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BOTANICAL BRIEFING

Cerrado plant traits (CPT): a database of functional traits across vegetation types in a global biodiversity hotspot

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• **Background** Trait-based ecology has become central for understanding plant form, function and ecosystem processes, but progress has been hampered by biased representation in trait databases. As such, global trait syntheses remain strongly biased towards temperate forest biomes. Tropical savannas are the most extensive, biodiverse and disturbance-driven ecosystems worldwide, yet are poorly represented in functional trait databases, limiting ecological inference and applied decision-making.

• **Scope** Here, we introduce the Cerrado Plant Traits (CPT), an open-access initiative compiling and standardizing plant functional trait data for the Brazilian Cerrado, the most biodiverse tropical savanna in the world. CPT integrates trait information for all major plant organs (whole-plant, root, shoot, leaf, flower, fruit and seed) across vegetation types in the Cerrado, drawing on a collaborative and inclusive research network. The current version of CPT compiles data from 148 datasets, totalling 113 859 curated trait records for 2134 taxonomically verified species across 150 families. Trait records span pristine, degraded and restored environments and capture both interspecific and intraspecific variation. Whole-plant and leaf traits dominate the current dataset, whereas below-ground and reproductive traits remain comparatively underrepresented, highlighting key priorities for future research.

• **Conclusions** By substantially increasing the representation of savanna species in global trait repositories, CPT enables tests of ecological hypotheses across multiple levels of organization, analyses of trait–environment relationships across fire, soil and climatic gradients, and robust comparisons across forest–savanna transitions. Beyond its scientific value, CPT provides a practical, standardized resource to support conservation planning, restoration programmes and evidence-based policy in a biodiversity hotspot facing accelerating land-use and climate pressures.

Key words: Biodiversity, Cerrado, conservation, functional ecology, restoration, savanna, trait database.

INTRODUCTION

Ecology has long relied on species abundance and distribution to answer fundamental questions, guide conservation efforts and support predictive models, but these metrics lack the functional depth necessary to inform modern ecological science and practice precisely. More recently, however, trait-based ecology has emerged as a unifying framework in the field of plant ecology and evolution, allowing species, communities and ecosystems to be compared based on functional traits that reflect plant growth, persistence and reproduction (Violle *et al.*, 2007). Over the past decade, numerous efforts have been made to synthesize trait distribution and variation on a global scale, including the whole spectra of plant form and function (e.g. Díaz *et al.*, 2016; Carmona *et al.*, 2021; Carmona and Beccari, 2025).

These advances were possible only because of three key milestones. First, the identification of trait roles and their synergy or trade-offs led to the identification of economics spectra for diverse organs and tissues, such as leaves (Wright *et al.*, 2004), wood (Chave *et al.*, 2009) and roots (Weemstra *et al.*, 2016). Similar frameworks have been developed for organs such as seeds (Saatkamp *et al.*, 2019), flowers (Roddy *et al.*, 2021) and fruits (Silveira *et al.*, 2026), but empirical support remains limited owing to data scarcity. Second, the publication of handbooks for trait measurements (e.g. Pérez-Harguindeguy *et al.*, 2013; Klimešova *et al.*, 2019; Wigley *et al.*, 2020, Poschlod *et al.*, 2026) has greatly increased the standardization of sampling across ecosystems, lineages and plant organs, allowing ecologically meaningful comparisons. Third, the availability of open access trait databases (e.g. Maitner *et al.*, 2018; Kattge *et al.*, 2020; Wielget *et al.*, 2020) provided multiple opportunities for researchers to address ecological questions across scales and levels of organization. However, despite all these advances, a persistent limitation is that current trait spectra rely heavily on data from biomes and lineages of temperate climate, especially of the Northern Hemisphere, constraining our understanding of plant ecological strategies in tropical, seasonal and disturbance-prone ecosystems, especially the savannas, the second most diverse and widespread biome in tropical regions of the Southern Hemisphere (Murphy *et al.*, 2016).

The savanna biome occupies vast areas across the tropics and subtropics in the Americas, Africa, Australia and parts of south and south-eastern Asia (Dinerstein *et al.*, 2017). They are maintained by a combination of climatic seasonality, resource availability (water and nutrients) and disturbances (fire and herbivory) (Sankaran *et al.*, 2005; Staver

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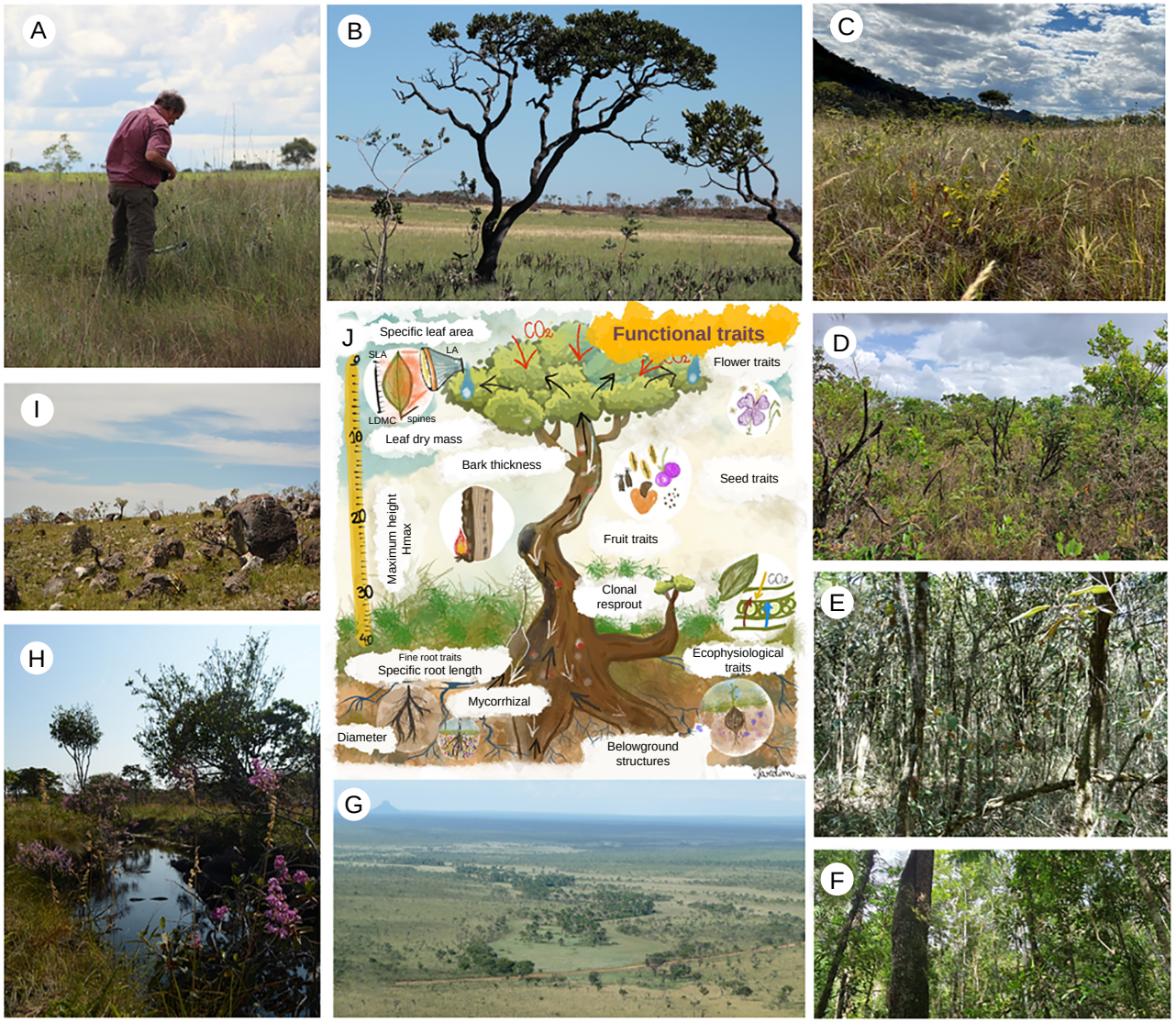


FIG. 1. Physiognomic variation of the Brazilian Cerrado. (A) William Bond in *campo sujo*. (B, C) *Campo limpo* in Central (B) and southeastern (C) Brazil. (D–F) Typical *cerrado sensu stricto* (D), *cerradão* woodlands (E) and gallery forest (F). (G–I) Overview of a Cerrado landscape showing habitat heterogeneity (G), which includes wetlands (H) and rocky outcrop vegetation (I). Cerrado Plant Traits aims to provide data on all plant organs to allow future analyses of trait integration. Photographs by Alessandra Fidelis (A, C, G), Natália Medeiros (B), Davi Rossatto (D–F) and Lara Amaral-Garcia (I). Illustration by Raissa Jardim.

et al., 2011; Dantas *et al.*, 2016; Bond, 2019). These environmental aspects filter for functional strategies centred on drought tolerance, nutrient conservation, resprouting ability from below-ground specialized organs, fire resistance and/or dependence, and tolerance to herbivory; a suite of strategies associated with traits that are still poorly represented in global trait compilations dominated by temperate forest species (Ratnam *et al.*, 2011; Wigley *et al.*, 2020; Zhou *et al.*, 2025).

Savannas harbour endemic and threatened biodiversity (Parr *et al.*, 2014; Murphy *et al.*, 2016; Costa *et al.*, 2026) structured into a continuous, megadiverse C_4 grass-dominated understorey, rich in forbs and varied growth forms, alongside a discontinuous, species-rich woody component. Both layers are characterized by complex and highly diverse underground structures (Lehmann *et al.*, 2011; Scogings and Sankaran, 2019; Pilon *et al.*, 2021; Siebert *et al.*, 2024). These ecosystems are major carbon sequestration compartments of the biosphere, supporting climate change mitigation policies (Zhou *et al.*, 2023). However, the paucity of plant functional trait data for savanna species, including those related to C storage and sequestration, represents a significant barrier to improving our understanding of how best to manage and restore savanna biodiversity to secure species persistence and to provide ecosystem services essential to support human livelihoods (Bispo *et al.*, 2024). To close this gap, we introduce the Cerrado Plant Traits (CPT), an inclusive network compiling functional trait data for the Cerrado.

The Cerrado is the most biodiverse savanna in the world, with ~13 000 bryophytes and vascular plant species (Flora e Funga do Brasil, 2025), which originally covered 200 million hectares but has now been reduced to half of its original native extent (Strassburg *et al.*, 2017). Its flora comprises a remarkable diversity of plant lineages, including highly specialized growth forms shaped by recurrent natural fires, nutrient

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limitation, seasonal droughts and remarkable habitat heterogeneity across the landscape, which leads to diverse ecosystems, including grasslands, savannas and even associated forests (Oliveira and Marquis, 2002; Simon *et al.*, 2009; Françoso *et al.*, 2015). The biome is threatened by multiple factors, including land-use change and climate change (Strassburg *et al.*, 2017; Hofmann *et al.*, 2025; Segura-Garcia *et al.*, 2026). Unfortunately, only ~3 % of the Cerrado area is under strict legal protection, and 62 % of all Cerrado vegetation remnants are located within private landholdings (Bispo *et al.*, 2024). In recent years, there have been many attempts to synthesize knowledge of different aspects of Cerrado ecology, including its herbaceous (De Castilho Silva *et al.*, 2024) and woody flora (Alvarez *et al.*, 2025; Pontara *et al.*, 2025), pollination (Cardoso *et al.*, 2026), seed dispersal (Kuhlmann and Ribeiro, 2016, Bello Carvalho *et al.*, 2023), fire (Arruda *et al.*, 2024; Pivello *et al.*, 2025; Segura-Garcia *et al.*, 2025) and restoration ecology (Pilon *et al.*, 2023). Yet, despite decades of ecological research, functional trait data for Cerrado species remain scattered in localized studies, often using different methodologies, limiting their broader integration into global frameworks and databases.

The CPT initiative was established to address this gap by compiling, standardizing and making available curated trait data across all plant organs, growth forms and vegetation types. CPT presents the first consolidated output of the initiative, offering an open access dataset that considerably expands the representation of savanna species, focused on the Cerrado, in global trait repositories. By making these datasets open access, CPT aims to advance trait-based ecology of the Cerrado and analogous savannas, facilitating large-scale comparisons, enhancing vegetation models and supporting conservation and restoration strategies in a biome facing accelerating human pressures (de Marco *et al.*, 2023).

DATA ACQUISITION AND ORGANIZATION

Over time, several definitions and delimitations of the Cerrado have been proposed by different authors (Ab'Saber 1977, 2003, Ribeiro and Walter, 2008; Batalha, 2011). Although different perspectives and approaches led to distinct interpretations of the geographical and ecological boundaries of the biome, a pragmatic definition is required. We adopted the official definition of the Cerrado based on the geographical limits established by the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografica e Estatística [IBGE], 2019). All vegetation types occurring within this boundary, from grasslands (*campo limpo*) to gallery forests (Fig. 1), were included, in addition to patches of *campo rupestre* situated inside these limits (Ribeiro and Walter, 2008). Therefore, any study conducted within the geographical extent of the biome, including grasslands, savannas and forests, was eligible to contribute data to the CPT (Fig. 1). We are aware of a few *campo rupestre* patches occurring outside of the geographical limits of the IBGE biome, but they were retained because of the natural patchy distribution of this ecosystem.

We requested data of bryophytes, ferns and lycophytes, gymnosperms and angiosperms occurring in the Cerrado, including species that are not exclusively native to the biome. Our focus was on wild species; thus cultivated, domesticated and agricultural or silvicultural species were excluded. However, traits of non-native and naturalized species were retained, because these might assist in the management of biological invasions.

Both unpublished and published primary data from scientific articles, books, preprints, theses, dissertations and monographs, in addition to ongoing or completed experiments that generated plant functional trait measurements, were accepted. We also recorded whether data were obtained from plants collected in pristine (natural), degraded (e.g. urban or agricultural) or restored conditions. Data were collected by organizing a collaborative research network with standardized protocols, as described below, but no systematic literature mining was performed.

To provide a broad overview of plant functional strategies in the Cerrado, we compiled a database organized into seven trait categories (Fig. 1J), comprising different traits and functions (Table 1). For each trait category, we developed a template file that was distributed to potential collaborators and made available online. Each template consisted of an Excel file with multiple tabs containing metadata and data-entry sheets. The metadata provided detailed explanations of variable definitions, units of measurement, data provenance, sampling methods and contributor information. Because intraspecific functional variation can be as large as interspecific variation and has important implications for functional ecology (Siefert *et al.*, 2015), the CPT templates were designed to capture such variation by providing data on standard deviation and sample size for all quantitative traits.

TABLE 1. List of seven trait categories with respective overall function and examples in the Cerrado Plant Trait database.

Trait category	Functions	Examples	Number of traits	Number of species
Whole-plant	Broad interactions with the environment	Height, growth form, resprouting capacity	14	1192
Leaf	Light interception, water relationships	Specific leaf area, stomatal conductance, maximum photosynthetic rate	48	772
Shoot	Biomechanical support, water relationships	Wood density, water retention capacity, bark thickness	14	501
Root and below-ground	Nutrient acquisition, regeneration	Specific root length, root biomass	13	310
Flower	Sexual reproduction and pollination	Flower length, pollination syndrome	21	978
Fruit	Seed dispersal	Fruit colour, dispersal syndrome	15	171
Seed	Persistence, germination and recruitment	Seed dry mass, seed water content	29	415

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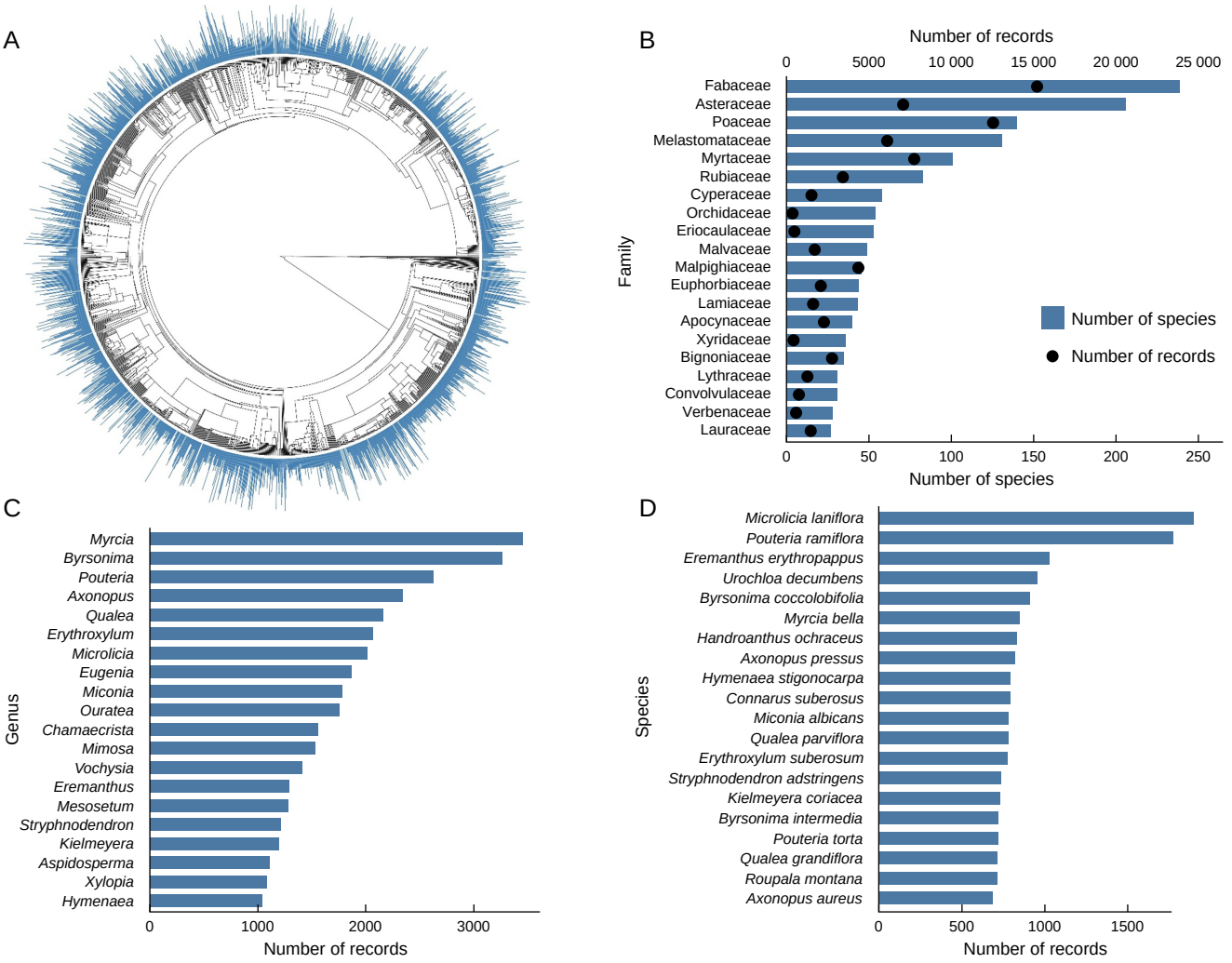


FIG. 2. (A) Trait coverage across angiosperm phylogeny, sourced in the V.PhyloMaker R package (Jin and Qian, 2022). The blue bars show the logarithm of the number of records. (B–D) The 20 families (B), genera (C) and species (D) with most trait records available in Cerrado Plant Trait database.

Two online workshops were held to allow collaborators to provide feedback and clarify questions about the project. After this consultation period, consolidated templates were distributed in March 2024, and completed datasets were returned by contributors up to October 2024.

DATA CURATION, HARMONIZATION AND INTEGRATION

The structural consistency of the dataset columns from each dataset was verified. When inconsistencies were identified (such as changes in column names, units of measurement, deletions or unintended insertions), the authors were notified to make the necessary adjustments. Once the columns were verified, the datasets were consolidated into a single file for each dataset.

Scientific names were checked according to the Flora and Funga of Brazil repository (https://floradobrasil.jbrj.gov.br; Brazil Flora Group *et al.*, 2022), using the scientific name verification tool of the Brazilian Aquatic Plants Data Repository (https://sites.icb.ufmg.br/plantasaquaticasbrasil/). In cases of synonymy, the names were updated to their respective accepted forms. In the final version, only species with accepted names were retained. Records identified only to the family or genus level were excluded. Geographical coordinates were standardized to decimal degrees, and spatial consistency was verified using functions from the R package CoordinateCleaner (Zizka *et al.*, 2019).

After the data submission deadline (1 October 2024), each dataset was reviewed individually for completeness and consistency. We inspected continuous trait columns for outliers using visual distribution checks (histograms and boxplots) in the R environment. Suspicious values were flagged when they exceeded three interquartile ranges from the median or were biologically implausible. After taxonomic curation, the database includes 113 859 trait records. Datasets needing revisions after curation were returned to authors to check for consistency and then integrated into the final dataset after corrections. Outliers were retained if their values were deemed correct by authors. This first release of the CPT compiles data from 148 datasets, resulting in a total of 117 471 trait records.

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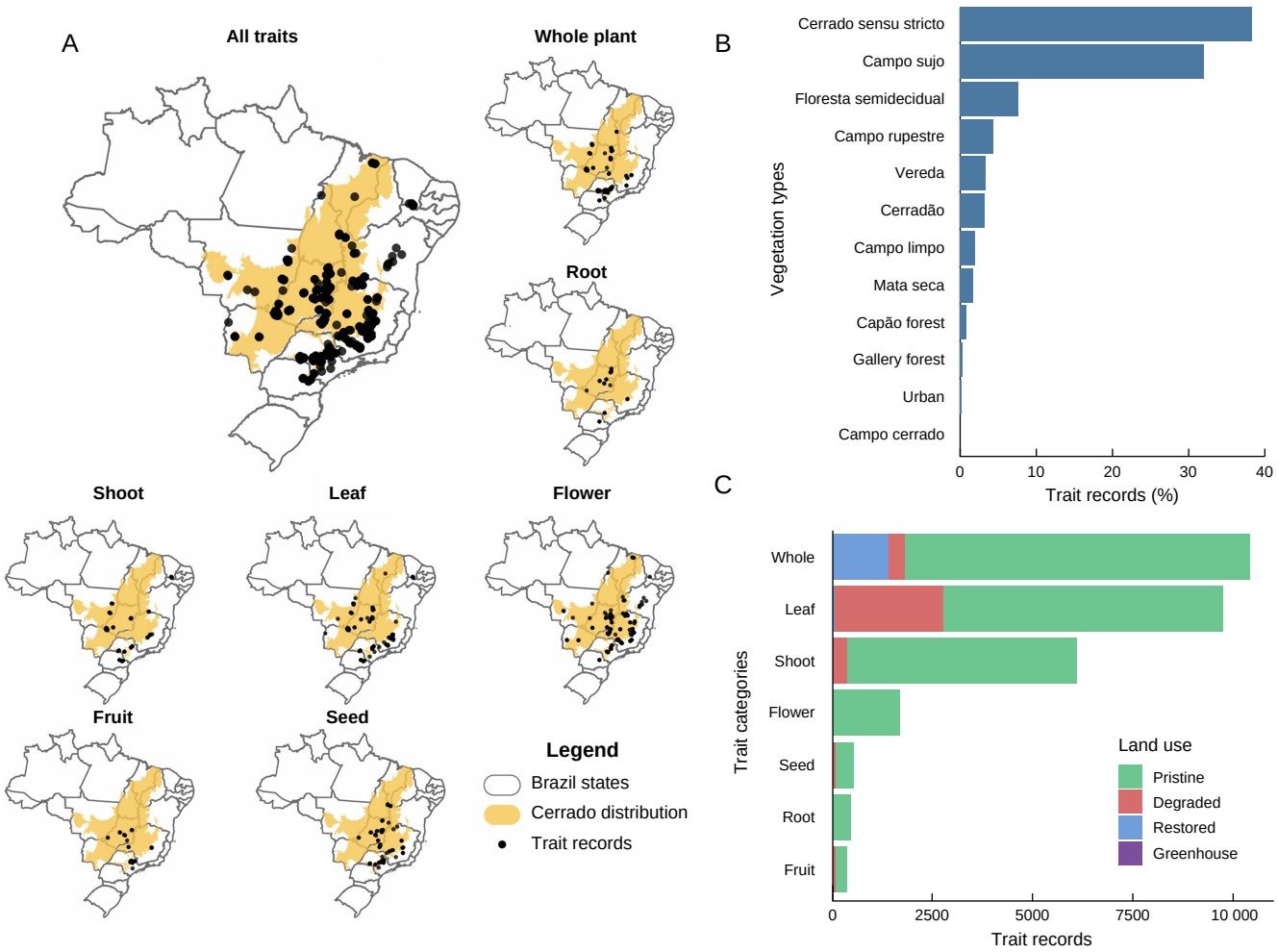


FIG. 3. (A) Distribution of sites where trait distribution is available in the Cerrado Plant Trait database. Points located outside the geographical limits of the Cerrado biome as defined by IBGE correspond to naturally occurring patches. (B, C) Trait distribution across the Cerrado physiognomies (B) and across conservation contexts (C).

CURRENT STATE OF THE CERRADO PLANT TRAITS DATABASE

We started with an initial list of 3230 taxa, which was reduced to 2134 taxonomically verified species distributed among 150 families (Fig. 2A, B) and 695 genera (Fig. 2C). Angiosperms formed the largest group in CPT, with Fabaceae (239 species; 15 208 records), Asteraceae (206; 7101), Poaceae (140; 12 519), Melastomataceae (131; 6131), Myrtaceae (101; 7779) and Rubiaceae (83; 3424; Fig. 2A) standing as the most represented families. As in many trait databases, there was a strong imbalance of representation within families, with some species accounting for a disproportionately large fraction of the records (e.g. *Microlicia laniflora*; Fig. 2D). The ten most represented species accounted for 9.4 % of total records, whereas the 1461 least represented species accounted for 10 % of total records. Monocots were underrepresented in the list of top families, genera and species (Fig. 2B–D).

Sampling was largely concentrated in the central and southeastern Cerrado, except for flower traits, which achieved a more even geographical coverage (Fig. 3A). With the exception of few flower and seed traits, there were no trait data in Matopiba (an acronym for the states Maranhão, Tocantins, Piauí and Bahia), the emerging agricultural frontier in Brazil (Santos and Ruchkys, 2025). Records outside the IBGE official boundaries refer to enclaves distributed in neighbouring biomes. Trait records covered the full range of Cerrado vegetation types, including *campo limpo*, *campo sujo*, *campo cerrado*, *campo rupestre* enclave, cerrado *sensu strictu*, *cerradão*, *vereda*, gallery forest, dry forest, *capão* forest, semideciduous forest and urban area. Pristine sites accounted for 74.6 % of the records, which were largely concentrated on cerrado *sensu stricto* and *campo sujo* (Fig. 3B). Traits for Cerrado species occurring in urban contexts accounted for only 0.04 % of total records (Fig. 3B), and those were only for flower traits. Nearly 11.3 % of the records originated from degraded landscapes (e.g. agricultural matrices, urban environments), and 4.6 % from restored areas. Information regarding land use was missing in 9.5 % of the records (Fig. 3C).

Trait information was organized into seven functional categories: whole-plant, leaf, shoot, root, flower, fruit and seed (see Table 1; Supplementary Data Table S1). In this first release, trait categories with the greatest representation were leaf and whole-plant, together accounting for 66.1 % of all records (Fig. 4A). Root traits were less represented in the

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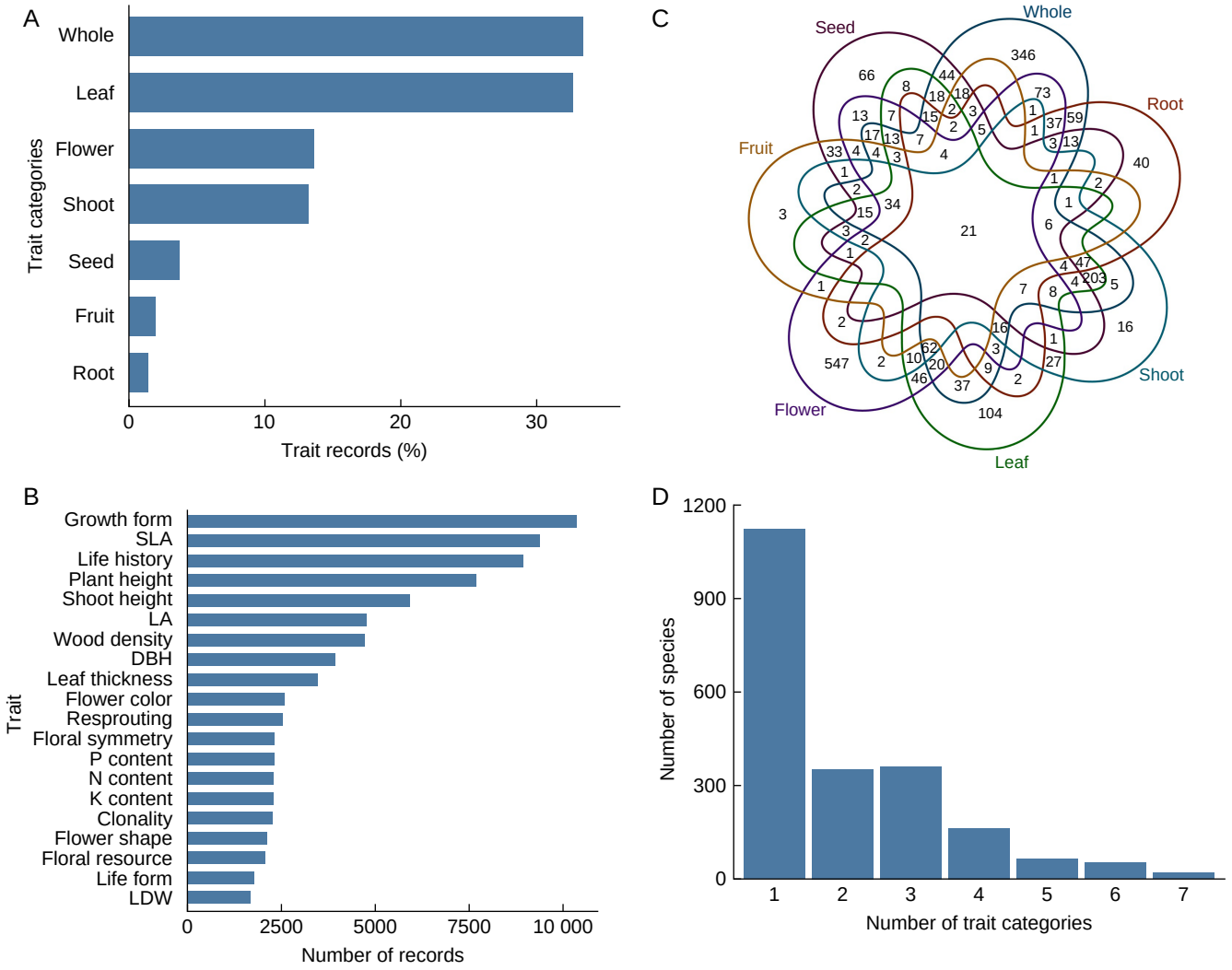


FIG. 4. Trait distribution in the Cerrado Plant Trait database. (A) Trait distribution across trait categories. (B) The 20 most representative traits in CPT ranked by order. (C) Venn diagram showing the overlap in trait distribution across trait categories. (D) Number of species with trait data per trait category.

database, with only 1.4 % of all records (Fig. 4A). The most frequently measured traits across the database were growth form (with 10 371 records), specific leaf area (9375), life history (8942), plant height (7714), shoot height (5928), leaf area (4774) and wood density (4730) (Fig. 4B). Trait overlap among categories varied significantly. A total of 21 species had at least one trait measured in all seven functional categories, whereas 1121 species had records restricted to a single category (Fig. 4C, D). We found 937 species (43.9 %) presenting broad functional coverage (at least ten traits), whereas 471 species (22.0 %) were represented by fewer than five traits. Only 39 (1.8 %) species had records for ≥50 traits, reflecting the typical heterogeneity found in large, multi-source trait databases (Kattge *et al.*, 2020).

DATA ACCESSIBILITY AND FUTURE PROSPECTS

The CPT database is organized into a structure that facilitates transparency and interoperability. It is divided into two sections: (1) general metadata, including taxonomic information, growth form, geographical coordinates, vegetation type, land-use classification and dataset provenance; and (2) trait records, in which each column corresponds to a single functional trait measured, followed by standard deviation and sample size in the case of quantitative traits. All files are provided as supplementary material and is archived in a permanent public repository (10.6084/m9.figshare.32895932) to ensure permanent accessibility. To keep expanding the network, we will continue to update the database with complementary traits and records via online collaborative repositories. This infrastructure will facilitate the storage and sharing of code, allowing for seamless expansion and integration of new digital projects.

The CPT database will empower researchers to revisit classic hypotheses in functional ecology, better assess how plant trait spectra vary across ecological gradients of precipitation, soil fertility and fire regimes within savannas (e.g. Bernardino *et al.*, 2022; Neves *et al.*, 2022; Flake *et al.*, 2025; Paudel *et al.*, 2025; Zanzarini *et al.*, 2025) and across forest–savanna transitions (Dantas *et al.*, 2016), and test whether trait–environment relationships identified in other

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biomes hold in the most diverse tropical savanna in the world. In addition to enabling rigorous comparative analyses across biogeographical regions (Ratter *et al.*, 2003; Amaral *et al.*, 2017), lineages and niche partitioning among growth forms (Rossatto *et al.*, 2013), it will also play crucial roles in understanding interspecific and intraspecific trait variation (e.g. Bedetti *et al.*, 2011; Rossatto and Franco, 2017).

From the applied perspective, the CPT database will play a central role in advancing trait-based conservation and restoration in the Cerrado. By providing a unified and openly accessible dataset, the CPT establishes a robust foundation for investigating trait-based dynamics during woody encroachment (Cruz Júnior *et al.*, 2025; Costa *et al.*, 2026; Rossatto and Scalon, 2026), below-ground biomass accumulation (Bombo *et al.*, 2025), regeneration ecology (Daibes *et al.*, 2022; Paraguassu *et al.*, 2026), invasion ecology (Le Stradic *et al.*, 2025) and restoration planning (Coutinho *et al.*, 2023). However, in order to succeed, future efforts will need to enhance trait data collection on below-ground organs, herbaceous species and in both degraded and restored sites, particularly in underrepresented regions, such as the Matopiba (Fig. 3A).

Despite substantial progress made by the CPT initiative, several pressing challenges remain. Among them, mitigating the geographical, ecological and phylogenetic biases is a main priority. Although we aimed to maximize the representativeness of CPT across taxonomic, geographical and ecological diversity of the Cerrado, the current compilation does not represent a random or systematic sample. Instead, it reflects uneven research effort, with geographical (e.g. central and southeastern Cerrado), ecological (e.g. woody species) and functional (e.g. leaf and whole-plant traits) biases. Consequently, our database should be used with caution, particularly when extrapolating patterns across the biome. The number of taxonomically validated species in CPT is currently 15.06 % of the Cerrado flora (Flora e Funga do Brasil, 2025). Furthermore, data integration across plant organs is needed before more reliable assessments of plant spectra in the Cerrado can be achieved (Carmona and Beccari, 2025). Another limitation is ensuring methodological consistency, which requires standardized data sampling using reliable protocols. Mitigating these limitations will make the next version of CPT more comprehensive and integrated, which could be achieved through sustained funding to support data curation and integration.

Although the CPT functions primarily as an inclusive network for compiling data from a wide diversity of contributors, future efforts need to include targeted data mining aimed at filling critical taxonomic and geographical gaps, thereby increasing the overall coverage of the dataset beyond the immediate network of contributors. Focus should be given to undersampled regions and poorly represented lineages and trait categories. Two parallel strategies will drive future expansions. First, coordinated collaborative authorship will enable systematic extraction and incorporation of trait data from articles, books, theses, dissertations, technical reports and grey literature. Second, greater engagement with non-English and regionally published literature (Serrano *et al.*, 2025) will help to reduce linguistic and geographical biases and contribute to a more comprehensive representation of Cerrado biodiversity. Such efforts will be crucial for integrating functional trait information across the full breadth of Cerrado vegetation types and for strengthening the ability of the CPT to support large-scale ecological inference.

CONCLUSION

By assembling trait data from all plant organs, CPT is expected to deliver significant contributions for functional ecology and more inclusive conservation practices. In particular, the CPT database will enable more rigorous tests of ecological hypotheses, deepen our understanding of plant functional spectra and support comparative analyses across regions, taxa and ecological scales (De Bello *et al.*, 2025). Beyond its scientific importance, its standardized structure provides an open access tool for conservation planning, public policy development and restoration programmes, allowing practitioners and decision-makers to ground decisions in empirical data. By bridging basic and applied science, we hope that CPT becomes a useful and updatable platform for advancing both ecological knowledge and effective conservation action in the most biodiverse and threatened savanna in the world.

SUPPLEMENTARY DATA

The supplementary material contains the raw database for all plant organs. A figshare link with the full database will be made available upon acceptance of the paper.

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CONFLICTS OF INTEREST

A. C. Franco is a guest editor for the Special Issue. Apart from that, we declare no conflict of interest.

AUTHOR CONTRIBUTIONS

L.A.-G., C.A.O.-P., K.A., L.G.B.-D., A.F., P.K.M., N.F.M., D.N., N.S., D.R.R. and F.A.O.S. conceived the study and organized the consortium; P.H.A.M. analysed the data with support from C.A.O.-P. and D.N.; F.A.O.S. wrote the first version of the manuscript, with comments from L.A.-G., C.A.O.-P., K.A., L.G.B.-D., A.F., P.K.M., N.F.M., D.N., N.S. and D.R.R.; all coauthors provided data and edited the first draft of the manuscript.

DATA AVAILABILITY

All databases are provided as supplementary material.

REFERENCES

Ab'Saber AN. 1977. *Os domínios morfoclimáticos na América do Sul. Primeira aproximação*. São Paulo: Universidade de São Paulo.

Ab'Saber AN. 2003. *O domínio dos Cerrados. Os domínios de natureza no Brasil: potencialidades paisagísticas*. São Paulo: Ateliê Editorial, 115–135.

Alvarez F, **Marimon-Junior BH**, **Marimon BS**, ***et al.* 2025**. Tree species hyperdominance and rarity in the south American Cerrado. *Communications Biology* **8**: 695. doi: 10.1038/s42003-025-07623-w

Amaral AG, **Munhoz CBR**, **Walter BMT**, **Aguirre-Gutiérrez J**, **Raes N. 2017**. Richness pattern and phytogeography of the Cerrado herb–shrub flora and implications for conservation. *Journal of Vegetation Science: Official Organ of the International Association for Vegetation Science* **28**: 848–858. doi: 10.1111/jvs.12541

Arruda VLS, **Alencar AAC**, **de Carvalho Júnior OA**, ***et al.* 2024**. Assessing four decades of fire behavior dynamics in the Cerrado biome (1985 to 2022). *Fire Ecology* **20**: 64.

Batalha MA. 2011. O cerrado não é um bioma. *Biota Neotropica* **11**: 21–24. doi: 10.1590/S1676-06032011000100001

Bedetti CS, **Aguiar DB**, **Jannuzzi MC**, **Moura MZD**, **Silveira FAO. 2011**. Abiotic factors modulate phenotypic plasticity in an apomictic shrub [*Miconia albicans* (SW.) Triana] along a soil fertility gradient in a Neotropical savanna. *Australian Journal of Botany* **59**: 274–282. doi: 10.1071/BT10275

Béllo Carvalho R, **Malhi Y**, **Oliveras Menor I. 2023**. Frugivory and seed dispersal in the Cerrado: Network structure and defaunation effects. *Biotropica* **55**: 849–865. doi: 10.1111/btp.13234

Bernardino PN, **Dantas VL**, **Hirota M**, **Pausas JG**, **Oliveira RS. 2022**. Savanna–forest coexistence across a fire gradient. *Ecosystems* **25**: 279–290. doi: 10.1007/s10021-021-00654-4

Bispo PDC, **Picoli MCA**, **Marimon BS**, ***et al.* 2024**. Overlooking vegetation loss outside forests imperils the Brazilian Cerrado and other non-forest biomes. *Nature Ecology & Evolution* **8**: 12–13. doi: 10.1038/s41559-023-02256-w

Bombo AB, **Fidelis A**, **Le Stradic S. 2025**. Modifications in fire frequency impact belowground plant components in old-growth grasslands, posing risks to their resilience. *American Journal of Botany* **112**: e70108. doi: 10.1002/ajb2.70108

Bond WJ. 2019. *Open ecosystems: ecology and evolution beyond the forest edge*. Oxford, UK: Oxford University Press. doi: 10.1093/oso/9780198812456.001.0001

Cardoso JCF, **Trevizan R**, **Maruyama PK**, ***et al.* 2026**. Pollination and plant reproduction in the Cerrado, the world's most biodiverse savanna. *Biological Reviews of the Cambridge Philosophical Society* **101**: 74–105. doi: 10.1111/brv.70073

Carmona CP, **Beccari E. 2025**. The path toward a unified trait space: synthesizing plant functional diversity. *New Phytologist* **248**: 2236–2242. doi: 10.1111/nph.70584

Carmona CP, **Bueno CG**, **Toussaint A**, ***et al.* 2021**. Fine-root traits in the global spectrum of plant form and function. *Nature* **597**: 683–687. doi: 10.1038/s41586-021-03871-y

Chave J, **Coomes D**, **Jansen S**, **Lewis SL**, **Swenson NG**, **Zanne AE. 2009**. Towards a worldwide wood economics spectrum. *Ecology Letters* **12**: 351–366. doi: 10.1111/j.1461-0248.2009.01285.x

Costa LS, **Munhoz CBM**, **Bustamante MMDC. 2026**. Woody encroachment in savannah and open ecosystems: a global analysis of patterns and impacts. *Annals of Botany* mcag113. doi: 10.1093/aob/mcag113

Coutinho AG, **Carlucci MB**, **Cianciaruso MV. 2023**. A framework to apply trait-based ecological restoration at large scales. *Journal of Applied Ecology* **60**: 1562–1571. doi: 10.1111/1365-2664.14439

Cruz Júnior PFD, **Pinheiro LFS**, **Rossatto DR**, **Kolb RM. 2025**. Woody encroachment and leaf functional traits of ground-layer savanna species. *Flora* **326**: 152709. doi: 10.1016/j.flora.2025.152709

Daibes LF, **Ordóñez-Parra CA**, **Dayrell RLC**, **Silveira FAO. 2022**. Regeneration from seeds in south American savannas, in particular the Brazilian Cerrado. In: *Plant regeneration from seeds*. London, UK: Elsevier, 183–197. doi: 10.1016/B978-0-12-823731-1.00002-0

Dantas VL, **Hirota M**, **Oliveira RS**, **Pausas JG. 2016**. Disturbance maintains alternative biome states. *Ecology Letters* **19**: 12–19. doi: 10.1111/ele.12537

De Bello F, **Fischer FM**, **Puy J**, ***et al.* 2025**. Raunkiæran shortfalls: challenges and perspectives in trait-based ecology. *Ecological Monographs* **95**: e70018. doi: 10.1002/ecm.70018

De Castilho Silva AW, **Pontara V**, **Bueno ML**, **Villa PM**, **Walter BMT**, **Meira-Neto JAA. 2024**. The bulk of a plant hotspot: composition, species richness and conservation status of the Cerrado herbaceous–subshrub flora. *Folia Geobotanica* **59**: 39–49. doi: 10.1007/s12224-024-09451-y

De Marco P, **De Souza RA**, **Andrade AFA**, ***et al.* 2023**. The value of private properties for the conservation of biodiversity in the Brazilian Cerrado. *Science* **380**: 298–301. doi: 10.1126/science.abq7768

Díaz S, **Kattge J**, **Cornelissen JHC**, ***et al.* 2016**. The global spectrum of plant form and function. *Nature* **529**: 167–171. doi: 10.1038/nature16489

Dinerstein E, **Olson D**, **Joshi A**, ***et al.* 2017**. An ecoregion-based approach to protecting half the terrestrial realm. *BioScience* **67**: 534–545. doi: 10.1093/biosci/bix014

Flake SW, **Elliott PJ**, **Durigan G**, **Rossatto DR**, **Hoffmann WA. 2025**. Linking leaf traits and litter flammability using a novel framework, tested with Brazilian Cerrado trees. *Functional Ecology* **39**: 1247–1261. doi: 10.1111/1365-2435.70032

Flora e Funga do Brasil. 2025. *Jardim Botânico do Rio de Janeiro*. http://floradobrasil.jbrj.gov.br/ (3 July 2004, date last accessed).

Françoso RD, **Brandão R**, **Nogueira CC**, **Salmona YB**, **Machado RB**, **Colli GR. 2015**. Habitat loss and the effectiveness of protected areas in the Cerrado biodiversity hotspot. *Natureza & Conservação* **13**: 35–40. doi: 10.1016/j.ncon.2015.04.001

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Brazil Flora Group, **Gomes-da-Silva J**, **Filardi FL**, ***et al.*** **2022**. Brazilian Flora 2020: leveraging the power of a collaborative scientific network. *Taxon* **71**: 178–198. doi: 10.1002/tax.12640

Hofmann GS, **Weber EJ**, **Bastazini VAG**, ***et al.*** **2025**. Climate change in the Brazilian Cerrado: a looming threat to terrestrial biodiversity. *WIREs Climate Change* **16**: e70022. doi: 10.1002/wcc.70022

Instituto Brasileiro de Geografica e Estatística (IBGE)**. 2019**. Biomas e Sistema Costeiro-Marinho do Brasil. Compatível com a escala 1:250.000. Rio de Janeiro: IBGE. https://www.ibge.gov.br/geociencias/informacoes-ambientais/vegetacao/15842-biomas.html

Jin Y, **Qian H. 2022**. V. PhyloMaker2: An updated and enlarged R package that can generate very large phylogenies for vascular plants. *Plant Diversity*, **44**: 335–339. doi: 10.1016/j.pld.2022.05.005

Kattge J, **Bönisch G**, **Díaz S**, ***et al.*** **2020**. TRY plant trait database—enhanced coverage and open access. *Global Change Biology* **26**: 119–188. doi: 10.1111/gcb.14904

Klimešová J, **Martínková J**, **Pausas JG**, ***et al.*** **2019**. Handbook of standardized protocols for collecting plant modularity traits. *Perspectives in Plant Ecology, Evolution and Systematics* **40**: 125485. doi: 10.1016/j.ppees.2019.125485

Kuhlmann M, **Ribeiro JF. 2016**. Evolution of seed dispersal in the Cerrado biome: ecological and phylogenetic considerations. *Acta Botanica Brasilica* **30**: 271–282. doi: 10.1590/0102-33062015abb0331

Lehmann CER, **Archibald SA**, **Hoffmann WA**, **Bond WJ. 2011**. Deciphering the distribution of the savanna biome. *New Phytologist* **191**: 197–209. doi: 10.1111/j.1469-8137.2011.03689.x

Le Stradic S, **Damasceno G**, **Cancian LF**, **Donadieu M**, **Kollmann J**, **Fidelis A. 2025**. High root biomass and variation in root functional traits allow non-native grass species to invade tropical open savannahs in Brazil. *Journal of Vegetation Science: Official Organ of the International Association for Vegetation Science* **36**: e70051. doi: 10.1111/jvs.70051

Maitner BS, **Boyle B**, **Casler N**, ***et al.*** **2018**. The BIEN R package: a tool to access the botanical information and ecology network (BIEN) database. *Methods in Ecology and Evolution* **9**: 373–379. doi: 10.1111/2041-210X.12861

Murphy BP, **Andersen AN**, **Parr CL. 2016**. The underestimated biodiversity of tropical grassy biomes. *Philosophical Transactions of the Royal Society B: Biological Sciences* **371**: 20150319. doi: 10.1098/rstb.2015.0319

Neves SPS, **Mendes Dos Santos MG**, **Vitória AP**, **Rossatto DR**, **De Miranda LAP**, **Funch LS. 2022**. The roles of functional traits in canopy maintenance along a savanna/seasonally dry tropical forest gradient in northeastern Brazil. *Flora* **292**: 152090. doi: 10.1016/j.flora.2022.152090

Oliveira PS, **Marquis RJ.** eds. **2002**. *The Cerrados of Brazil: ecology and natural history of a neotropical savanna*. New York: Columbia Univ. Press.

Paraguassu RP, **Vieira DLM**, **Borghetti F**, **Schmidt IB. 2026**. Small seeds and large knowledge gaps: understanding the regeneration traits of Brazilian savannah grasses necessary for restoration. *Annals of Botany* mcag139. doi: 10.1093/aob/mcag139

Parr CL, **Lehmann CER**, **Bond WJ**, **Hoffmann WA**, **Andersen AN. 2014**. Tropical grassy biomes: misunderstood, neglected, and under threat. *Trends in Ecology & Evolution* **29**: 205–213. doi: 10.1016/j.tree.2014.02.004

Paudel P, **Olin S**, **Tjoelker M**, **Pontarp M**, **Metcalfe D**, **Smith B. 2025**. Savanna ecosystem structure and productivity along a rainfall gradient: the role of competition and stress tolerance mediated by plant functional traits. *Biogeosciences* **22**: 6153–6171. doi: 10.5194/bg-22-6153-2025

Pérez-Harguindeguy N, **Díaz S**, **Garnier E**, ***et al.*** **2013**. New handbook for standardised measurement of plant functional traits worldwide. *Australian Journal of Botany* **61**: 167–234. doi: 10.1071/BT12225

Pilon NAL, **Campos BH**, **Durigan G**, ***et al.*** **2023**. Challenges and directions for open ecosystems biodiversity restoration: an overview of the techniques applied for Cerrado. *Journal of Applied Ecology* **60**: 849–858. doi: 10.1111/1365-2664.14368

Pilon NA, **Cava MG**, **Hoffmann WA**, **Abreu RC**, **Fidelis A**, **Durigan G. 2021**. The diversity of post-fire regeneration strategies in the cerrado ground layer. *Journal of Ecology* **109**: 154–166. doi: 10.1111/1365-2745.13456

Pivello VR, **Martins M**, **Christianini AV**, **Carmignotto AP**, **Gomes BF**, **Fidelis A. 2025**. Fire in the Cerrado. In: **Fidelis A**, **Pivello VR.** eds. *Fire in the south American ecosystems. Ecological studies*, Vol. **250**. Cham: Springer, Pp 113-155. doi: 10.1007/978-3-031-89372-8_5

Pontara V, **Dexter KG**, **Rezende VL**, **Da Silva VFB**, **Campos PV**, **Bueno ML. 2025**. Disentangling the evolutionary history of the woody species in Earth's most diverse tropical savanna. *Journal of Biogeography* **52**: e15160. doi: 10.1111/jbi.15160

Poschlod P, **Mašková T**, **Chen S-C**, ***et al.*** **2026**. A handbook for standardised measurements of plant reproductive traits: from pollen grain to seedling. *Australian Journal of Botany* **74**, BT25074. doi: 10.1071/BT25074

Ratnam J, **Bond WJ**, **Fensham RJ**, ***et al.*** **2011**. When is a 'forest' a savanna, and why does it matter? *Global Ecology and Biogeography: A Journal of Macroecology* **20**: 653–660. doi: 10.1111/j.1466-8238.2010.00634.x

Ratter JA, **Bridgewater S**, **Ribeiro JF. 2003**. Analysis of the floristic composition of the Brazilian cerrado vegetation III: comparison of the woody vegetation of 376 areas. *Edinburgh Journal of Botany* **60**: 57–109. doi: 10.1017/S0960428603000064

Ribeiro JF, **Walter BMT. 2008**. As principais fitofisionomias do bioma Cerrado. In: **Sano S.M**, **Almeida SP**, **Ribeiro JF.** eds. *Cerrado: ecologia e flora. Ecologia e flora*. Brasília: Embrapa, 151–222.

Roddy AB, **Martínez-Perez C**, **Teixido AL**, ***et al.*** **2021**. Towards the flower economics spectrum. *New Phytologist* **229**: 665–672. doi: 10.1111/nph.16823

Rossatto DR, **Da Silveira Lobo Sternberg L**, **Franco AC. 2013**. The partitioning of water uptake between growth forms in a Neotropical savanna: do herbs exploit a third water source niche? *Plant Biology* **15**: 84–92. doi: 10.1111/j.1438-8677.2012.00618.x

Rossatto DR, **Franco AC. 2017**. Expanding our understanding of leaf functional syndromes in savanna systems: the role of plant growth form. *Oecologia* **183**: 953–962. doi: 10.1007/s00442-017-3815-6

Rossatto DR, **Scalon MC. 2026**. Carbon starvation as a mechanistic explanation for the gradual decline of savanna ground-layer species under tree encroachment. *Annals of Botany* mcag122. doi: 10.1093/aob/mcag122

Saatkamp A, **Cochrane A**, **Commander L**, ***et al.*** **2019**. A research agenda for seed-trait functional ecology. *New Phytologist* **221**: 1764–1775. doi: 10.1111/nph.15502

Sankaran M, **Hanan NP**, **Scholes RJ**, ***et al.*** **2005**. Determinants of woody cover in African savannas. *Nature* **438**: 846–849. doi: 10.1038/nature04070

Santos LF, **Ruchkys UA. 2025**. A geospatial insight into farmland abandonment in Matopiba: the emerging frontier of Brazilian agriculture. *Regional Environmental Change* **25**: 66. doi: 10.1007/s10113-025-02401-0

Scogings PF, **Sankaran M.** eds. **2019**. *Savanna woody plants and large herbivores*. Hoboken, NJ: Wiley. doi: 10.1002/9781119081111

Segura-Garcia C, **Alencar A**, **Arruda VLS**, ***et al.*** **2025**. The fire regimes of the Cerrado and their changes through time. *Philosophical Transactions of the Royal Society B: Biological Sciences* **380**: 20230460. doi: 10.1098/rstb.2023.0460

Segura-Garcia C, **Janssen TA**, **Libonati R**, ***et al.*** **2026**. Human ignitions dominate the fire regimes of the Brazilian Cerrado. *Communications Earth & Environment*. doi: 10.1038/s43247-026-03633-6

Serrano FC, **Marconi V**, **Deinet S**, ***et al.*** **2025**. Knowledge from non-English-language studies broadens contributions to conservation policy and helps to tackle bias in biodiversity data. *Journal of Applied Ecology* **62**: 2148–2162. doi: 10.1111/1365-2664.70092

Siebert F, **te Beest M**, **Fynn R**, ***et al.*** **2024**. Past, present, and future of forbs in old-growth tropical and subtropical grasslands. *Annual Review of Ecology, Evolution, and Systematics* **55**: 395-421. doi: 10.1146/annurevecolsys-102722-022331

Siefert A, **Violle C**, **Chalmandrier L**, ***et al.*** **2015**. A global meta-analysis of the relative extent of intraspecific trait variation in plant communities. *Ecology Letters* **18**: 1406–1419. doi: 10.1111/ele.12508

Silveira FAO, **Messeder JVS**, **Fuzessy LF. 2026**. Fruit traits: the ugly duckling in the whole spectrum of plant form and function. *New Phytologist* **250**: 2001–2006. doi: 10.1111/nph.71008

Simon MF, **Grether R**, **De Queiroz LP**, **Skema C**, **Pennington RT**, **Hughes CE. 2009**. Recent assembly of the Cerrado, a neotropical plant diversity hotspot, by in situ evolution of adaptations to fire. *Proceedings of the National Academy of Sciences of the United States of America* **106**: 20359–20364. doi: 10.1073/pnas.0903410106

Staver AC, **Archibald S**, **Levin SA. 2011**. The global extent and determinants of savanna and forest as alternative biome states. *Science* **334**: 230–232. doi: 10.1126/science.1210465

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Strassburg BBN, **Brooks T**, **Feltran-Barbieri R**, ***et al.* 2017**. Moment of truth for the Cerrado hotspot. *Nature Ecology & Evolution* **1**: 0099. doi: 10.1038/s41559-017-0099

Violle C, **Navas M**, **Vile D**, ***et al.* 2007**. Let the concept of trait be functional! *Oikos* **116**: 882–892. doi: 10.1111/j.0030-1299.2007.15559.x

Weemstra M, **Mommer L**, **Visser EJW**, ***et al.* 2016**. Towards a multidimensional root trait framework: a tree root review. *New Phytologist* **211**: 1159–1169. doi: 10.1111/nph.14003

Weigelt P, **König C**, **Kreft H. 2020**. GIFT – A Global Inventory of Floras and Traits for macroecology and biogeography. *Journal of Biogeography* **47**: 16-43. doi: 10.1111/jbi.13623

Wigley BJ, **Charles-Dominique T**, **Hempson GP**, ***et al.* 2020**. A handbook for the standardised sampling of plant functional traits in disturbance-prone ecosystems, with a focus on open ecosystems. *Australian Journal of Botany* **68**: 473–531. doi: 10.1071/BT20048

Wright IJ, **Reich PB**, **Westoby M**, ***et al.* 2004**. The worldwide leaf economics spectrum. *Nature* **428**: 821–827. doi: 10.1038/nature02403

Zanzarini V, **Rossatto DR**, **Fidelis A. 2025**. Changes in plant flammability-related traits to fire regime characteristics and biomass conditions in the Cerrado. *American Journal of Botany* **112**: e70110. doi: 10.1002/ajb2.70110

Zhou Y, **Bomfim B**, **Bond WJ**, ***et al.* 2023**. Soil carbon in tropical savannas mostly derived from grasses. *Nature Geoscience* **16**: 710–716. doi: 10.1038/s41561-023-01232-0

Zhou Y, **Case MF**, **Staver AC. 2025**. Root trait (multi)functionality in savanna trees: progress and challenges. *The Journal of Ecology* **113**: 1022–1041. doi: 10.1111/1365-2745.70016

Zizka A, **Silvestro D**, **Andermann T**, ***et al.* 2019**.CoordinateCleaner: standardized cleaning of occurrence records from biological collection databases. *Methods in Ecology and Evolution* **10**: 744–751. doi: 10.1111/2041-210X.13152

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