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Floristics and Reproductive Phenology of Trees and Bushes in Central West Brazil

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ABSTRACT

Environmental conditions such as temperature, soil, photoperiodic factors and precipitation can determine the physical environment favoring the occurrence of given species and interfere with the reproductive period of plants. This work involved monthly excursions to a slope in the Serra de Maracaju between December 2009 and November 2010. Samples were collected in eight 25 x 50 m plots, transverse to the slope, totaling 1 ha sampled. Floristic richness included 79 species distributed into 58 genera and 31 families. Floristic Similarity Analysis and Principal Component Analysis showed the occurrence of two plant formations on the slope: seasonal deciduous forest and *cerradão* on the eutrophic soil of the slope. Flowering and fruiting occurred in the rainy season; correlation with rainfall, mean temperature and photoperiod were negative for flowering and positive for fructification. Trees and bushes presented uniform flowering and a moderately seasonal fructification, which is unexpected in seasonal environments. We discuss the implications of the patterns found and make comparisons with others studies.

Key words: *Cerradão*, community, deciduous forest, eutrophic soil.

INTRODUCTION

Environmental conditions such as temperature, soil, photoperiodic factors and precipitation can determine the physical environment favoring the occurrence of given species and interfere with the reproductive period of plants (Towsend et al. 2006). In tropical and subtropical regions, phenological events are mainly associated with rain (Frankie et al. 1974) and soil moisture conditions (Morellato et al. 2000). In temperate areas, phenophases depend more on length and temperature of the day (Opler et al. 1976).

The *Cerrado*, a Savanna-like formation, is the second most important Brazilian morphoclimatic zone (Rodrigues 2005), gathering different natural phytophysionomies (Eiten 1982), according to local edaphic, topographic and climatic factors (Oliveira and Marquis 2002). Its significant species richness may be surrounded by different vegetation types such as Amazonian and Atlantic forests, thorn forest (*Chaco*) and *caatinga*, subtropical fields, and wet and dry areas (Simon et al. 2009).

The fact that dry forests are interspersed with *Cerrado* in great tracts of land throughout South America (Mendonça et al. 1998) can be explained

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by climatological events that go back to the typically dry Quaternary period, which would have enabled the expansion of these forests and of more opened plant formations as fields, *Cerrado* and *caatinga*. Areas with dry forests differ in that they have more fertile soils, a higher pH and a concentration of certain nutrients (Mendonça et al. 1998).

Cerrado and forest remnants are often interspersed on Brazilian *Serra* slopes in the states of Minas Gerais (Oliveira-Filho et al. 1994), Goiás (Felfili et al. 2007) and Mato Grosso do Sul (Salis et al. 2004, G.A. Damasceno-Júnior, unpublished data, B.G. Fina, unpublished data, Ramos and Sartori 2013). More recent rugged landscapes are usually richer in given soil elements, which can favor the settlement of different, albeit geographically close plants (Reatto et al. 2008). Phenological studies at a community level can help functionally classify vegetation (Vasconcelos et al. 2010) and are crucial to understand plant reproduction and ecology (Oliveira 2008).

Studies in Venezuelan savanna and semi-deciduous forest communities report that most species blossom in the rainy season and in the rainy and dry seasons, respectively (Monasterio and Sarmiento 1976). In *Cerrado* communities located in different Brazilian regions, flowering usually occurs at the beginning of the rainy season (Batalha and Mantovani 2000) or, more rarely, during the dry season (Miranda 1995). However, other studies suggest that in transition periods flowering intensity in the *Cerrado* could be influenced by photoperiod (Batalha and Martins 2004) or by the association of the biological features of *Cerrado* species (Sarmiento and Monasterio 1983) and edaphic conditions (Vasconcelos et al. 2010).

Fruit types and, consequently, dispersal modes also seem to be associated with climatic factors (Morellato and Leitão-Filho 1992, Batalha and Martins 2004). In *Cerrado* communities, zoochory prevails during the rainy season, while auto- and anemochory are more frequent in the

dry period (Morellato and Leitão-Filho 1992, Batalha and Martins 2004, Miranda 1995).

The basalt plateau of the Paraná Basin extends from South-Central Brazil to Uruguay. Within the state of Mato Grosso do Sul in West-Central Brazil, it comprises a set of escarpments called the Serra de Maracaju (Martins 2003). Although the southern part of this Serra has rugged landscapes and steep hillsides with different altitudes, phytophysionomies, and floristic compositions, it has been scarcely studied (B.G. Fina, unpublished data, Ramos and Sartori 2013) and no work has conjointly addressed its floristic and phenological aspects.

Based on the physical proximity of the vegetation growing on the same side of this Serra de Maracaju slope and considering that they are part of the *Cerrado* area, we hoped to find both different formations influenced by soil fertility and reproductive phenophases regulated by abiotic factors such as rainfall, day length and temperature (monthly means).

The purpose of this study was to discover 1) if the floristic composition corroborates the fact that different phytophysionomies grow on the slope, 2) whether there is a relation between soil fertility and floristics, 3) if flowering, fructification and dispersal syndromes are uniform throughout the year, and 4) whether flowering and fructification periods relate to abiotic factors.

MATERIALS AND METHODS

GENERAL CHARACTERIZATION OF THE STUDY AREA

Study area is located 47 km from Campo Grande, Mato Grosso do Sul, Brazil, between 20°05' to 20°30' S and 54°45' to 54°15' W, at an approximate altitude of 500 m above sea level (see Figure 1). Vegetation is essentially *Cerrado* interspersed with seasonal forests (RADAMBRASIL 1982), which, according to UNESCO (1973), are classified as tropical and subtropical drought-deciduous forests. The study area is located in the Serra de Maracaju, which practically crosses the state longitudinally

and is characterized by significant topographic variations, a great quantity of fountainheads, springs and two main watercourses: the Paraguay and the Paraná Rivers.

Local soils are classified as dystrophic purple latosol and dark red alic and litholic eutrophic

latosol (Oliveira et al. 2006). The slope studied here is not deforested and evidence shows it has not burnt for at least 50 years, but cattle grazes in some of its parts. Climate is hot and dry, classified as Aw (Köppen 1948), with rain throughout the year and a mean rainfall.

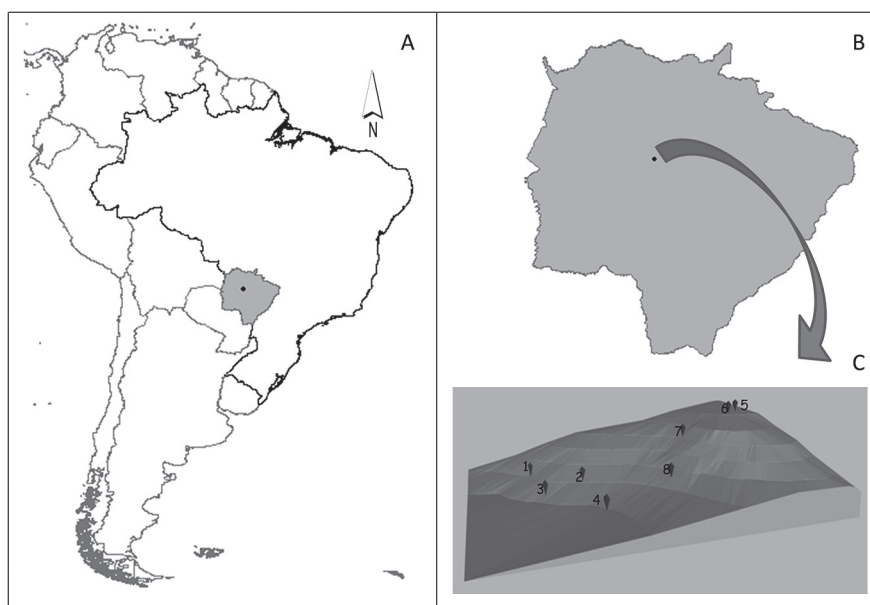


Figure 1 - Slope studied in the Serra de Maracaju (C), Jaraguari (black point) (B), South America (white), Mato Grosso do Sul, Brazil (gray) (A). (in Figure C, 1,2,3,4,5,6,7,8 identify the plots).

DATA COLLECTION AND ANALYSIS

In 34 ha covered with native vegetation, eight 25 x 50 m plots transverse to slope were delimited (see Figure 1), totaling 1 ha sampled. All trees and bushes were sampled in each plot. To complete the floristic survey, fertile materials were collected during random walks near each plot.

Flowering and fructification periods of bush and tree individuals were followed up in those plots at community level and recorded monthly on a spreadsheet (presence/absence) between December 2009 and November 2010; the maturity stages of flowers (bud and pre-anthesis) and fruits were disregarded.

Species were assorted by habit according to Cain and Castro (1959), modified by Whittaker

(1975): trees are woody plants over 3 m high and bushes are 1-3 m high. At family level, nomenclature follows APG III (2009). Materials were deposited at the CGMS herbarium. Dispersal syndromes classification, into anemochoric (winged diaspores), zoochoric (by animals) and autochoric (by explosion or gravity), follows Pijl (1982).

To compare the floristic data obtained in our plots, we used the Sørensen similarity index (Müller-Dombois and Ellenberg 1974). A dendrogram was constructed based on the group mean values (UPGMA). Spearman correlation analysis (Zar 1984) was used to ascertain the relations between monthly rainfall, day length and temperature (monthly means) and flowering and fructification, during the year of study and between 2000 and 2010. The relation of

the day length with flowering and fructification, was estimated only for the year study. The abiotic data used in the correlation analyses of the year of study were those measured 2 months before collection, since the response of plants to the effect of climate is usually delayed (Marques et al. 2004)

We also checked if flowering and fruiting were different between floristic groups, through the Mann-Whitney test (Zar 1984), if the proportions of anemo-, zoo- and autochory were different by performing a chi-square test (Zar 1984), and, using species number, if flowering, fructification and dispersal syndromes were uniform throughout the year, using circular statistics (Zar 1984); circular statistics is highly recommended to investigate data generated from circular scales (Morellato et al. 2010).

Monthly mean day lengths were obtained from the Brazilian Observatory (Moreira 2011). A climatogram was created according to Walter (1986). Monthly mean rainfall and temperature from 2000 to 2010

was provided by the Center for Meteorological Analyses of the Universidade Anhanguera-UNIDERP (University for the Development of the State and of the Pantanal Region), which is located 32 km away from our study site ($20^{\circ}26'19.4''$ S; $54^{\circ}32'18.3''$ W; 669 m); monthly rainfall below 100 mm was considered the least wet season. The cumulative rainfall of the year of study was 1,673.5 mm, which is higher than the 1,468.8 mm mean of the previous 10 years. Mean temperature of the year was 23.6°C and that of the previous 10 years was 23.4°C .

Our climatogram (see Figure 2) showed that the wet season runs from September to March, whereas the period from April to August is less humid, although there is no water deficit. The monthly mean average rainfall during the 10 previous years was 122.4 mm, while that of the year of study was 139.5 mm.

Fifteen soil samples were collected in each plot, 0-20 cm deep. Sampled points were randomly

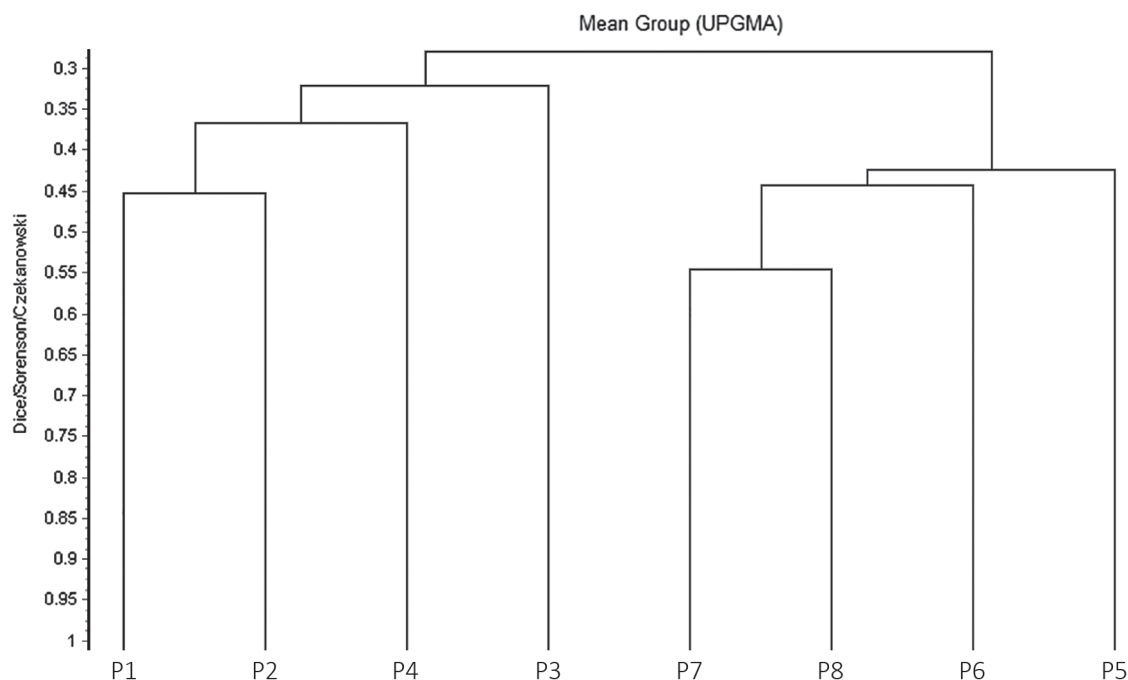


Figure 2 - Climatic diagram (2000 to 2010) built from the data obtained from the Center for Meteorological Analyses of the University for the Development of the State and of Pantanal Region (Universidade Anhanguera-UNIDERP), Mato Grosso do Sul, Brazil.

chosen along each plot to constitute a one and only sample. Contents of macro- and micronutrients, and Al, Cation Exchange Capacity (CEC), pH, organic matter, V% and BS (base sum) were assessed. The analyses were performed at the laboratory of the Federal University of São Carlos at Araras, SP, Brazil. When comparing soil features, we performed a Principal Component Analysis (PCA) with 13 variables, excluding the graphic representations of H+Al, BS, CEC and V%.

RESULTS

Floristic richness included 75 species distributed into 58 genera and 31 families (see Table I). In the plots, 54 species belonging to 40 genera and 23 families were sampled (see Table II). The families with highest species richness were: Fabaceae, 10 spp or 13.3%, Myrtaceae and Malvaceae, seven spp or 9.3% each (see Table I). The remaining families were represented by 51 species (see Table I).

TABLE I
List of families and species present in the plots and respective growth habits on an escarpment slope of the Serra de Maracaju, Mato Grosso do Sul, Brazil. (* species obtained in the plots, ** vegetative material; plots: P1, P2, P3, P4, P5, P6, P7 and P8; Voucher – herbarium CGMS).

Family	Species	Growth habit	P1	P2	P3	P4	P5	P6	P7	P8	Voucher
Anacardiaceae	<i>Astronium fraxinifolium</i> Schott ex Spreng.	Tree	X				X	X			31398
	<i>Lithraea molleoides</i> Engl.	Tree			X		X		X	X	31399
	<i>Myracrodruon urundeuva</i> Allemão*	Tree								X	31400
Annonaceae	<i>Annona cornifolia</i> A. St.-Hil.	Shrub									31401
	<i>Annona crassiflora</i> Mart.	Shrub					X				31402
	<i>Rollinia emarginata</i> Schtdl.	Tree	X	X							31403
Apocynaceae	<i>Aspidosperma cuspa</i> (Kunth) S.F. Blake ex Pittier	Tree	X	X		X		X		X	31405
	<i>Aspidosperma</i> sp.	Tree		X		X					31406
Asteraceae	<i>Dasyphyllum brasiliense</i> (Spreng.) Cabrera*	Shrub									31404
	<i>Jacaranda cuspidifolia</i> Mart.	Tree						X			**
Bignoniaceae	<i>Tabebuia aurea</i> (Silva Manso) Benth. e Hook. f. ex S. Moore	Tree	X				X	X	X	X	31407
	<i>Tabebuia roseoalba</i> (Ridl.) Sandwith	Tree								X	31408
Burseraceae	<i>Protium heptaphyllum</i> (Aubl.) Marchand*	Tree									**
Cannabaceae	<i>Celtis spinosa</i> Spreng.	Tree	X								31409
Celastraceae	<i>Maytenus</i> sp.	Tree	X								31410
Chrysobalanaceae	<i>Hirtella</i> sp.*	Tree									**
Combretaceae	<i>Buchenavia tomentosa</i> Eichler*	Tree									**
	<i>Terminalia argentea</i> Mart.	Tree		X	X	X	X	X	X	X	31411
Clusiaceae	<i>Kielmeyera coriacea</i> Mart. e Zucc.	Tree					X	X			31412
Dilleniaceae	<i>Curatella americana</i> L.	Tree					X		X	X	31413
	<i>Davilla elliptica</i> A. St.-Hil.	Tree					X			X	31414
Erythroxylaceae	<i>Erythroxylum</i> cf. <i>cuneifolium</i> (Mart.) O.E. Schulz	Shrub	X			X		X		X	31415
	<i>Erythroxylum</i> cf. <i>suberosum</i> A. St.-Hil.	Tree		X	X	X	X	X	X	X	31416
Euphorbiaceae	<i>Acalypha villosa</i> Jacq.	Shrub	X	X		X					31417
	<i>Sebastiania brasiliensis</i> Spreng.	Tree	X			X					31418
Fabaceae	<i>Anadenanthera colubrina</i> (Vell.) Brenan	Tree			X		X			X	29181

TABLE I (continuation)

Family	Species	Growth habit	P1	P2	P3	P4	P5	P6	P7	P8	Voucher
Fabaceae	<i>Bauhinia longifolia</i> D. Dietr.	Shrub		X		X					31419
	<i>Bauhinia mollis</i> (Bong.) D. Dietr.	Shrub					X				31420
	<i>Bauhinia unguolata</i> L.	Tree	X	X	X						31421
	<i>Bauhinia</i> sp.1	Tree			X				X		31422
	<i>Bauhinia</i> sp.2	Tree					X				31423
	<i>Hymenaea martiana</i> Hayne*	Shrub									**
	<i>Machaerium acutifolium</i> Vogel*	Tree									**
	<i>Pterogyne nitens</i> Tul.*	Tree									**
	<i>Sclerolobium</i> sp.*	Tree									**
Lythraceae	<i>Adenaria floribunda</i> Kunth*	Shrub									31424
	<i>Lafoensia pacari</i> A. St.-Hil.	Tree				X			X		31425
	<i>Byrsonima</i> sp.	Shrub							X		31426
Malpighiaceae	<i>Byrsonima intermedia</i> A. Juss.	Shrub					X				31427
	<i>Mascagnia</i> sp.*	Tree									**
	<i>Guazuma ulmifolia</i> Lam.	Tree		X	X					X	31428
Malvaceae	<i>Helicteres lhotzkyana</i> (Schott e Endl.) K. Schum.	Tree	X		X	X	X				31429
	<i>Luehea paniculata</i> Mart.*	Tree	X	X	X	X	X	X	X	X	31431
	<i>Luehea</i> sp.	Tree			X						
	<i>Pseudobombax</i> cf. <i>tomentosum</i> (Mart. e Zucc.) Robyns	Tree	X				X	X	X		31432
	<i>Sterculia striata</i> A. St.-Hil. e Naudin*	Tree									**
Moraceae	<i>Ficus insipida</i> Willd.	Tree						X			31433
	<i>Sorocea</i> cf. <i>bonplandii</i> (Baill.) W.C. Burger, Lanj. e Wess. Boer*	Tree									**
	<i>Campomanesia</i> sp.	Tree								X	31435
	<i>Myrcia guianensis</i> (Aubl.) DC.	Shrub					X			X	31436
	<i>Myrcia laruotteana</i> Cambess.	Tree	X		X						31437
Myrtaceae	<i>Myrcia tomentosa</i> (Aubl.) DC.	Tree	X	X			X			X	31438
	<i>Myrcia torta</i> DC.	Shrub									31439
	Myrtaceae sp. 1	Shrub							X	X	31440
Nyctaginaceae	<i>Psidium guineense</i> Sw.	Tree			X	X					31441
	<i>Guapira areolata</i> (Heimerl) Lundell*	Tree									**
Opiliaceae	<i>Agonandra brasiliensis</i> Miers ex Benth. e Hook. f.*	Tree									**
Primulaceae	<i>Rapanea gardneriana</i> (A. DC.) Mez*	Shrub									31430
Proteaceae	<i>Roupala montana</i> Aubl.	Tree							X	X	31442
Rhamnaceae	<i>Rhamnidium elaeocarpum</i> Reissek	Tree				X		X	X	X	31443
	<i>Alibertia edulis</i> (Rich.) A. Rich. ex DC.	Shrub	X	X	X	X	X	X	X	X	31444
Rubiaceae	<i>Alibertia</i> sp.	Tree	X								**
	<i>Calycophyllum multiflorum</i> Griseb.*	Tree									31445
	<i>Chomelia</i> cf. <i>pohliana</i> Müll. Arg.*	Shrub									**

TABLE I (continuation)

Family	Species	Growth habit	P1	P2	P3	P4	P5	P6	P7	P8	Voucher
Rubiaceae	<i>Guettarda viburnoides</i> Cham. e Schltdl.	Tree			X	X		X	X	X	31446
	<i>Randia armata</i> (Sw.) DC.	Tree			X						31447
Salicaceae	<i>Casearia rupestris</i> Eichler	Tree	X	X	X						31448
	<i>Xylosma venosa</i> N.E. Br.*	Tree									31449
	<i>Cupania castaneifolia</i> Mart.*	Tree									**
Sapindaceae	<i>Dilodendron bipinnatum</i> Radlk.	Shrub		X						X	31450
	<i>Magonia pubescens</i> A. St.-Hil.*	Tree									**
Sapotaceae	<i>Chrysophyllum marginatum</i> (Hook. e Arn.) Radlk.	Tree				X				X	31451
	<i>Pouteria gardneri</i> (Mart. e Miq.) Baehni	Tree	X								31452
Vochysiaceae	<i>Callisthene fasciculata</i> Mart.	Tree	X	X	X	X	X	X	X	X	31453
	<i>Qualea parviflora</i> Mart.	Tree	X	X	X	X	X	X	X	X	31454

Based on the floristic plot data, group mean (UPGMA) revealed the presence of two plant groupings (see Figure 3). Grouping 1 (A1) was formed by plots 1, 2, 3 and 4 and grouping 2 (A2) by plots 5, 6, 7 and 8. Both A1 and A2 comprised 38 species, 16 of which were exclusive to each (see Table I); the Sørensen index yielded a 0.71 cophenetic correlation coefficient.

Ordination through Principal Component Analysis (PCA) of the soil of the eight plots analyzed (see Figure 4) presented a cumulative variance of 59.0%, and eigenvalues of axes 1 and 2 were 2.11 and 2.56, respectively. These results were similar to those of the floristic groupings (see Figure 3), the only difference being the distance between plots 4 and 5. Considering the groupings found through floristic similarity, A1 and A2 were practically equal for fertility ($p=0.74$). Among the floristic groupings, phosphorus (P) ($p<0.01$), copper (Cu) ($p<0.01$) and zinc (Zn) ($p=0.01$) differ significantly (see Table III).

During the period of the study, 54 species were monitored for reproductive phenology at community level: 25 flowered and 52 fruiting (see Table II; see Figure 2). As for the 38 species found in each area, 19 and 22 species were observed in flower in A1 and A2, respectively (see

Table II). The difference between both groupings was not significant ($U=53.5$; $p=0.28$). Flowering was uniform during the analyzed year for both groupings A1 and A2; mean angles were 268.6° (A1+A2), 249.0° (A1), corresponding to the month of September, and 236.8° (A2), corresponding to August (see Table V).

The number of flowering species was negatively related to rainfall in A2 and presented no correlations to temperature or day length in either grouping (see Table IV).

Fructification occurred in 35 species in A1 and in 36 species in A2 without any significant difference ($U=59.5$; $p=0.47$) and was moderately seasonal for both groupings A1 and A2; mean angles were 10.1° , 11.4° and 11.9° , respectively, corresponding to January for all (see Table V). Fructification was explained by the abiotic factors analyzed (see Table IV).

With regards to dispersal, zoochory predominated in 32 species, followed by anemo- and autochory with 13 and 11 species, respectively. Zoochory also prevailed in both groupings (see Table II), and there were no differences between the distribution of dispersal syndromes ($\chi^2=1.173$; $p=0.56$). All syndromes were seasonal throughout the year in both groupings. Mean

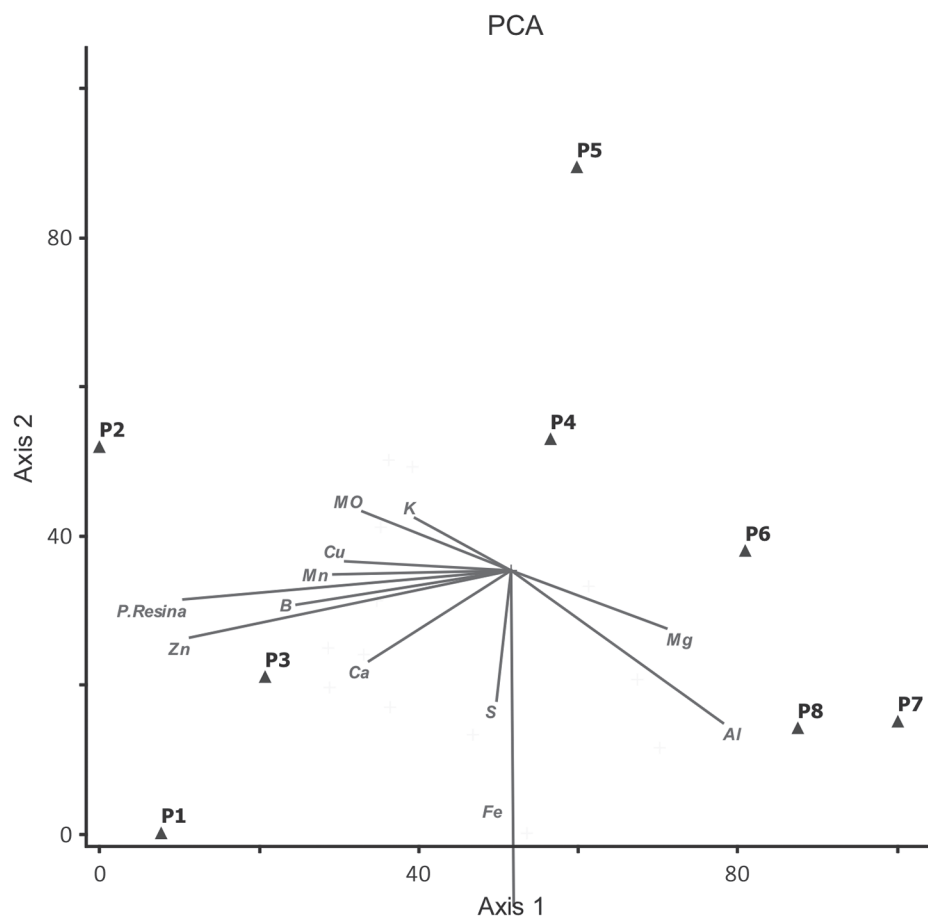


Figure 3 - Dendrogram produced through group mean (UPGMA) for the plots analyzed through the Sørensen similarity index in the floristic study on an escarpment slope in the Serra de Maracaju, Mato Grosso do Sul, Brazil (cophenetic correlation = 0.71).

TABLE II

List of families and species, dispersal syndromes, flowering and fructification in the plots of an escarpment slope of the Serra de Maracaju, Mato Grosso do Sul, Brazil. (Jan = January, Feb = February, Mar = March, Apr = April, May = May, Jun = June, Jul = July, Aug = August, Sep = September, Oct = October, Nov = November, Dec = December; Ane = Anemochory, Zoo = Zoochory, Aut = Autochory; ■ Flowering; ■ Fructification; □ Flowering and Fructification. 2009 and 2010 represent the reproductive phenophases.

Family	Species	Dispersal syndromes	2009	2010											
			Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	
Anacardiaceae	<i>Astronium fraxinifolium</i> Schott ex Spreng.	Ane													
	<i>Lithraea molleoides</i> Engl.	Zoo													
Annonaceae	<i>Annona cornifolia</i> A. St.-Hil.	Zoo													
	<i>Annona crassiflora</i> Mart.	Zoo													
	<i>Rollinia emarginata</i> Schltld.	Zoo													

TABLE II (continuation)

Family	Species	Dispersal syndromes	2009 2010											
			Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Apocynaceae	<i>Aspidosperma cuspa</i> (Kunth) S.F. Blake ex Pittier	Ane												
	<i>Aspidosperma</i> sp.	Ane												
Bignoniaceae	<i>Tabebuia aurea</i> (Silva Manso) Benth. e Hook. f. ex S. Moore	Ane												
	<i>Tabebuia roseoalba</i> (Ridl.) Sandwith	Ane												
Cannabaceae	<i>Celtis spinosa</i> Spreng.	Zoo												
Celastraceae	<i>Maytenus</i> sp.	Zoo												
Combretaceae	<i>Terminalia argentea</i> Mart.	Ane												
Clusiaceae	<i>Kielmeyera coriacea</i> Mart. e Zucc.	Ane												
Dilleniaceae	<i>Curatella americana</i> L.	Zoo												
	<i>Davilla elliptica</i> A. St.-Hil.	Zoo												
Bignoniaceae	<i>Tabebuia aurea</i> (Silva Manso) Benth. e Hook. f. ex S. Moore	Ane												
	<i>Tabebuia roseoalba</i> (Ridl.) Sandwith	Ane												
Cannabaceae	<i>Celtis spinosa</i> Spreng.	Zoo												
Celastraceae	<i>Maytenus</i> sp.	Zoo												
Combretaceae	<i>Terminalia argentea</i> Mart.	Ane												
Clusiaceae	<i>Kielmeyera coriacea</i> Mart. e Zucc.	Ane												
Dilleniaceae	<i>Curatella americana</i> L.	Zoo												
	<i>Davilla elliptica</i> A. St.-Hil.	Zoo												
Erythroxylaceae	<i>Erythroxylum</i> cf. <i>cuneifolium</i> (Mart.) O.E. Schulz	Zoo												
	<i>Erythroxylum</i> cf. <i>suberosum</i> A. St.-Hil.	Zoo												
Bignoniaceae	<i>Jacaranda cuspidifolia</i> Mart.	Ane												
Euphorbiaceae	<i>Acalypha villosa</i> Jacq.	Aut												
	<i>Sebastiania brasiliensis</i> Spreng.	Aut												
Fabaceae	<i>Anadenanthera colubrina</i> (Vell.) Brenan	Aut												
	<i>Bauhinia longifolia</i> D. Dietr.	Aut												
	<i>Bauhinia mollis</i> (Bong.) D. Dietr.	Aut												
	<i>Bauhinia unguolata</i> L.	Aut												
	<i>Bauhinia</i> sp.1	Aut												
	<i>Bauhinia</i> sp.2	Aut												

TABLE II (continuation)

Family	Species	Dispersal syndromes	2009 2010											
			Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Lythraceae	<i>Lafoensia pacari</i> A. St.-Hil.	Ane												
	<i>Byrsonima</i> sp.	Zoo												
Malpighiaceae	<i>Byrsonima intermedia</i> A. Juss.	Zoo												
Malvaceae	<i>Guazuma ulmifolia</i> Lam.	Zoo												
	<i>Helicteres lhotzkyana</i> (Schott e Endl.) K. Schum.	Aut												
	<i>Luehea paniculata</i> Mart.	Ane												
Malvaceae	<i>Luehea</i> sp.	Ane												
	<i>Pseudobombax</i> cf. <i>tomentosum</i> (Mart. e Zucc.) Robyns	Ane												
Moraceae	<i>Ficus insipida</i> Willd.	Zoo												
Myrtaceae	<i>Campomanesia</i> sp.	Zoo												
	<i>Myrcia guianensis</i> (Aubl.) DC.	Zoo												
	<i>Myrcia laruoiteana</i> Cambess.	Zoo												
	<i>Myrcia tomentosa</i> (Aubl.) DC.	Zoo												
	<i>Myrcia torta</i> DC.	Zoo												
	Myrtaceae sp. 1	Zoo												
	<i>Psidium guineense</i> Sw.	Zoo												
Proteaceae	<i>Roupala montana</i> Aubl.	Ane												
Rhamnaceae	<i>Rhamnidium elaeocarpum</i> Reissek	Zoo												
Rubiaceae	<i>Alibertia edulis</i> (Rich.) A. Rich. ex DC.	Zoo												
	<i>Alibertia</i> sp.	Zoo												
	<i>Guettarda viburnoides</i> Cham. e Schltldl.	Zoo												
	<i>Randia armata</i> (Sw.) DC.	Zoo												
Salicaceae	<i>Casearia rupestris</i> Eichler	Zoo												
	<i>Dilodendron bipinnatum</i> Radlk.	Ane												
Sapotaceae	<i>Chrysophyllum marginatum</i> (Hook. e Arn.) Radlk.	Zoo												
	<i>Pouteria gardneri</i> (Mart. e Miq.) Baehni	Zoo												
Vochysiaceae	<i>Callisthene fasciculata</i> Mart.	Ane												
	<i>Qualea parviflora</i> Mart.	Ane												

angles were: $(A1+A2)=17.9^\circ$, $A1=17.3$ and $A2=22.7$, corresponding to January, for zoochory; $(A1+A2)=267.6^\circ$, $A1=263.1^\circ$, corresponding to September, and $A2=32.6^\circ$ corresponding to February, for anemochory; and finally, $(A1+A2)=$

32.6° and $A2=45.0^\circ$ corresponding to February, and $A1=29.6^\circ$, corresponding to January, for autochory (see Table V). These months represent the largest production for each syndrome and suggest that they prevail in the rainy period.

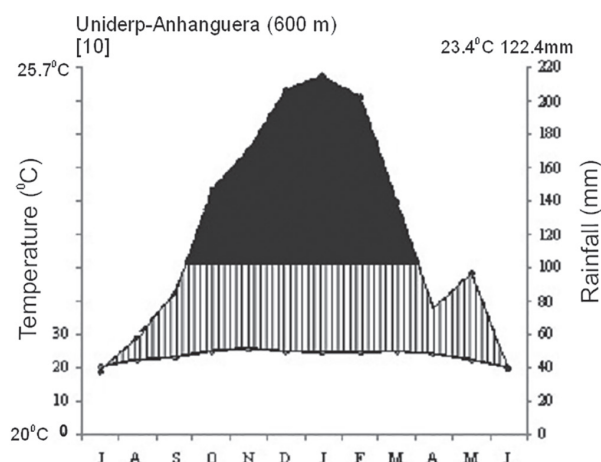


Figure 4 - Ordination through Principal Component Analysis (PCA) of the eight plots analyzed on an escarpment slope of the Serra de Maracaju, Mato Grosso do Sul, Brazil. The percentage of cumulative variance explained by the two axes is 39.34 and 59%. (P.Resin = phosphorus, M.O.= organic matter, K= potassium, Ca= calcium, Mg= magnesium, Al= aluminum, S= sulfur, B= boron, Cu= copper, Fe= iron, Zn= zinc, Mn= manganese).

DISCUSSION

The high specific richness of Fabaceae and Myrtaceae in western and southeastern Brazil (B.G. Fina, unpublished data, Ruggiero et al. 2002) consolidates the link between the *Cerrado* and the Atlantic Forest (Pinto and Oliveira-Filho 1999). The present study showed that Fabaceae

TABLE III

Mean and standard deviation from mean (SDM) of soil fertility at 0-20 cm depth in the eight plots sampled on an escarpment slope in the Serra de Maracaju, Mato Grosso do Sul, Brazil. Elements S, B, Cu, Fe, Mn and Zn in mg/dm³, organic matter (M.O.) in g/dm³. Except for pH, the other elements and parameters are in mmolc/dm³. V% = percentage of base saturation; BS = base sum (K+Ca+Mg); H+Al= potential acidity; CTC= Cation Exchange Capacity (BS+H+Al). (A1= plots 1,2,3,4; A2= plots 5,6,7,8; P.Resin = phosphorus; M.O.= organic matter; K= potassium; Ca= calcium; Mg= magnesium; Al= aluminum; S= sulfur; B= boron; Cu= copper; Fe= iron; Zn= zinc; Mn= manganese).

	X ± DPM		
	A1	A2	P
P Resin	210.25 ± 65.98	22.29 ± 22.29	<0.01
M.O.	72.50 ± 14.91	62.50 ± 14.84	0.38
pH	5.68 ± 0.15	5.78 ± 0.17	0.41
K	2.35 ± 0.78	1.83 ± 0.97	0.43
Ca	253.00 ± 29.02	213.50 ± 36.36	0.14
Mg	70.75 ± 5.19	87.25 ± 18.79	0.14
H+Al	39.75 ± 5.91	35.00 ± 3.92	0.23
Al	0.63 ± 0.15	0.80 ± 0.20	0.21
SB	326.10 ± 31.30	302.58 ± 49.96	0.46
CTC	365.85 ± 31.97	337.58 ± 47.09	0.36
V	89.00 ± 1.63	89.5 ± 2.38	0.74
S	10.50 ± 5.57	9.00 ± 2.83	0.65
B	0.89 ± 0.47	0.49 ± 0.16	0.16
Cu	10.73 ± 1.38	6.95 ± 2.91	<0.01
Fe	101.00 ± 24.86	96.75 ± 24.12	0.81
Mn	285.75 ± 90.17	193.50 ± 57.39	0.14
Zn	2.20 ± 0.61	1.08 ± 0.24	0.01

TABLE IV

Correlation between abiotic factors and reproductive phenology of trees and bushes on an escarpment slope in the Serra de Maracaju, Mato Grosso do Sul, Brazil. (A1= plots 1,2,3 and 4; A2= plots 5,6,7 and 8; r = result of Spearman analysis; p= significance). ¹ Study period, ² 10 years.

	A1+A2	p	A1	p	A2	P
Flowering X Rainfall ¹	r = -0.53	0.08	r = 0.59	0.46	r = -0.71	0.01
Flowering X Rainfall ²	r = -0.15	0.64	r = -0.40	0.19	r = -0.59	0.05
Flowering x Day length ¹	r = -0.23	0.47	r = -0.47	0.13	r = -0.32	0.31
Flowering x Mean temperature ¹	r = 0.05	0.87	r = -0.46	0.13	r = -0.46	0.13
Flowering x Mean temperature ²	r = -0.56	0.06	r = -0.24	0.44	r = -0.24	0.44
Fructification X Rainfall ¹	r = 0.76	<0.01	r = 0.78	<0.01	r = 0.80	<0.01
Fructification X Rainfall ²	r = 0.73	<0.01	r = 0.68	0.02	r = 0.62	0.03
Fructification X Day length ¹	r = 0.87	<0.01	r = 0.89	<0.01	r = 0.9	<0.01
Fructification X Mean temperature ¹	r = 0.74	<0.01	r = 0.68	0.02	r = 0.63	0.03
Fructification X Mean temperature ²	r = 0.89	<0.01	r = 0.88	<0.01	r = 0.79	<0.01

TABLE V
Circular analysis of the reproductive phenology of number of trees and bush species on an escarpment slope in the Serra de Maracaju, Mato Grosso do Sul, Brazil. (A1= plots 1,2,3 and 4; A2= plots 5,6,7 and 8; z= result of circular analysis; p= significance).

	A1+A2	p	A1	p	A2	P
Flowering	Z=7.96E-01	0.45	Z=1.40	0.25	Z=1.82	0.16
Fructification	Z=24.43	2.47E-11	Z=25.89	5.73E-12	Z=18.61	8.29E-09
Zoochory	Z=59.6	0	Z=73.2	0	Z=48.3	0
Anemochory	Z=7.4	5.94E-04	Z=8.7	1.61E-04	Z=9.9	4.79E-05
Autochory	Z=101.0	0	Z= 145.2	0	Z=107.8	0

also prevails in environments with different, albeit close, formations, as observed by Gentry (1993) in neotropical environments. Malvaceae, the third most representative family in this study, is also reported among the main families occurring in the Serra de Maracaju in other localities (Ramos and Sartori 2013), while, according to Heywood et al. (2007), this family is common in savanna, “scrub” and forest edges.

Grouping 1 (A1) corresponds to a remnant of seasonal deciduous forest characterized by the occurrence of the same species, significant levels of leaf deciduousness in the dry period, according to field observations, and eutrophic soil. The presence of characteristic species of dry forests as *Sebastiania brasiliensis*, *Bauhinia unguolata*, *Rollinia emarginata*, *Randia armata* and *Casearia rupestris* is reported in other studies on similar formations (Nascimento et al. 2004, Salis et al. 2004, G.A. Damasceno-Junior, unpublished data, Pott et al. 2011). Grouping 2 (A2) here considered as *cerradão* shows characteristic species such as *Curatella americana*, *Jacaranda cuspidifolia*, *Annona crassiflora*, *Byrsonima intermedia*, *Davilla elliptica*, *Roupala montana*. Our results are in agreement with previous studies such as Ribeiro and Walter (2008), and Ratter et al. (2006). *Curatella americana* is common in savannas from Central America to southern Brazil, and the presence of *Roupala montana* indicates soil fertility (Ratter et al. 2006).

Soil fertility analysis with a pH between 5.5 and 6.0, base saturation higher than 50% and rugged

landscapes, suggest eutrophic soil, according to the parameters listed by Ratter et al. (2003) and Reatto et al. (2008). The high content of phosphorus, zinc and copper available in A1 together with deeper soils reinforce the fact that it is a deciduous forest, according to Eiten (1982). A2 is a eutrophic *cerradão* since its pH is higher than expected dystrophic *Cerrado* in central Brazil, where it usually varies between 4.0 and 4.8 (Ratter et al. 1978). In addition, such plant formations prevail in basalt formations (Reatto et al. 2008), which is the case of the Serra de Maracaju (Martins 2003). Deciduous forest with fertile soil interspersed with *Cerrado* (*cerradão*) could have resulted from dry climate episodes during the Pleistocene, as described by Prado (2000) for South American areas. These formations in the Serra de Maracaju would have acted as corridors for species since they can shelter those common to other plant formations, such as the thorn forest (Chaco) and dry forests (Salis et al. 2004).

The uniform flowering and the negative correlation between flowering and rain, day length and mean temperature in the area of study can be explained by the fact that the soil contains water all year round, since it is interspersed with streams and springs in addition to rocky outcrops that possibly favor water retention. This pattern suggests that the tree and shrub species do not depend directly on rain to flower and probably rely on their deep roots to maintain their water supply (Sarmiento and Monasterio 1983, Batalha and Martins 2004).

The moderately seasonal fructification and positive correlation between fructification and average rainfalls stresses the importance of favorable water conditions to yield fleshy fruits since, during the rainy season, easily access to water contributes to fruit development (Marco and Paéz 2002); the positive correlation between fructification and both day length and mean temperature was expected in this seasonal formation (Morellato et al. 1990, Morellato et al. 2000).

The preponderance of zoochory followed by anemochory and autochory has already been reported in semi-deciduous forest and semi-deciduous altitude forests (Morellato and Leitão-Filho 1992, Kinoshita et al. 2006), in *Cerrado* (Batalha and Martins 2004), and it also prevails in tropical forests (Fleming 1979). The period when most species blossomed and fruited, independently of their respective dispersal modes, coincided with that of studies in *Cerrado* formations of west-central Brazil (Batalha and Martins 2004) and in semi-deciduous altitude forests and semi-deciduous forests of the southeastern region of Brazil (Morellato and Leitão-Filho 1992).

The intense deciduousness of some species observed during a given period of the year apparently suggests that the area of the Serra de Maracaju studied here is constituted by a one and only plant formation. Nevertheless, two adjacent phytophysiognomies, seasonal forest and *cerradão*, could be distinguished through floristic composition and soil fertility. These must be further analyzed both to confirm this classification and to conduct other studies on the slopes of this *serra*. The set formed by given tree and shrub species suggests that this portion of the Serra de Maracaju is floristically linked to the Atlantic Domain (dry forests) and the *Cerrado* (*cerradão*), a biogeographical aspect that should be further explored in future studies.

The correlations between reproductive phenophases and the abiotic variables did not differ between deciduous forest and *cerradão*. The

phenological pattern obtained for flowering differed from what was expected in seasonal environments. This is possibly related to the specificities of the plant communities assessed and their evolutionary history. The preponderance of zoochory highlights the importance of animal-plant interaction to maintain the studied community. Nevertheless, abiotic syndromes do play a crucial role in the Serra de Maracaju formed by many slopes that create physical barriers to biotic agents.

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RESUMO

Fatores ambientais, tais como temperatura, solo, fotoperíodo e precipitação podem determinar o ambiente físico favorecendo a ocorrência de espécies e interferir no período reprodutivo das plantas. Este trabalho foi realizado através de excursões mensais para uma encosta da Serra de Maracaju, entre dezembro de 2009 e novembro de 2010. As amostras foram coletadas em oito parcelas, 25 x 50 m, posicionado transversalmente ao declive, totalizando 1 ha amostrado. A riqueza florística desta encosta incluiu 79 espécies distribuídas em 58 gêneros e 31 famílias. A análise de similaridade florística e a análise de Componentes Principais mostraram a ocorrência de duas formações vegetais na encosta: floresta estacional decidual e *cerradão* no solo eutrófico da encosta. Floração e frutificação ocorreram na estação chuvosa; correlação com a precipitação, temperatura média e do fotoperíodo foram negativas para a floração e positiva para a frutificação. Árvores e arbustos apresentaram floração uniforme e uma frutificação moderadamente

sazonal, que é inesperado em ambientes sazonais. Nós discutimos as implicações dos padrões encontrados e fizemos comparações com outros estudos.

Palavras-chave: *Cerradão*, comunidade, floresta decídua, solo eutrófico.

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