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Is the herb-shrub composition of *veredas* (Brazilian palm swamps) distinguishable?

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ABSTRACT

Vereda (Brazilian palm swamp) is a poorly known savannic phytophysognomy that occurs on moist soils with high herb-shrub floristic richness. This study aimed to document the herb-shrub species of *veredas* of the Estação Ecológica Serra Geral do Tocantins - EESGTO, and compare this flora with other *veredas* in Brazil. Furthermore, we assessed the similarity of the herb-shrub flora of the studied *veredas* with that of inventories of other savannas and grasslands in order to evaluate whether *veredas* possess an exclusive flora. Ordination analysis was performed to understand the floristic relationship among these areas. We recorded 213 species, 105 genera and 49 families at EESGTO, including five new floral records for the Cerrado and 78 for the state of Tocantins. The floristic similarity among *veredas* at EESGTO and the other sites was low. For all sites, a total of 1,324 species were recorded, of which 342 were unique to *veredas* and 187 unique to moist grasslands (*campos limpos úmidos*). After reviewing databases, 14.3 % of these species remained exclusive to *veredas* and moist grasslands. The ordination analysis indicated a gradient in floristic composition from wet to dry phytophysognomies. In conclusion, we recognize a flora that distinguishes *veredas* from other Cerrado phytophysognomies.

Keywords: Cerrado, Jalapão, *Mauritia flexuosa* L.f., *Vereda*, wetlands

Introduction

The Cerrado domain occurs mainly in the Central-West Region of Brazil. It has high levels of plant diversity and endemism, and comprises a vegetation mosaic that encompasses grasslands, savannas and forests (Mendonça *et al.* 2008; Ribeiro & Walter 2008; Forzza *et al.* 2012). The Cerrado possesses a wide range of elevational, climatic and edaphic conditions (Oliveira-Filho *et al.* 1989; Silva & Bates 2002; Klink & Machado 2005), resulting in great variation in environmental conditions, leading to the distinct flora of its phytophysognomies (Felfili & Silva 1993; Munhoz & Felfili 2007; Abreu *et al.* 2014).

Vereda (Brazilian palm swamp) is a humid savannic phytophysognomy that occurs on moist soils and is characterized by a dominant herb-subshrub layer and the presence of the palm tree *Mauritia flexuosa* (buriti) (Ribeiro & Walter 2008). *Veredas* possesses high floristic richness and diversity, which are associated with their heterogeneous environments, including differences in soil texture, organic matter and drainage, ranging from permanently flooded to well drained in the dry season (Guimarães *et al.* 2002; Ramos *et al.* 2006; Resende *et al.* 2013). *Veredas* occur throughout the entire Cerrado and are very common in the eastern portion of the state of Tocantins, especially in the Jalapão region (Villela & Nogueira 2011).

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The Jalapão region encompasses a large extension of protected areas, including five conservation units, of which three are considered as strictly protected (IUCN category I) and two others classified as sustainable. The Estação Ecológica Serra Geral do Tocantins (EESGTO) is one of the three strictly protected areas, and encompasses large areas of *veredas*, which were used, prior to the creation of the EESGTO, as harvest areas for the extraction of the capim-dourado - *Syngonanthus nitens* (Eriocaulaceae) floral scapes, and the buriti petiole (Arecaceae) (Schmidt *et al.* 2007). These species are used as raw material for handicrafts, which are commercialized throughout Brazil (Schmidt *et al.* 2007).

The Jalapão region is conserved primarily because of the predominance of sandy soil, which is unsuitable for agriculture, and has a low human population density (Schmidt *et al.* 2007). The economic activities in the region are based on extractivism, subsistence agriculture and raising livestock (Seplan 2003a; b; Schmidt *et al.* 2011). However, in the last decade there has been a major incentive to stimulate extensive agriculture expansion in areas of Cerrado in Tocantins (Cifuentes 2014). The decree that created Matopiba (Decree No. 8,447 of 6th may 2015) is a good example of such incentives. This decree aimed to promote and coordinate public policies to increase agricultural production and livestock in the states of Maranhão, Tocantins, Piauí and Bahia (Brasil 2015). This agribusiness expansion in the north-northern Cerrado has led to increased rates of deforestation (Ferreira *et al.* 2009). Biologically, the north-northern region of the Cerrado is one of the poorest-known areas in the biome (Amaral *et al.* 2017), yet it experienced its highest levels of deforestation between the years 2002-2008 (Silva *et al.* 2006; MMA 2010). Despite the high levels of threat, the region of Serra Geral contains important protected areas for Cerrado biodiversity, such as Parque Nacional Nascentes do Parnaíba, Estação Ecológica Serra Geral do Tocantins, Parque Estadual do Jalapão and Área de Proteção Ambiental Rio Preto. The region of Serra Geral is being classified as an area of extremely high priority for conservation, with some sites being categorized as insufficiently known (MMA 2010; 2015), making this region a priority area for research and conservation.

Despite the importance of *veredas* for maintaining floristic diversity and water resources in the Cerrado (Araújo *et al.* 2002; Oliveira *et al.* 2009; Moreira *et al.* 2015), these wetlands need to be studied in order to support public policy for their conservation (Rosolen *et al.* 2015). There have been no evaluations of the uniqueness of the flora of *veredas* in relation to other phytophysognomies. In this paper, we seek to synthesize the floristic knowledge of *veredas* in the Central-West Region of Brazil. Our aims were to: i) conduct a herb-shrub survey of the *veredas* in the Estação Ecológica Serra Geral do Tocantins; ii) synthesize the information about the floristic composition of *veredas* in Brazil, and iii) investigate the floristic affinities between

veredas, grasslands and savannic phytophysognomies of the Cerrado. We aimed to answer the following question: How unique is the herb-shrub flora of this humid savanna?

Materials and methods

Study Area

The study was conducted at Estação Ecológica Serra Geral do Tocantins (EESGTO), which encompasses 716,306 ha (Silva & Bates 2002) between the eastern portion of the state of Tocantins and the western portion of the state of Bahia (10°25'-11°21'S 47°13'-45°50'W) (Fig. 1). The region comprises a set of depressions and adjacent plateaus forming table-mountains and inselbergs (Villela & Nogueira 2011). The soil types are mostly characterized as Quartzipsamment (sandy soil), dystrophic and alic (Embrapa 1999; Mamede *et al.* 2002). According to the Köppen classification system, the climate is Aw - tropical with two distinct seasons, a dry winter (April to September) and a humid summer (October to March) (Alvares *et al.* 2014). The average annual temperature is around 27 °C and the annual precipitation is about 1500–2000 mm (Seplan 2003b).

Botanical collections were carried out in five *vereda* sites (Fig. 1): V1- southern part of EESGTO, located on the bank of the Balsas river (11°07'40"S 46°54'20"W); V2- located in the Lagoa Espraçada Region (10°36'48.70"S 46°31'41.50"W); V3- located on the left bank of the Novo river, upstream view (V3; 10°51'49.30"S 46°36'54.30"W); V4- situated on the right bank of the Novo river, downstream view (10°52'03"S 46°36'55.40"W); and V5- northern part of the EESGTO, located on the bank of the Preto river (10°36'48.70"S 46°31'41.50"W).

Data collection and analysis

The floristic survey was carried out at EESGTO in the beginning (November-December 2014) and in the end (May 2015) of the wet season, when there are more herb-shrub species flowering in humid environments (Munhoz & Felfili 2005). Vascular species were recorded using random sampling following the procedure described by Filgueiras *et al.* (1994). Reproductive material was collected and pressed, and identified to species by experts and by comparisons with voucher specimens in the herbaria of the Instituto Brasileiro de Geografia e Estatística (IBGE) and the Universidade de Brasília (UB), where the material was incorporated. The familial circumscription followed the Angiosperm Phylogeny Group IV (APG IV 2016). Ferns identification were confirmed by the Brazilian Flora database (Flora do Brasil 2020 em construção).

A list containing families, species, *vereda* sites and vouchers was compiled. We evaluated the occurrences of all species sampled in EESGTO using the Species List of the Brazilian Flora database (Flora do Brasil 2020 em



Is the herb-shrub composition of *veredas* (Brazilian palm swamps) distinguishable?

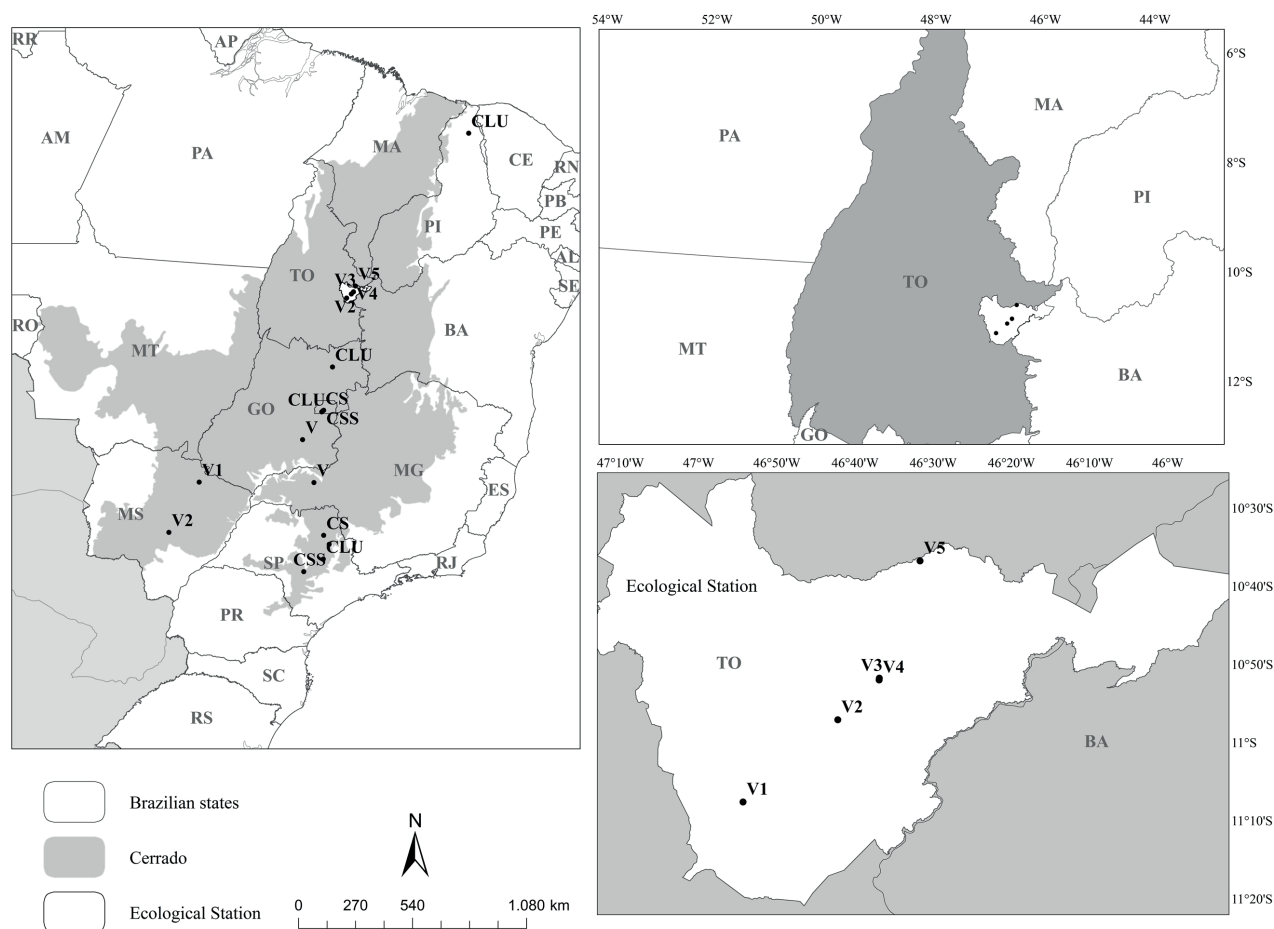


Figure 1. Location of the study sites in the Estação Ecológica Serra Geral do Tocantins, Brazil, and other Cerrado locations. The subtitle of each site are a combination of the abbreviation for the state and the phytophysiognomy: CSS = cerrado *sensu stricto*, CS = campo sujo (dry shrub grassland), CLU = campo limpo úmido (moist grassland) and V1, V2, V3, V4 and V5 = *veredas* 1, 2, 3, 4 and 5.

construção). The herb-shrub flora found in the *veredas* of EESGTO was compared with eight other *vereda* sites across Brazil (Tab. 1). Herbs, subshrubs, shrubs, palm trees and vines, classified according to Eiten (1992), were included in the list. Palm swamps occurring in areas of Mato Grosso do Sul, which are characterized by the absence of buritis (Moreira *et al.* 2015), were considered as moist grasslands (*campo limpo úmido*), according to Ribeiro & Walter (2008).

The compiled herb-shrub flora of the *veredas* was compared with floristic surveys performed in dry savannas (cerrado *sensu stricto*) and grasslands (dry shrub grassland – *campo sujo* and moist grassland – *campo limpo úmido*), for a total of 24 areas representing a broad latitudinal range of the Cerrado (Tab. 1). Species that were identified to only the genus or family level, and species requiring confirmation (*cf.*), were excluded from the list. To determine if species were unique to humid phytophysiognomies, we searched SpeciesLink database (SPLink 2016) by species, and if a species had at least of 10 records in another phytophysiognomy it was not considered unique.

Floristic relationship was performed in order to compare the 13 *vereda* areas and the 24 other phytophysiognomies by Detrended Correspondence Analysis (DCA), using the ‘vegan’ package, version 2.3-1 (Oksanen *et al.* 2015), of R (R Development Core Team 2015). Species that appeared at only one site were excluded (McCune *et al.* 2002). Similarity between areas was measured using the Jaccard index. To avoid a false increase in species and floristic differences between areas, we checked all botanical names using the package ‘flora’, version 0.2.4 (Carvalho 2015) in R version 3.0.3 (R Development Core Team 2015).

Results

Floristic richness and composition of the herb-shrub flora of veredas in the Estação Ecológica Serra Geral do Tocantins

We collected 646 specimens from the five *vereda* sites of EESGTO, representing 213 species, 105 genera and 49 families



Table 1. Cerrado phytophysiognomies compared in the present study. Cod. = Site codes; Prec. = annual mean precipitation (mm/year); T = annual average temperature (°C); N = number of herbaceous vascular plant species used in the comparison matrix.

Cod.	Sites	Phytophysiognomy	Prec.	T	Latitude (S)/Longitude (W)	Altitude (m)	References	N
CSS_DF	Reserva Ecológica do IBGE, DF	Cerrado s.s.	1.500	21	15°55'00.00"/47°53'00.00"	1178	Silva & Nogueira 1999	144
CSS_SP1	Reserva Pé-de-Gigante, SP	Cerrado s.s.	1.400	20	21°38'00.00"/47°39'00.00"	720	Batalha & Mantovani 2001	181
CSS_SP2, 3	Pratânia, Pratânia, SP	Cerrado s.s.	1.453	20.8	22°48'00.00"/48°44'00.00"	725	Ishara & Maimoni-Rodella 2012	121
CS_SP	Itirapina, SP	Dry shrub grassland	1.523	20	22°15'00.00"/47°53'00.00"	700	Tannus & Assis 2004	177
CS_DF	Fazenda Água Limpa, DF	Dry shrub grassland	1.500	21	15°56'00.00"/47°55'00.00"	1178	Munhoz & Felfili 2004	224
CLU_DF	Fazenda Água Limpa, DF	Moist grassland	1.500	21	15°59'00.00"/47°58'00.00"	1178	Munhoz & Felfili 2007	224
CLU_SP	Itirapina, SP	Moist grassland	1.523	20	22°15'43.00"/47°54'00.00"	700	Tannus & Assis 2004	105
CLU_GO	Alto Paraíso de Goiás, GO	Moist grassland	1.300	23	14°04'08,83"/47°30'33,01"	992	Munhoz & Felfili 2006	207
CLU_PI	Parque Nacional Sete Cidades Park, PI	Moist grassland	1.650	26.7	04°05'55.26"/41°42'09.83"	290	Mendes <i>et al.</i> 2014	92
V_MS1	Camapuã, Aquidauana, Bonito, Sidrolândia, Maracajú, Coxim, MS	Moist grassland/ Palm swamp	2.000	25	18°58'52.34"/53°11'36.86"	510	Moreira <i>et al.</i> 2015	183
V_MS2	Anhanduí, Ribas do Rio Pardo, Fátima do Sul, Costa Rica, Chapadão do Sul, Brasilândia, MS	Palm swamp	2.000	25	21°07'26.25"/54°28'52.15"	453	Moreira <i>et al.</i> 2015	174
V_GO1, 2, 3	Rio Peixe, Rio Corumbá, Rio Paranaíba, GO	Palm swamp	2.000	24	17°00'63.00"/48°47'33.00"	899	Resende <i>et al.</i> 2013	152, 157, 154
V_TM1, 2, 3, 4	Clube Caça e Pesca Itororó, Campo Florido, Estação Ecológica do Panga 1, 2, MG	Palm swamp	1.900	26	18°59'59.00"/48°18'00.00"	860	Araújo <i>et al.</i> 2002	246, 216, 183, 203
V_TO1, 2, 3, 4, 5	Rio Balsas, Rio Novo right bank, Rio Novo left bank, Rio Preto, Lagoa Espraiada, TO	Palm swamp	1.700	27	11°07'40.00"/46°54'20.00"	490	Current study	127, 128, 125, 133, 127

(Tab. S1 in supplementary material). Nineteen species were identified to the genus level, including *Bisboeckelera*, which, along with *Chelonanthus alatus*, *Paepalanthus polytrichoides*, *Xyris eglerti* and *Xyris brevifolia*, were new records for the flora of the Cerrado. The first four species had floristic records for the Amazon region whereas the fifth had records for the Atlantic Forest. A total of 78 new species occurrence were recorded for the state of Tocantins. The richest families in EESGTO were Poaceae (40), Cyperaceae (32), Xyridaceae (23) and Eriocaulaceae (18), which together accounted for 62.8 % of the species. *Rhynchospora* was the most common genus in the *veredas* and in the other phytophysiognomies that were analyzed (Tab. S1 in supplementary material). Even though

41 % of the species occurred in a single site, the *veredas* of EESGTO exhibited 60 % similarity according to Jaccard's similarity index. Thirty-five percent of the species occurred in all the *veredas* of EESGTO. *Vereda* site V2 was the most floristically distinct, with 29 unique species.

Floristic richness and composition of the herb-shrub flora of veredas in Brazil

Analyzing the 13 *veredas* from this study and the literature, we recorded 602 species (Tab. S2 in supplementary material). Only the following species were present at all sites: *Andropogon bicornis*, *Anthraenantia lanata*, *Ascolepis brasiliensis*,



Ludwigia nervosa, *Mauritia flexuosa* and *Rhynchospora globosa*. The floristic similarity between EESGTO sites and the other *vereda* sites was low (~ 22 %, Jaccard index). Of the 125 species of the family Poaceae included in the matrix, approximately 27 % occurred in one site, while only six occurred in all 13 sites. The DCA indicated that the flora of the southeast portion of Goiás and the flora of western Minas Gerais possessed floristic affinities (Fig. 2).

Floristic affinities between *veredas*, grasslands and savannic phytogeonomies in Brazil

The greatest floristic affinities (53 %) were found between *veredas* and moist grasslands (*campo limpo úmido*), followed by dry shrub grassland (*campo sujo*) (19.6 %) and dry savanna (*cerrado sensu stricto*) (14.3 %). The DCA performed in order to compare the *veredas* with the other types of phytogeographies indicated two groups, which were separated based on soil moisture and geographic distance (Fig. 3). On the first axis, humid sites appeared on the left and drained-soil sites on the right. On the second axis, the groups were separated by geographic distance.

For the 24 analyzed sites, we registered a total of 1,324 species, of which 602 occurred in *veredas* and 294 in moist grassland (*campo limpo úmido*). We recorded 342 species unique to *veredas*, 187 unique to moist grasslands and 710 unique to both of these vegetation types (Tab. S2 in supplementary material). However, after searching the SpeciesLink database (SPLink 2016) for records of these species in other vegetation types, we remained with 189 (14.3 %) species exclusive to only wet phytogeographies, 80 (6 %) in *veredas*, 59 (4.5 %) in moist grassland and 50 (3.7 %) in other phytogeographies.

Discussion

Floristic richness and composition of the herb-shrub flora of *veredas* in the Estação Ecológica Serra Geral do Tocantins

The *veredas* of the EESGTO showed high floristic richness, as was also found for the other *veredas* and moist grassland areas of the Cerrado, and with the same richest families (Poaceae and Cyperaceae) and genera (*Rhynchospora* and *Xyris*) (Araújo *et al.* 2002; Munhoz & Felili 2007; Resende *et al.* 2013). The floristic variation found among sites may be due to the site size, and/or differences in soil humidity among the areas, which selects species adapted to moist soil as well, where the number of species can be higher in the drained portion and reduced in the permanent flooded portion (Munhoz & Felili 2007).

The new occurrence records found in the *veredas* of EESGTO contributed to the flora of the state of Tocantins, increasing the vascular flora checklist (Mendonça *et al.* 2008; Forzza *et al.* 2012). These new records emphasize the

lack of knowledge about the biodiversity in the northern/northeastern portion of the Cerrado (Proença *et al.* 2010). Previously, these species had only been recorded in the Amazon and Atlantic Forest (Flora do Brasil 2020 em construção).

The wide geographic range of the Cerrado enables the sharing of species of flora between it and other Brazilian biomes (Françoso *et al.* 2016; Teixeira *et al.* 2017). The limits of the Cerrado offer the opportunity for recruitment of species from a variety of forest types of wet and dry vegetation (Simon *et al.* 2009). Besides the sharing of tree species between forests, the Cerrado herbaceous flora also shares many species with the Atlantic Forest, followed by the Amazon forest (Amaral *et al.* 2017). Moreover, it is hypothesized that the lineages of Cerrado species originated in other Brazilian biomes in the early Cretaceous period, the period of time when the Cerrado domain was formed (Ledru 2002; Pennington *et al.* 2004).

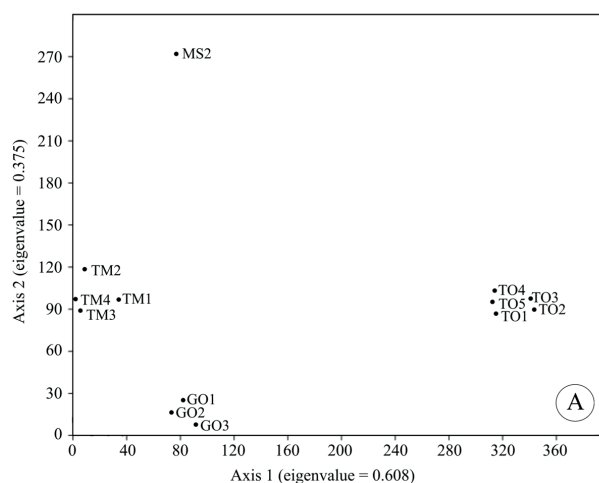
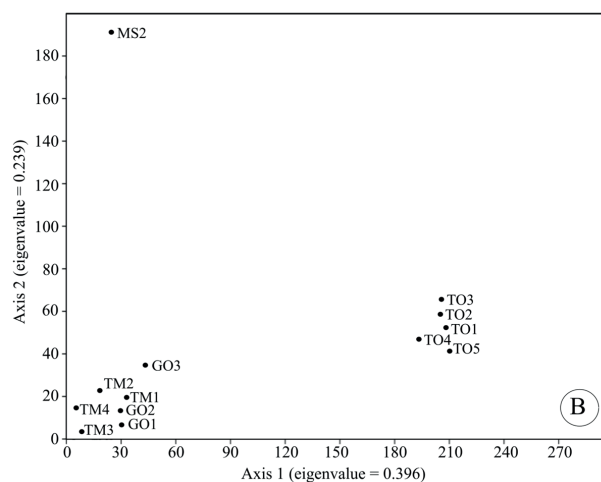


Figure 2. Positioning by axes ordination (DCA) of herb-shrub components of 13 *veredas* at specific (A) and generic (B) levels. MS₂ = *vereda* in Mato Grosso do Sul, GO₁, 2 and 3 = *veredas* in Goiás, TM₁, 2, 3 and 4 = *veredas* in Minas Gerais and TO₁, 2, 3, 4 and 5 = *veredas* in EESGTO.



Floristic richness and composition of the herb-shrub flora of veredas in Brazil

The EESGTO *vereda* sites showed a high level of similarity in species composition, even though the number of unique species in each site was relatively high. This floristic affinity can be explained by the geographic proximity of the sites, which implies similarities in climate and soil characteristics. However, when all 13 *veredas* were compared they showed low floristic similarity, due to the greater geographic distances among them. This pattern has been observed for other phytophysiognomies of the Brazilian savanna that have broad longitudinal distributions and a great number of species (Ratter *et al.* 2003; Silva *et al.* 2006). In a comparison of tree composition of different sites of cerrado *sensu stricto*, the proximate sites showed floristic similarity, probably in response to environmental interactions (Oliveira-Filho *et al.* 1989).

The ordination of the *vereda* sites at species and genus levels showed distinct groups, with the Minas Gerais *veredas* being closest to those in Goiás, but the *veredas* of Tocantins and Mato Grosso do Sul were distant from each other. Similar patterns were found in studies that compared *veredas* in the same region, with neighboring sites possessing high floristic similarity (Resende *et al.* 2013; Moreira *et al.* 2015). The separation of the *vereda* sites highlighted the regional distinctions between them, and the fact that many species are distributed sporadically or in a mosaic (Castro *et al.* 1999).

Floristic affinities between veredas, grasslands and savannic phytophysiognomies in the Cerrado

Veredas and moist grassland areas were closer to each other when compared to dry savanna, and the ordination was arranged from moist sites to dry sites with low floristic sharing among the 24 areas analyzed. The herb-subshrub flora of cerrado *sensu stricto* was the most different when compared with the other phytophysiognomies. About 85% of the species registered for cerrado *sensu stricto* did not occurred in the *veredas*, and its flora composed 29 % of the species matrix. Our study found a predictable herbaceous flora distinguishable in response to differences in edaphic characteristics and soil humidity (Munhoz & Felfili 2007). Areas of moist grassland in the state of Piauí, which are closest to the Tocantins *veredas*, showed high floristic similarity when compared at the species and genus levels. In the same way, the areas of cerrado *sensu stricto* located in state of São Paulo and dry shrub grassland (*campo sujo*) located in the Federal District showed high similarity. Soil moisture acts as an environmental filter selecting species adapted to this condition (Keddy 2010). Variation in environmental factors, such as climate and soil characteristics, is usually determined by the longitudinal gradient, and is reflected in the dynamic change in distribution patterns of woody species in the Cerrado (Castro *et al.* 1999; Ratter *et al.* 2003).

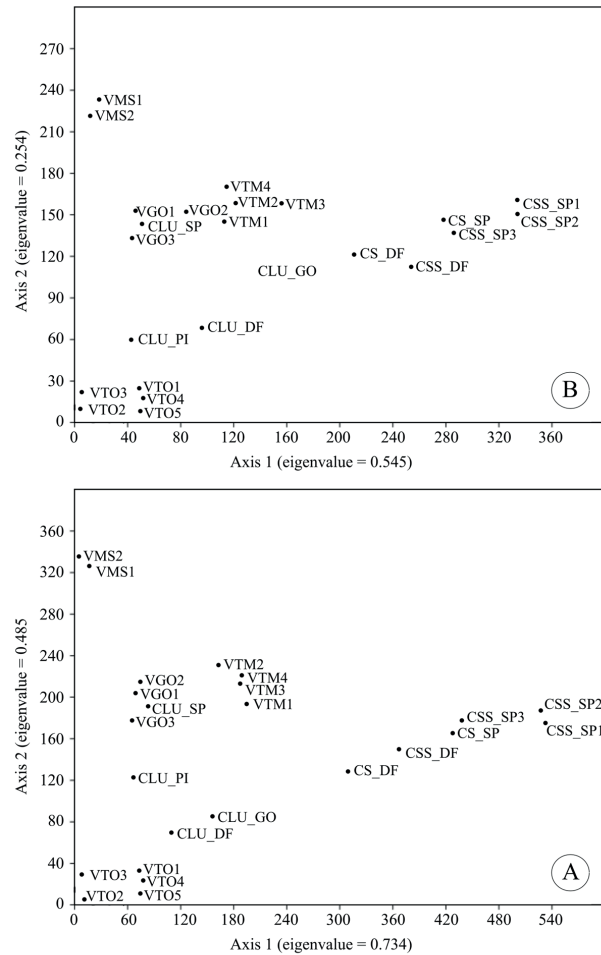


Figure 3. Positioning by axes ordination (DCA) of herb-shrub components of 24 different Cerrado phytophysiognomies at specific (A) and generic (B) levels. CSS_DF_, CSS_SP_1, 2 and 3 = sites in cerrado *sensu stricto*; CS_SP, CS_DF = sites in *campo sujo* (dry shrub grassland); CLU_DF, CLU_SP, CLU_GO, CLU_PI, V_MS_1 = sites in *campo limpo úmido* (moist grassland); V_MS_2, V_GO_1, 2 and 3, V_TM_1, 2, 3 and 4, V_TO_1, 2, 3, 4 and 5 = sites in *veredas* (palm swamps).

The occurrence of vegetation depends mainly on its formation and disturbance history over time (Ledru 2002), and floristic sharing between areas is greatly influenced by the surrounding vegetation types (Ratter *et al.* 2003). For example, moist grasslands (*campo limpo úmido*) share most of their flora with *veredas*, which are 47 % distant floristically from any other phytophysiognomy. Thus, even though the Cerrado vegetation seems to be homogeneous, these comparisons reveal a considerable heterogeneity among environments. Nevertheless, the surrounding vegetation does not have a deep influence on the landscapes of *veredas* since this physiognomy provides for the establishment of plants with morpho-structural adaptations for survival in conditions of water saturation (Blom & Voeselek 1996). Therefore, these environments have a peculiar flora that is distinct from other vegetation formations, and thus require special treatment with regard to conservation (Moreira *et al.* 2015).



A high percentage of the *vereda* flora was considered unique, demonstrating the lack of systematic inventories in this environment. We can assume that *veredas* are isolated environments. The moist soil with high organic matter content works as an environmental filter that has, over time, selected a large number of species (Bijos 2017). Thus, *veredas* and moist grasslands had low floristic sharing and can be considered as wet islands, surrounded by savanna on well-drained soil.

Our study demonstrated that the *veredas* in the Jalapão region are important repositories of floral biodiversity. The region also produced new floral records for the Cerrado. The high percentage of exclusive species suggests that *veredas* are a distinguishable savanna, when compared to the other Cerrado phytophysognomies. The low similarity between the vegetation of *veredas* and the other savanna environments reinforces their importance for consideration by public conservation policies. Our findings, therefore, suggest increased attention should be made to the conservation of *veredas* (Conama 2012), as well as to the moist grasslands that were very similar to them, but yet possessed their own unique flora.

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