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A STUDY IN AN AREA OF TRANSITION BETWEEN SEASONALLY DRY TROPICAL FOREST AND MESOTROPHIC CERRADÃO, IN MATO GROSSO DO SUL, SOUTHWESTERN BRAZIL

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This study describes the tree vegetation and soils occurring in a seasonally dry tropical forest (SDTF) and mesotrophic cerradão transition in southwestern Brazil. All trees ≥ 5 cm diameter were measured in 20 plots of 20 × 25 m, 10 in SDTF, and 10 in mesotrophic cerradão. Ten soil samples of 0−20 cm depth were made per plot and mixed in plot groups to produce two composite samples. A total of 71 species was recorded. *Anadenanthera colubrina* had the highest importance values in both formations. Differences in soil fertility were found between SDTFs (eutrophic soils) and mesotrophic cerradão (mesotrophic soils). A non-metric multidimensional scaling and cluster analysis confirmed the soil fertility segregation, and also showed an agreement between soil fertility and variance in species composition gradients. The mesotrophic cerradão showed higher species richness since it also includes many species typical of more dystrophic and open forms of Cerrado.

Keywords. Cerrado, non-metric multidimensional scaling, soil–vegetation relationships, species diversity.

Introduction

The Cerrado biome is a typical savanna formation that previously occupied 2 million km^2 of Brazil before the replacement of huge areas by crops and man-made sown pasture in the recent agricultural revolution (Ratter *et al.*, 1997). Within this biome, seasonally dry tropical forest (hereafter SDTF), often called 'dry forest' (mata seca), and a characteristic savanna forest (called mesotrophic cerradão) occur under the same climatic conditions (Furley & Ratter, 1988). The SDTFs are restricted to more fertile eutrophic soils, while mesotrophic cerradão occurs on slightly less fertile mesotrophic soils (Ratter, 1971; Ratter *et al.*, 1973, 1977, 2006, 2011; Furley & Ratter,

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1988). It is worth pointing out, however, that although areas of more fertile soils are frequent in many parts of the Cerrado biome, by far the greatest part has very dystrophic soils carrying sparser forms of Cerrado or cerradão lacking the characteristic marker species of more fertile soils (Furley & Ratter, 1988; Ratter *et al.*, 1977, 2011).

According to Silva & Bates (2002) the Cerrado forest formations (cerradões) now occupy less than 1% of the total area of the biome. This is due partly to destruction by cultivators in the past who recognised their soils were more fertile. However, this is no longer the case since modern mechanised Cerrado agriculture prefers vast areas of flat topography, such as chapadas, where – although the soils are very dystrophic – the terrain allows maximum use of heavy machinery and nutrient differences can be counteracted by use of fertilisers.

Previously, however, the situation was rather different and mesotrophic cerradão in many areas was an important and sometimes a dominant part of Cerrado vegetation (Ratter *et al.*, 2006, 2011). It was still abundant in the times of the construction of the Belo Horizonte–Brasília highway and those in eastern Mato Grosso in the 1960s (Rizzini, 1979; Ratter *et al.*, 2006), and more recently in the area of the Rio Maranhão in the state of Goiás (Ratter, 1992; Silva & Scariot, 2003, 2004).

The present paper is devoted to the study of the vegetation and soils occurring in an SDTF/mesotrophic cerradão transition in western Brazil.

Material and Methods

Area of study

The study was carried out in the area of the Municipality of Miranda in the state of Mato Grosso do Sul, southwestern Brazil (20°16′S, 56°14′W) (Fig. 1). The regional climate is tropical, humid and strongly seasonal, classified as *Aw* following Köppen (1948). The mean annual temperature is 25°C and the rainy season is concentrated from November to March, with average annual precipitation of 1200–1700 mm.

The Pre-Cambrian Cuiabá landscape group characterises the principal depression of Miranda with altitudes of 100−200 m. Mica schist is the predominant rock and Dark Red Latosols are the principal soils (Brasil, 1982a).

Cerrado (*sensu lato*) in its various forms from cerradão to campo limpo is the predominant vegetation of the Rio Miranda basin, but close to the Rios Aquidauana and Miranda there are Eutrophic somewhat Humic Gleys that carry SDTFs (Brasil, 1982a, 1982b; Mato Grosso do Sul, 1988, 1989).

The study site consists of adjacent areas of SDTF, with taller trees 15−25 m and very sparse ground vegetation, and mesotrophic cerradão with trees of 10−12 m and a dense lower vegetation of herbs, shrubs and young trees. The SDTF area is on a slope, with the cerradão occupying a flat area above, and there is a rather gradual transition between the two. The whole study area is protected and belongs to the Bandeirantes Settlement.

FIG. 1. Map showing the location of the Municipality of Miranda in the state of Mato Grosso do Sul (MS), central-western Brazil.

Vegetation structure and soil data

Ten contiguous plots of 20 × 25 m (0.5 ha) were established in the SDTF, and another 10 plots of the same size in mesotrophic cerradão. All trees with diameter at breast height (dbh) ≥ 5 cm were recorded using the nomenclature of APG III (2009). Ten soil samples of 0–20 cm depth were taken in each plot and mixed to make a single composite plot sample and these were analysed by the Laboratory of Soil Analysis of the Universidade Federal de Lavras (UFLA), following the protocol of Embrapa (1997).

Data analysis

The basal area (BA), relative and total abundance (RA and TA), relative and total frequency (RF and TF), relative and total dominance (RDo and TDo), and importance value (IV) were calculated for all species following Mueller-Dombois & Ellenberg (1974). The Shannon-Wiener index (H') and Pielou index (J') (Brower & Zar, 1984) were used to determine floristic diversity. All the values were calculated using the Mata Nativa 2 program (Cientec, 2007).

Classification and ordination analyses were carried out using the packages of the R software (R Development Core Team, 2012). The function ‘pvclust’ (Suzuki & Shimodaira, 2011) was used to perform a cluster analysis with Bray-Curtis distances of floristic dissimilarity between the 20 plots and the unweighted paired groups as a linkage method to produce the dendrograms (McCune & Grace, 2002) with multiscale bootstrap resampling as support values (Fig. 3). A non-metric multidimensional scaling (NMDS) using a generalised additive modelling ‘surf’ function was also made to investigate the variance in species composition (Fig. 2). This technique is available as metaMDS in the package ‘vegan’ (Oksanen *et al.*, 2012). Finally, to check the agreement between the variance and the explanatory variables, the soil parameters were examined to select a subset of predicting environmental variables. To do this the forward selection function available in the ‘packfor package’ (Blanchet *et al.*, 2008) was used.

Results and Discussion

A total of 888 individual trees belonging to 24 families and 71 species was sampled. The mesotrophic cerradão was more diverse with 56 species, while the SDTF had 43. The Fabaceae were the richest family in both communities, with 14 species in the SDTF (34.14% of its total) and 17 in the mesotrophic cerradão (29.31%). Malvaceae were the second richest family in the mesotrophic cerradão, with six species representing 39.21%, while Anacardiaceae, Apocynaceae, Bignoniaceae and Malvaceae had three species each in the SDTF, representing 27.9% of the total (Table 1). Many authors have reported the richness of the Fabaceae in the Cerrado biome, while in the SDTF this family is the richest recorded anywhere (Gentry, 1995; Pennington *et al.*, 2000) with the exception of the Caribbean where Myrtaceae dominate (Lugo *et al.*, 2006).

The total tree density in the SDTF was 578 individuals/ha and the top five species were *Casearia gossypiosperma*, *Anadenanthera colubrina*, *Myracrodruon urundeuva*,

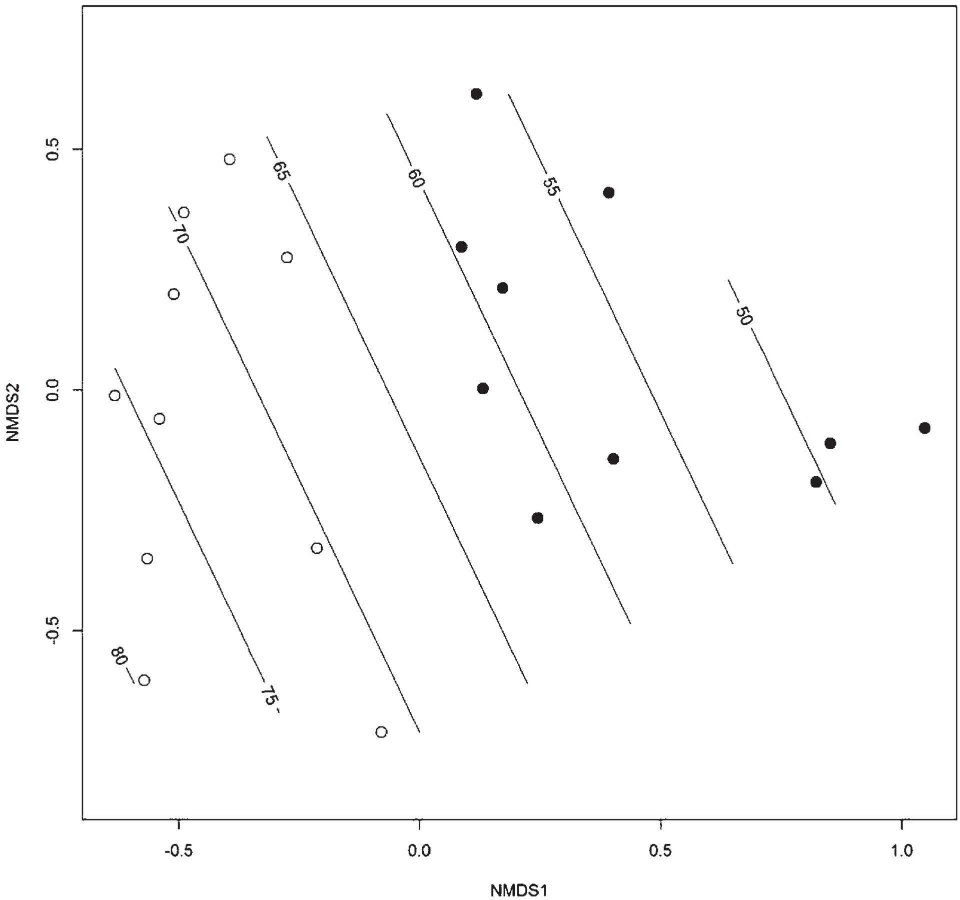

FIG. 2. Non-metric multidimensional scaling (NMDS) of the 20 forest plots. The base saturation (V%) is fitted to this surface using a generalised additive model, as implemented in the surf function of the R package labdsv. Stress = 0.20. Open circles – seasonally dry tropical forests (STDF); black bullets – mesotrophic cerradão.

Balfourodendron riedelianum and *Astronium fraxinifolium* (taxon authors in Table 1), representing 54.32% (Table 2). Other authors also described most of these species as 'common' or 'characteristic of' SDTF (Ratter *et al.*, 1978; Dubs, 1992; Salis *et al.*, 1995; Neri *et al.*, 2012). The total density in the mesotrophic cerradão was 1198 individuals/ha and the commonest five species were *Tabebuia roseoalba*, with 14.86%, *Tachigali vulgaris* (10.35%), *Casearia gossypiosperma* (7.35%), *Anadenanthera colubrina* (7.35%) and *Myracrodruon urundeuva* (6.68%) (Table 3). *Tabebuia roseoalba*, *Anadenanthera colubrina*, *Casearia gossypiosperma* and *Myracrodruon urundeuva* are clearly related to fertile soils (Ratter *et al.*, 1977; Pott & Pott, 1994; Lehn *et al.*, 2008), whereas *Tachigali vulgaris* is more common in dystrophic cerradão or more open forms of Cerrado and is often a short-lived colonising species (Ratter, 1992; Carvalho,

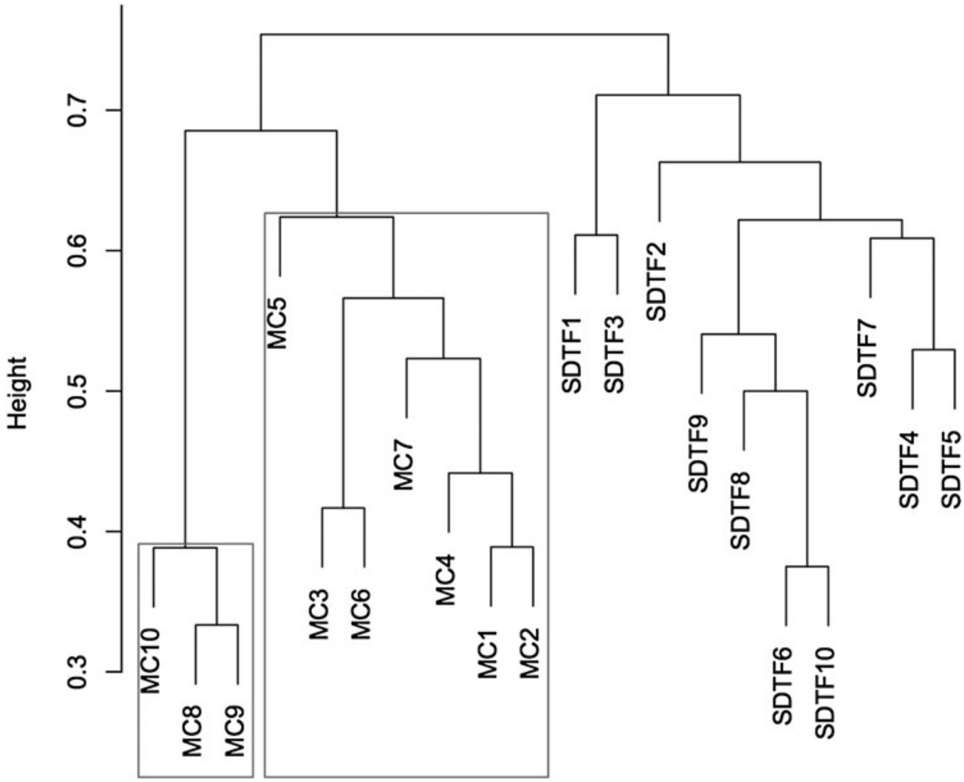

FIG. 3. Cluster analysis of the 20 forest plots. MC – mesotrophic cerradão; SDTF – seasonally dry tropical forest; the rectangles indicate bootstrap support > 0.95. Distance measure = Bray-Curtis; linkage method = average; co-phenetic correlation = 0.81.

1994; Ratter *et al.*, 2011). *Tabebuia roseoalba*, the most abundant species in our mesotrophic cerradão, is also an important element in SDTF throughout the Cerrado biome (Oliveira Filho *et al.*, 1998; Silva & Scariot, 2003, 2004; Salis *et al.*, 2004).

The diversity indices in the SDTF were *H′* 2.95 and *J′* 0.78. Silva & Scariot (2004) found similar values in another SDTF of the Cerrado biome (*H′* 2.99 and *J′* 0.77). Moreover, Rodal & Nascimento (2006), studying an SDTF in the Caatinga biome, also found a similar result (*H′* 2.72). Ratter (1992) stated that SDTFs generally have low alpha diversity caused by the domination of certain characteristic species, such as *Astronium fraxinifolium*, *Anadenanthera colubrina* and *Myracrodruon urundeuva* (Ratter *et al.*, 1978; and Table 2). Our Pielou value corroborates this since it indicates just such an uneven distribution of species in our SDTF. This pattern may be explained by the disjunct distribution of SDTFs (Prado & Gibbs, 1993; Pennington *et al.*, 2000), causing lower migration rates and therefore high abundance in local species (Hubbell, 2001).

The Shannon-Wiener index of our mesotrophic cerradão was *H′* 3.32, rather lower than the *H′* 3.47−3.85 recorded by Costa & Araújo (2001), Pereira Silva *et al.* (2004), Marimon Junior & Haridasan (2005) and Kunz *et al.* (2009). According to Oliveira Filho & Ratter (2002), the richness of tree species in a dystrophic cerradão can be up to 150 species. This number is much less in mesotrophic cerradão, where dominance of a group of characteristic species causes lower alpha diversity. However, it is probably always higher than that of SDTF since, in addition to the characteristic marker species of more fertile soils, it contains a large number of typical Cerrado species more tolerant of dystrophic soils (see wide tolerance (WT) species in Table 1).

In terms of forest structure, *Anadenanthera colubrina* had the highest IV in both formations (22.5% in SDTF and 11.03% in mesotrophic cerradão), and also the highest BA values (4.22 m^2/ha in SDTF and 2.19 in mesotrophic cerradão). The top five species in IV (Table 2) agree with other authors' observations in diverse locations (Ratter *et al.*, 1978; Furley & Ratter, 1988; Oliveira Filho *et al.*, 1998). The strong dominance of some species and low alpha diversity pattern are not unusual in tropical forests, although much more common in seasonal forests (Richards, 1952; Oliveira Filho & Ratter, 2000).

According to the Embrapa (2006) classification system, the SDTF soil is eutrophic, i.e. with base saturation (V%) higher than 70%, whereas the mesotrophic cerradão soil is, as one would expect, mesotrophic (V% ranging from 50 to 70%) (Table 4). The soils of both areas were slightly acid and, apart from P, K, Ca, cationic exchange capacity and silt, all other soil parameters were significantly different.

The highest value in the forward selection procedure was base saturation (adjusted $R^2 = 0.17$; $P < 0.05$). After the variance explained by V%, the residuals explained by other variables were insignificant. Our results agree with the observations of Ratter *et al.* (1973) and Furley & Ratter (1988) who found such differences in soil fertility between SDTFs and mesotrophic cerradões. Ratter (1992) noted *Myracrodruon urundeuva*, *Anadenanthera colubrina*, *Astronium fraxinifolium*, *Aspidosperma subincanum* and *Cedrela fissilis* as strong SDTF indicators, while *Dipteryx alata*, *Magonia pubescens* and *Terminalia argentea* were classified as mesotrophic cerradão indicators. However, these authors pointed out that usually there is a rather gradual transition between the two communities.

The non-metric multidimensional scaling (NMDS) emphasised the formation of a gradient in relation to soil fertility (V%) (Fig. 2) and the cluster analysis confirmed the soil fertility segregation (Fig. 3). Both analyses showed an agreement between soil fertility and variance in species composition gradients. The bootstrap value (AU) was high in mesotrophic cerradão (Fig. 3) and, although there are a considerable number of species shared between these communities, this result supports the recognition of SDTF and mesotrophic cerradão as different, although closely related, communities. In fact, our hypothesis is that most of the SDTF species have a narrow niche breadth, explaining our cluster segregation, and corroborating the patterns of high beta diversity in neotropical SDTF (Gillespie *et al.*, 2000; Trejo & Dirzo, 2002; Linares-Palomino, 2006; Lott & Atkinson, 2006; Queiroz, 2006; Castillo-Campos *et al.*, 2008). The postulated narrow niche breadth of characteristic SDTF species is demonstrated by the constancy of calcicolous flora in so many disjunct areas and its absence from poor soils.

TABLE 1. Species recorded in seasonally dry tropical forest and mesotrophic cerradão

Family	Species	SDTF	MC	SP
Anacardiaceae	*Astronium fraxinifolium* Schott ex Spreng.	X	X	WC
	Myracrodruon urundeuva Allemão	X	X	C
	Spondias mombin L.	X	X	C
Annonaceae	*Oxandra reticulata* Maas	X	X	?
Apocynaceae	*Aspidosperma macrocarpon* Mart.	X	X	WT
	Aspidosperma subincanum Mart. ex A.DC.	X		C
	Aspidosperma tomentosum Mart.	X		WT
Arecaceae	*Acrocomia aculeata* (Jacq.) Lodd. ex Mart.	X	X	C
Bignoniaceae	*Handroanthus impetiginosus* Mattos	X	X	C
	Handroanthus ochraceus (Cham.) Mattos	X	X	WT
	Jacaranda cuspidifolia Mart. ex A.DC.		X	C
	Tabebuia aurea (Manso) Benth. & Hook.f.		X	WT
	Tabebuia roseoalba (Ridl.) Sandwith	X	X	WC
Boraginaceae	*Cordia glabrata* (Mart.) A.DC.	X	X	C
Combretaceae	*Combretum leprosum* Mart.	X	X	C
	Terminalia argentea (Cambess.) Mart.		X	WC
Dilleniaceae	*Curatella americana* L.		X	WC
Fabaceae	*Albizia niopoides* (Spruce ex Benth.) Burkart	X	X	WC
	Anadenanthera colubrina (Vell.) Brenan	X	X	C
	Andira cujabensis Benth.		X	WT
	Andira inermis (W.Wright) DC.	X		?
	Bowdichia virgilioides Kunth		X	WT
	Caesalpinia sp.	X		?
	Dalbergia sp.	X		?
	Dimorphandra mollis Benth.		X	WT
	Dipteryx alata Vogel	X	X	C
	Erythrina cf. *dominguezii* Hassl.	X		C
	Hymenaea courbaril L.	X	X	WT
	Hymenaea martiana Hayne	X		?
	Hymenaea stigonocarpa Mart. ex Hayne	X	X	WT
	Inga laurina (Sw.) Willd.		X	?
	Inga vera Willd.		X	?
	Lonchocarpus sericeus (Poir.) DC.	X		?
	Machaerium hirtum (Vell.) Stellfeld		X	C
	Plathymenia reticulata Benth.	X	X	WT
	Pterogyne nitens Tul.		X	C
	Senna sp.	X		?
	Tachigali aurea Tul.	X	X	WT
	Tachigali vulgaris L.G.Silva & H.C.Lima		X	WT
	Vatairea macrocarpa (Benth.) Ducke	X	X	WT
Indet.	Indet. 1	X		?
Indet.	Indet. 2		X	?
Lamiaceae	*Vitex cymosa* Bert. ex Spreng.	X	X	C
Lauraceae	*Ocotea* sp.	X		?
Lythraceae	*Lafoensia pacari* A.St.-Hil.		X	WT

TABLE 1. (*Cont'd*)

Malvaceae	*Ceiba pubiflora* (A.St.-Hil.) K.Schum.	X	X	C
	Eriotheca pubescens (Mart. & Zucc.) Schott & Endl.		X	WT
	Guazuma ulmifolia Lam.		X	C
	Luehea paniculata Mart. & Zucc.		X	C
	Sterculia apetala (Jacq.) H.Karst.	X	X	C
Meliaceae	*Cedrela fissilis* Vell.	X	X	C
	Trichilia elegans A.Juss.	X	X	WT
Myrtaceae	*Eugenia* sp.	X	X	?
Oleaceae	*Priogymnanthus hasslerianus* (Chodat) P.S.Green		X	C
Rhamnaceae	*Rhamnidium elaeocarpum* Reissek		X	C
Rubiaceae	*Cordiera sessilis* (Vell.) Kuntze	X		WT
Rutaceae	*Balfourodendron riedelianum* (Engl.) Engl.	X		?
	Zanthoxylum caribaeum Lam.	X		C
	Zanthoxylum rhoifolium Lam.		X	WT
	Zanthoxylum rigidum Humb. & Bonpl. ex Willd.		X	C
Salicaceae	*Casearia gossypiosperma* Briq.	X	X	C
	Casearia sylvestris Sw.		X	WT
Sapindaceae	*Dilodendron bipinnatum* Radlk.		X	C
	Magonia pubescens A.St.-Hil.		X	C
	Matayba guianensis Aubl.	X		WT
	Talisia esculenta (A.St.-Hil.) Radlk.	X	X	C
Sapotaceae	*Pouteria gardneri* (Mart. & Miq.) Baehni	X	X	C
	Pouteria ramiflora (Mart.) Radlk.		X	WT
Urticaceae	*Cecropia pachystachya* Trécul		X	WT
Vochysiaceae	*Qualea grandiflora* Mart.		X	WT
	Qualea parviflora Mart.		X	WT

SDTF – seasonally dry tropical forest; MC – mesotrophic cerradão; SP – soil preference: WC – weakly calcicolous; WT – wide tolerance; C – calcicolous; ? – not known (estimates based on observations of Ratter *et al.*, 2011).

Mesotrophic cerradão typically occurs as a transition band on intermediate soils between dystrophic Cerrado (or cerradão) and SDTF (Ratter *et al.*, 1977; Furley & Ratter, 1988; Pott & Pott, 2003). However, in some areas such as the valley of the Rio Paranã in the state of Goiás it covers large areas (Ratter, 1992; Silva & Scariot, 2003). Typical transitions between SDTF and Cerrado with intermediate areas of mesotrophic cerradão have been recorded over a large area of central Brazil in the states of Bahia, Goiás, Maranhão, Mato Grosso, Mato Grosso do Sul, Minas Gerais, Piauí, Rondônia, Tocantins and the Federal District (Ratter *et al.*, 2011 and unpublished survey records).

Species recorded as important in both communities such as *Anadenanthera colubrina*, *Myracrodruon urundeuva* and *Tabebuia roseoalba* are the same as shown by other authors (e.g. Ratter, 1977; Felfili, 2003) to characterise disjunct SDTF fragments in various parts of Brazil. According to Prado & Gibbs (1993), *Myracrodruon urundeuva* and *Anadenanthera colubrina* have a wide distribution in neotropical areas and can be

TABLE 2. Phytosociological parameters of the seasonally dry tropical forest area; species in order of importance value

Species	N	BA	TD	RA	TF	RF	TDo	RDo	IV	IV (%)
Anadenanthera colubrina	30	4.2286	60	10.38	90	7.09	8.457	50.23	67.697	22.57
Casearia gossypiosperma	55	0.4296	110	19.03	100	7.87	0.859	5.10	32.008	10.67
Myracrodruon urundeuva	28	0.5657	56	9.69	90	7.09	1.131	6.72	23.495	7.83
Astronium fraxinifolium	20	0.2611	40	6.92	90	7.09	0.522	3.10	17.108	5.70
Balfourodendron riedelianum	24	0.2414	48	8.30	60	4.72	0.483	2.87	15.896	5.30
Combretum leprosum	14	0.3098	28	4.84	70	5.51	0.620	3.68	14.036	4.68
Oxandra reticulata	20	0.1340	40	6.92	60	4.72	0.268	1.59	13.236	4.41
Lonchocarpus sericeus	12	0.2917	24	4.15	70	5.51	0.583	3.46	13.129	4.38
Tabebuia roseoalba	10	0.1780	20	3.46	50	3.94	0.356	2.11	9.512	3.17
Cedrela fissilis	7	0.3031	14	2.42	40	3.15	0.606	3.60	9.173	3.06
Vatairea macrocarpa	8	0.1188	16	2.77	50	3.94	0.238	1.41	8.117	2.71
Albizia niopoides	7	0.1835	14	2.42	40	3.15	0.367	2.18	7.751	2.58
Ceiba pubiflora	4	0.1521	8	1.38	40	3.15	0.304	1.81	6.340	2.11
Aspidosperma macrocarpon	5	0.0833	10	1.73	30	2.36	0.167	0.99	5.082	1.69
Eugenia sp.	6	0.0328	12	2.08	30	2.36	0.066	0.39	4.828	1.61
Pouteria gardneri	3	0.0611	6	1.04	30	2.36	0.122	0.73	4.126	1.38
Handroanthus impetiginosus	2	0.1357	4	0.69	20	1.57	0.271	1.61	3.879	1.29
Erythrina cf. *dominguezii*	2	0.0981	4	0.69	20	1.57	0.196	1.16	3.432	1.14
Senna sp.	2	0.0658	4	0.69	20	1.57	0.132	0.78	3.048	1.02
Aspidosperma subincanum	2	0.0502	4	0.69	20	1.57	0.100	0.60	2.863	0.95
Talisia esculenta	2	0.0176	4	0.69	20	1.57	0.035	0.21	2.476	0.83
Matayba guianensis	2	0.0092	4	0.69	20	1.57	0.018	0.11	2.376	0.79
Cordia glabrata	2	0.0631	4	0.69	10	0.79	0.126	0.75	2.229	0.74
Hymenaea stigonocarpa	2	0.0483	4	0.69	10	0.79	0.097	0.57	2.053	0.68
Dalbergia sp.	1	0.0733	2	0.35	10	0.79	0.147	0.87	2.005	0.67
Handroanthus ochraceus	2	0.0278	4	0.69	10	0.79	0.056	0.33	1.809	0.60
Zanthoxylum rhoifolium	1	0.0436	2	0.35	10	0.79	0.087	0.52	1.651	0.55
Spondias mombin	1	0.0377	2	0.35	10	0.79	0.075	0.45	1.581	0.53
Sterculia apetala	1	0.0316	2	0.35	10	0.79	0.063	0.38	1.509	0.50

TABLE 2. (*Cont'd*)

Plathymenia reticulata	1	0.0286	2	0.35	10	0.79	0.057	0.34	1.474	0.49
Acrocomia aculeata	1	0.0232	2	0.35	10	0.79	0.046	0.28	1.409	0.47
Vitex cymosa	1	0.0154	2	0.35	10	0.79	0.031	0.18	1.316	0.44
Indet. 1	1	0.0111	2	0.35	10	0.79	0.022	0.13	1.266	0.42
Trichilia elegans	1	0.0109	2	0.35	10	0.79	0.022	0.13	1.263	0.42
Ocotea sp.	1	0.0072	2	0.35	10	0.79	0.014	0.09	1.218	0.41
Aspidosperma tomentosum	1	0.0087	2	0.35	10	0.79	0.017	0.10	1.236	0.41
Dipteryx alata	1	0.0081	2	0.35	10	0.79	0.016	0.10	1.230	0.41
Hymenaea martiana	1	0.0050	2	0.35	10	0.79	0.010	0.06	1.192	0.40
Tachigali aurea	1	0.0062	2	0.35	10	0.79	0.012	0.07	1.208	0.40
Hymenaea courbaril	1	0.0058	2	0.35	10	0.79	0.012	0.07	1.202	0.40
Andira inermis	1	0.0062	2	0.35	10	0.79	0.012	0.07	1.208	0.40
Caesalpinia sp.	1	0.0032	2	0.35	10	0.79	0.006	0.04	1.171	0.39
Cordiera sessilis	1	0.0026	2	0.35	10	0.79	0.005	0.03	1.164	0.39

N – individuals/0.5 ha; BA – basal area; TD – total density (individuals/ha); RA – relative abundance; TF – total frequency; RF – relative frequency; TDo – total dominance; RDo – relative dominance; IV – importance value.

TABLE 3. Phytosociological parameters of the mesotrophic cerradão areas; species in order of importance value

Species	N	BA	TD	RA	TF	RF	TDo	RDo	IV	IV (%)
Anadenanthera colubrina	44	2.1995	88	7.35	100	5.0	4.399	20.75	33.099	11.03
Myracrodruon urundeuva	40	1.5176	80	6.68	90	4.5	3.035	14.32	25.497	8.50
Tabebuia roseoalba	89	0.4767	178	14.86	100	5.0	0.953	4.50	24.356	8.12
Tachigali vulgaris	62	0.4518	124	10.35	90	4.5	0.904	4.26	19.113	6.37
Aspidosperma macrocarpon	29	0.6229	58	4.84	80	4.0	1.246	5.88	14.719	4.91
Casearia gossypiosperma	44	0.2094	88	7.35	100	5.0	0.419	1.98	14.322	4.77
Ceiba pubiflora	10	0.8877	20	1.67	80	4.0	1.775	8.38	14.046	4.68
Dilodendron bipinnatum	26	0.3553	52	4.34	90	4.5	0.711	3.35	12.193	4.06
Trichilia elegans	38	0.1052	76	6.34	80	4.0	0.210	0.99	11.337	3.78
Priogymnanthus hasslerianus	6	0.6228	12	1.00	50	2.5	1.246	5.88	9.378	3.13
Oxandra reticulata	29	0.1476	58	4.84	60	3.0	0.295	1.39	9.234	3.08
Magonia pubescens	21	0.3335	42	3.51	40	2.0	0.667	3.15	8.652	2.88
Dipteryx alata	10	0.2967	20	1.67	40	2.0	0.593	2.80	6.469	2.16
Hymenaea courbaril	5	0.3113	10	0.83	40	2.0	0.623	2.94	5.772	1.92
Astronium fraxinifolium	8	0.0415	16	1.34	70	3.5	0.083	0.39	5.227	1.74
Tabebuia aurea	7	0.1561	14	1.17	50	2.5	0.312	1.47	5.142	1.71
Handroanthus impetiginosus	4	0.2861	8	0.67	30	1.5	0.572	2.70	4.867	1.62
Luehea paniculata	10	0.0735	20	1.67	50	2.5	0.147	0.69	4.863	1.62
Qualea grandiflora	11	0.1466	22	1.84	30	1.5	0.293	1.38	4.720	1.57
Combretum leprosum	6	0.2344	12	1.00	20	1.0	0.469	2.21	4.213	1.40
Cordia glabrata	5	0.0873	10	0.83	50	2.5	0.175	0.82	4.159	1.39
Sterculia apetala	3	0.2168	6	0.50	30	1.5	0.434	2.05	4.047	1.35
Pouteria gardneri	8	0.0173	16	1.34	40	2.0	0.035	0.16	3.498	1.17
Guazuma ulmifolia	7	0.0281	14	1.17	40	2.0	0.056	0.26	3.433	1.14
Plathymenia reticulata	6	0.0331	12	1.00	40	2.0	0.066	0.31	3.314	1.10
Casearia sylvestris	8	0.0257	16	1.34	30	1.5	0.051	0.24	3.078	1.03
Terminalia argentea	6	0.0240	12	1.00	30	1.5	0.048	0.23	2.729	0.91
Qualea parviflora	4	0.0576	8	0.67	30	1.5	0.115	0.54	2.711	0.90
Machaerium hirtum	3	0.1184	6	0.50	20	1.0	0.237	1.12	2.618	0.87

TABLE 3. (*Cont'd*)

Lafoensia pacari	5	0.0264	10	0.83	30	1.5	0.053	0.25	2.584	0.86
Eugenia sp.	5	0.0144	10	0.83	30	1.5	0.029	0.14	2.471	0.82
Handroanthus ochraceus	3	0.0990	6	0.50	20	1.0	0.198	0.93	2.435	0.81
Talisia esculenta	4	0.0138	8	0.67	30	1.5	0.028	0.13	2.298	0.77
Tachigali aurea	3	0.0097	6	0.50	30	1.5	0.019	0.09	2.092	0.70
Vatairea macrocarpa	3	0.0082	6	0.50	20	1.0	0.016	0.08	1.578	0.53
Cedrela fissilis	3	0.0054	6	0.50	20	1.0	0.011	0.05	1.552	0.52
Acrocomia aculeata	2	0.0066	4	0.33	20	1.0	0.013	0.06	1.396	0.47
Pterogyne nitens	2	0.0064	4	0.33	20	1.0	0.013	0.06	1.395	0.46
Dimorphandra mollis	1	0.0733	2	0.17	10	0.5	0.147	0.69	1.359	0.45
Jacaranda cuspidifolia	1	0.0630	2	0.17	10	0.5	0.126	0.59	1.262	0.42
Vitex cymosa	1	0.0418	2	0.17	10	0.5	0.084	0.39	1.062	0.35
Cecropia pachystachya	1	0.0401	2	0.17	10	0.5	0.080	0.38	1.045	0.35
Bowdichia virgilioides	1	0.0347	2	0.17	10	0.5	0.069	0.33	0.994	0.33
Eriotheca pubescens	2	0.0117	4	0.33	10	0.5	0.023	0.11	0.944	0.31
Curatella americana	2	0.0081	4	0.33	10	0.5	0.016	0.08	0.910	0.30
Spondias mombin	1	0.0093	2	0.17	10	0.5	0.019	0.09	0.754	0.25
Indet. 2	1	0.0079	2	0.17	10	0.5	0.016	0.07	0.742	0.25
Hymenaea stigonocarpa	1	0.0054	2	0.17	10	0.5	0.011	0.05	0.718	0.24
Albizia niopoides	1	0.0059	2	0.17	10	0.5	0.012	0.06	0.723	0.24
Inga laurina	1	0.0065	2	0.17	10	0.5	0.013	0.06	0.728	0.24
Zanthoxylum rigidum	1	0.0063	2	0.17	10	0.5	0.013	0.06	0.726	0.24
Inga vera	1	0.0018	2	0.17	10	0.5	0.004	0.02	0.684	0.23
Andira cujabensis	1	0.0018	2	0.17	10	0.5	0.004	0.02	0.684	0.23
Zanthoxylum caribaeum	1	0.0035	2	0.17	10	0.5	0.007	0.03	0.700	0.23
Rhamnidium elaeocarpum	1	0.0026	2	0.17	10	0.5	0.005	0.02	0.691	0.23
Pouteria ramiflora	1	0.0003	2	0.17	10	0.5	0.001	0	0.670	0.22

N – individuals/0.5 ha; BA – basal area; TD – total density (individuals/ha); RA – relative abundance; TF – total frequency; RF – relative frequency; TDo – total dominance; RDo – relative dominance; IV – importance value.

TABLE 4. Average, standard deviation and *t* test of the edaphic parameters in the forest plots

	SDTF		MC		
	Average	SD	Average	SD	*t* test
pH (H_2O)	6.16	0.52	5.23	0.42	**0.01**
P (mg/dm^3)	14.95	5.56	11.48	5.95	0.19
K (mg/dm^3)	129.40	23.21	114.80	14.71	0.11
Ca (cmol/dm^3)	6.95	2.10	5.39	1.24	0.06
Mg (cmol/dm^3)	2.30	0.61	1.39	0.19	**0.01**
Al (cmol/dm^3)	0.02	0.04	0.11	0.07	**0.01**
H+Al (cmol/dm^3)	3.48	1.04	6.11	2.40	**0.01**
SB (cmol$_c$/dm^3)	9.58	2.67	7.09	1.38	**0.02**
CEC (cmol$_c$/dm^3)	9.60	2.67	7.20	1.33	**0.02**
CEC (pH 7.0) (cmol$_c$/dm^3)	13.09	2.91	13.20	1.63	0.92
V (%)	72.89	7.58	54.65	13.83	**0.01**
M (%)	0.22	0.47	1.67	1.17	**0.01**
Organic matter (dag/kg)	5.10	0.64	4.57	0.42	**0.04**
P rem (mg/l)	56.71	7.53	62.82	4.39	**0.04**
Sand (mg/dm^3)	71.70	1.49	74.60	0.84	**0.01**
Silt (mg/dm^3)	11.70	1.64	10.80	1.48	0.21
Clay (mg/dm^3)	16.60	1.07	14.60	1.51	**0.01**

SDTF – seasonally dry tropical forest; MC – mesotrophic cerradão; SB – sum of bases; CEC – cation exchange capacity; V – base saturation; M – aluminium saturation; P rem – phosphorus remnant.

found in both very humid and dry locations. The presence of these species that occur both in the Caatinga vegetation of northeast Brazil and in the Missiones and western Piedmont areas of Argentina supports the suggestion of Prado & Gibbs (1993) that they belonged to a continuum of dry forest vegetation during the Pleistocene.

CONCLUSIONS

Our study area represents a fairly typical transition of mesotrophic cerradão and SDTF. As shown in other studies, the SDTF occurred on the more fertile soils (eutrophic according to the Embrapa 2006 classification), while those of the cerradão with somewhat lower levels of nutrients were mesotrophic. *Anadenanthera colubrina* had the highest importance value in both vegetation types, while other characteristic species of eutrophic and mesotrophic soils such as *Myracrodruon urundeuva* and *Tabebuia roseoalba* were also important. The cerradão showed higher species richness since it also includes many species typical of more dystrophic and open forms of Cerrado.

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