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Inventory

Floristic composition, pollination and seed-dispersal systems in a target cerrado conservation area

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Abstract: Cerrado remnants can hold an important diversity of plant species of environmental and ecological relevance. We presented a checklist of vascular plants based on 12 years of inventory carried out in 36 plots (10 m x 2 m; 0.18 ha in total) and during unsystematic walks in a remnant area of *cerrado sensu stricto* located at Itirapina municipality, state of São Paulo, southeastern Brazil. The list comprised 195 plant species, corresponding to 54 families and 131 genera. The richest families were Fabaceae (25 species), Asteraceae (16), Myrtaceae (16), Rubiaceae (11), Bignoniaceae and Malpighiaceae (10 each), Melastomataceae (9), and Erythroxylaceae, Sapindaceae and Annonaceae (6). Predominant life forms included shrubs and trees, with 68% of the species, followed by lianas with 12%, sub-shrub and herbs with 10% each. Bees were the dominant pollinators (67,5%) and the majority of species had seeds dispersed by animals (56.8%), mostly by birds, followed by wind (33.3%) and self-dispersed (11.2%). More than 60% of the total species were classified as "typical" Cerrado species. *Bowdichia virgilioides* was the only species classified as Near Threatened (NT) and 157 were regarded as Data Deficient (DD). Our dataset provides floristic, structural, and ecological information for one of the targeted areas for Cerrado survey at São Paulo state, contributing to the understanding of diversity patterns and future conservation and restoration actions in this threatened hotspot.
Keywords: *Brazilian savanna; hotspot; life form; functional traits.*

Composição florística, modos de polinização e dispersão de sementes de uma área de cerrado relevante para conservação

Resumo: Apresentamos uma lista de verificação de plantas vasculares baseada em 12 anos de inventário realizado em 36 parcelas (10 m x 2 m; 0,18 ha no total) e caminhadas assistemáticas em uma área remanescente de cerrado *sensu stricto* localizada em Itirapina, município do estado de São Paulo, sudeste do Brasil. A lista é composta por 195 espécies de plantas, correspondendo a 54 famílias e 131 gêneros. As famílias mais ricas foram Fabaceae (25 espécies), Asteraceae (16), Myrtaceae (16), Rubiaceae (11), Bignoniaceae e Malpighiaceae (10 cada), Melastomataceae (9) e Erythroxylaceae, Sapindaceae e Annonaceae (6). As formas de vida predominantes incluíram arbustos e árvores (33,7% das espécies), seguidas por lianas (12%), arbustos e ervas (10%). As abelhas foram os polinizadores dominantes (67,5%) e o principal modo de dispersão foi a zoocoria (56,8%), representada principalmente por pássaros, seguida por vento (33.3 %) e auto (11.2 %). Mais de 60% das espécies encontradas foram classificadas como espécies "típicas" de Cerrado. *Bowdichia virgilioides* foi a única espécie pertencente a uma categoria de ameaça "Quase Ameaçada (NT)", sendo 157 delas classificadas na categoria "Deficiente de Dados (DD)". Nosso conjunto de dados fornece informações florísticas, estruturais e ecológicas para uma das áreas-alvo do levantamento do Cerrado no estado de São Paulo, sudeste do Brasil, contribuindo para a compreensão dos padrões de diversidade e futuras ações de conservação neste *hotspot* ameaçado.
Palavras-chave: *Savana brasileira; hotspot; formas de vida; características funcionais.*

Introduction

The Cerrado – the Brazilian savanna - is the second most extensive biome in South America. It is the source of many water springs encompassing the main hydrographic basins and the largest reservoirs of freshwater in this continent, the Guarani Aquifer (Pereira et al. 2021). Cerrado is one of the 25 global *hotspots* (Myers et al. 2000) for biodiversity conservation (Mittermeier et al. 2005), and the most diverse neotropical savanna (Klink & Machado 2005), providing diverse and important ecosystem services essential to sustain agricultural systems (Lambers et al. 2020). Due to the extensive land conversion to agriculture and the high susceptibility to climatic change (Strassburg et al. 2017), the Cerrado is also the most severely threatened biome in Brazil (Lopes et al. 2021).

The Cerrado is a heterogeneous ecosystem regarding biodiversity and phytophysionomy: ranging from grassland with small and sparse shrubs, savanna with predominant woody vegetation (trees of approximately 6-7 m height) and discontinuous tree cover, to forest formation with a canopy height of 12–15 m (Coutinho 2006, Sano et al. 2008). This heterogeneity is indicated by a high endemism rate (44%), representing about 12% of all Brazilian species (Klink & Machado 2005). The cerrado *sensu stricto* is considered one of the most common phytophysiognomies, occurring in approximately 70% of all territorial extensions of its domain (Eiten 1972).

From 1990 to 2010, the net loss rate of Cerrado natural vegetation was around 117.870 km^2 (Beuchle et al. 2015). However, more recent data from the Brazilian Annual Land Use and Land Cover Mapping Project (MapBiomas, Collection 5.0; https://mapbiomas.org) showed that the accumulated losses, ranging from 1985 to 2019, is in reality, 408,6 thousand hectare.

It is estimated that the Cerrado ecosystem may disappear by 2050 (Strassburg et al. 2017) if extensive farming expansion, including agriculture and cattle ranching, is not contained and if conservation and preservation programs of biodiversity are not adopted (Strassburg et al. 2017). In addition, a recent study concluded that both the hydrology and ecology of the Cerrado will be strongly affected considering climate change in the near future (Rodrigues et al. 2020).

The state of São Paulo presents the lowest area of Cerrado remnant cover indices, around 13% of the original distribution (Sano et al. 2010). Public and multi-stakeholder conservation programs can change this imminent extinction scenario, cooperating with national and international biodiversity safeguarding goals in the Cerrado (Strassburger et al. 2016, 2017). The first step to improving conservation and restoration actions is conducting plant inventories to assess species diversity and differences in the community composition and structure among areas through time and biogeographic patterns (Lima et al. 2020). After that, acquiring functional traits, for example, running qualitative or quantitative studies of pollination and seed dispersal syndromes associated with vegetation stratification is essential to preserve Cerrado's dynamics (Gottsberger & Silberbauer-Gottsberger 2018) and guide future restoration actions (Buisson et al. 2020).

The remnant Cerrado studied was fragmented nearly 30 years ago. The total density is 15,522 individuals per hectare – with the largest diameter and maximum registered being 34.7 cm and 12 m, respectively. Myrtaceae, Fabaceae and Malpighiaceae as the richest families and *Bauhinia rufa* (Bong.) Steudel, *Xylopia aromatica* (Lam.) Mart., *Miconia rubiginosa* (Bonpl.) A.DC, *Virola sebifera* Aubl. and *Myrcia guianensis* (Aubl.) DC. are the species with highest abundance (Reys et al. 2013). In the cerrado sensu stricto studied, the edge effect and cardinal orientation intensifies the reproductive phenophases and synchronizes individuals of *Xylopia aromatica* and *Myrcia guianensis* (Camargo et al. 2011, Vogado et al. 2016). Also, the edges influence the structure of the liana community, increasing the species richness, abundance, and host occupancy (Melis et al. 2021). Climate seasonality directly affects leaf fall and flush, flowering, fruiting and germinative strategies (Camargo et al. 2013, 2018, Escobar et al. 2018, 2021, Martins et al. 2021), certainly shaping the floristic diversity found in the area. Although several ecological aspects of the cerrado study area have been investigated, an accurate list of the flowering plants, however, has not yet been published.

Here, we presented a checklist of vascular plants, and associated pollination and seed-dispersal systems, based on 12 years of inventory carried in a cerrado sensu stricto remnant on Southeastern Brazil, described as a priority area for survey and conservation in the state of São Paulo by Metzger & Rodrigues (2008). This study aims to provide a starting point to implement public policies to management, land use, conservation, restoration and future ecological studies.

Material and Methods

1. Study site

The study area is a remnant of Cerrado located in a private land at Itirapina municipality, state of São Paulo (22°10'31.41" S; 47°52'26.3" W), southeastern Brazil (Figure 1a). The average altitude of the area is 760 meters above sea level. The Cerrado is described as a savanna biome composed by different vegetation physiognomies, including the woody savanna, widespread in the neotropical region (Coutinho 2006). The cerrado *sensu stricto* is a typical dominant woody vegetation of the Cerrado (Coutinho 2006) and at the study area (Reys et al. 2013). The study area is a rectangular fragment that has been anthropized for nearly 30 years, with sides facing the four cardinal points: west: a highway; east: a remnant of Cerrado and a pasture; south and north: sugarcane crops (Figure 1b).

The cerrado vegetation surveyed presents a discontinuous tree cover around 6-7 meters high (emergent trees reaching up to 12 meters) and discontinuous herbaceous layer with grasses and some herbs, bromeliads, and palms (Camargo et al. 2011, Reys et al. 2013) (Figure1c-d). The average canopy openness varies from 24% (edges) to 15% (interior) (Reys et al. 2013). The climate of the cerrado study area is seasonal, with a dry cold season from April to September and a rainy warm season from October to March (Camargo et al. 2018, Escobar et al. 2018). The mean annual temperature is 20 °C, with a maximum of 32 °C (February) and a minimum of 18 °C (July). The mean total annual rainfall is 1524 mm (Camargo et al. 2018, Escobar et al. 2018). Soil is classified as Latosol-Argisol according to the Brazilian Soil Classification System (EMBRAPA 1999, Reys et al. 2013).

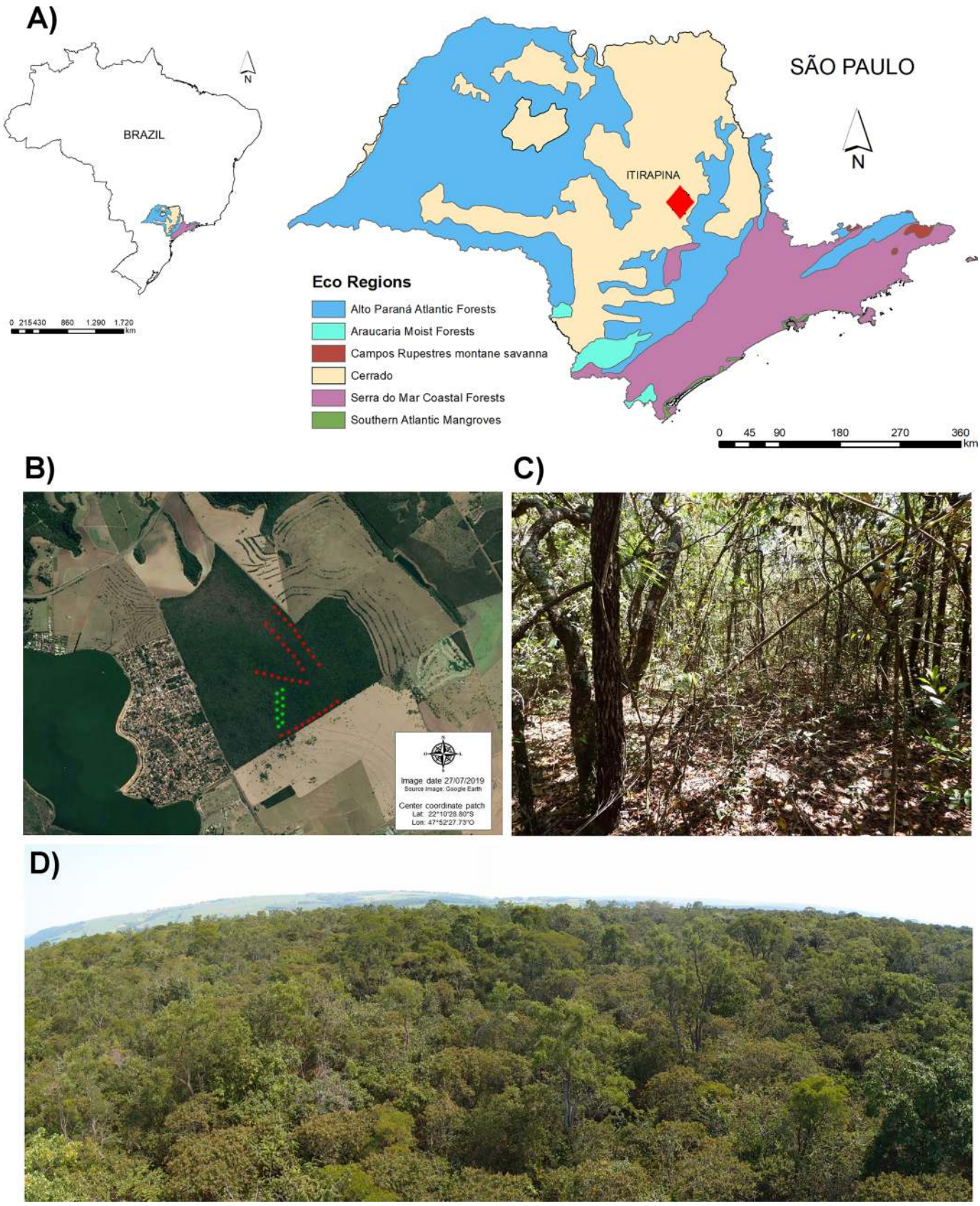


Figure 1. Map and vegetation of the study site. (A) Geographical location of the Itirapina municipality, belonging to the Cerrado Eco Region (Olson et al. 2001), São Paulo State, Southeastern Brazil; (B) Satellite image of the cerrado *sensu stricto* fragment studied with a scheme of the sampled plots (red dots: sample plots according to Reys et al. (2013); green dots: sample plots of this study), Fazenda São José da Conquista; (C) Photograph showing the vegetation interior; (D) Photograph taken from the top of a phenological tower, showing the cerrado sensu stricto fragment from above. Red diamond represents the Itirapina municipality on the São Paulo State map. (Photographs by G. M. Marcusso and B. Alberton, respectively).

2. *Data collection*

First, we established 36 plots of 25 m x 2 m at least 50 meters apart and equally distributed throughout the south and east sides of the fragment: east edge (10 plots), south edge (10 plots), east interior (8 plots), and south interior (8 plots), as described by Reys et al. (2013) (Figure 1b). The plots were arranged in two parallel lines on both sides, with one line on the edge – defined as the area of contact with the matrix – and another line 100 meters from the edge. Within the 36 plots we marked, sampled and identified all trees and scrubs with a diameter ≥ 3 cm at 30 cm from their ground base (Reys et al. 2013). Later, in 2015, we added 10 more plots (2 m x 50 m, 20 m apart) in the same study area, adopting the rapid sampling method (Gentry´s 0.1-ha transects) created and used by Gentry (1982), including all woody individuals with diameter at breast height ≥ 2,5 cm (Figure 1b).

Next, we collected floriferous branches and reproductive structures of tree, shrub, herb, and climber species during unsystematic walks, aiming to fully cover all Cerrado areas through monthly field trips from 2004 to 2018. We identified taxa according to specialized literature and taxonomic experts, compared them with herbarium collections and deposited fertile voucher specimens in the Herbarium Rioclarense (HRCB). We verified the species and family names using Flora do Brasil (2020). The results are presented under APG (2009) and APG IV (2016). Finally, we divided species into four groups according to life form (trees, shrubs, sub-shrub and herbs, and climbers) and dispersal system (Escobar et al. 2018, Van der Pijl 1982). We classified all species as "typical" Cerrado species or belonging to other physiognomies in accordance with Durigan et al. (2004, 2012). We checked the degree of threaten plants in the International Union for Conservation of Nature (IUCN) Red List of Threatened Species and in the Official Red List of Endangered Species of the Brazilian Flora (Flora do Brasil 2020) and classified in (EW – Extinct in the Wild, CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatened, DD – Data Deficient, LC – Least Concern).

We characterized diaspores of the surveyed species and fit them into the dispersion syndromes as self-, wind- and animal-dispersed diaspores according to Escobar et al. (2018, 2021) and Van der Pijl (1982). The inference of pollinators was made based on an extensive bibliographic survey, searching by the pollinators of Cerrado species from our study site performed by Martins (2019) and Martins et al. (2021).

Results

The list of plants included a total of 195 species belonging to 54 families and 131 genera (99 monospecific). We could not identify to the species level nine plant morphotypes. The richest families were Fabaceae (25 species), Asteraceae (16), Myrtaceae (16), Rubiaceae (11), Bignoniaceae and Malpighiaceae (10), Melastomataceae (9), Erythroxylaceae, Sapindaceae and Annonaceae (6), corresponding to 58% of the total surveyed species. Moreover, 27 of the 54 families surveyed had only one species (50%), and 12 families (22%) had only two species (Table 1). Considering only taxa identified to the genus level, there was also a predominance of arboreal and shrub life forms (34%, 64 spp each), followed by lianas (12%, 23 spp), sub-shrub (10%, 20 spp), and herbs (10%, 19 spp) (Figures 2 and 3). Within our Cerrado remnant, there were 27 species considered as Least Concern (LC), one as Near Threatened (NT) – *Bowdichia virgilioides* Kunth -, and 157 as Data Deficient (DD) (Table 1).

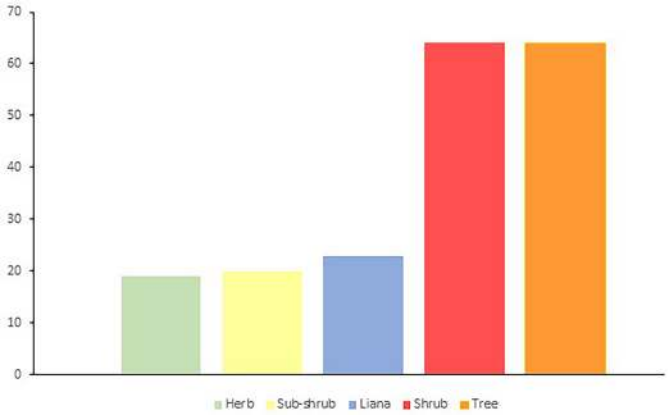


Figure 2. Number of plant species by life form surveyed in the cerrado *sensu stricto*, Itirapina, São Paulo State, Southeastern Brazil. Number of species = 195.

Table 1. List of plant species recorded in the cerrado *sensu stricto*, Itirapina, São Paulo State, Southeastern Brazil, and their respective voucher number, life form, dispersion syndrome, pollinator system, typical Cerrado species according to Durigan et al. (2004, 2012) and threat status according to the International Union for Conservation of Nature (IUCN) Red List of Threatened Species and in the Official Red List of Endangered Species of the Brazilian Flora (Flora do Brasil, 2020) and classified in (EW – Extinct in the Wild, CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatened, DD – Data Deficient, LC – Least Concern and typical cerrado species. Dispersal syndromes: Self= self-dispersed, Wind = wind-dispersed, Animal= Animal-dispersed; Pollination: butt = butterfly; dvi = diverse insects; hum = hummingbird, sph = sphingidae; ND = not determined, Y = yes, N= no. *most frequent species of the southern cerrado based on the woody flora list provided by Bridgewater et al. (2004). ** pollinator based on plant genera.

Family	Species	Voucher HRCB	Life form	Dispersion syndrome	Pollinator system	Typical cerrado species	Threat status
Amaranthaceae	*Froelichia procera* (Seub.) Pedersen	65975	Herb	Self	wind	N	DD
	Gomphrena sp.	66008	Herb	Self	bee	Y	DD
Anacardiaceae	*Anacardium humile* A.St.-Hil.	65976	Tree	Animal	bee	Y	LC
Annonaceae	*Annona coriacea* Mart.*	Reys et al. (2013)	Shrub	Animal	beetle	Y	LC
	Duguetia furfuracea (A.St.-Hil.) Saff.*	65977	Tree	Animal	beetle	Y	DD
	Duguetia lanceolata A.St.-Hil.	65978	Tree	Animal	beetle	N	LC
	Guatteria australis A.St.-Hil.	65979	Tree	Animal	beetle	N	LC
	Xylopia aromatica (Lam.) Mart.*	65980	Tree	Animal	beetle	Y	LC

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Family	Species	Voucher HRCB	Life form	Dispersion syndrome	Pollinator system	Typical cerrado species	Threat status
Apocynaceae	*Aspidosperma tomentosum* Mart. & Zucc.*	Reys et al. (2013)	Tree	Wind	moth	Y	LC
	Ditassa sp.	65981	Liana	Wind	beetle	N	DD
	Mandevilla hirsuta (A. Rich.) K. Schum.	65983	Liana	Wind	moth**	Y	LC
	Oxypetalum appendiculatum Mart.	65982	Liana	Wind	wasp	Y	DD
	Temnadenia violacea (Vell.) Miers	65984	Liana	Wind	hum	Y	LC
Araliaceae	*Didymopanax vinosus* (Cham. & Schltdl.) Marchal	65985	Shrub	Animal	bee	Y	DD
Arecaceae	*Syagrus flexuosa* (Mart.) Becc.*	Reys et al. (2013)	Herb	Animal	bee	Y	DD
Aristolochiaceae	*Aristolochia labiata* Willd.	65987	Liana	Wind	fly	N	LC
Asteraceae	*Acanthospermum* sp.	65988	Herb	Wind	bee**	N	DD
	Asteraceae	66007	Herb	Wind	bee	N	DD
	Baccharis dracunculifolia DC.*	65989	Shrub	Wind	bee	Y	DD
	Bidens gardneri Baker	65990	Herb	Animal	butt	Y	DD
	Calea cuneifolia DC.	65991	Sub-shrub	Wind	bee	Y	DD
Asteraceae	*Chresta sphaerocephala* DC.	65993/74534	Shrub	Wind	bee	Y	LC
	Chromolaena laevigata (Lam.) R. M. King & H. Rob.	65994	Shrub	Wind	butt	N	DD
	Chromolaena maximilianii (Schrad. ex DC.) R.M.King & H.Rob.	65996	Shrub	Wind	bee	N	DD
	Eupatorium sp.	65997	Sub-shrub	Wind	bee	N	DD
	Gochnatia pulchra Cabrera*	66001	Tree	Wind	bee	Y	DD
	Heterocondylus alatus (Vell.) R. M. King & H. Rob.	65998	Shrub	Wind	bee**	N	DD
	Lepidaploa psilostachya (DC.) H. Rob.	66005	Sub-shrub	Wind	bee	N	DD
	Moquiniastrum barrosoae (Cabrera) G. Sancho	65999	Shrub	Wind	butt	N	DD
	Piptocarpha rotundifolia (Less.) Baker*	66002	Tree	Wind	bee	Y	DD
	Vernonanthura ferruginea (Less.) H. Rob.	66003	Shrub	Wind	bee	N	DD
	Vernonia sp.	66006	Sub-shrub	Wind	bee	N	DD
Bignoniaceae	*Adenocalymma axillare* (K. Schum.) L. G. Lohmann	66015	Liana	Wind	bee	Y	DD
	Amphilophium elongatum (Vahl) L. G. Lohmann	66009	Liana	Wind	bee	Y	DD
	Anemopaegma sp.	66010	Liana	Wind	bee	N	DD
	Fridericia florida (DC.) L. G. Lohmann	66018	Liana	Wind	bee	Y	DD
	Fridericia platyphylla (Cham.) L. G. Lohmann	66011	Liana	Wind	bee	Y	DD
	Fridericia samydoides (Cham.) L. G. Lohmann	66013	Liana	Wind	bee	N	DD
	Handroanthus ochraceus (Cham.) Mattos	Reys et al. (2013)	Tree	Wind	bee	Y	DD
	Jacaranda caroba (Vell.) DC.*	66014	Shrub	Wind	bee	Y	DD
	Jacaranda rufa Silva Manso	Reys et al. (2013)	Shrub	Wind	hum	Y	DD
	Pyrostegia venusta (Ker Gawl.) Miers	66017	Liana	Wind	bee	Y	DD
Bixaceae	*Cochlospermum regium* (Mart. ex Schrank) Pilg.	66019	Shrub	Wind	dvi	Y	LC
Burseraceae	*Protium heptaphyllum* (Aubl.) Marchand*	66020	Tree	Animal	dvi	Y	DD
	Protium sp.	66021	Tree	Animal	bee	N	DD
Calophyllaceae	*Kielmeyera grandiflora* (Wawra) Saddi	66023	Tree	Wind	bat	Y	DD
Caryocaraceae	*Caryocar brasiliense* Cambess.*	66024	Tree	Animal	bee	Y	LC
Celastraceae	*Peritassa campestris* (Cambess.) A. C. Sm.	66025	Shrub	Animal	bee	N	DD
	Plenckia populnea Reissek*	Reys et al. (2013)	Tree	Wind	fly	Y	DD
	Tontelea micrantha (Mart. ex Schult.) A. C. Sm.	66027	Shrub	Animal	bee	N	DD
Chrysobalanaceae	*Licania humilis* Cham. & Schltdl.	Reys et al. (2013)	Tree	Animal	bee	Y	DD
Commelinaceae	*Commelina benghalensis* L.	66028	Herb	Self	bee	N	DD
	Commelina diffusa Burm.f.	66029	Herb	Self	bee	N	DD
Connaraceae	*Connarus suberosus* Planch.*	Reys et al. (2013)	Shrub	Animal	bee	Y	DD
	Rourea induta Planch.*	66030	Shrub	Animal	bee	Y	DD
Convolvulaceae	*Ipomoea procurrens* Meisn.	66031	Liana	Self	wind	Y	DD
Cyperaceae	*Cyperus* sp.	66032	Herb	Self	bee	N	DD

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Family	Species	Voucher HRCB	Life form	Dispersion syndrome	Pollinator system	Typical cerrado species	Threat status
Dilleniaceae	*Curatella americana* L.	66033	Shrub	Animal	bee	Y	DD
	Davilla elliptica A.St.-Hil.*	66034	Shrub	Animal	sph	Y	DD
Ebenaceae	*Diospyros lasiocalyx* (Mart.) B.Walln.	66035	Tree	Animal	bee	Y	DD
Erythroxylaceae	*Erythroxylum buxus* Peyr.	Reys et al. (2013)	Shrub	Animal	bee	Y	DD
	Erythroxylum cuneifolium (Mart.) O. E. Schulz*	66037	Shrub	Animal	wasp	Y	DD
	Erythroxylum microphyllum A.St.-Hil.	66036	Shrub	Animal	bee	Y	DD
	Erythroxylum pelleterianum A.St.-Hil.	74536	Shrub	Animal	bee	Y	LC
	Erythroxylum suberosum A.St.-Hil.*	66038	Shrub	Animal	wasp	Y	DD
	Erythroxylum tortuosum Mart.*	66040	Shrub	Animal	wasp	Y	DD
Euphorbiaceae	Euphorbiaceae	66043	ND	ND		N	DD
	Manihot tripartita subsp. *humilis* (Müll.Arg.) D.J.Rogers & Appan	66041	Shrub	Animal	bee**	Y	DD
	Sapium glandulosum (L.) Morong	66042	Shrub	Animal	dvi	N	DD
Fabaceae	*Anadenanthera colubrina* (Vell.) Brenan*	66044	Tree	Wind	bee	Y	DD
	Anadenanthera peregrina var. *falcata* (Benth.) Altschul*	66045	Tree	Wind	bee	Y	DD
	Andira humilis Mart. ex Benth.	66046	Tree	Animal	bee**	Y	DD
	Bauhinia rufa (Bong.) Steud.*	66047	Shrub	Self	bat	Y	DD
	Bowdichia virgilioides Kunth*	74539	Tree	Wind	bee	Y	NT
	Chamaecrista campestris H. S. Irwin & Barneby	66050	Sub-shrub	Self	bee	N	DD
	Chamaecrista desvauxii (Collad.) Killip	66051	Sub-shrub	Self	bee	Y	DD
	Chamaecrista flexuosa (L.) Greene	66053	Sub-shrub	Self	bee	Y	DD
	Copaifera langsdorffii Desf.	74530	Tree	Animal	bee	Y	DD
	Crotalaria martiana Benth.	66055	Shrub	Self	bee**	Y	DD
	Dalbergia miscolobium Benth.*	Reys et al. (2013)	Tree	Wind	bee	Y	DD
	Dimorphandra mollis Benth.*	66056	Tree	Zoochoric	bee	Y	DD
	Fabaceae sp	66070	ND	ND		N	DD
	Leptolobium dasycarpum Vogel	Reys et al. (2013)	Shrub	Wind	bee	Y	DD
	Machaerium acutifolium Vogel*	66057	Tree	Wind	bee	Y	DD
	Machaerium brasiliense Vogel	66058	Tree	Wind	bee	Y	DD
	Mimosa debilis Humb. & Bonpl. ex Willd. var. debilis	66060	Sub-shrub	Self	bee	Y	DD
	Mimosa gracilis var. *capillipes* (Benth.) Barneby	66059	Herb	Self	bee	N	DD
	Plathymenia reticulata Benth.*	66061	Tree	Wind	bee	Y	LC
	Pterodon emarginatus Vogel	Reys et al. (2013)	Tree	Wind	bee	N	DD
	Pterodon pubescens (Benth.) Benth.*	66062	Tree	Wind	bee	Y	DD
	Senna rugosa (G. Don) H. S. Irwin & Barneby*	66063	Sub-shrub	Self	bee	Y	DD
	Stryphnodendron rotundifolium Mart.	66065	Tree	Animal	bee	Y	DD
	Stryphnodendron sp.	66067	Tree	Animal	bee	N	DD
	Stylosanthes acuminata M. B. Ferreira & Sousa Costa	66069	Sub-shrub	Animal	bee	Y	DD
Iridaceae	*Trimezia juncifolia* (Klatt) Benth. & Hook.	66071	Herb	Self	bee	Y	DD
Lacistemataceae	*Lacistema hasslerianum* Chodat	66072	Tree	Animal	wind	Y	DD
Lamiaceae	*Aegiphila verticillata* Vell.	66074	Tree	Animal	bee	Y	DD
	Hyptis campestris Harley & J.F.B. Pastore	74537	Herb	Self	bee	N	DD
Lauraceae	*Ocotea corymbosa* (Meisn.) Mez	66076	Tree	Animal	dvi	Y	DD
Lauraceae	*Ocotea pulchella* (Nees & Mart.) Mez*	66077	Tree	Animal	fly	Y	LC
Loganiaceae	*Strychnos brasiliensis* Mart.	66082	Liana	Animal	moth	Y	DD
	Strychnos pseudoquina A. St.-Hil. *	66083	Shrub	Animal	moth	Y	DD

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Family	Species	Voucher HRCB	Life form	Dispersion syndrome	Pollinator system	Typical cerrado species	Threat status
Malpighiaceae	*Banisteriopsis argyrophylla* (A. Juss.) B. Gates	66084	Sub-shrub	Wind	bee**	N	DD
	Banisteriopsis campestris (A. Juss.) Little	66085	Sub-shrub	Wind	bee	Y	DD
	Banisteriopsis stellaris (Griseb.) B. Gates	66088	Liana	Wind	bee	N	DD
	Byrsonima basiloba A. Juss.*	66090	Shrub	Animal	bee	Y	DD
	Byrsonima coccolobifolia Kunth*	Reys et al. (2013)	Shrub	Animal	bee	Y	LC
	Byrsonima crassifolia (L.) Kunth*	Reys et al. (2013)	Shrub	Animal	bee	N	DD
	Byrsonima intermedia A. Juss.*	66091	Shrub	Animal	bee	Y	DD
	Malpighiaceae	66095	ND	ND		N	DD
	Malpighiaceae	66096	ND	ND		N	DD
	Peixotoa reticulata Griseb.	66094	Liana	Wind	bee	N	DD
Malvaceae	*Eriotheca gracilipes* (K.Schum.) A. Robyns*	66097	Tree	Wind	bee	Y	DD
	Peltaea polymorpha (A.St.-Hil.) Krapov. & Cristȼbal	66098	Shrub	Self	bee	Y	DD
Melastomataceae	*Leandra solenifera* Cogn.	Reys et al. (2013)	Shrub	Animal	bee	N	DD
	Miconia albicans (Sw.) Triana*	66100	Tree	Animal	bee	Y	DD
	Miconia fallax DC.	Reys et al. (2013)	Shrub	Animal	bee	Y	DD
	Miconia ligustroides (DC.) Naudin*	66103	Shrub	Animal	bee	Y	DD
	Miconia paucidens DC.	66104	Shrub	Animal	bee	N	LC
	Miconia pepericarpa DC.	66108	Shrub	Animal	bee	Y	DD
	Miconia rubiginosa (Bonpl.) DC.*	66106	Tree	Animal	bee	Y	DD
	Miconia stenostachya DC.*	66109	Tree	Animal	bee	Y	DD
	Pleroma stenocarpum (Schrank et Mart. ex DC.) Triana	66110	Tree	Wind	bee	Y	DD
Moraceae	*Brosimum gaudichaudii* Trécul*	66111	Tree	Animal	wind	Y	DD
	Ficus citrifolia Mill.	Reys et al. (2013)	Tree	Animal	wasp	N	DD
Myristicaceae	*Virola sebifera* Aubl.*	66112	Tree	Animal	bee	Y	DD
Myrtaceae	*Blepharocalyx salicifolius* (Kunth) O.Berg*	Reys et al. (2013)	Shrub	Animal	bee	Y	LC
	Campomanesia pubescens (Mart. ex DC.) O. Berg*	66114	Shrub	Animal	bee	N	LC
	Eugenia bimarginata DC.*	66116	Tree	Animal	bee	Y	DD
	Eugenia punicifolia (Kunth) DC.	Reys et al. (2013)	Shrub	Animal	bee	Y	DD
	Eugenia pyriformis Cambess.	66120	Shrub	Animal	bee	N	DD
	Myrcia bella Cambess.	66121	Shrub	Animal	bee	Y	DD
	Myrcia guianensis (Aubl.) DC.	66122	Tree	Animal	bee	Y	LC
	Myrcia splendens (Sw.) DC.	66123	Tree	Animal	bee	Y	DD
	Myrcia tomentosa (Aubl.) DC.*	Reys et al. (2013)	Tree	Animal	bee**	Y	DD
	Myrcia venulosa DC.	66125	Tree	Animal	bee	N	LC
	Myrtaceae	66128	ND	Animal	ND	N	DD
	Myrtaceae	66129	ND	Animal	ND	N	DD
	Psidium australe Cambess.	66126	Shrub	Animal	bee**	N	DD
	Psidium grandifolium Mart. ex DC.	Reys et al. (2013)	Shrub	Animal	bee**	Y	LC
	Psidium sp.	66127	Shrub	Animal	bee**	N	DD
	Siphoneugena crassifolia (DC.) Proença & Sobral	Reys et al. (2013)	Tree	Animal	bee**	N	DD
Nyctaginaceae	*Guapira noxia* (Netto) Lundell	66130	Tree	Animal	bee**	Y	DD
	Guapira opposita (Vell.) Reitz	74533	Tree	Animal	bee**	Y	DD
Ochnaceae	*Ouratea spectabilis* (Mart.) Engl.*	66131	Tree	Animal	bee**	Y	LC
Orchidaceae	*Galeandra montana* Barb. Rodr.	66132	Herb	Wind	bee**	Y	DD
	Ionopsis utricularioides (Sx.) Lindl.	74535	Herb	Wind	bee**	N	LC
	Pelexia laminata Schltr.	66133	Herb	Wind	bee**	Y	DD

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Family	Species	Voucher HRCB	Life form	Dispersion syndrome	Pollinator system	Typical cerrado species	Threat status
Oxalidaceae	*Oxalis hirsutissima* Mart. & Zucc.	66134	Sub-shrub	Self	bee**	Y	DD
Passifloraceae	*Passiflora foetida* L.	66135	Liana	Animal	bee**	Y	DD
Peraceae	*Pera glabrata* (Schott) Poepp. ex Baill.*	66136	Tree	Animal	bee**	Y	DD
Poaceae	*Ichnanthus inconstans* (Trin. ex Nees) D"ll	66138	Herb	Animal	bee**	N	DD
	Urochloa brizantha (Hochst. ex A. Rich.) R. D. Webster	66137	Herb	Animal	bee**	N	DD
Polygalaceae	*Bredemeyera floribunda* Willd.*	Reys et al. (2013)	Shrub	Animal	bee**	Y	DD
	Securidaca rivinifolia A.St.-Hil. & Moq.	66139	Sub-shrub	Wind	bee**	Y	DD
Primulaceae	*Myrsine guianensis* (Aubl.) Kuntze	66141	Tree	Animal	bee**	Y	DD
	Myrsine umbellata Mart.	Reys et al. (2013)	Tree	Animal	bee**	Y	DD
Proteaceae	*Roupala montana* Aubl.	Reys et al. (2013)	Shrub	Wind	bee**	Y	DD
Rubiaceae	*Amaioua guianensis* Aubl.	66143	Tree	Animal	bee**	N	DD
	Coccocypselum lanceolatum (Ruiz & Pav.) Pers.	66145	Herb	Animal	bee**	Y	DD
	Cordiera sessilis (Vell.) Kuntze	66146	Shrub	Animal	bee**	N	DD
	Declieuxia fruticosa (Willd. Ex Roem. & Schult.) Kuntze	66149	Shrub	Animal	bee**	Y	LC
	Palicourea sp.	66151	Sub-shrub	Animal	bee**	N	DD
	Palicourea r¡gida Kunth	66150	Sub-shrub	Animal	bee**	Y	DD
	Palicourea racemosa (Aubl.) Borhidi	66156	Sub-shrub	Animal	bee**	N	DD
	Psychotria hoffmannseggiana (Willd. ex Schult.) Mll. Arg.	66152	Shrub	Animal	bee**	N	DD
	Psychotria trichophora Mll. Arg.	66157	Shrub	Animal	bee**	N	DD
	Rubiaceae	66160	ND	ND		N	DD
	Tocoyena formosa (Cham. & Schltdl.) K. Schum.*	66158	Shrub	Animal	sph	Y	DD
Salicaceae	*Casearia* Jacq.	66162	Shrub	Animal	fly**	N	DD
	Casearia sylvestris Sw.*	66161	Shrub	Animal	fly	N	DD
Sapindaceae	*Serjania lethalis* A. St.-Hil.	66165	Liana	Wind	bee	N	DD
	Serjania meridionalis Cambess.	66167	Liana	Wind	bee	N	DD
	Serjania regnellii Schltdl.	66168	Liana	Wind	bee**	N	DD
	Serjania sp. 1	66163	Liana	Wind	bee	N	DD
	Serjania sp. 2	66164	Liana	Wind	bee	N	DD
	Talisia angustifolia Radlk.	74532	Shrub	Animal	dvi**	N	LC
Sapotaceae	*Pouteria ramiflora* (Mart.) Radlk.*	66173/74538	Tree	Animal	butt	Y	DD
	Pouteria torta (Mart.) Radlk.*	66177	Tree	Animal	butt	Y	LC
Siparunaceae	*Siparuna guianensis* Aubl.*	66179/74531	Tree	Animal	fly	Y	DD
Smilacaceae	*Smilax brasiliensis* Spreng.	66182	Shrub	Animal	fly	N	DD
Solanaceae	*Cestrum* sp.	66183	Shrub	Animal	sph	N	DD
	Solanum lycocarpum A.St.-Hil.*	66184	Shrub	Animal	bee	Y	DD
	Solanum paniculatum L.	66185	Shrub	Animal	bee	Y	DD
Styracaceae	*Styrax ferrugineus* Nees & Mart.*	66186	Shrub	Animal	bee	Y	DD
Talinaceae	*Talinum paniculatum* (Jacq.) Gaertn.	66140	Herb	Self	bee	N	DD
Verbenaceae	*Lippia lupulina* Cham.	66188	Sub-shrub	Self	butt	Y	DD
	Lippia origanoides Kunth	66189	Sub-shrub	Self	butt	N	DD
	Lippia sp.	66187	Sub-shrub	Self	butt**	N	DD
Vitaceae	*Cissus erosa* Rich.	66191	Liana	Animal	fly	Y	DD
Vochysiaceae	*Qualea dichotoma* (Mart.) Warm.*	Reys et al. (2013)	Tree	Wind	bee	N	DD
	Qualea grandiflora Mart.*	66192	Tree	Wind	sph	Y	DD
	Qualea multiflora Mart. *	66194	Tree	Wind	bee	Y	DD
	Vochysia cinnamomea Pohl*	66195	Tree	Wind	bee	Y	DD
	Vochysia tucanorum Mart. *	66196	Tree	Wind	bee	Y	DD



Figure 3. Diversity of plant species and life-forms in the cerrado *sensu stricto*, Itirapina, São Paulo State, Southeastern Brazil. Liana: (A) *Temnadenia violacea* (Vell.) Miers - hummingbird pollination, (B) *Amphilophium elongatum* (Vahl) L.G.Lohmann - bee pollination and (C) *Serjania lethalis* A.St.-Hil. - bee pollination; Trees: (D) *Copaifera langsdorffii* Desf. - bee pollination, (E) *Pouteria torta* (Mart.) Radlk. - diverse insects' pollination, (F) *Ouratea spectabilis* (Mart.) Engl. - bee pollination and (G) *Anadenanthera peregrina* (L.) Speg.- bee pollination; Sub-shrub: (H) *Senna rugosa* (G.Don) H.S.Irwin & Barneby - bee pollination, (I) *Palicourea rigida* Kunth - hummingbird pollination and (J) *Banisteriopsis campestris* (A. Juss.) Little - bee pollination; Shrub: (K) *Talisia angustifolia* Radlk. - diverse insects' pollination, (L) *Byrsonima intermedia* A. Juss. - bee pollination and (M) *Casearia sylvestris* Sw. - fly pollination; Herb: (N) *Mimosa gracilis* Benth. - bee pollination., (O) *Commelina erecta* L. - bee pollination and (P) *Gomphrena macrocephala* A.St.-Hil. – bee pollination. (Photos MGG Camargo).

Besides that, the typical Cerrado species according to Durigan et al. (2004, 2012) found in our study area are 62.7% of the species (123) surveyed at the remnant.

Bee pollination were the dominant system, corresponding to 133 plant species (68.2%), followed by diverse insects (6.2%, 12 spp), butterflies (3.1%, 6 spp), flies (3.6%, 7 spp), beetles (3.1%, 6 spp), moths (3.6%, 7 spp), wind (1.5%, 3 spp), wasps (2.6%, 5 spp), hummingbirds (1.5%, 3 spp), sphingid moths (2.1%, 4 spp) and bats (1%, 2 spp) (Figures 4 and 5).

As for the dispersal systems, the animal-dispersed diaspores predominated (55.4%, 108 spp), followed by wind (33.3%, 65 spp) and self-dispersion (11.2%, 22 spp). Animal seed dispersal was predominant in trees and shrubs (Figure 6) and presented birds as the main dispersion agents (LPC Morellato and collab. Unpublished information).

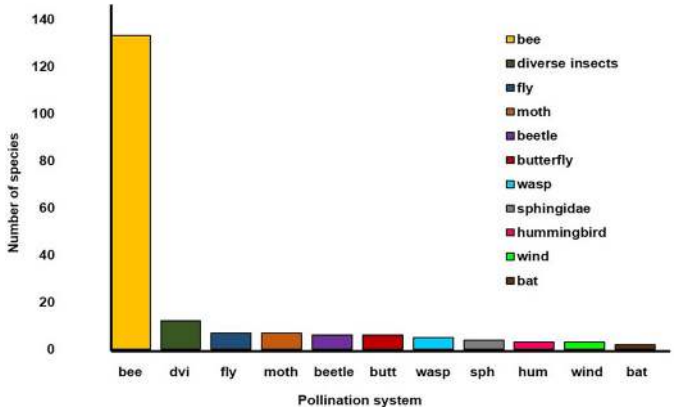


Figure 4. Number of species by pollination system recorded in the cerrado *sensu stricto*, Itirapina, São Paulo State, Southeastern Brazil. Pollination systems: bee, diverse insects (dvi), fly, moth, beetle, butterfly, wasp, sphingidae (sph), hummingbird (hum), wind and bat



Figure 5. Examples of species by seed dispersal syndromes collected in the cerrado *sensu stricto*, Itirapina, São Paulo State, Southeastern Brazil. Wind-dispersed: (A) *Piptocarpha rotundifolia* (Less.) Baker, (B) *Banisteriopsis stellaris* (Griseb.) B. Gates, (C) *Eriotheca gracilipes* (K.Schum.) A. Robyns; Self-dispersed: (D) *Bauhinia rufa* (Bong.) Steud., (E) *Anadenanthera peregrina* var. *falcata* (Benth.) Altschul - with unripe fruit and a detail of the ripe fruits, (F) *Lippia origanoides* Kunth – with unripe fruit and a detail of the ripe fruits; Animal-dispersed: (G) *Myrcia guianensis* (Aubl.) DC., (H) *Miconia rubiginosa* (Bonpl.) DC., (I) *Erythroxylum pelleterianum* A.St.-Hil. (Photos MGG de Camargo).

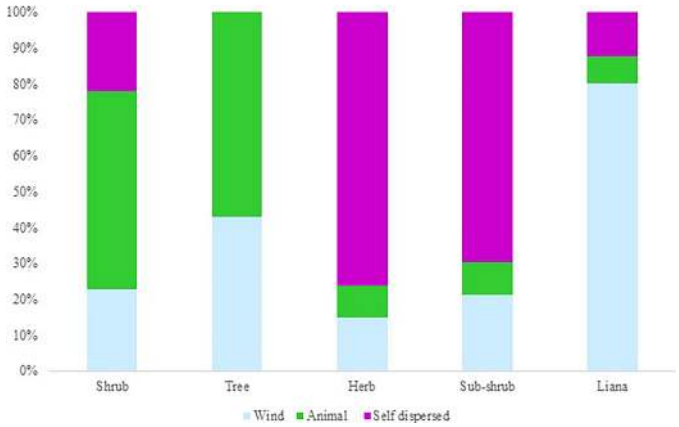


Figure 6. Number of plant species by seed dispersal syndromes according to the life forms collected in the cerrado *sensu stricto*, Itirapina, São Paulo State, Southeastern Brazil

Discussion

We found a species richness (195) similar to other studied remnants of cerrado *sensu stricto* in São Paulo state, which used comparable sampling effort and inclusion criteria. For instance, 254 species were listed in Assis, São Paulo, by Durigan et al. (1999), 141 in Santa Rita do Passa Quatro by Waiser & Godoy (2001), and 177 species in Botucatu by Ishara et al. (2008). However, the taxonomy used in those papers did not follow the APG III classification (2009), limiting a comprehensive floristic comparison. The proportion of species distribution by family found in our cerrado checklist was very similar to the pattern found in previous studies carried out in Brazilian Cerrado areas (Ratter et al. 2003, Gottsberger & Silberbauer-Gottsberger 2006, Mantovani & Martins 1993, Felfili et al. 2002, Batalha & Martins 2001, Weiser & Godoy 2001, Durigan et al. 2001, Fidelis & Godoy 2003, Ishara et al. 2008, Carvalho et al. 2010, Reys et al. 2013), with Fabaceae, Malpighiaceae and Rubiaceae always among the most representative families. Compared to Reys et al. (2013) survey, the present species list has increased to 40% the number of species, indicating the need for long-term, extensive surveys.

We surveyed 59 out of the 100 most frequent woody species listed to the Cerrado in Southern floristic province in Brazil (include São Paulo, Paraná and Minas Gerais states) based on Bridgewater et al. (2004). Among the species described on the Bridgewater et al. (2004) list as the most common species in number of individuals we found in our site: *Qualea grandiflora* Mart., *Byrsonima coccolobifolia* Kunth, *Piptocarpha rotundifolia* (Less.) Baker, *Erythroxylum suberosum* A.St.-Hil., *Caryocar brasiliense* Cambess., *Xylopia aromatica* (Lam.) Mart., *Byrsonima intermedia* A. Juss., *Casearia sylvestris* Sw., *Annona coriacea* Mart., *Ocotea pulchella* (Nees & Mart.) Mez and *Qualea multiflora* Mart. It is important to highlight that most of these plants have been studied due to therapeutic properties as a result of their chemical composition. For example, *Qualea grandiflora* presents bioactivity against *Plasmodium falciparum* (Cordeiro et al. 2017). Flavonoids isolated from *Casearia sylvestris* and *Byrsonima coccolobifolia* have been described as possible leishmanicidal (Antinarelli et al. 2015, Souza et al. 2014). Antioxidant, anxiolytic, antiulcer, insecticide, and antiparasitic properties of *Annona coriacea* – a species which presents a diversity of secondary metabolites may be promising for pharmacological use (Rocha et al. 2020) – have begun to be studied. *Erythroxylum suberosum* has been reported to have antifungal and antibacterial activities (Violante et al. 2012), as well. These results reinforce the assumption that the high biodiversity of the Cerrado found even in small fragments like our study site, can be a source of new compounds with possible applications in therapeutic resources and further solidify the argument that the studied area must be preserved.

The only species belonging to a Near Threatened (NT) class found in our study site was the *Bowdichia virgilioides* Kunth (Table 1) a species distributed across the Amazon Rainforest, Caatinga, Central Brazilian Savanna (Cerrado), Atlantic Rainforest and Pantanal domains (Flora do Brasil 2020). Circumstances such as deforestation and over-extraction (due to the use in construction and furniture), —associated with biological characteristics such as low density and dormancy of its seeds — contributes to its endangered status (Rosa-Magri & Meneghi 2014). Extinction of plant species leads to a loss of many ecological functions, community stability, and resilience, aside from secondary extinctions as a function of loss of key interactions (Rossati et al. 2015).

Our study highlights the elevated number of plant species surveyed classified as Data Deficient (DD) (Table 1), showing the relatively low amount of available data about this domain species and the necessity of many complementary studies. However, some studies have shown that the data-deficient species described in many inventories are of extreme conservation concern, usually including species with a great risk for extinction (Bland et al. 2015), or naturally rare (Corlett 2016, Roberts et al. 2016). In addition, the Cerrado of South America has the highest number of rare species showing the urgent need to include them in conservation planning (Maciel & Martins 2021). Due to the great heterogeneity within the Cerrado domain and the alarming rate of destruction in recent years (MapBiomas, Collection 5.0), it is imperative that we conduct additional studies to provide more floristic and functional data for the remaining remnants. A more comprehensive floristic survey will improve the knowledge, and fill gaps in biodiversity data (Roberts et al. 2016) on this domain, allowing us to propose better management strategies and contribute to improve models of restoration for the Cerrado (Pelizzaro et al. 2017, Buisson et al. 2017, 2018). The proportions of plants in each life form category were consistent with most of the previous studies that describe cerrado *sensu stricto* as a vegetation dominated by trees and shrubs (50% of wood cover) (Coutinho 2006, Silva et al. 2015). However, in an inventory carried out in Pratania, SP, Carvalho et al. (2010) listed 37.5% shrubs, followed by herbs (27.5%), trees (23%), and lianas (12%). These conflicting results are possibly due to the level of preservation of the studied area and frequency of fires (Durigan et al. 2007).

A recent inventory has mapped only 1% of remnant areas of Cerrado vegetation protected for the São Paulo State (Instituto Florestal 2020). This is alarming data, highlighting the need for more protective measures of conservation from what has left of this important vegetation domain. In terms of importance, even for a small patch of vegetation, our study has reported the occurrence of several endemic cerrado species, as: *Caryocar brasiliense* Cambess., *Anacardium humile* A.St.-Hil., *Aspidosperma tomentosum* Mart. & Zucc., *Licania humilis* Cham. & Schltdl., *Erythroxylum tortuosum* Mart., *Dalbergia miscolobium* Benth., *Dimorphandra mollis* Benth., *Ouratea spectabilis* (Mart.) Engl. e *Stryphnodendron rotundifolium* Mart. Plant species of a wider distribution, such as: *Duguetia lanceolata* A.St.-Hil., *Guatteria australis* A.St.-Hil., *Peritassa campestris* (Cambess.) A. C. Sm., *Sapium glandulosum* (L.) Morong, *Pterodon emarginatus*

Vogel e *Campomanesia pubescens* (Mart. ex DC.) O. Berg., found in this study area, can also be observed in other vegetation physiognomies (e.g.: semideciduous forest and Rain Forest) and vegetation domains (e.g.: Atlantic rainforest and Pantanal) (Flora do Brasil 2020), since our cerrado site belongs to the ecotone region of Cerrado and Atlantic Rainforest.

Our cerrado *sensu stricto* species were pollinated mainly by bees, with more than a half of species presenting bee-pollinated flowers (Figure 4), as expected for Cerrado and other tropical vegetation systems (Gottsberger & Silberbauer-Gottsberger 2006, Monteiro et al. 2021, Genini et al. 2021) and stressing the relevance of preserving Cerrado remnants for this key ecosystem service. For the same community, Martins et al. (2021) found that plant species with different flower colors presented distinct flowering peaks over the year but maintained color diversity over time. For example, while white flowers peaked in the transition between dry and wet season, matching with the community flowering peak, yellow flowers were distributed all year long, being an important resource during the dry season, when a reduced number of species is flowering (Martins et al. 2021). The observed flowering pattern provide functional diversity over time, contributing to the presence of different groups of pollinators such as bees, small insects, flies and hummingbirds, and nocturnal pollinators such as Sphingidae moths and bats (Gottsberger & Silberbauer-Gottsberger 2006, Amorim et al. 2009, Martins et al. 2021).

The observed predominance of seed dispersal by animals is expected for woody-dominated Cerrado phytophysiognomies (Weiser and Godoy 2001, Gottsberger & Silberbauer-Gottsberger 2006, Gottsberger & Silberbauer-Gottsberger 2018) and previously indicated for our study area (Camargo et al. 2013, Escobar et al. 2018). Wind-dispersed species are the second most important seed dispersal system, followed by self- dispersed seeds. The fruiting pattern of our community is seasonal according to the dispersal system (Camargo et al. 2013, Escobar et al. 2018). Animal-dispersed fruits are produced all over the year, but mainly during the wet season (Camargo et al. 2013, Escobar et al. 2018). Some animal-dispersed species such as *Miconia rubiginosa* (Bonpl.) DC., *Pouteria torta* (Mart.) Radlk., *Tocoyena formosa* (Cham. & Schltdl.) K.Schum. and *Xylopia aromatica* (Lam.) Mart. produce fruits even in the dry season and are important to guarantee resources for the frugivores in the area (Escobar et al. 2018). Fruiting peaks of self- and wind-dispersed species are observed at the dry season, when the wind dispersal is more efficient (Camargo et al. 2013, Escobar et al. 2018). The proportion of seed dispersal function groups and fruiting time has been recently related to germination strategies (Escobar et al. 2018, 2021), a matter of key relevance for restoration and that needs further investigation for Cerrado species.

The cerrado remnant studied can be considered a conservation priority due to the high diversity of data-deficient species and the importance for ecosystem services. Our checklist pointed out a high diversity of data-deficient species, a category considered equivalent to threatened by extinction by some authors (Bland et al. 2015, Corlett 2016, Roberts et al. 2016). Consequently, our study area may represent a conservation priority based on the degree of knowledge gap and extinction risk of some species, associated with high diversity and potential ecosystem services provided. Our survey also indicated that even a small remnant can congregate a richest collection of species, plant functional types and life forms representatives of the Cerrado and concentrate an enormous value for biodiversity conservation, ecosystem services and restoration, holding several culturally important species (Pellizaro et al. 2017, Lemes et al. 2020).

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Author Contributions

RB, MTGG, MGGC and LPCM designed the study; all authors collected data in the field and helped in data compilation. MTGG curated the data, LPCM resource acquisition and management, RB and MTGG wrote the manuscript. All authors read the manuscript and contributed with suggestions.

Conflicts of Interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

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