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Original Article

Updated flora of a Southern Cerrado fragment reveals threat to its biodiversity

Márcia Cristina Martins da Silva[1,2], Dalva Maria da Silva Matos[1], Vânia Regina Pivello[3,*]

[1]Universidade Federal de São Carlos, Departamento de Hidrobiologia, Laboratório de Ecologia e Conservação, São Carlos, SP, Brazil.
[2]Instituto Chico Mendes de Conservação da Biodiversidade, NGI Cuniã-Jacundá, Porto Velho, RO, Brazil.
[3]Universidade de São Paulo, Instituto de Biociências, Departamento de Ecologia, Laboratório de Ecologia da Paisagem e Conservação, São Paulo, SP, Brazil.
*Corresponding author: vrpivel@ib.usp.br

ABSTRACT

This study brings the updated flora of the Cerrado Pé-de-Gigante (CPG) – which is part of the Vassununga State Park and one of the largest remnants of the Cerrado biome in São Paulo state, in Brazil – as well as information regarding the conservation status of the CPG flora. The plant list was produced through a systematic review of existing literature, virtual herbaria, and on-site field validation. In such an area of just over 1200 hectares, we documented a total of 683 plant species, including angiosperms, ferns, lycophytes and bryophytes. Notably, our fieldwork revealed 11 previously unrecorded plant species. Concerning the conservation condition of the native flora, four are in threat categories - three as Vulnerable (VU) and one Endangered (EN) – and five are Near Threatened (NT); we also highlight the presence of 18 exotic species with invasive potential that pose a significant threat to the local ecosystems by contributing to habitat degradation and species extinction. We emphasize the relevance of the CPG in the context of biodiversity conservation, especially considering that the remaining Cerrado vegetation in São Paulo state is found mostly in small fragments and often inadequately protected.

Keywords: Brazilian savanna; Cerrado; flora; protected area; systematic review.

Introduction

The Brazilian Cerrado, the world's most biodiverse savanna, is also among the most threatened natural environments. It has already lost half of its original area primarily to agribusiness (Brannstrom *et al.*, 2008; Oliveira *et al.*; 2017). This region is home to 13,205 plant species (Flora e Funga do Brasil, 2024) and 1,122 vertebrate animals (Mittermeier *et al.*, 2004), with high rates of endemism (Myers *et al.*, 2000), thanks to the diverse range of habitats provided by various savanna, grassland, and forest physiognomies that make up the Cerrado Domain (Ab'Saber, 1977; Oliveira-Filho & Ratter, 2002).

In addition to its physiognomic diversity, the Cerrado plays a significant role from a hydrological perspective as it supplies water to eight of the twelve largest Brazilian watersheds (Lahsen *et al.*, 2016). Despite its immense importance in the biological context and as an ecosystem service provider, the uncontrolled conversion of Cerrado lands for agriculture has led to accelerated biodiversity loss and the depletion of its natural wealth (Strassburg *et al.*, 2017; Zenni *et al.*, 2018). Currently, the Brazilian

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agricultural frontier is advancing into the MATOPIBA region, encompassing the states of Maranhão, Tocantins, Piauí, and Bahia (northeastern part of the country), where most of the remaining Cerrado is concentrated (Brannstrom *et al.*, 2008; Dionizio & Costa, 2019).

In São Paulo state (southeastern Brazil), the conversion of natural areas to agroforestry began much earlier, with a massive loss of nearly 90% of the original Cerrado vegetation occurring between the 1960s and 2000 (Kronka *et al.*, 2005). Nowadays, it is reduced to approximately 211,925 hectares, mostly as small and isolated fragments (Rodrigues *et al.*, 2008; Mendonça & Costa, 2018). Even in protected areas, which are intended to conserve the Cerrado's natural resources, the invasion by exotic species, particularly African grasses (Pivello *et al.*, 1999; Dodonov *et al.*, 2013; Durigan & Ratter, 2016), as well as inadequate management practices (*e.g.*, total fire suppression, which may promote vegetation encroachment and biodiversity loss), pose a significant threat to numerous endemic species and put them at imminent risk of extinction (Pivello, 2011; Hoffmann *et al.*, 2012; Durigan & Ratter, 2016; Pilon *et al.*, 2021; Wieczorkowski & Lehmann, 2022).

Facing this devastating scenario in a biodiversity hotspot (Myers *et al.*, 2000), it is of extreme importance and urgency not only to adequately maintain existing protected areas but also to generate knowledge for decision-making on conservation and restoration, encompassing all the Cerrado phytophysiognomies (Strassburg *et al.*, 2017).

The Cerrado Pé-de-Gigante, which is part of Vassununga State Park and one of the largest fragments dedicated to protecting the biome in São Paulo state, comprises a variety of the Cerrado Domain vegetation (Pivello & Varanda, 2005). However, in recent decades, this vegetation has been subject to degradation processes caused by woody encroachment and invasive species, especially in the more open phytophysiognomies (Fundação Florestal, 2020). As a result, native species are likely being lost. Therefore, this research aims to update the flora of the Cerrado Pé-de-Gigante by providing data obtained through a systematic review and field survey. It is also our aim to give a picture of the conservation status of the CPG vegetation. The information presented here is essential for understanding changes that have already occurred in the vegetation and for establishing a reference floristic list to guide conservation and restoration efforts for this valuable remaining Cerrado fragment.

Material and Methods

Study site

The Vassununga State Park (PEV) is an integral protection area established in 1970, encompassing six distinct fragments. Five of these fragments are remnants of the Atlantic Forest (semideciduous forest), while one belongs to the Cerrado biome, known as the Cerrado Pé-de-Gigante (CPG), which is the primary focus of this study (see Fig. 1).

Located in the municipality of Santa Rita do Passa Quatro, São Paulo state, in southeastern Brazil (21°37'30" S and 47°37'30" W), the CPG covers an area of 1,212.92 ha (Pires Neto *et al.*, 2005). The regional climate, classified as Köppen's Cwa type, is characterized by high temperatures, an average annual rainfall of approximately 1,400 mm, and dry winters with precipitation typically falling below 30 mm (Climate-Data, 2022).

Around 94% of the CPG soils are Quartzarenic Neosols (Brazilian soil classification, following EMBRAPA, 2018), or Entisol (according to the North American classification; USDA, 1999). These soils support several savanna phytophysiognomies, including cerradão (woodland savanna), cerrado *sensu stricto* (typical savanna), and campo sujo (open savanna), which collectively cover the majority of the CPG vegetation (98.2%) (Cooper *et al.*, 2005; Bitencourt & Mesquita Junior, 2005; Ruggiero *et al.*, 2006) and represent a collection of Cerrado biome remnants. Additionally, there is a small patch of Red and Red-Yellow Latosol (with higher clay content) covered by a semideciduous seasonal forest and small portions of Hydromorphic Neosols (alluvial soils) where the riparian forest of the Paulicéia stream flourishes. This stream originates inside the CPG and flows into the Mogi-Guaçu River (Ruggiero *et al.*, 2002; Bitencourt & Mesquita Junior, 2005; Cooper *et al.*, 2005). CPG is surrounded by extensive monocultures of *Eucalyptus* L´Hér. species and a small portion of sugarcane plantations (Mesquita Junior, 1998; Batalha & Mantovani, 2005; Cooper *et al.*, 2005).

Systematic review

To produce a complete and updated list of the CPG plant species we undertook a systematic review of the literature up to 2021 which was complemented with material collected in field campaigns conducted in 2021.

Literature search

Literature search was performed on the database *Web of Science* (WoS; http://webofknowledge.com/). The terms and *Boolean* operators used were: (Pé-de-Gigante OR Vassununga*) AND (Cerrado OR Savanna OR Savannah), from 1945 to the present. The field "Topic" was selected since it performs the search for terms in title, abstract and keywords. An advanced search for "Subject" was also carried out in the database of the *CAPES Periodic Portal* (http://www.periodicos.capes.gov.br/), using the same abovementioned terms. This search comprised scientific publications from 1972 to the present, anywhere in the text, and the option "expand results" was selected for accessing the cited references.

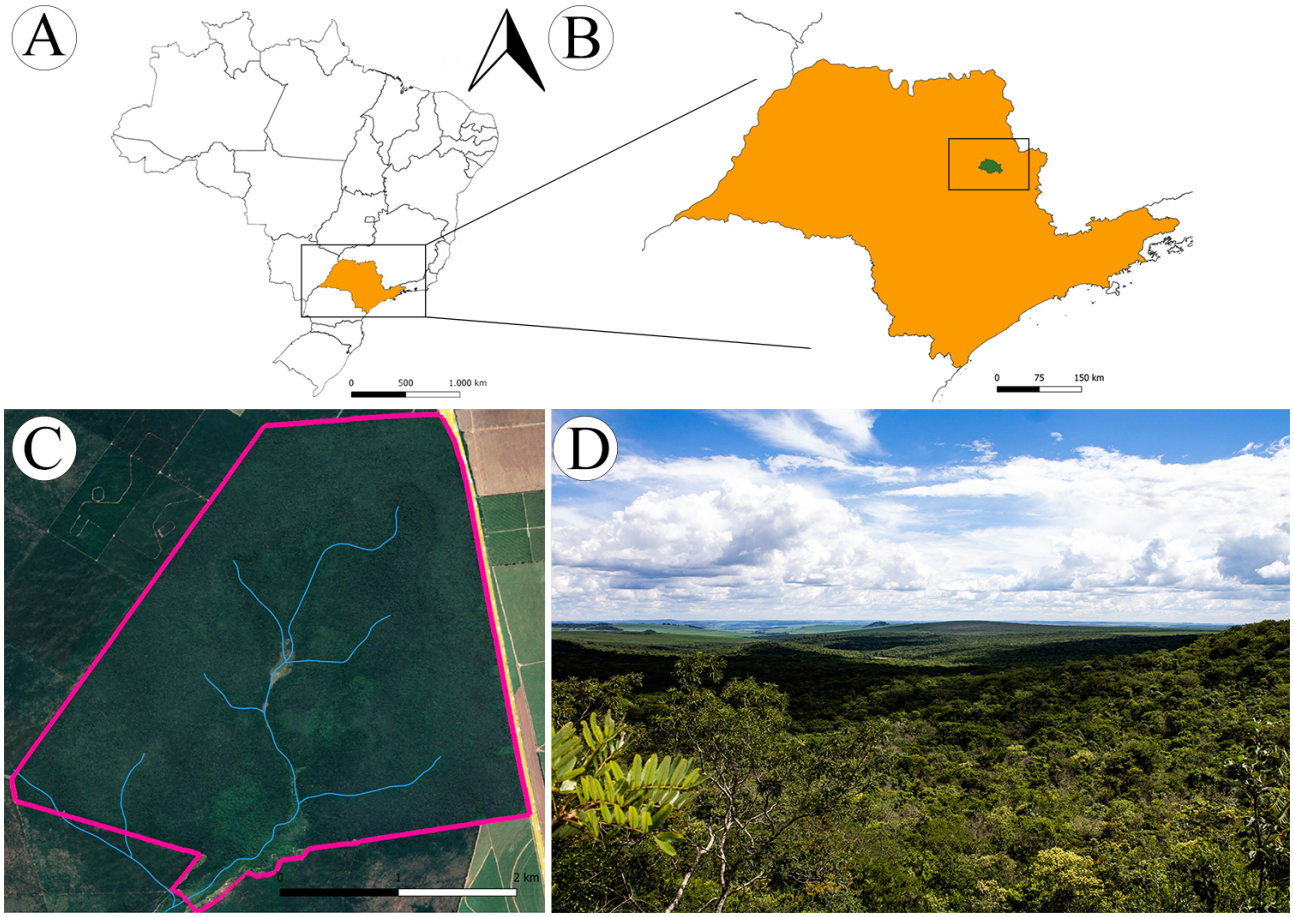

Figure 1. The Cerrado Pé-de-Gigante, at Vassununga State Park, Santa Rita do Passa Quatro, São Paulo state, Brazil. A. In orange: São Paulo state, Brazil; B. Green area inside the rectangle: Santa Rita do Passa Quatro municipality; C. Magenta polygon: CPG boundaries; in blue: Paulicéia stream and tributaries (Source: Google Earth Pro from March 24, 2021, accessed on December 3, 2022.) D. View from the *Trilha do Mirante* (Belvedere Trail), in the CPG. (Photo by Martins, MC.)

All publications that addressed the flora subject (*e.g.*, floristic surveys, description of new species, taxonomic reviews, field experiments based on plant surveys) in the study area were selected. We also supplemented the data with species records available in the Vassununga State Park Management Plan (Fundação Florestal, 2020) and Batalha and Mantovani (2005). The former is based on Franco *et al.* (2008), who conducted a rapid field survey across seven segments of the CPG. The latter comprises a book chapter containing a floristic survey conducted by the authors between 1995 and 1997.

Access to virtual herbaria data

This step was performed by conducting searches on the SpeciesLink (https://specieslink.net/search) and Reflora Virtual Herbarium (http://floradobrasil.jbrj.gov.br/reflora/herbarioVirtual) databases, with a specific focus on occurrence data for plants that have been deposited and digitized in physical herbaria. In the search form, we applied the following filter definitions: kingdom = "Plantae" and municipality = "Santa Rita do Passa Quatro." This allowed us to inspect the notes provided on the labels of each specimen and exclude any surveys conducted in other fragments of the PEV (i.e., Praxedes, Maravilha, Capetinga Leste, Capetinga Oeste, and Capão da Várzea fragments, which are covered by seasonal semideciduous forest), as well as those from other areas within the municipality or surveys lacking specific location information. This approach enabled us to select only the occurrences that explicitly mentioned the CPG.

New occurrence records from field surveys

We carried out a monthly field survey from January 2021 to January 2022, focusing on the herbaceous and subshrub communities. It is worth mentioning that these guilds are often overlooked in floristic surveys (Rossatto *et al.*, 2008; Durigan *et al.*, 2018). We sampled individuals under 1 m in height from 324 plots (0.5 x 0.5 m), organized into 36 transects, following the methodology outlined by Pivello *et al.* (1999). Species were identified in the field whenever possible. If not, specimens were collected, pressed, dried

at 60º C and identified in the laboratory, with the aid of identification keys, specific botanical literature, comparisons with specimens available in virtual herbaria (*SpeciesLink* and *Reflora*), and expert consultation. Specimens with fertile material were herborized and deposited in the Dom Bento José Pickel Herbarium (SPSF, Instituto Florestal, São Paulo, SP, Brazil). The final species list includes the newly recorded occurrences.

Data processing and species list

The botanical classification followed the Classification System of the Angiosperm Phylogeny Group (APG IV, 2016) and the Pteridophyte Phylogeny Group (PPG I, 2016). We cross-referenced and corrected potentially outdated scientific names by consulting the *Reflora* database (Flora e Funga do Brasil, 2024), *Plants of the World Online* (POWO, 2022) and *The Plant List* catalog (The Plant List, 2013) for names not found in *Reflora*. Our dataset also encompassed the following information: i) origin (native or exotic to Brazil); ii) herbarium deposit voucher code, referencing both the species we collected and the specimens available on *SpeciesLink* or *Reflora*. The *Instituto Horus* database (https://bd.institutohorus.org.br/especies) was used to define a species as invasive. Species lacking a voucher were assigned the *Reflora* code (i.e., codes beginning with "FB##"), enabling the verification of their description and additional details (Flora e Funga do Brasil, 2024); iii) conservation status in terms of extinction risk assessment, following the criteria and categories established by the IUCN, as adopted by the National Flora Conservation Center (CNCFlora, 2024) and also according to the IUCN Red List itself (https://www.iucnredlist.org/); and iv) habit classification, categorized into three groups based on information from the literature: C = species mentioned as climbing plants, lianas or scramblers; H = species of the herbaceous-subshrub stratum, encompassing herbs, grasses, subshrubs, camephytes, epiphytes, geophytes, bryophytes, hemicryptophytes, therophytes, semi-parasites, and vascular parasites; and T = shrubby-tree stratum, covering shrubs, trees and phanerophytes.

Removal of uncertain records

We opted to remove *Eugenia anomala* D.Legrand (Myrtaceae) from the list due to uncertain classification. It had been documented by Andena *et al.* (2012) as *Eugenia myrcianthes* var. *nana* D.Legrand, currently its synonym (POWO, 2022). That study, however, was not primarily botanical, and we could not find any additional records or references for this species in the literature, virtual herbaria, or during our field survey. *Adiantum fructuosum* Poepp. ex Spreng. (Pteridaceae), as reported by Batalha & Mantovani (2000; 2001; 2005), was also excluded from our final list based on the following criteria: i) it is a taxon prone to confusion and frequently misidentified in herbaria (Lellinger, 1991), ii) a specialized publication on ferns did not record this species in a survey conducted in the CPG (Colli *et al.*, 2004) and iii) the species is likely not found in Brazil (Prado & Hirai, 2020). *Ditassa nitida* Decne. (Apocynaceae) is a species native to the Atlantic Forest, with occurrence records exclusively in the states of Rio de Janeiro and Espírito Santo. Although Batalha & Mantovani (2000) initially reported this species in the CPG, they later excluded it from the CPG in an updated flora catalog (Batalha & Mantovani, 2005). Consequently, this species was also omitted from our final list. A similar situation applied to *Syagrus petraea* (Mart.) Becc. (Arecaceae) because this species is not native to Brazil but is instead found in Bolivia. It is treated as a synonym of *S. loefgrenii* Glassman in Brazilian (Noblick, 2017). *Diospyros brasiliensis* Mart. ex Miq. (Ebenaceae) was solely recorded in the PEV Management Plan (Fundação Florestal, 2020), however, due to its status as a Near Threatened species (Moraes *et al.*, 2022) and its limited distribution to the Atlantic Forest (ombrophylous forest and restinga forest) (Flora e Funga do Brasil, 2024; Moraes *et al.*, 2022), we disregarded this record for the CPG.

Results

Systematic review

We identified 143 publications in the *CAPES Periodic Portal* spanning the years from 1999 to 2021 and 11 publications in the *Web of Science*, covering the years 1999 to 2017. This totaled 154 publications found across the databases. After excluding duplicate articles (n = 23), it became evident that a portion of the publications (n = 116) contained data beyond the scope of the CPG or were not restricted to its flora. Some of them focused on subjects such as fauna-flora interactions. Ultimately, we extracted 15 publications (Table 1), which, along with the book chapter by Batalha & Mantovani (2005) and the PEV Management Plan (Fundação Florestal, 2020), were employed to compile the final species list.

In the *SpeciesLink* database, we discovered 2,340 records of specimens within the municipality of Santa Rita do Passa Quatro. Six records lacked identification below the family level and were consequently excluded. Among the 187 records identified to the genus level, only *Senecio* sp. (Asteraceae) was added to our list. This decision was made as the other genera had already been accounted for in the species-level identifications, and nine additional genera were noted as having been collected in different locations. After removing specimens recorded outside the CPG, eliminating repeated data (i.e., collected by more than one person) of the same species, and filtering out duplicate specimens, we recorded a total of 408 species at this stage (see Table S1). In the *Reflora Virtual Herbarium,* we obtained 430 records.

Table 1. Publications considered for building the Cerrado Pé-de-Gigante flora, in chronological sequence.

1999 a 2009	2010 a 2020	2021
A= (Pivello *et al.* 1999**); B=** (Batalha & Mantovani 2000); **C=** (Batalha & Mantovani 2001); **D=** (Weiser & Godoy 2001); **E=** (Ruggiero *et al.* 2002); **F=** (Fidelis & de Godoy 2003); **G=** (Colli *et al.* 2004); **H=** (Batalha & Mantovani 2005); **I=** (Varanda & Pais 2006); **J=** (Guimarães & Santos 2006); **K=** (Varanda *et al.* 2008)	**L=** (Aidar *et al.* 2010); **M=** (Andena *et al.* 2012); **N=** (Latansio-Aidar *et al.* 2014); **O=** (Miatto *et al.* 2016); **P=** (Abe *et al.* 2018); **Q=** (Fundação Florestal 2020)	**R=** New records, from data obtained in our field survey.

From this dataset, we selected 147 species, including two new records for the CPG, both belonging to Rubiaceae, as per expert identification by P.G. Delprete.

Field surveys and newly collected records

The data collected in the field, which focused on the herbaceous and subshrub strata (Fig. 2), resulted in 768 individuals, representing 107 species, of which 11 were recorded as new occurrences in the CPG (Table S1): *Pfaffia gnaphaloides* (L.f.) Mart. (Amaranthaceae), *Tridax procumbens* L. and *Trichogonia attenuata* G.M.Barroso (Asteraceae), *Evolvulus sericeus* Sw. (Convolvulaceae), *Euphorbia comosa* Vell. (Euphorbiaceae), *Sinningia allagophylla* (Mart.) Wiehler (Gesneriaceae), *Salvia minarum* Briq. (Lamiaceae), *Cuphea inaequalifolia* Koehne (Lythraceae), *Oeceoclades maculata* (Lindl.) Lindl. (Orchidaceae), *Oxalis hirsutissima* Mart. & Zucc. (Oxalidaceae) and *Aristida riparia* Trin. (Poaceae).

Characterization of the final list

After completing all the steps outlined above, we accumulated a total of 2,172 mentions of plant species within the CPG. Following the correction of species identifications to align with currently accepted names and the elimination of repeated species, we compiled a list of 683 species for the CPG (Table S1), comprising angiosperms, bryophytes (i.e., Dicranaceae), ferns and lycophytes (i.e., Anemiaceae, Blechnaceae, Cyatheaceae, Dennstaedtiaceae, Gleicheniaceae, Polypodiaceae, Pteridaceae and Thelypteridaceae), with only one at the genus level (*Senecio* L.).

The 20 richest families (Fig. 3) were, in descending order: Fabaceae (n = 84), Asteraceae (n = 71), Rubiaceae (n = 37), Poaceae (n = 36), Myrtaceae (n = 29), Apocynaceae (n = 26), Bignoniaceae (n = 26), Malpighiaceae (n = 23), Malvaceae (n = 20) and Euphorbiaceae (n = 18). These top ten families collectively represent over 50% of the total species in the CPG. Of the recorded species, 34.9% are exclusively from the arboreal shrub layer (Fig. 4).

Within the list of 683 species that make up the CPG's floristic inventory, we identified 18 exotic species (Table S1). Notably, one-third of these exotic species belonged to the Poaceae family (grasses). Of these exotic species, six are categorized as invasive (Table S1), including one Orchidaceae (*Oeceoclades maculata*), one Zingiberaceae (*Hedychium coronarium*), and four Poaceae (*Megathyrsus maximus*, *Melinis minutiflora*, *M. repens* and *Urochloa decumbens*).

Conservation status

The conservation status assessments provided by CNCFlora and the IUCN Redlist for species with some degree of threat were similar in some cases, but divergent in others. According to CNCFlora, five species in the CPG were classified as Near Threatened (NT): *Aspidosperma polyneuron* (Apocynaceae), *Handroanthus impetiginosus* (Bignoniaceae), *H. serratifolius* (Bignoniaceae), *Zeyheria tuberculosa* (Bignoniaceae) and *Bowdichia virgilioides* (Fabaceae); three species are categorized as Vulnerable (VU): *Mostuea muricata* (Gelsemiaceae), *Cedrela fissilis* (Meliaceae) and *Cissus inundata* (Vitaceae); and one species is considered Endangered (EN): *Anemopaegma arvense* (Bignoniaceae) (Table S1). The IUCN Red List indicated one NT species: *Handroanthus impetiginosus* (in accordance with CNCFlora); five VU species: *Machaerium villosum*, *Manihot gracilis*, *Myrcia pubipetala*, *Zeyheria tuberculosa* (classified as NT by CNCFlora) and *Cedrela fissilis* (in line with CNCFlora); and two EN: *Aspidosperma polyneuron* and *Handroanthus serratifolius* (both considered NT by CNCFlora) (see Table S1 for details). The IUCN classification is a little more rigorous for species occurring in the CPG.

Discussion

By providing an updated inventory of the plant communities in Cerrado Pé-de-Gigante, we could show some changes the vegetation has undergone since its last survey and establish a completer and more updated floristic list that can be used as a reference for conservation and restoration efforts. The presence of 683 species in CPG underscores its remarkable floral diversity. Notably, among these species, 11 were newly recorded occurrences during our field inspections, being herbs or sub-shrubs widely distributed in Brazil, with some being considered ruderal (such as *Euphorbia comosa* and *Oxalis hirsutissima*). Additionally, two of these newly recorded species are classified as invasive (*Tridax procumbens* and *Oeceoclades maculata*), and there is a possibility that these invasive species have recently arrived in CPG or, similar to the other nine species, they may have not been previously collected or even noticed in the park. This likely reflects the common

Figure 2. Some herbaceous and subshrub species from the Cerrado Pé-de-Gigante (Vassununga State Park, São Paulo state, Brazil). A. *Alstroemeria gardneri* Baker (Alstroemeriaceae); B. *Froelichia procera* (Seub.) Pedersen (Amaranthaceae); C. *Achyrocline satureioides* (Lam.) DC. (Asteraceae); D. *Chrysolaena obovata* (Less.) Dematt. (Asteraceae); E. *Moquiniastrum pulchrum* (Cabrera) G.Sancho (Asteraceae); F. *Anemopaegma arvense* (Vell.) Stellfeld ex de Souza (Bignoniaceae); G. *Commelina obliqua* Vahl (Commelinaceae); H. *Dichorisandra hexandra* (Aubl.) C.B.Clarke (Commelinaceae); I. *Bulbostylis hirtella* (Schrad.) Urb. (Cyperaceae); J. *Cerradicola lamprophylla* (Harms) L.P.Queiroz (Fabaceae); K. *Cyanocephalus rugosus* (Benth.) Harley & J.F.B.Pastore (Lamiaceae); L. *Hypenia pauliana* (Epling) Harley (Lamiaceae); M. *Hyptis campestris* Harley & J.F.B.Pastore (Lamiaceae); N. *Salvia minarum* Briq. (Lamiaceae); O. *Cuphea inaequalifolia* Koehne (Lythraceae); P. *Waltheria communis* A.St.-Hil. (Malvaceae); Q. *Cissampelos ovalifolia* DC. (Menispermaceae); R. *Ionopsis utricularioides* (Sw.) Lindl. (Orchidaceae); S. *Loudetiopsis chrysothrix* (Nees) Conert (Poaceae); T. *Echinolaena inflexa* (Poir.) Chase (Poaceae). (Photos by Martins, MC.)

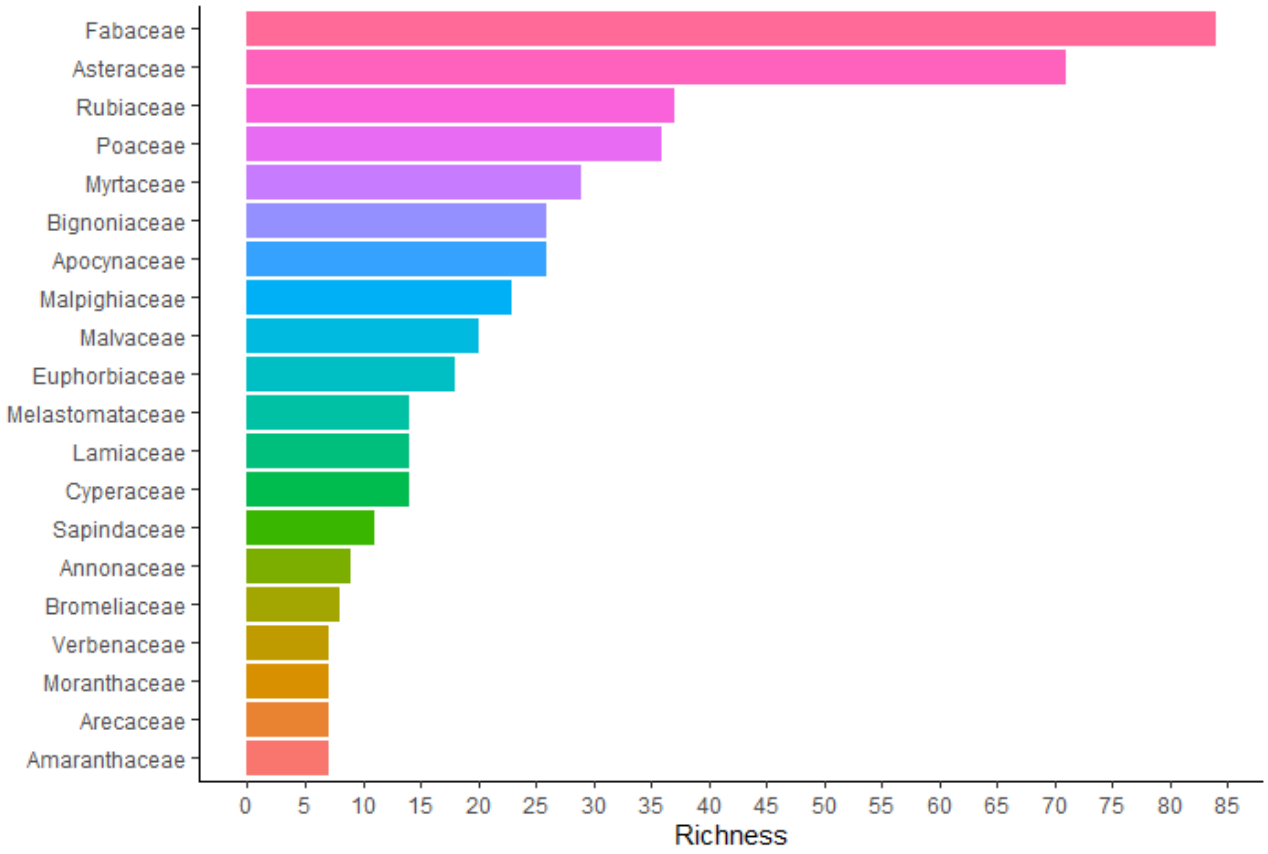

Figure 3. Botanical families in the Cerrado Pé-de-Gigante (Vassununga State Park, São Paulo state, Brazil) flora comprising more than seven species.

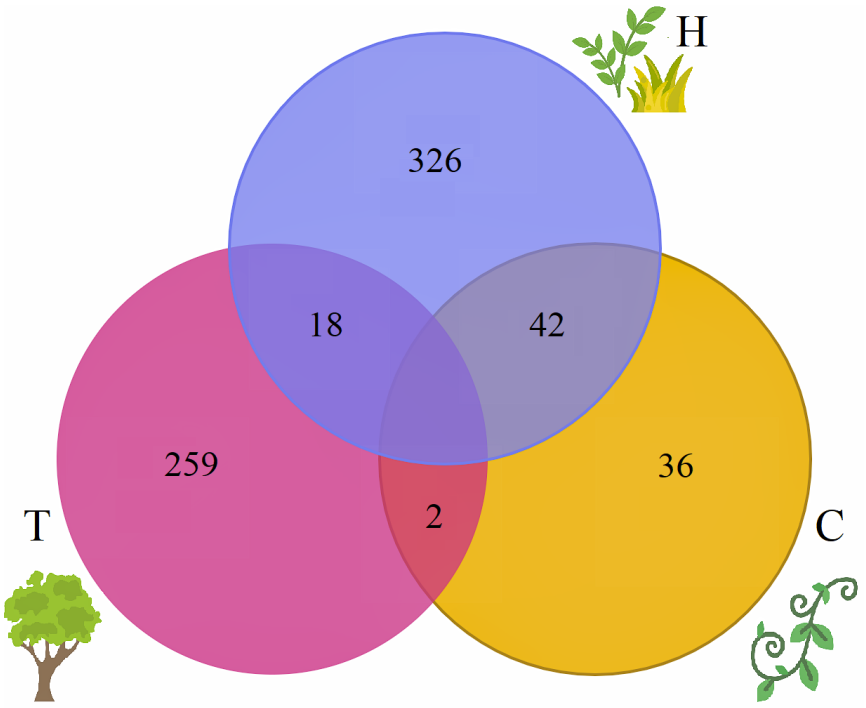

Figure 4. Venn diagram with the number of recorded species in the Cerrado Pé-de-Gigante (Vassununga State Park, São Paulo state, Brazil) according to habit and vegetation stratum. Intersections show species with more than one type of habit (C= climbers; H= herbaceous-subshrubs; T= shrub-trees)

underrepresentation of herbaceous and subshrub species in floristic surveys (Rossatto *et al.*, 2008; Durigan *et al.*, 2018). It is important to note that this stratum, despite being historically neglected, comprises the greatest botanical richness within the Cerrado, which is known to include more than 13,205 plant species, with an estimated ratio of herbs to woody species at 5.6:1 (Flora e Funga do Brasil, 2024; Durigan *et al.*, 2018). Fortunately, recent years have witnessed a shift, with more studies directed toward this often-overlooked community (Klunk *et al.*, 2018; Pilon *et al.*, 2021; Rios *et al.*, 2021; Souza *et al.*, 2021; Gallo *et al.*, 2022; Pinheiro *et al.*, 2022). While the herb-subshrub stratum prevails in the CPG, the arboreal stratum accounts for about 35% of the species. Nonetheless, the vegetation in the herb-subshrub stratum is almost twice as dense compared to the Cerrado overall pattern, where woody species typically constitute around 17-20% of the flora (Mendonça *et al.*, 2008, Durigan *et al.*, 2018).

Adjacent to the PEV (and CPG) are the Porto Ferreira State Park and the Jataí Ecological Station (EEJ), both of which enjoy full protection status. These areas have comprehensive lists of plant species as does the CPG. Among the ten botanical families with the highest richness observed in CPG, except for Poaceae and Apocynaceae, the other eight families were also observed in the Porto Ferreira State Park. It is noteworthy that although the Porto Ferreira State Park is predominantly covered by Atlantic Forest vegetation, it shares significant botanical similarities with the CPG. (Sabino *et al.*, 2021). Moreover, located less than 20 km apart from the CPG, we find the Jataí Ecological Station (EEJ) (Fundação Florestal, 2013; 2020), an area encompassing more than 9,000 ha, with 82% of it consisting of Cerrado phytophysiognomies (Fundação Florestal, 2013). Despite being considerably larger than the CPG, the EEJ has a list of 335 woody, epiphytic and aquatic macrophyte species, with no recorded entries for the herb-subshrub stratum (Toppa, 2004; Bataghin *et al.*, 2012; Fundação Florestal, 2013). The absence of such records suggests the potential addition of species, even though 74% of the EEJ is comprised of *cerradão* (forest) physiognomy (Toppa, 2004). Yet, the two protected areas – CPG and EEJ – share several species of woody flora, with the most frequent species in the *cerradão* and *cerrado sensu stricto* being: *Pterodon pubescens* (Benth.) Benth., *Xylopia aromática* (Lam.) Mart., *Copaifera langsdorffii* Desf., *Myrcia guianensis* (Aubl.) DC., *Diptychandra aurantiaca* Tul., *Anadenanthera peregrina* (L.) Speg., *Qualea grandiflora* Mart., *Ouratea spectabilis* (Mart.) Engl. and *Pouteria torta* (Mart.) Radlk. (Batalha & Mantovani, 2001; Fundação Florestal, 2013). When considering other significant Cerrado fragments in the state of São Paulo, particularly those classified as fully protected within the national system of protected areas (as shown in Table S2), we observe a notable floristic resemblance to the herbaceous flora, specifically the Poales group, found in CPG. This underscores the significance of each of these protected areas in contributing to the diversity of Cerrado in the state of São Paulo.

When considering the classification of the CPG flora according to their conservation status, 38.8% of the total species are considered of least concern (LC) by at least one of the IUCN and CNCFlora classification systems. This indicates that a significant portion of the flora is in good condition within the park. However, it is concerning that 57.4% of the species have not been evaluated (NE category) by either IUCN or CNCFlora. This high number of species without a defined conservation status in the CPG may suggest that the number of species at risk of extinction can be significantly higher than currently recognized. The five species categorized as Near Threatened (NT) are woody, with their status attributed to population decline resulting from overharvesting of timber (CNCFlora, 2024; Schulze *et al.*, 2008). The Vulnerable (VU) species are primarily affected by habitat degradation, driven by the conversion of Cerrado areas into pasture, plantations, and urban expansion. The discontinuous geographic distribution of some species renders them highly susceptible to local extinctions (CNCFlora, 2024). Indeed, the state of São Paulo faces a significant challenge with the conversion of natural areas into lands dedicated to agriculture and livestock. Currently, approximately 72.9% of its total land cover has been transformed for this purpose, totaling around 18.5 million ha. Among these areas, over 10 million ha are designated for pasture, while the remaining land is allocated to temporary crops, primarily sugarcane, perennial crops such as coffee and orange, and silviculture activities (MapBiomas Brasil, 2023).

In addition to the threats posed by habitat loss and fragmentation, the native species in the CPG face competition from exotic invasive species, which further exacerbates the challenges to their survival. In the more open physiognomies, where the establishment of heliophytic species is favoured, invasive grasses (Poaceae) with the potential to seriously impact native species at various scales have been documented (Pivello *et al.*, 1999; Dodonov *et al.*, 2019). These Poaceae species also exhibit invasive behavior. For instance, *Melinis minutiflora* and *M. repens* are highly abundant, with the former widely distributed inside CPG and the latter mainly on the edges; *Urochloa decumbens* is found in patches both inside and outside the CPG; *Megathyrsus maximus* forms dense patches along the CPG border adjoining the Anhanguera highway and has already entered the reserve. Another notable example is *Hedychium coronarium,* a rhizomatous herbaceous plant originating from Asia, which frequently invades riparian forests and wetlands in Brazil. Large patches of *H. coronarium* have been documented along the banks of the Paulicéia stream. This species exhibits phenotypic plasticity, making it highly competitive compared to native plant species (Castro *et al.,* 2021). Furthermore, it has the potential to disrupt natural decomposition processes and microbial activity (Castro *et*

al., 2020). The process of biological invasion triggered by these species can alter the structure and composition of the environment, potentially leading to the de-characterization of the ecosystem and, ultimately, the loss of biodiversity due to local extinctions (Matos & Pivello, 2009; Simberloff & Rejmánek, 2011).

If, on the one hand, the process of woody vegetation encroachment occurring in CPG tends to lessen the expansion of exotic invasive grasses due to their reduced metabolic efficiency under shaded conditions (Sarmiento, 1992; Pinheiro *et al.,* 2016), on the other hand, numerous native heliophytic species are being lost (Pinheiro *et al.*, 2016; Marroni, 2019). This presents a significant challenge for the conservation of the more open phytophysiognomies in CPG biodiversity, as both the control of biological invasions and woody encroachment must be considered. Furthermore, both of these processes are highly detrimental to the natural biodiversity and are occurring in numerous other Cerrado fragments (Klink & Machado, 2005; Rosan *et al.,* 2019). Therefore, monitoring the flora is essential for detecting these problems timely and taking necessary actions.

Despite the multitude of threats facing the CPG flora, the park continues to harbour a remarkably high number of species. This resilience may be attributed to its proximity to the EEJ, facilitating gene flows between the two areas. It is worth noting that both the PEV and EEJ are the largest Cerrado protection areas in the state of São Paulo, further emphasizing their importance in conserving biodiversity within the region. However, the documentation of endangered and invasive species serves as a warning, flagging the need for careful attention to the CPG vegetation.

Species lists play a fundamental role in the conservation and monitoring of the biota for several key reasons. First, they serve to document the richness and diversity of species within a given location, making it possible to understand local biological diversity and providing valuable information for taxonomic, ecological and evolutionary studies. Second, species lists enable the assessment of population trends over time, including fluctuations in population sizes. By identifying changes such as increases or decreases in populations, these lists help pinpoint species that may be at risk of extinction. As such, they are essential tools for guiding the establishment of biodiversity conservation priorities. Lastly, species lists play a crucial role in promoting the sustainable management of natural resources by providing a comprehensive understanding of species composition and distribution. This knowledge allows for the design of strategies to mitigate threats such as habitat loss and invasive species, ultimately supporting the long-term health and resilience of ecosystems.

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Authors' contributions

MCMS: Substantial contribution in the study design, data sampling and processing, data analyses and interpretation, and manuscript writing; DSMS: Substantial contribution in the study design and supervision; contribution to data interpretation and manuscript revision; VRP: Substantial contribution in the study design, project coordination and supervision; data interpretation, manuscript writing and revision. All authors contributed to data analysis, writing of the paper and discussion.

Conflict of interest

The authors declare that they have no conflicts of interest.

Data availability

The dataset generated in this study is available in the Zenodo repository: https://zenodo.org/records/10583396

The new species occurrences for the CPG are deposited in the Dom Bento José Pickel Herbarium (SPSF, Instituto Florestal, São Paulo, SP, Brazil).

Supplementary Material

The following online material are available for this article

Table S1. Flora recorded in the Cerrado Pé-de-Gigante (Vassununga State Park, Santa Rita do Passa Quatro, São Paulo State, Brazil).

Table S2. Graminoid species occurring along the nine relevant Cerrado protected areas in the São Paulo state, compared to Cerrado Pé-de-Gigante (Vassununga State Park, São Paulo state, Brazil).

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