 | 0.35 |
| *Myrsine* sp. | 1 | 0.10 | 0.20 | 0.04 | 0.33 |
| *Roupala montana* Aubl. | 1 | 0.10 | 0.20 | 0.04 | 0.33 |
| *Ouratea hexasperma* (A.St.-Hil.) Baill. | 1 | 0.10 | 0.20 | 0.03 | 0.33 |
| *Psidium* sp. 1 | 1 | 0.10 | 0.20 | 0.03 | 0.33 |
| *Erythroxylum suberosum* A.St.-Hil. | 1 | 0.10 | 0.20 | 0.03 | 0.32 |
| *Enterolobium gummiferum* (Mart.) J.F.Macbr. | 1 | 0.10 | 0.20 | 0.02 | 0.32 |
| *Guapira graciliflora* (Schmidt) Lundell | 1 | 0.10 | 0.20 | 0.02 | 0.32 |
| *Stryphnodendron adstringens* (Mart.) Coville | 1 | 0.10 | 0.20 | 0.02 | 0.32 |
| *Myrcia splendens* (Sw.) DC. | 1 | 0.10 | 0.20 | 0.02 | 0.31 |

Table 2. (*Cont'd*)

| | | | | | |
|---|---|---|---|---|---|
| *Siparuna guianensis* Aubl. | 1 | 0.10 | 0.20 | 0.02 | 0.31 |
| *Vochysia cinnamomea* Pohl | 1 | 0.10 | 0.20 | 0.02 | 0.31 |
| *Zanthoxylum rhoifolium* Lam. | 1 | 0.10 | 0.20 | 0.02 | 0.31 |
| *Aspidosperma cuspa* (Kunth) S.F.Blake ex Pittier* | 1 | 0.10 | 0.20 | 0.01 | 0.31 |
| *Copaifera langsdorffii* Desf. | 1 | 0.10 | 0.20 | 0.01 | 0.31 |
| *Myrsine umbellata* Mart. | 1 | 0.10 | 0.20 | 0.01 | 0.31 |
| *Psidium rufum* DC. | 1 | 0.10 | 0.20 | 0.01 | 0.31 |
| Total | 1051 | 100 | 100 | 100 | 300 |

*N* = number of individuals; RD = relative density; RF = relative frequency; RDo = relative dominance; IV = importance value; * = indicator species of mesotrophic cerradão.

*brasiliense*, *Annona crassiflora* and *Styrax ferrugineus* were grouped towards one end of this axis.

The results of the TWINSPAN analysis are reported in the next section as it is easier to consider them in conjunction with the discussion.

## Discussion

The cerradão is a forest physiognomy intermediate between cerrado and seasonal semi-deciduous forests, and includes species from both vegetation types (Marimon-Júnior & Haridasan, 2005; Ribeiro & Walter, 2008). The cerrado woody flora is commonly composed of a small number of dominant families, such as Leguminosae, Malpighiaceae, Melastomataceae, Myrtaceae, Rubiaceae and Vochysiaceae (Ratter *et al.*, 2006; Mendonça *et al.*, 2008). In general, the families with a greater number of species in dystrophic cerradão are Leguminosae and Vochysiaceae (Costa & Araújo, 2001; Marimon-Júnior & Haridasan, 2005). Leguminous species are generally nitrogen fixers and, therefore, should have competitive advantage in cerradão areas with dystrophic soils (Araújo & Haridasan, 1988). In the PESCAN cerradão the leguminous *Sclerolobium paniculatum*, *Bowdichia virgilioides*, *Dipteryx alata* and *Vatairea macrocarpa* had importance values higher than 10. *Dipteryx alata* is usually a dominant species of mesotrophic cerradão as it prefers mesotrophic soils (Ratter *et al.*, 2006). The presence of this species in the cerradão of PESCAN is probably due to the occurrence of an isolated area of higher nutrient availability. Such areas are not uncommon in the cerrado landscape; for example, one was encountered on Fazenda Palestina in the Brazilian Federal District where there was a mosaic of small patches of dystrophic and mesotrophic cerradão (fide J. Ratter). On the other hand, *Bowdichia virgilioides* and *Vatairea macrocarpa* are found with greater importance values in cerradões on dystrophic soils and in more open cerrado (Costa & Araújo, 2001).

An important aspect of the plant community investigated was the prevalence of small trees, indicating much recent regeneration and causing the low value of basal area per hectare (see Table 3). This type of distribution is generally reported in

TABLE 3. Comparison of the structural characteristics of cerradão of the Serra de Caldas Novas State Park, Goiás, Brazil with 10 other cerradões in different parts of Brazil

| Locality/state | C | S | H′ | G | Dens. | Location | Reference |
|---|---|---|---|---|---|---|---|
| Caldas Novas, Goiás # | D1 | 99 | 3.7 | 14.3 | 1051 | 17°46′S, 48°39′W | Present study |
| Planaltina, Distrito Federal # | D6 | 81 | — | 21.0 | 2231 | 15°29′S, 47°37′W | Ribeiro *et al.*, 1985 |
| Uberlândia 1, Minas Gerais # | D3 | 93 | 3.5 | 17.1 | 2071 | 19°09′S, 48°23′W | Costa & Araújo, 2001 |
| Brotas, São Paulo # | D5 | 118 | 3.3 | — | 3787 | 22°15′S, 48°02′W | Gomes *et al.*, 2004 |
| Luis Antônio, São Paulo # | D4 | 121 | 3.4 | 24.6 | 8540 | 21°40′S, 47°40′W | Pereira-Silva *et al.*, 2004 |
| Nova Xavantina, Mato Grosso # | D10 | 77 | 3.7 | 21.4 | 1884 | 14°41′S, 52°20′W | Marimon-Júnior & Haridasan, 2005 |
| Goianésia, Goiás # | D9 | 57 | 3.5 | 23.1 | 1440 | 15°05′S, 49°08′W | Felfili *et al.*, 2007 |
| Uberlândia 2, Minas Gerais # | D11 | 83 | 3.2 | — | 1797 | 18°46′S, 48°21′W | Rodrigues, 2009 |
| Poconé, Mato Grosso ## | D2 | 33 | — | 4.7 | 869 | 16°40′S, 56°45′W | Guarim *et al.*, 2000 |
| S. A. do Leverger, Mato Grosso ## | D7 | 18 | 1.7 | — | 355 | 19°05′S, 57°39′W | Fonseca *et al.*, 2004 |
| Alto Paraíso, Goiás ## | D8 | 39 | 3.2 | 16.0 | 716 | 14°09′S, 47°30′W | Felfili *et al.*, 2007 |

C = site code; S = species richness; H′ = Shannon diversity index; G = basal area per hectare; Dens. = density per hectare; # = dystrophic cerradão; ## = mesotrophic cerradão. Note the characteristic lower species diversity on the three mesotrophic sites (Poconé, S. A. do Leverger and Alto Paraíso). This is usually caused by the dominance of mesotrophic species.

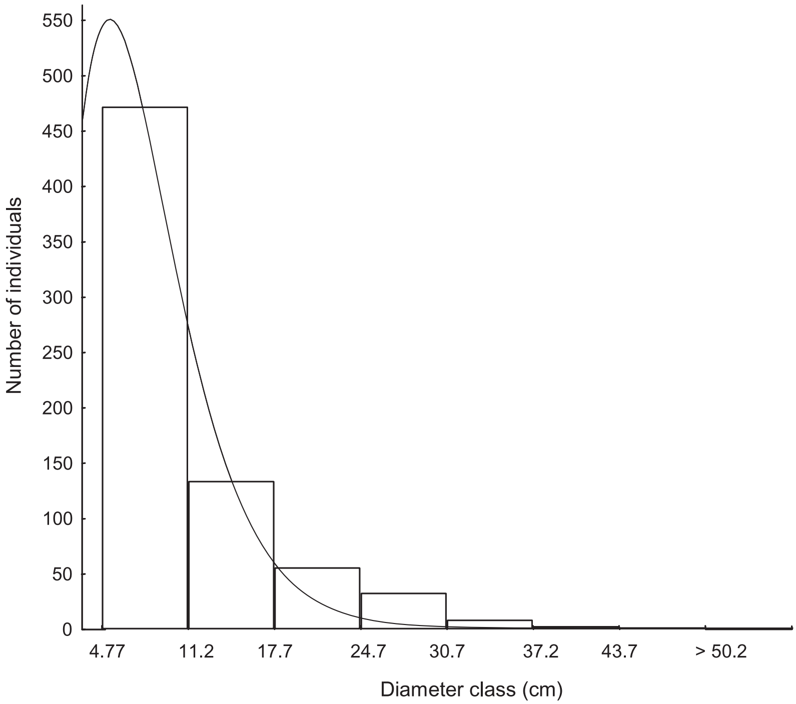


FIG. 2. Tree diameter distribution in the cerradão in the Serra de Caldas Novas State Park. The grey line represents gamma distribution ($r^2 = 0.95$; $P < 0.0001$).

semideciduous (Oliveira-Filho *et al.*, 2001) and mixed tropical forests (Alder, 1995). The H/D ratios and the asymmetry to the left of the diameter distribution, with a good fit to the gamma distribution ($r^2 = 0.95$; $P < 0.0001$), was another consequence of most individuals being small.

A very small basal area value, as found by Guarim *et al.* (2000) in Mato Grosso State (Table 3), indicates selective logging of trees. The small basal area value found in the present study (14.3 $m^2$ $ha^{-1}$) can be explained by the fact that the sampled community was dominated by a large number of small to medium-sized individuals forming a large number of stems per unit area and high rates of canopy cover. This pattern, together with the density of *Sclerolobium paniculatum* and *Xylopia aromatica*, points to recent disturbance in the study site (see Costa & Araújo, 2001; Pereira-Silva *et al.*, 2004). *Sclerolobium paniculatum*, a species with a short lifespan but with great potential for colonising on dystrophic soils, is common as large colonies in cerrado (Costa & Araújo, 2001) and as isolated individuals in semideciduous and evergreen forests (Araújo *et al.*, 1997). It is notable for its abundant fruit production – so great that it often results in the death of the individuals, causing populations to have great numbers of dead trees. This in a more extreme form is characteristic of the monocarpic genus *Tachigali* Aubl. to which *Sclerolobium paniculatum* has recently been transferred by A. T. Oliveira-Filho.

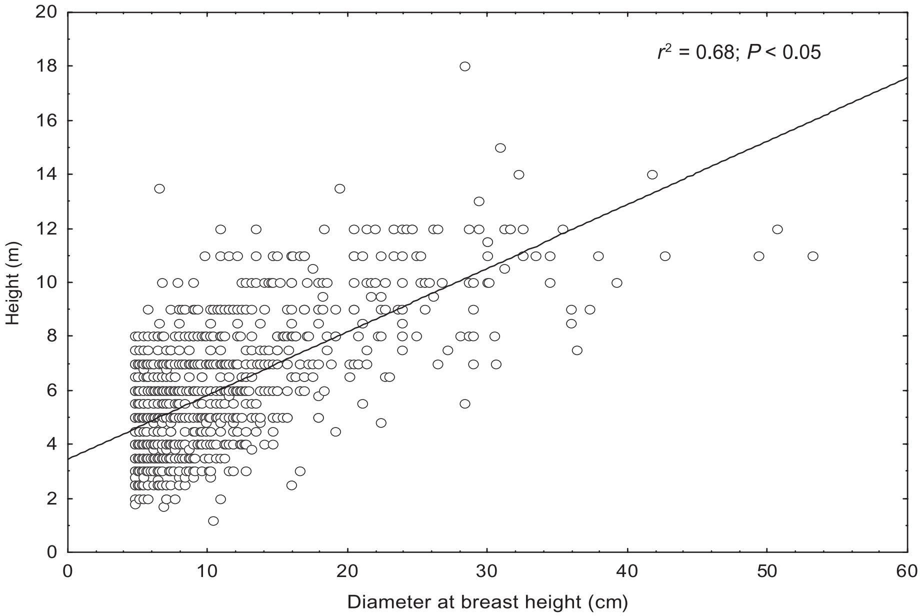


FIG. 3. Relationship between the diameter at breast height and total height in the cerradão in the Serra de Caldas Novas State Park.

The floristic similarity between our study area and the other 10 communities of cerradões elsewhere in Brazil with which it was compared was low, and there was a clear separation between the areas of dystrophic and mesotrophic cerradão (Fig. 5). Areas of dystrophic cerradão in the Triângulo Mineiro formed a distinct group, with high floristic similarity indicated by cluster analysis. The species assembly observed in the present study was floristically more similar to D3 (Uberlândia 1) than to D11 (Uberlândia 2). Based on floristic similarity, the analysis clustered the mesotrophic cerradões (D2, D7 and D8) of more fertile soils and separated them from the other eight sites. Even with the limited comparison of only 11 areas in different floristic regions, the results corroborated the observations of Ratter *et al.* (2003) for cerradões.

Classification of the 11 areas of cerradão using the TWINSPAN method separated them into three distinct groups. The first division separated off a group of mesotrophic cerradão areas: Poconé (D2) and Santo Antonio do Leverger (D7), both in Mato Grosso State, and Alto Paraíso (D8) in Goiás State showed a significant eigenvalue (0.633, Fig. 6) and were dominated by *Callisthene fasciculata*, a strong indicator species of mesotrophic areas (Ratter *et al.*, 1977). The second division separated off the areas of cerradão in the dystrophic soils of São Paulo State (Luis Antonio) (D4) and Brotas (D5) (eigenvalue = 0.545), with *Amaioua guianensis* Aubl. as the indicator species in those areas. The remaining areas (Fig. 6), which formed a third group, were divided on the basis of *Andira cuiabensis* Benth., the

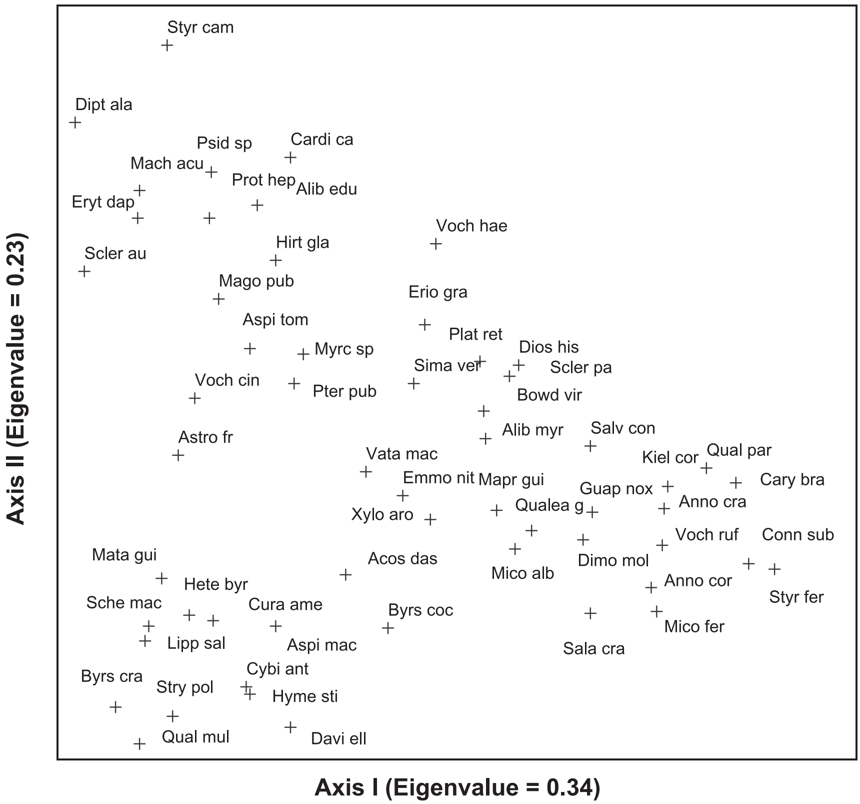


FIG. 4. Ordination of arboreal plant species of the fragment of cerradão in the Serra de Caldas Novas State Park using the DECORANA method.

indicator species observed in Goianésia (D9) and Nova Xavantina (D10). Our experience suggests that the indicator species of the present analysis are of rather different significance. The first division is based on *Callisthene fasciculata*, the indicator par excellence of mesotrophic cerradão. However, the second is *Amaioua guianensis*, a common species of cerradão and forest of dystrophic soil, which is widespread from the Guianas to the south of Brazil. The third is *Andira cuiabensis*, with probably more differential significance than the previous indicator. It is a species of dystrophic soils of cerrado and cerradão with a distinctly western distribution, occurring in the most westerly sites of the analysed areas.

Strategies for conservation and management of cerradão fragments should take into account the dichotomy between mesotrophic and dystrophic cerradões and that it is important to conserve both. *Callisthene fasciculata*, *Myracrodruon urundeuva* M.Allemão, *Anadenanthera colubrina* (Vell.) Brenan, *Dilodendron bipinnatum* and many other species listed in the publications of Ratter *et al.* are indicators of mesotrophic soils and thus are found in mesotrophic cerradões and the related

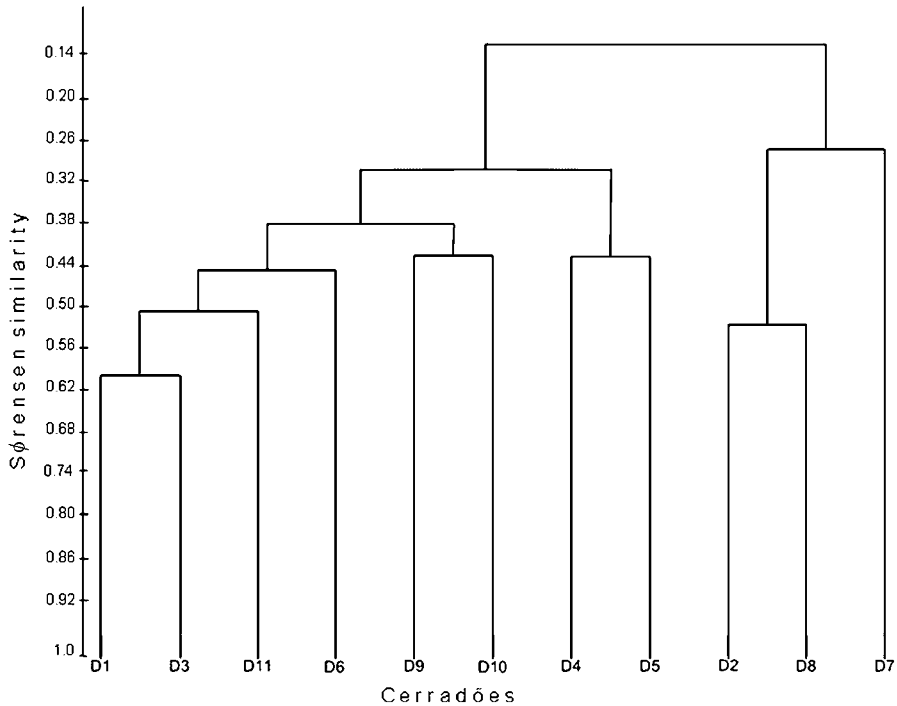


FIG. 5. Cluster analysis, using the Sørensen similarity index, between the cerradão of the Serra de Caldas Novas State Park and 10 other cerradões in different parts of Brazil. D1 = present study; D2 = Poconé; D3 = Uberlândia 1; D4 = Luis Antônio; D5 = Brotas; D6 = Planaltina; D7 = S. A. do Leverger; D8 = Alto Paraíso; D9 = Goianésia; D10 = Nova Xavantina; D11 = Uberlândia 2. See Table 3 for further details of the sites.

deciduous forests on mesotrophic soils (Siqueira *et al.*, 2009). Although *Magonia pubescens* is characteristic of mesotrophic cerradão (Ratter *et al.*, 1977, 2006), it has a higher environmental plasticity and can also occur on poor soils (Marimon-Júnior & Haridasan, 2005) in central Brazil. *Sclerolobium paniculatum* is a very cosmopolitan species on dystrophic soil, occurring in all areas compared in this study, and usually with large populations (Marimon-Júnior & Haridasan, 2005; Rodrigues, 2009). *Bowdichia virgilioides*, *Qualea grandiflora* and *Xylopia aromatica* were among the five most important species at PESCAN, and were also more frequent on dystrophic soils. These species are common in cerradão, and *Xylopia aromatica* is one of the most common colonising species of disturbed areas of this habitat. *Qualea grandiflora* is the most commonly recorded woody species in the core area of the cerrado biome (Ratter *et al.*, 2003, 2006, 2011) and although it is an obligate aluminium accumulator occurs as frequently on mesotrophic as on dystrophic soil (Araújo & Haridasan, 1988). This demonstrates the remarkable ability of Vochysiaceae to accumulate aluminium even if it occurs only as a trace in the soil.

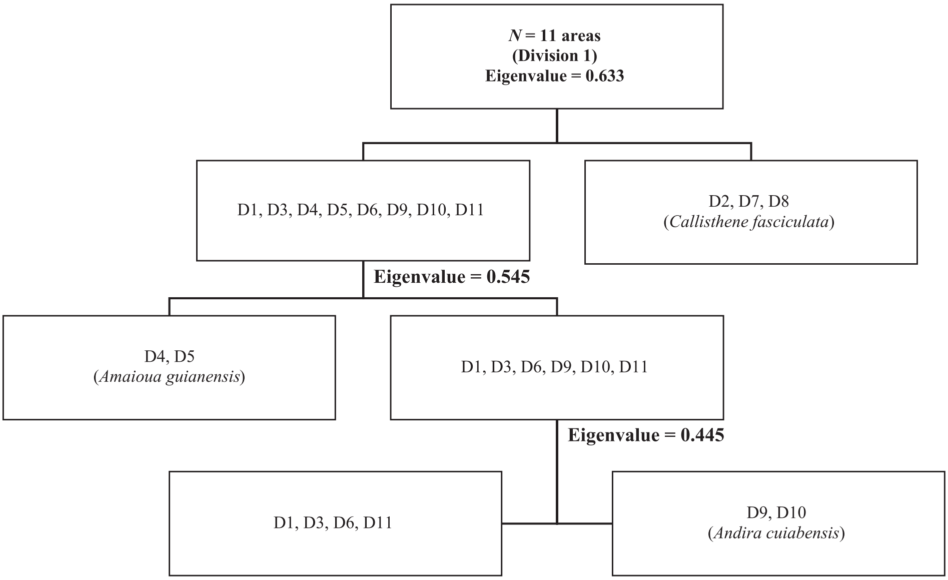


FIG. 6. Classification by the TWINSPAN method of 11 cerradão areas at different sites in central Brazil. The first division separates the dystrophic and mesotrophic sites. In parentheses are the indicator species of each of the divisions with its respective eigenvalue. D1 = present study; D2 = Poconé; D3 = Uberlândia 1; D4 = Luis Antônio; D5 = Brotas; D6 = Planaltina; D7 = S. A. do Leverger; D8 = Alto Paraíso; D9 = Goianésia; D10 = Nova Xavantina; D11 = Uberlândia 2.

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