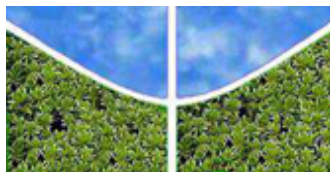


UNIVERSIDADE DE BRASÍLIA
INSTITUTO DE CIÊNCIAS BIOLÓGICAS
DEPARTAMENTO DE BOTÂNICA
PROGRAMA DE PÓS-GRADUAÇÃO EM BOTÂNICA

**FITOFISIONOMIAS RUPESTRES NA ESTAÇÃO
ECOLÓGICA DA UnB - FAZENDA ÁGUA LIMPA,
DISTRITO FEDERAL, BRASIL**

ROSA CRISTINA DA CONCEIÇÃO CARTAGENES

Brasília – DF
Maio 2026



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Dissertação apresentada ao Programa de Pós-Graduação em Botânica do Departamento de Botânica, Instituto de Ciências Biológicas da Universidade de Brasília (UnB) como parte dos requisitos necessários para obtenção do título de Mestre em Botânica

Aluna: Rosa Cristina da Conceição Cartagenes

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Brasília, DF

Mai 2026

FITOFISIONOMIAS RUPESTRES NA ESTAÇÃO ECOLÓGICA DA UnB - FAZENDA ÁGUA LIMPA, DISTRITO FEDERAL, BRASIL

Trabalho realizado junto ao Programa de Pós-Graduação em Botânica da Universidade de Brasília, como requisito parcial para a obtenção do título de Mestre em Botânica.

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“Olhai os lírios do campo, como eles crescem: não trabalham, nem fiam...

E eu vos digo que nem mesmo Salomão, em toda a sua glória, se vestiu como qualquer um deles!”

Jesus Cristo, Evangelho Segundo São Mateus, séc. I d.C.

"...O sertão aceita todos os nomes: aqui é o Gerais,
lá é o Chapadão, lá acolá é a caatinga..."
..."Os lugares sempre estão aí em si, para
confirmar..."

"...Esses Gerais em serras planas, beleza por ser
tudo tão grande, repondo a gente pequenino..."

“Grande Sertão: Veredas”, J. Guimarães Rosa, 1956

In Memoriam

Sra. Rosalia Conceição Cartagenes: Dona Rosinha

Sr. Luiz de França Cartagenes: o Lói ...

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Ao Eterno: “*todas as coisas foram feitas por Ele e sem Ele nada do que foi feito se fez*”.

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INTRODUÇÃO GERAL

O Cerrado Brasileiro é reconhecido como a savana tropical mais biodiversa do planeta: um notável *hotspot* ambiental (Mittermeier *et al.* 1999), com a mais rica flora vascular em ambiente savânico no mundo (Ratter *et al.* 1997). Caracterizado como um mosaico hiperdiverso em ecossistemas savânicos, campestres e florestais (Eiten 1978, Ribeiro & Walter 2008), sua flora vascular abriga quase 13.000 espécies (Flora e Funga do Brasil, 2026). É o segundo maior bioma da América Latina e do Brasil, estendendo-se por cerca de 203.644.800 hectares (2.036.448 km²), 23,9% do território brasileiro (MAPBIOMAS 2025). Seus ecossistemas abertos, que se desdobram em feições campestres e savânicas, estão entre os mais pressionados por mudanças do uso do solo e consequente degradação de vastas extensões do bioma, com perdas críticas de habitats e alto risco de extinção de espécies. A conversão e perda de cobertura vegetal nativa é estimada em mais de 50% do bioma (Alencar *et al.* 2020, IBGE 2020), num lapso temporal acelerado, que tem superado a velocidade da destruição de biomas icônicos como a Amazônia e a Mata Atlântica. Formações savânicas foram as áreas mais desmatadas nas estatísticas recentes de desmatamento no país - 52,4% - (MAPBIOMAS 2025), e no Cerrado a degradação concentra-se principalmente em áreas savânicas e campestres, com ênfase na expansão agropastoril.

Ecossistemas não-florestais representam cerca de 27% da cobertura vegetal nativa do Brasil (Overbeck *et al.* 2022). Vegetação campestre graminosa e savanas esclerófilas ocorrem em grandes extensões no Cerrado, mas também dispersas em outros biomas brasileiros (Overbeck *et al.* 2015, Fernandes *et al.* 2016, Sano *et al.* 2019). Ecossistemas não-florestais, ecossistemas graminosos e campestres (Bond & Parr 2010, Overbeck *et al.* 2015) ou simplesmente flora herbáceo-arbustiva (Amaral *et al.* 2017), têm se tornado uma preocupação crescente quanto à sua proteção legal, considerando-se sua importância crucial na estrutura das comunidades biológicas e na manutenção da biodiversidade global, bem como pelos serviços ecossistêmicos essenciais prestados (Soares *et al.* 2021, Buisson *et al.* 2021, Overbeck *et al.* 2022). Pesquisadores igualmente têm observado a subvalorização e negligência histórica que as sociedades humanas têm relegado a estes ecossistemas abertos, destituídos de maiores atenções, reconhecimento e valoração social, bem como superexpostos à devastação pela ausência de políticas públicas adequadas à conservação e restauração de extensas áreas naturais degradadas e ocupadas por atividades econômicas que eliminam sua biodiversidade e inviabilizam seus ciclos vitais e serviços ecossistêmicos (Veldman *et al.* 2015, Amaral *et al.* 2017).

Olhar sócio-histórico: a “ditadura da árvore” nas políticas ambientais brasileiras

No Brasil, certamente o viés da primazia da vegetação florestal em detrimento à herbáceo-arbustiva tem origem em profundas raízes históricas e sociológicas, remontando ao século XVI e reportando ao próprio evento colonizador, construído no repertório europeu dos descobrimentos de além-mar, de terras e povos selvagens ornados por litorais florestais e paradisíacos da Mata Atlântica (Ribeiro 1996). O primeiro ciclo econômico nas Américas, gerador de lucros estáveis e importantes para a Coroa Portuguesa, se consubstanciou no extrativismo de um produto florestal - o pau-brasil, *Paubrasilia echinata* (Lam.) Gagnon, H.C.Lima & G.P.Lewis - de tamanha proeminência econômica e cultural que atribuiu o nome definitivo à terra - Brasil (Dias *et al.* 1921). Significativamente, até a atualidade o sobrenome mais utilizado no Brasil, teoricamente reportando às famílias portuguesas que colonizaram o interior florestal do território, é o Silva - proveniente latino de *selva*, floresta (IBGE 2016). Ao longo dos séculos, a construção da identidade e publicidade da exuberância tropical do Brasil - destacado sobretudo por sua biodiversidade - propagada por escribas e religiosos e registrada por naturalistas e artistas em suas espetaculares viagens (p. ex., Rodrigues-Ferreira 1783-1792; Debret 1816-1831; Spix & Martius 1817-1820; Saint-Hilaire 1816-1831; Wallace 1823; Coudreau, 1895-1896), dispôs da ênfase dos ciclos econômicos que se sucedem no Brasil, onde produtos arbóreos foram elementos fundamentais e força motriz das transformações econômicas. Do pau-brasil à seringueira - *Hevea brasiliensis* (Willd. ex A.Juss.) Müll.Arg., que ainda no século XX sustentou um ciclo econômico tardio (Rocha 2025), nossa história de sucessos econômicos e degradação ambiental é profundamente entrelaçada às florestas e árvores do Brasil.

Alguma atenção aos campos e savanas viria apenas no século XVIII, principalmente em forma de exploração fortemente predatória, a partir da descoberta de impressionantes jazidas auríferas e de outros minerais preciosos, promovendo o deslocamento da economia e a interiorização urbana para as Minas Gerais, no interior do Sudeste Brasileiro; posteriormente, para Goiás, já em pleno Centro-Oeste. Ouro Preto, Diamantina, Cristalina e uma extensa toponímia minerária desde então se estendeu do sudeste para o centro-norte do território nacional, batizando em suas rotas os acidentes geográficos, a fauna e flora representativa com epítetos nativos (Saint-Hilaire 1941) dos povos destituídos de seus modos de vida (frequentemente, da própria vida) nestes sertões e veredas interioranos (Sick 1957).

Acompanhando tal enredo, as políticas ambientais no país se sucederam, se não superestimando os ecossistemas florestais, nitidamente ignorando as feições abertas, arbustivas e graminosas que se estendiam por uma infinidade de quilômetros pelo Brasil Central até parte do litoral norte e nordeste do país. A primeira legislação de proteção ambiental do Brasil, promulgada pela Coroa Portuguesa em 1605 - Regimento do Pau-Brasil - previa penalidades severas para limitar a exploração da valiosa madeira, cuja extração excessiva já tornava insustentável o volume de negócios lucrativos. Em 1850, a Lei de Terras criminalizava o corte ilegal de “madeira-de-lei” e o uso do fogo em áreas florestais. Mais de três séculos depois, na República, surge a primeira legislação consolidada e específica de proteção ambiental - o Decreto nº 23.793 de 1934, conhecido como o primeiro “Código Florestal Brasileiro” - onde, novamente, é o elemento arbóreo-florestal que define o escopo das preocupações ambientais nacionais (Moura *et al.* 2023). Desde então, sucessivas políticas públicas foram expressas em “códigos florestais” (1965, 1994 e 2012), sendo que o mais recente - Lei nº 12.651/2012 - embora afirme dispor “sobre a proteção da vegetação nativa”, sua popularização persistiu sob a designação de “Novo Código Florestal”. Isso reflete o nítido viés de preponderância arbórea no entendimento popular e governamental referente às prioridades de conservação.

Nas últimas décadas, estudiosos têm reforçado a urgência em registrar e mapear a riqueza biodiversa do Cerrado, sobretudo nos ecossistemas herbáceo-arbustivos, que apresentam maior riqueza em espécies e elevado grau de endemismo, contribuindo com seis vezes mais espécies do que as plantas arbóreas (Filgueiras 2002; Mendonça *et al.* 2008, Brazil Flora Group [BFG] 2015) e com alto grau de dissimilaridade entre suas diversas feições (Batalha & Martins 2007). Grande parte dos levantamentos florísticos e estudos fitossociológicos no Cerrado até a última década focaram os hábitos arbóreos e seus componentes lenhosos (Ratter *et al.* 1997, Ratter *et al.* 2003, Moura *et al.* 2007; Lima *et al.* 2010; Solórzano *et al.* 2012; Medeiros & Walter 2012, entre outros), e o conhecimento científico tornou-se proporcionalmente escasso para o estrato herbáceo-arbustivo que caracteriza campos e savanas (Furley & Ratter 1988, Munhoz & Felfili 2006; Parr *et al.* 2014). São fitofisionomias negligenciadas a despeito de sua extrema relevância, tanto por sua riqueza megadiversa quanto pelos serviços ecossistêmicos fundamentais associados (Alves *et al.* 2014, Durigan *et al.* 2018, Bonanomi *et al.* 2019, Miola *et al.* 2021), exigindo estudos aprofundados para a compreensão das complexas relações e trocas bióticas entre comunidades muito diversas que se sobrepõem (Marques *et al.* 2019).

Entre as fitofisionomias proporcionalmente menos estudadas destaca-se o Cerrado Rupestre: de ocorrência esparsa e fragmentada no bioma, trata-se de um subtipo de vegetação arbóreo-arbustivo que ocorre em ambientes rupestres litólicos, com cobertura arbórea variável de 5% a 20% e altura média de 2 a 4 metros, comportando substrato limitado a solos rasos entre afloramentos rochosos; predominantemente em terrenos de altitude (Ribeiro & Walter 1998, 2008, Pinto *et al.* 2009). Já a fitofisionomia herbáceo-arbustiva aqui destacada, o Campo Rupestre, enquanto fitofisionomia do Cerrado, é definido por Ribeiro & Walter (1998, 2008) como um “tipo fitofisionômico predominantemente herbáceo-arbustivo”, um “complexo de vegetação que agrupa paisagens em microrrelevos com espécies típicas”.

Nas últimas décadas os Campos Rupestres têm sido objeto de estudos ecológicos e florísticos que os colocam além de fitofisionomia do Cerrado: são ecossistemas descritos como “savanas montanas megadiversas” (Alves & Kolbek 2010, Fernandes *et al.* 2016). Comportando cerca de 15% da diversidade florística brasileira em menos de 0,8% de área territorial do país (Silveira *et al.* 2016, Zappi *et al.* 2017, Neves *et al.* 2018), o Campo Rupestre no Brasil têm sido referenciado como província fitogeográfica (Colli-Silva *et al.* 2019), a partir de análises florísticas e filogenéticas (Vasconcelos *et al.* 2020, Padilha *et al.* 2024) que sobretudo confirmam seu extraordinário nível de endemismo, refletidos por contínuos e consistentes trabalhos de coleta e pesquisa envidados por diversos cientistas históricos (Magalhães 1966, Joly 1970, Rizzini 1979, Ferri 1980, Eiten 1983, Giulietti & Pirani 1988, Harley 1995, Giulietti *et al.* 1997, citando apenas alguns), que há muito dedicam atenção e foco público sobre este ecossistema extraordinário.

O interesse ecológico sobre as feições rupestres altitudinais tem sido relativamente tardio no Brasil; no entanto, na última década verifica-se a intensificação e multiplicidade de estudos e questionamentos classificatórios para identificação, registro e esforços de proteção viáveis para a conservação destes mosaicos vegetacionais hiperdiversos que não dispõem de categorização de consenso (Alves *et al.* 2014, Silveira 2017, Mucina 2018). Contextualmente, estudos para a caracterização florística e ecológica dos ambientes rupestres na porção mais extensa do Cerrado - o Planalto Central do Brasil - eram relativamente escassos, com o crescimento de interesse por sua pesquisa marcadamente após o ano 2000 (Pereira & Fernandes 2022, Mews *et al.* 2014, Maracahipes *et al.* 2011, Moura *et al.* 2011, Lenza *et al.* 2011, Lima *et al.* 2010, Pinto *et al.* 2009), e são de grande relevância como contribuição ao conhecimento, à conservação e à construção de políticas públicas adequadas e

imprescindíveis para a proteção de porções significativas da biodiversidade nacional e mundial.

Deste modo, a presente dissertação tem como objetivo contribuir para o conhecimento florístico sobre o Campo Rupestre e o Cerrado Rupestre no Brasil Central, e está dividida em dois capítulos. O primeiro visa realizar um levantamento bibliográfico sistematizado para revisar a aplicação dos conceitos de Cerrado Rupestre e Campo Rupestre, tanto como fitofisionomias como complexos mosaicos de vegetação de altitude. O segundo capítulo buscou mapear e caracterizar fitofisionomias rupestres na Estação Ecológica da Universidade de Brasília (EEUnB), situada na Fazenda Água Limpa (FAL), DF (Figura 1), deste modo contribuindo para a identificação de ecossistemas vulneráveis e *hotspots* de biodiversidade no Cerrado do Distrito Federal.



Figura 1. Vista do horizonte da paisagem campestre em relevo ondulado, a partir de platô rupestre (aproximadamente 1.200m de altitude) em antigo mirante na Estação Ecológica da Fazenda Água Limpa, Distrito Federal (foto Rosa Cartagenes, fev.2024).

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CAPÍTULO I. *CAMPO RUPESTRE* AND *CERRADO RUPESTRE*: A REVIEW OF THE TERMS AND THEIR APPLICATION IN BRAZIL¹

Abstract

Non-forest ecosystems, rich in biodiversity and endemic species, have been, to some extent, neglected in terms of research and conservation when compared to the tree component of tropical forests. Two of these ecosystems, the *campo rupestre* and the *cerrado rupestre*, occur in the Brazilian highlands and have been used under different concepts, leading to debate regarding their characteristics and biogeography. This review of the terms “*campo rupestre*” and “*cerrado rupestre*” in scientific and historical literature aims to document the evolution of their use, the different meanings in which they have been employed, and to suggest an alternative way to clarify their usage. A scoping review, combined with a systematic review, was conducted in the Web of Science and Google Scholar databases using a Boolean search method, including their English equivalents (*rocky fields*, *rocky grasslands*, *rupestrian grasslands*, *rupestrian cerrado*, and *rupestrian savanna*), to observe the historical evolution of identification, characterization, and descriptors. “*Cerrado rupestre*” and its English versions yielded 55 indexed results in *Web of Science* and 2,140 citations in *Google Scholar*. “*Campo rupestre*” and its English versions were mentioned 1,006 times in *Web of Science* and 15,500 times in *Google Scholar*. The Web of Science search was refined by geographic restriction, subject filtering by topic, and by fields of knowledge, with a focus on Ecology and Biodiversity within Plant Sciences. The Google Scholar platform was used as a supplementary source of non-indexed texts and publications, which proved relevant to the historical and conceptual development of both terms. Additional items were suggested by experts to supplement the final lists provided. A selection of publications is presented that document the history of the classification of open, herbaceous-shrubby upland vegetation in Brazil during the 19th and 20th centuries, with an emphasis on the *campo rupestre*, along with a post-2000 analysis of the most relevant items that demonstrate different conceptions and delimitations of the terms *campo rupestre* and *cerrado rupestre*. The *cerrado rupestre* proved to be much less frequent in the literature, and its history and conceptualization were traced from the late 20th century to the present day. We selected 27 relevant texts for each term to develop our discussions. The terminology for *campo rupestre* is discussed in light of

¹ Translated and formatted for The Botanical Review – NYBG

its altitudinal range and geographic coverage, the concept of peinobiomes, the application of Ocbil's theory, and a proposal to use broader (*lato sensu*) and more restricted (*stricto sensu*) qualifiers for this term. The *cerrado rupestre*, defined as a savannic plant physiognomy associated with rock outcrops, is not defined by the altitude, with studies concentrated in Central-Western Brazil. Basic research, combined with ecological and conservation programs, is still needed to inform and consolidate effective public policies in prioritizing these unique environments.

Keywords: Boolean searches, Brazil, Cerrado, grasslands, high-altitude vegetation, rock outcrops, rupestrian phytophysiognomies, savanna.

Introduction

Unlike the well-known lush forests, the presence of herbaceous-shrubby vegetation in Brazil has been neglected, attracting less attention even when considering how biodiverse and rich in endemism this vegetation can be (Overbeck *et al.* 2022). Open landscapes and associated ecosystems with rocky substrates at high altitudes have been known by different names and definitions throughout the history of botany. In eastern Brazil, the interest and enthusiasm shown by the first European naturalists who encountered these mountainous landscapes while exploring and collecting plants for the *Herbier Impérial du Brésil* were remarkable (Pignal *et al.* 2012). The earliest modern descriptions date back to the early 19th century, when Saint-Hilaire (1779–1853) stated that the montane fields (*campos montanos*) crown table mountains or *plateaus* (*taboleiros*) with “hard, dry vegetation on soils consisting only of rocks, stones, and coarse white quartz sand” (Saint-Hilaire, 1941). The author also mentions that it took a long time to analyze the numerous plants collected there, in what can be considered a very early report on the plant diversity found in these high-altitude mountains. In 1892, Eugen Warming (Warming, 1973), while studying the Cerrado in Lagoa Santa, Minas Gerais, considered altitude to be the most important factor in the establishment of this open vegetation, thus describing an “alpine” flora, similar to the herbaceous-shrubby vegetation found on the rocky outcrops of the European Alps. During the first half of the last century, this mountainous flora was referred to as *campo alpestre* and *campo alpino* (A. A. Silveira, 1922; Sampaio, 1938; Mello-Barreto, 1942). Rizzini (1963) used the term “*campos altimontanos*”, including in this category Brazilian ecosystems above 1,000 m a.s.l. Finally,

Magalhães (1966), while studying the Cerrado in Minas Gerais, coined the term “*campo rupestre*” to refer to the flora found on quartzite substrate at altitudes generally above 1,000 m a.s.l., combining a specific substrate with the altitudinal factor. (Joly, 1970) uses this same term for a broader concept, including the high-altitude vegetation of Minas Gerais and the state of Goiás, on quartzite or sandstone substrates, also adding the metamorphic igneous rocks on the highest mountain in Eastern Brazil (Pico da Bandeira, Caparaó National Park, states of Minas Gerais and Espírito Santo) as well as those found in the highest sections of the Serras do Mar and Mantiqueira ranges (Serra dos Órgãos National Park and Itatiaia National Park, Rio de Janeiro).

After this period, the term *campo rupestre* came to be frequently used in scientific literature. Rizzini (1979) was the first author to subdivide the *campo rupestre* into various substrate categories, such as the ferruginous substrate (*campo de canga couraçada*), specifically for outcrops of lateritic crust (or iron ore) in the Iron Quadrangle (Minas Gerais); quartzite substrate (*campo quartzítico*) along the Espinhaço Range (Minas Gerais and Bahia) and on igneous or metamorphic rocks (*campo altimontano*) for the Serras do Mar and Mantiqueira ranges (São Paulo/Rio de Janeiro/Espírito Santo). The subdivision of the *campo rupestre* substrate was restricted by Ferri (1980) and Eiten (1983) to include only vegetation on quartzite substrate, while the igneous (granitic, gneissic) and metamorphic substrates further to the east and southeast were referred to as *campo de altitude* (Ferri, 1980) or *campo montano* (Eiten, 1983). Ribeiro *et al.* (1983) propose a new classification system with an identification key for the vegetation types of the Cerrado, referring to the high-altitude vegetation complex of Central Brazil (Goiás and Federal District - DF) as *highland rupestre vegetation*. The research group of Giulietti *et al.* (1987) and Giulietti & Pirani (1988) established the use of the term *campo rupestre* for floristic purposes in the states of Minas Gerais and Bahia, describing it as a mosaic of plant communities found on quartzite (or sandstone) substrate and above 900 m a.s.l., with different habitats ranging from dry and flooded open fields to vegetation growing on rocky outcrops. These types are determined by factors such as local topography, microclimate, and the accumulation of organic matter in the substrate, but there is a general predominance of herbaceous and shrubby plants. Semir (1991) divided high-altitude vegetation in Eastern and Central Brazil into complexes, proposing the “altitude rupestrian complex on quartzite” and the “altitude rupestrian complex on granite.” Zoologists (Parker & Rocha, 1991) used the term *campo rupestre* in the context of the Bolivian savanna. Eiten (1992) established the similarity between the *campo rupestre* on quartzite substrates and other minerals (iron ore, manganese, bauxite) in the Espinhaço

Range (Minas Gerais and Bahia) and in the Chapada dos Veadeiros (Goiás). Prance (1994) referred to the *campo rupestre* as an archipelago of highlands (as ‘*campo rupestre* archipelago’). Harley (1995) used the term *campo rupestre* to describe the mosaic of vegetation found in the elevated areas of the Espinhaço Range (Minas Gerais and Bahia) and in Goiás (Chapada dos Veadeiros), on strongly acidic rocks, establishing the differences between the *campo rupestre* in Bahia and the surrounding Caatinga and local forests, and in relation to the *campos de altitude* found further south and east, in the Serra do Mar and the Serra da Mantiqueira. A very similar definition was used by Kuhlmann et al. (1994) for the vegetation of the Serra do Espinhaço in Minas Gerais, although they slightly modified the term to *campos montano-rupestres*.

The definitions by Giulietti & Pirani (1988), Kuhlmann (1994), Harley (1995), and Giulietti & Pirani (1997) include a mosaic of vegetation types above 900 or 1000 m a.s.l.; however, these do not refine a classification of the different vegetation types within the *campo rupestre*, sometimes including high-altitude forests, grasslands and wetlands, for practical purposes, mainly for floristic surveys. This broader definition by the aforementioned authors contrasts with the more descriptive and restricted vegetation types defined by Ribeiro & Walter (1998, 2008), describing the type of herbaceous-shrubby vegetation found at altitudes above 900 m a.s.l., occupying highly dystrophic substrates associated with rocky outcrops, recognizing the existence of *campo rupestre* in Minas Gerais and Bahia. The *campo rupestre* is included among open (*campestre*) vegetation, alongside *campo sujo* (grassland with sparse shrubs) and *campo limpo* (‘clear’ grassland) (Ribeiro & Walter, 1998), in Cerrado biome.

These authors also adopted the term *cerrado rupestre*, first coined by Oliveira Filho & Martins (1986) in reference to a vegetation physiognomy, as a subtype of the *cerrado stricto sensu*, characterized by the presence of trees and shrubs embedded in a continuous layer of herbaceous and grassy vegetation, which, in the case of the *cerrado rupestre*, is distributed over stony or rocky substrate. The *cerrado rupestre* is thus interpreted as a phytophysiology, alongside the *dense cerrado*, the *typical cerrado*, and the *sparse cerrado*. The rocks in question are sandstone or quartzite, forming shallow, acidic, and poor soils (Ribeiro & Walter, 1998) (see Table 1).

After the year 2000, most authors reiterated the use of the term *campo rupestre* (e.g., Alves et al. 2007; Alves & Kolbek, 2010; Echternacht et al. 2011; Pinto et al., 2011; Fernandes et al., 2016; Colli-Silva et al., 2019; Bueno et al., 2021—see Table 2). The term *cerrado rupestre* has been used by many authors over the past decade (e.g., Lima et al. 2010, Pinto et al. 2011,

Lenza *et al.* 2011, Mews *et al.* 2014, Negreiros *et al.* 2014; Zappi *et al.* 2014; Schaefer *et al.* 2016; Fernandes *et al.* 2018; Pinto *et al.* 2021—see Table 3).

Given the different terms and their interpretations used to characterize and define rupestrian ecosystems in Brazil, the need arose to conduct a systematic review of the terms *campo rupestre*, *cerrado rupestre* and their English equivalents (highland rocky field, rocky grassland, rupestrian grassland, and, for *cerrado rupestre*, rupestrian cerrado, rupestrian savanna or savannah) to support current research on high-altitude vegetation types in the Distrito Federal (located within the state of Goiás), where there is a perception that these vegetation types are currently understudied. We also aim to improve the understanding and application of the terms “*campo rupestre*” and “*cerrado rupestre*” and move toward standardizing the terms and their meanings, in order to provide a more solid basis for prioritizing the conservation of these vegetation complexes.



Figure 1. Team collecting in a seasonally flooded *campo rupestre* in Ecological Station of UnB, FAL – DF, in an area dominated by *Lagenocarpus rigidus* Nees (Cyperaceae) (photo Camila Castro, March 2025).

Materials and Methods

Scope review. Compilation of the history of the term *campo rupestre*. The historical review that underlies the introduction (Table 1) was compiled by searching and selecting references

by year of first publication and identifying authors who described this vegetation and exerted scientific influence during this period, mainly using the Google Search and Google Scholar platform (2025). It can be understood as a scoping review, since it focused on articles, books, and theses prior to the 21st century that were not readily available in digital format. Bibliographic references for these texts or direct access to original texts were verified in other sources Scope Review. Compilation of the history of the term "campo rupestre" (rocky field). The historical review that underpins the introduction (Table 1) was compiled by searching and selecting references by year of first publication and identifying authors who described this vegetation and exerted scientific influence during this period, mainly using the Google Search and Google Scholar platforms (2025). It can be understood as a scoping review, since it focused on articles, books, and theses prior to the 21st century that were not readily available in digital format. The bibliographic references of these texts or direct access to the original texts were verified in other sources (including physical books, libraries, and private collections) to obtain a more comprehensive view of the different concepts involving the vegetation of the Brazilian highlands.

Systematic review. A systematic literature review was conducted, searching for the Portuguese terms “campo rupestre” (and English variants “rocky fields”, “rocky grasslands”, and “rupestrian grasslands”) and “cerrado rupestre” (and English variants “rupestrian cerrado” and “rupestrian savanna” or “savannah”), both as isolated expressions and as terms combined with Boolean addition, concurrency and exclusion connectors. The searches were conducted in the Web of Science Core Collection (Web of Science, 2025) in September 2025 and in the Google Scholar database (Google Scholar, 2025) during August 2025. The latter includes other bibliographic sources, such as *Scielo*, *ResearchGate*, the Brazilian Society for the Advancement of Science (SBPC) and BioTaxa, as well as data repositories from major Brazilian universities (for theses and dissertations). The Boolean operators AND, OR, and NOT were used to generate a descriptive and quantitative search matrix (Tranfield *et al.* 2003). For searches in Web of Science, the descriptors AND (+) and OR were used as integrative connectors, whereas for Google Scholar we used the descriptors “rocky savanna” + “vegetation” and “rocky field” + “flora,” since this platform does not directly support exclusionary descriptors. Plant families, when cited, follow the Angiosperm Phylogeny Group (APG IV 2016), and botanical species follow Flora & Funga of Brazil (2025).

Refinement of the search. The resulting lists from Web of Science (2025) for *campo rupestre* and *cerrado rupestre* were then refined in a second step, initially by reading the

titles and excluding items from fields other than vegetation and ecology (e.g., zoology or exclusively geology). A more in-depth analysis of the abstracts of the remaining items led to the exclusion of those dealing with taxonomy, such as taxonomic reviews, species descriptions, or nomenclatural notes, as well as ecophysiology. These items were removed because they presented an analytical or descriptive focus on specific elements of the biology and physiology of the flora cited, without delving into the conceptual discussions of the characterization or identification of *campo rupestre* and *cerrado rupestre*.

Contemporary references (post-2000) were selected, prioritizing those with the greatest impact (number of citations, including cross-citations). In order to include important references not retrieved by the parameterized searches, additional references were obtained from the so-called ‘gray literature’ (e.g. Mahood *et al.* 2014; Woods *et al.* 2022), as various authors refer to literature not indexed in digital scientific research databases. This includes book chapters, publications in regional journals, and master’s and doctoral theses from the repositories of universities and academic institutions. It was necessary to cross-reference this alternative literature against indexed literature to investigate core information on *campo rupestre* and *cerrado rupestre* regarding topics such as vegetation and ecology, as well as to expand the referenced search based on suggestions from experts in these areas (J.R.R. Pinto & B.M.T. Walter). Abstracts from local conferences and congress presentations were excluded, e.g., since they are non-peer-reviewed publications.

Geographic scope. Items focused on countries other than Brazil were excluded from the selection, such as references to the Cerrado regions of Bolivia and Paraguay. The presence of studies involving the *campo rupestre* and *cerrado rupestre* in the Distrito Federal was targeted, directing our Web of Science (2025) search toward records in these areas.

Results

Web of Science Search

Campo Rupestre – An initial general search combining the main descriptors (all fields) “*campo rupestre*” OR “*campos rupestres*” (in Portuguese) OR “rupestrian grasslands” yielded 1,006 items. After excluding overlaps, rupestrian vegetation related to countries other than Brazil, and specifying the subject as a “topic,” the filtering yielded 489 items, distributed across 31 scientific fields, with a predominance of Plant Sciences (64.82%), followed by Ecology (17.17%) and Evolutionary Biology (14.92%) (Figure 2). The same search using only the English equivalent “rupestrian grasslands” (without citing the Portuguese

expressions “campo rupestre” or “campos rupestres”) retrieved 66 items in this database. The overlap between searches using the Portuguese expression and its English equivalent simultaneously resulted in 39 items.

A subsequent search for “*campo rupestre*” OR “*campos rupestres* + vegetation + Brazil” returned 661 results, most of which were related to the Serra do Espinhaço in the states of Minas Gerais and Bahia, Chapada Diamantina (Bahia), as well as areas on iron-rich substrates, *cangas* (Serra dos Carajás in the state of Pará, and the Iron Quadrangle in Minas Gerais). These items included ecological reports (interactions between fauna and flora) and reports on endemism in flora and fauna.

The term “rocky fields” as a topic yields 90 entries in the main *Web of Science* collection, with suggested connections to “Espinhaço range,” “campos rupestres,” “*Myrcia*,” “*Poales*,” and “*Chapada Diamantina*.” Although most citations of “rocky fields” in this database refer to Brazilian ecosystems, we also found articles regarding “rocky fields” in Japan (Okitsu & Ito, 1989), Russia (Golik *et al.* 2018), the Sahara Desert (Liz *et al.* 2023), and even on the planet Mars (Liu *et al.* 2021). Search terms such as “rocky fields”+“vegetation”+“Brazil” yielded 18 results, relating to flora and fauna in rocky ecosystems and covering various Brazilian biomes: Cerrado, Amazon, and Atlantic Forest, without specifically referring to the vegetation recognized here as *campo rupestre*.

A search using geographic delimiters based on our research focus, with the keywords “*campos rupestres*” + “Goiás,” returned 16 entries in this database, with the vast majority of articles (93.75%) published in the last decade. Entering “Distrito Federal” + “*campos rupestres*” retrieves three articles in Botany: two of which refer to new species in *Oocephalus* (Hyptidinae, Lamiaceae) and the reference article on the record of new species of Lychnophorinae from the Brazilian Central Plateau (Asteraceae:Vernonieae), including *Lychnophora planaltina*, endemic to the *campos rupestres* of the Distrito Federal (DF).

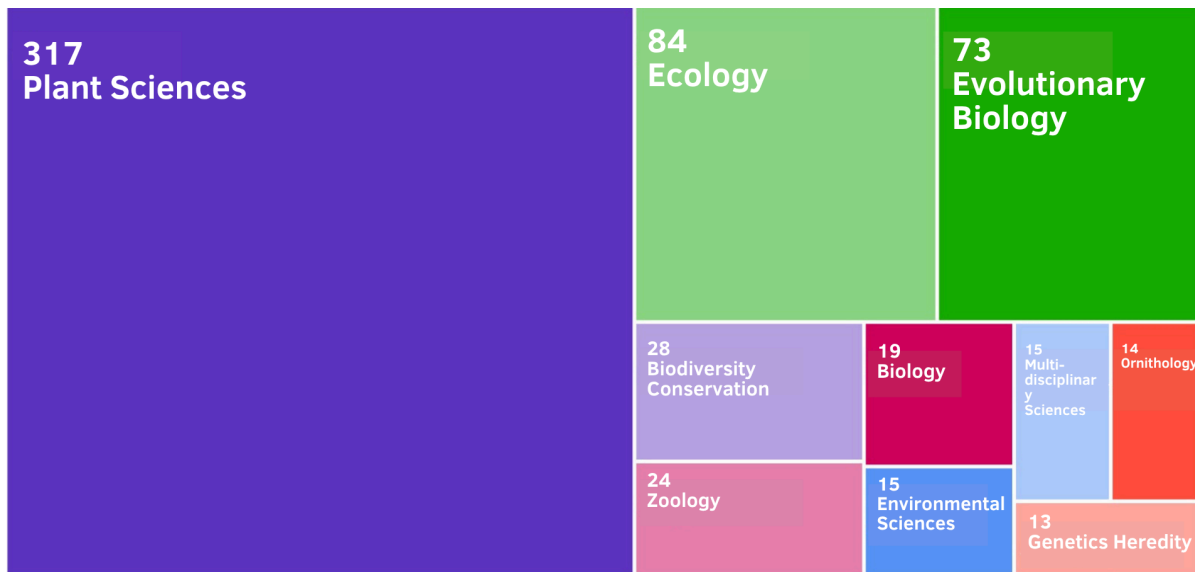


Figure 2 - Metrics of the thematic proportion involving *campo rupestre* OR *campos rupestres* AND *rupestrian grasslands* (Total: 489; 1985–2025) distributed across various fields of knowledge. Prevalence of these ten fields, from left to right: Plant Sciences, Ecology, Evolutionary Biology, Biodiversity Conservation, Zoology, Biology, Environmental Sciences, Multidisciplinary Sciences, Ornithology, Genetics and Heredity. Source: World of Science Analytics, September 2025.

Regarding the *campo rupestre*, two additional stages of analysis were conducted: from the 99 items resulting from the combination (*campo rupestre* + flora + Brazil), 57 items were initially excluded (mostly from Zoology and other fields of knowledge unrelated to flora and vegetation).

The selection of the descriptor “flora” as a restriction was optional to the descriptor “vegetation,” as we found during the research that the latter is used in the literature in a much broader sense than the former, serving as a generic reference in works across virtually all fields of knowledge. After reading the abstracts of the remaining 42 items, we eliminated those dealing with Taxonomy (descriptions of new species, systematics) and Ecophysiology. The final selection of 27 items is discussed forward (Table 2).

Cerrado Rupestre – The search for the term *cerrado rupestre* and its English equivalents—“rupestrian cerrado” or “rupestrian savanna” — in this database yielded 55 items, with just under half of the entries listed under Plant Sciences (49.09%), followed by Ecology (20%), Biodiversity Conservation (14.54%), Evolutionary Biology (9.09%) and Forestry (9.09%) (Figure 3). Of these items, 32 referred to the central areas of the Cerrado, the majority for the state of Goiás (23 items); the remainder for the states of Minas Gerais, Mato Grosso, Tocantins, and Bahia, with a single result citing the *cerrado rupestre* in the Federal District (DF) (Collevatti *et al.* 2009). By restricting the search to the research areas

“Plant Sciences”, “Environmental Sciences”, “Ecology” or “Biodiversity Conservation,” we obtained 41 items. Subsequently, we manually eliminated items related to Taxonomy and Anatomy (22), Ecophysiology (3), Phylogeography/Evolution (1), Remote Sensing (1), Conservation/Restoration (1), and those outside the study area (1). The remaining **12** items were added to Table 3, along with 21 items - many of whom were suggested by experts —Drs. Bruno Walter (Embrapa) and José Roberto Pinto (UnB) - and drawn from alternative scientific literature, and are not directly included in the most standardized databases. (Table 3)

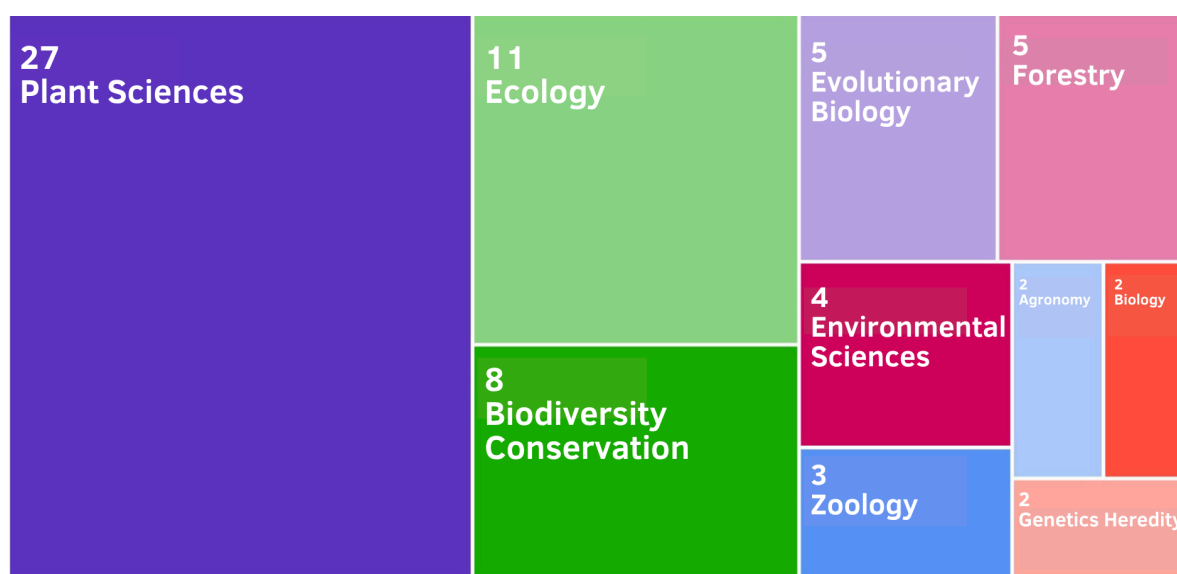


Figure 3 - Metrics of the thematic proportion related to the *cerrado rupestre* (Total: 55; 2009–2025) distributed across various fields of knowledge. Predominant, from left to right: Plant Sciences, Ecology, Biodiversity Conservation, Evolutionary Biology, Forestry, Environmental Sciences, Zoology, Biology, Agronomy, Genetics and Heredity. Source: World of Science Analytics, September 2025.

Google Scholar Search

Campo rupestre – A search for “*campo rupestre*” as a single descriptor yielded 10,100 results, while the English term “rupestrian grasslands” resulted in 1,550 items. The search terms “*campo rupestre*”+“flora”+“Brazil” yielded 7,330 results, including studies focused on the vegetation and ecology of rupestrian flora, as well as items related to biodiversity conservation, zoology, mineralogy, geology, sociology, and materials engineering. The search terms “rocky fields”+“flora”+“Brazil” yielded 945 results, and when “highlands” was added to the same search, 143 results were retrieved, including those cited as references and not necessarily about Brazil. When adding the descriptors “rupestrian grasslands”+“flora” to *Google Scholar*, 1,480 items were retrieved, with a significant number of articles on the flora, fauna, and ecology of Brazilian *campo rupestre*. The overlap of the expressions in Portuguese and English (“*campo rupestre*” + “rupestrian grasslands”) generated 712 items on this

platform. In the same database, the combined use of “*campo rupestre*”+flora+Cerrado (in Portuguese) yielded 6,220 items.

Cerrado Rupestre – A simple search for “*cerrado rupestre*” yielded 2,130 results, while the same search using the English term “rupestrian cerrado” found 120 results. However, the search for “rupestrian cerrado” + “rocky fields,” in English, found a single result regarding a new species of Parmeliaceae (Lecanoromycetes – Lichens) (Marcelli & Ribeiro, 2002).

The combination “*cerrado rupestre*”+“flora” yielded 1,660 results, but not all of these citations dealt specifically with vegetation, including many results related to fauna and geomorphology. The vast majority (about 98%) were published after the year 2000, suggesting a recent increase in awareness and interest in this topic. The simple combination of the terms “*cerrado rupestre*” + “flora” + “Brazil” yielded 89 results. An additional search for “rupestrian savanna” retrieved 25 records. The combination of “*cerrado rupestre*” + “rupestrian savanna” generated 13 items, and the combination of “rupestrian cerrado” AND “rupestrian savanna” OR “rupestrian savannah” resulted in six items.

Cross-referencing of complementary literature

Due to the high number of references prior to 2000 that address open, high-altitude vegetation in Brazil, leading to the concept of the *Campo Rupestre*, a historical overview is presented in Table 1, while Table 2 includes more recent studies that present definitions and records of high-altitude herbaceous-shrubby vegetation by geographic region. Table 1 comprises 21 historical references, not indexed in Web of Science and considered fundamental for understanding the development of this concept. Since the *Cerrado Rupestre* accounts for a smaller proportion of the studies conducted, Table 3 compiles its history and the main bibliographic items related to this term, having been enriched by 16 items not directly included in the Web of Science database, based on this research (Google Scholar database) or as suggested by experts in the field and considered important for outlining the use and consolidation of the term in the literature.

Table 1 - History of the nomenclature of open, herbaceous-shrubby high-altitude vegetation in the 19th and 20th centuries with an emphasis on the *campo rupestre* (CaR). *Cerrado rupestre*, hereinafter CeR. Abbreviations for Brazilian states: RJ – Rio de Janeiro, SP – São Paulo, MG – Minas Gerais, ES – Espírito Santo, BA – Bahia, GO – Goiás.

AUTHOR	YEAR	DESCRIPTION	Area/Occurrence
1.Saint-Hilaire	1822	<i>campo montanhoso</i>	Highlands of the Serra da Mantiqueira (RJ, SP, MG)

2.Warming	1892	<i>Highest mountain peaks covered by 'alpine flora'</i>	Lagoa Santa Karst, West of the Serra do Espinhaço, MG.
3.Silveira	1922 1924	<i>campo limpo, campo alpestre and campo alpino</i>	Open physiognomies in Brazilian mountain ranges (Serra do Cipó – MG and Caparaó – ES/MG)
4.Sampaio	1938	<i>campo alpino</i>	Mountaintops of Eastern Brazil (MG)
5.Mello-Barreto	1942	<i>campo alpino</i>	Mountaintops of Eastern Brazil (MG)
6.Azevedo	1962	<i>savana especial dos altos divisores (special savanna of the high divides)</i>	High-altitude areas in the South – MG
7.Rizzini	1963	<i>campo altimontano</i>	Stony habitats above 1,000 m a.s.l.
8.Magalhães	1966	<i>campo rupestre</i>	Exclusive to quartzitic substrate at high altitude
9.Joly	1970	<i>campo rupestre</i>	Vegetation on the highest parts of the mountains in Minas Gerais and Goiás—on quartzite or sandstone; peaks of the Caparaó, Órgãos, and Itatiaia mountains (Espírito Santo/Minas Gerais/Rio de Janeiro); on igneous or metamorphic rocks.
10.Rizzini	1979	<i>campo de canga couraçada; campo quartzítico; campo altimontano</i>	Iron-ore outcrops of the Quadrilátero Ferrífero, MG; Over quartzite outcrops along the Espinhaço Range (MG – BA); Over igneous or metamorphic rocks in the Serra da Mantiqueira and Serra do Mar (ES – RJ).
11.Ferri	1980	<i>campos rupestres</i> X <i>campos de altitude</i>	CaR: on quartzitic substrates; <i>de altitude</i> : other crystalline substrates.
12.Eiten	1983	<i>campos rupestres</i> X <i>campos montanos</i>	CaR: on quartzitic substrate; <i>montanos</i> : on granitic substrate
13.Ribeiro <i>et al.</i>	1983	<i>vegetação rupestre de altitude</i>	Plant physiognomy predominantly herbaceous-shrubby, with occasional presence of small trees. Vegetation that characterizes landscapes in micro-reliefs with typical species on rock outcrops. Altitudes above 900 m a.s.l., litholic, acidic, poor, sparse soil in rock crevices.
14.Giulietti & Pirani	1988	<i>campo rupestre</i>	Mosaic of plant communities influenced by local topography, microclimate, and substrate, generally above 900 m, steep areas with rock outcrops decomposing into sandy soils, plants mostly herbaceous-shrubby; Serra do Espinhaço (MG/BA).
15.Parker & Rocha	1991	<i>campo rupestre</i>	Altitude vegetation associated with the Bolivian Cerrado, zoological evidence related to bird distribution.

16.Eiten	1992	<i>campo rupestre</i>	Growing on both iron-ore (<i>canga</i>) and quartzitic substrates along the Espinhaço Range. Includes the Chapada dos Veadeiros (GO).
17.Prance	1994	<i>campo rupestre</i> archipelago	Mountainous region inland from the Brazilian Atlantic coast (MG – BA)
18.Kuhlmann <i>et al.</i>	1994	<i>campos montano-rupestres</i>	Highland vegetation in the Serra do Espinhaço (MG), on different substrates (quartzite, sandstone, iron ore), at high altitudes
19.Harley <i>in</i> Stannard	1995	<i>campo rupestre</i>	Vegetation mosaic found in the elevated areas of the Serra do Espinhaço (MG–BA), on strongly acidic rocks. In the Chapada Diamantina (BA), it differs from the surrounding Caatinga and the local forests.
20.Giulietti & Pirani	1997	<i>campo rupestre</i>	Herbaceous-shrubby vegetation on rocky or stony substrate, mainly in the Serra do Espinhaço (MG – BA).
21.Ribeiro & Walter	1998	<i>campo rupestre</i> and <i>cerrado rupestre</i>	CaR - Predominantly herbaceous-shrubby vegetation, encompassing a complex of vegetation that groups landscapes into micro-reliefs with typical species, distributed over rocky outcrops. Exposed to restrictive edaphic and climatic conditions, generally above 900 m in altitude, subject to strong winds and wide daily temperature variation. The soils are litholic, acidic, and strongly dystrophic. Exemplified by the Chapada Diamantina, BA. CeR – a subtype of <i>Cerrado stricto sensu</i>, with trees and shrubs and a continuous herbaceous layer, which, in the case of the <i>Cerrado Rupestre</i>, is distributed over stony or rocky substrate.

Table 2. Summary of studies presenting definitions, circumscriptions, and records of high-altitude herbaceous-shrub vegetation/*Campo Rupestre* (CaR) in Brazil since the year 2000, by geographic region (Abbreviations for Brazilian states: AM – Amazonas, BA – Bahia, CE – Ceará, ES – Espírito Santo, GO – Goiás, MA – Maranhão, MG – Minas Gerais, MS – Mato Grosso do Sul, MT – Mato Grosso, PA – Pará, PE – Pernambuco, PI – Piauí, PR – Paraná, RJ – Rio de Janeiro, RO – Rondônia, RR – Roraima, SP – São Paulo, TO – Tocantins). The biomes (in the Brazilian context) listed are **AF (Atlantic Forest)**, **AM (Amazon)**, **CA (Caatinga)**, **CE (Cerrado)**. Sources: 1 – Web of Science (2025), 2 – Based on this research or as indicated by experts: available via Google Scholar search (2025). OCBIL (theory): *Old, Climatically Buffered, Infertile Landscapes* (Hooper, 2009).

Author	Year	Source	Description	Location/Biomes
1. Benites <i>et al.</i>	2003	2	<i>Complexos Rupestres de Altitude</i> (Altitude Rupestrine complexes) including <i>campo rupestre</i> (quartzitic substrate) and <i>campos de altitude</i> (igneous substrate). These encompass unique ecosystems at the summits of Brazil's major mountain ranges.	Cadeia do Espinhaço – MG, BA (CR), Serra da Mantiqueira – MG, RJ, SP (<i>campo de altitude</i>). Chapada dos Veadeiros (GO), Chapada dos Guimarães (MT), Northern Roraima (RR) and other isolated occurrences of <i>campo rupestre</i> in quartzite are cited.

			They differ from the surrounding dominant biomes due to their soil and biota characteristics, exhibiting high diversity and endemism.	Biomes: AF, AM, CA, CE
2. Alves <i>et al.</i>	2007	1	CaR as vegetation bounded by a mosaic of rocky outcrops and shallow white sands.	Mainly above 1000 m in southeastern (MG) and northeastern (BA) Brazil. Biomes: AF, AM, CE
3. Ribeiro & Walter	2008	2	CaR as a herbaceous-shrubby phytophysiology involving vegetation complexes on micro-reliefs over rocky outcrops, with typical species, a wide temperature range, lithic, acidic, and dystrophic neosols (entisols).	Mainly above 900 m (sometimes 700 m); Chapada Diamantina (BA) is cited as an example of occurrence and reference from Chapada dos Guimarães (MT). Biomes: CA, CE
4. Alves & Kolbek	2010	1	CaR as a Brazilian azonal vegetation complex, with many distinct plant communities and diverse floristic affinities. It is always associated with rocky outcrops (especially quartzite) and derived sandy soils that are shallow, acidic, dystrophic, and well-drained.	Serra do Espinhaço (MG and BA) and edaphically similar areas in GO. Biomes: AF, AM, CA, CE
5. Vasconcelos	2011	2	CaR on Precambrian rocks remodeled since the Paleogene, mainly in quartzite, sandstone, and iron ore outcrops.	Above 900 m, highest sections of the Espinhaço Range (MG), the Mantiqueira Range (MG, SP, RJ), and the Serra do Mar Range (SP, RJ, ES), and also in isolated areas of Central Brazil (Chapada dos Veadeiros and Pireneus, GO; Serra da Canastra, MG). Biomes: AF, CA, CA
6. Balieiro <i>et al.</i>	2012	2	CaR as part of the high-altitude rock complex (HARC), with a focus on organic soil formation.	Sixteen sites in the Mantiqueira Mountains (MG) and the Espinhaço Range (MG, BA). Biomes: AF, CE
7. Messias <i>et al.</i>	2013	1	CaR in quartzite versus CaR in iron ore. Geology and geomorphology influence the formation of the floristic composition.	Both types are found in the Iron Quadrangle region (MG). Biomes: AF, CE
8. Alves <i>et al.</i>	2014	2	CaR: Complex of Brazilian endemic azonal vegetation within a matrix of zonal vegetation, with precipitation between 800 and 1500 mm/year and a dry season lasting 2 to 5 months. The	Above 900 m, in the Cerrado (MG, GO, TO) and the Caatinga (BA); biomes of the Brazilian Shield. Biomes: CA, CE

			complex mosaic includes vegetation on rocks, sand, aquatic plants, epiphytes, and penumbral plants	
9. Le Stradic <i>et al.</i>	2015	1	CaR: Unique plant communities of Neotropical montane grasslands, threatened by rock extraction. The herbaceous matrix of CaR, as a rich mosaic influenced by local topography and substrate, was studied.	Southern Espinhaço Range, Serra do Cipó National Park (MG). Biomes: AF, CE
10. Pugliesi & Rapini	2015	2	CaR as an open vegetation biome associated with quartzite soils, rich in endemism (paleomicroendemic species), influenced by the seasonal dry forests of the surrounding biome.	Above 900 m in Chapada Diamantina (BA). Biome: CA
11. Fernandes	2016	2	CaR (or rocky grasslands) as a geologically ancient ecosystem, with a high richness of herbaceous species and endemism, and a unique species composition. The vegetation is maintained by edaphic and climatic factors, wildfires, and possibly herbivory. Environmental filters and species interactions represent a source of biodiversity and ecosystem services in this megadiverse environment	It mentions the <i>tepui</i> s, mountains in the Amazon (Tunuí, Pacaás Novos, Ricardo Franco, Santa Bárbara, Cachimbo, Seringa, Carajás), Chapada Diamantina (BA), Espinhaço and Southern Espinhaço (MG), the Iron Quadrangle, Pontões Santo Antônio do Jacinto (MG), the Central Plateau (GO/TO), Serra da Canastra (MG), Caparaó (MG, ES), and Itatiaia (RJ) Biomes: AF, AM, CA, CE
12. Silveira <i>et al.</i>	2016	1	CaR <i>stricto sensu</i> as a mosaic of open vegetation types associated with rocky outcrops; CaR <i>lato sensu</i> : a mosaic of montane vegetation including herbaceous-shrubby types, with outcrops of quartzite, sandstone, or iron ore (<i>canga</i>), along with open sandy, stony, or marshy fields, similar to OCBIL.	Azonal vegetation in central and eastern Brazil, along the highlands of the Serra do Espinhaço (BA, MG). Biomes: CA, CE
13. Barbosa & Fernandes	2016	2	CaR as an ancient ecosystem formed by highly heterogeneous herbaceous-shrubby vegetation closely associated with rocky outcrops in the highest parts of the mountains, particularly on rocky substrates of quartzite, sandstone, and iron ore.	Above 900 m, mainly in the Serra do Espinhaço and Serra da Canastra (MG) and with some isolated areas in southeastern MG and central Brazil. Discrete regions in central Brazil (Chapada dos Veadeiros and Serra dos Pirineus, GO). Serra da Canastra & Mantiqueira (MG). Upper parts of the Carajás mountain range (PA) and on some isolated mountains in MS. Biomes: AM, CE

14. Castro <i>et al.</i>	2016	2	CaR as a physiognomy of the Cerrado biome, consisting of a mosaic of open habitats with sparse shrubs and trees among quartzite rock outcrops and predominantly acidic, shallow, and dystrophic soils, with high light levels and a seasonal climate featuring a well-defined dry season.	Between 900 and 1,200 m a.s.l., the study was conducted in the Serra do Cipó, Espinhaço Range (MG). Biome: CE
15. Zappi <i>et al.</i>	2017	1	CaR occurring on quartzite, sandstone, or iron ore substrates, where plant communities are subject to adverse environmental factors that determine local biodiversity and endemism. Designated as OCBIL.	Above 900 m. Serra do Espinhaço (MG and BA) and Iron Quadrangle, contrasting open vegetation with forests. Biome: CA, CE
16. Morellato & Silveira	2018	1	CaR <i>sensu lato</i> : open field with shrubby-herbaceous, fire adapted vegetation, mosaic of vegetation on rock outcrops (quartzitic, sandstone or iron-ore), including sandy, rocky and swampy fields. CaR <i>stricto sensu</i> : mosaic of open vegetation associated with rock outcrops, likened to OCBIL.	There is a high concentration of studies in the Serra do Cipó and Espinhaço ranges, but several other locations remain unexplored, even at a basic level of floristic knowledge. Biomes: AF, CE
17. Pontara <i>et al.</i>	2018	1	The CaR <i>lato sensu</i> is among the world's hotspots for plant diversity, with high endemism. A database of 2,049 woody plant species compiled from inventories, including <i>cerrado rupestre</i> and dwarf cloud forest among its vegetation types.	Espinhaço Mountains (MG). Biome: AF, AM, CA, CE
18. Mucina	2018	1	CaR as a mosaic of habitats on quartzite substrate, characterized by phosphorus-deficient dystrophic soils and the presence of grasses and shrubs. Ecosystem complex, encompassing vegetation complexes characterized by patches of grasses (C4 grasses, reeds, restioids) or continuous pastures and reed beds, interspersed with patches of low- to medium-height, sclerophyllous, and predominantly microphyllous scrub. Azonal ecosystem, belonging to the family of pedobiomes and, more specifically, of peinobiomes.	Higher elevations in eastern Brazil (mainly Minas Gerais, Bahia and Goiás). Includes the Serra da Canastra, the Chapada Diamantina, the Lençóis (BA), and the Sempre Vivas and Diamantina National Parks (MG). Western <i>campo rupestre</i> : Chapada dos Veadeiros (GO). An ecosystem that is not exclusive to Brazil, but analogous habitats (and vegetation) also occur on other continents in the Southern Hemisphere, particularly in Southern Africa and tropical Australia. Biomes: CA, CE
19. Neves <i>et al.</i>	2018	1	CaR as a hyperdiverse mosaic of rocky mountain savannas in South	From 900 to 2,033 m above sea level, the core area is in the

			America, on quartzite, sandstone, and iron ore substrates.	highlands of eastern Brazil (MG, BA), but with extensions into the mountains of central-western Brazil and eastern Bolivia, as well as in the Amazon. Biomes: AM, CA, CE
20. Colli-Silva <i>et al.</i>	2019	1	The CaR, as herbaceous-shrubby vegetation associated with rocky outcrops and shallow soils in the ancient Brazilian mountains. Based on endemism, proposes the bioregionalization of the phytogeographic provinces: Chapada Diamantina (BA) and Southern Espinhaço, subdivided in “Diamantina Plateau”, “Grão-Mogol” and “Iron Quadrangle” districts.	Two disjointed areas in eastern and central Brazil, Serra do Espinhaço (MG, BA) and Chapada dos Veadeiros (GO). Biomes: AF, CA, CE
21. Zappi <i>et al.</i>	2019	1	CaR as a complex vegetation mosaic dominated by open vegetation, including cerrado, open vegetation and rock outcrops but also forestal types (nebular forest, gallery forest). Found in highlands within the Brazilian biomes, including the Amazon, and characterized by high biodiversity and endemism. May occur over quartzitic or iron-ore substrates.	The areas with higher number of studies are in eastern Brazil, Cadeia do Espinhaço (MG) and Chapada Diamantina (BA). The Serra dos Carajás (PA) has <i>campo rupestre</i> isolated by an ombrophilous forest matrix. Biomes: AF, AM, CA, CE
22. Fernandes <i>et al.</i>	2020	1	The CaR as an ancient ecosystem dominated by grasses, with habitat types forming a mosaic rich in species of different vegetation types, substrates, and climatic diversity. Environmental filters lead to high levels of endemism. Floristic relationships between open, savanna, and forest vegetation are studied.	Above 900 m, mostly associated with the Espinhaço Range, ecotone between three biomes. Disjunct, small patches across these biomes, (MG, BA, GO). Amazon rainforest includes Carajás and tepuis, extreme west (Corumbá, Ricardo Franco Range, MS) and northeastern Brazil. Biomes: AF, AM, CA, CE
23. Miola <i>et al.</i>	2021	1	The CaR is a mosaic of fire-prone mountain herbaceous and shrubby vegetation that grows on quartzite, sandstone, or iron ore (<i>canga</i>) soils that are nutrient-poor, sandy, stony, or subject to seasonal flooding. Remnants of savanna and forest are also included in an azonal peñobio associated with the OCBIL.	Serra do Espinhaço Plateau (MG, BA) in eastern Brazil, an ecotone between three biomes. Other suggested mountain peaks. Possibility of <i>campo rupestre</i> in AM, CE, DF, ES, GO, MA, MS, PE, PI, PR, RO, SP. Biomes: AF, AM, CA, CE
24. Overbeck <i>et al.</i>	2022	1	CaR as open herbaceous-shrubby vegetation on mountain peaks on	Generally found above 800 m, concentrated in the highlands of

			different substrates (quartzite, ferruginous (<i>canga</i>), or sedimentary). The term is frequently used to describe a mosaic of different physiognomies.	eastern Brazil, but also present in other regions. Biomes: AF, AM, CA, CE
25. Schaefer	2023	2	CaR as a complex (CGR) in shallow, oligotrophic soils with high insolation, thermal amplitude, water deficit, and wind exposure, and also geographically isolated and highly prone to fires.	Generally above 900 m, Serra do Espinhaço (MG, BA), Quadrilátero Ferrífero (MG), Ibitipoca (MG), Serra da Mantiqueira (MG, RJ, SP) and even in the <i>tepui</i> s of the Amazon. Biomes: AF, AM, CA, CE
26. Azevedo <i>et al.</i>	2024	1	The CaR is one of six lithobiomes identified for Brazil, classified according to their matrix (quartzite or iron ore). An azonal ecosystem determined by abiotic factors such as altitude, climate, substrate, and soil nutrients.	CaRs <i>stricto sensu</i> in the Serra do Espinhaço (MG, BA), within a matrix of Atlantic Forest to the south and east, Cerrado to the west, and Caatinga to the north. Biomes: AF, CA, CE
27. Scheidegger <i>et al.</i>	2025	1	Highlighting the regions most affected by habitat loss and agricultural expansion, especially in the Cerrado and CaR, this study aims to guide policies and conservation actions to protect biodiversity and evolutionary heritage, helping to prevent irreversible loss of natural history.	Brazilian states mentioned in the text: BA, MG, PI, SP, TO (distribution of <i>Cambessedesia</i> , Melastomataceae). Biome: CE, CA

Table 3 – History of use and description of the *Cerrado Rupestre* (CeR), with a focus on the Cerrado Domain. (Abbreviations for Brazilian states: BA – Bahia, DF – Federal District, GO – Goiás, MG – Minas Gerais, MT – Mato Grosso, PA – Pará, PR – Paraná, TO – Tocantins). Sources: 1 – Web of Science (2025), 2 – Based on this research or as indicated by experts: available via Google Scholar search (2025), 3 – expert opinions: available on Google Scholar and in the Web of Science Cited References feature.

Author	Year	Source	Description	Location
1. Oliveira Filho & Martins	1986	3	Identification of Cerrado subtypes based on dominant soils, rockiness, and origin, coining the term “ <i>cerrado rupestre</i> ” for vegetation on quartzitic sands and lithosol.	Salgadeira/Chapada dos Guimarães (MT)
2. Ribeiro & Walter	1998	2	Subtype of the Cerrado <i>stricto sensu</i> , with trees and shrubs and continuous herbaceous layer, distributed over stony or rocky, shallow soils with rock outcrops. Shares species with the <i>campo rupestre</i> .	Cerrado biome, generally forming a mosaic with other vegetation types.
3. Munhoz & Proença	1998	2	Floristic list highlighting shrubby-herbaceous layer in <i>campo rupestre</i> , <i>cerrado rupestre</i> and <i>campo úmido</i> .	Alto Paraíso, Chapada dos Veadeiros (GO)

4. Rigonato	2005	2	“ <i>Cerrado rupestre de altitude</i> ” (i.e. highland rocky savanna)	Chapada dos Veadeiros (GO)
5. Amaral <i>et al.</i>	2006	2	<i>Cerrado Rupestre</i> with a less dense tree layer than the <i>Cerrado stricto sensu</i> , since the tree layer is less developed due to the rocky outcrops present in this vegetation type.	Fazenda Sucupira EMBRAPA, Brasília (DF)
6. Felfili & Fagg	2007	2	Diversity and structure of the <i>cerrado stricto sensu</i> on shallow, rocky cambisols and lithosols. Greater similarities among plots within the same site, indicating a geographic gradient that influences the floristic composition of the <i>cerrado stricto sensu</i> on rocky soils.	Patches of vegetation in northern GO and southern TO.
7. Scarano	2007	2	General view of vegetation growing on rock outcrops as a phytogeographic sub-unit recurrent in the majority of the main Brazilian biomes, including <i>cerrado rupestre</i> , <i>inselbergs</i> , <i>campo rupestre</i> and <i>campos de altitude</i> .	Cerrado, Atlantic Forest, Caatinga, and ecotones in the Pantanal and the Amazon Rainforest.
8. Ribeiro & Walter	2008	2	<i>Cerrado Rupestre</i> as a subtype of savanna (<i>Cerrado stricto sensu</i>) with 5–20% woody vegetation in rocky environments, trees 2–4 m tall, and the presence of a herbaceous-shrub layer. It occurs in mosaics that include other vegetation types.	Cerrado biome, neosols and lithosols formed from the decomposition of sandstones and quartzites, nutrient-poor and with low organic matter content.
9. Reatto <i>et al.</i>	2008	2	<i>Cerrado</i> : Rupestre shallow soils (horizons A + B < 50 cm), with a predominance of plants having a shallow root system.	Cerrado biome.
10. Pinto <i>et al.</i>	2009	2	On steep areas with rock outcrops. The <i>cerrado rupestre</i> is a savannic formation with tree cover between 5 – 70%, with distinct floristic composition, typical flora and particular endemism, while the <i>campo rupestre</i> is an open vegetation type (grassland) with predominance of herbaceous/shrubby plants.	Cocalzinho de Goiás (GO).
11. Ritter <i>et al.</i>	2010	1	Listed the phytophysiognomies: <i>cerrado stricto sensu</i> (50%) and <i>cerradão</i> (13%) in the northern sandstone plateaus in the north region, while <i>cerrado rupestre</i> (17%) and grassland with cerrado facies (20%) were more frequent in the southern river valley cliffs. As these remnants have floristic similarity with the core Cerrado, propose the correct denomination of savanna rather than steppe as they are currently known.	Campos Gerais (PR), Brazil, Southern boundary of the Cerrado Biome.

12. Lima <i>et al.</i>	2010	1	<i>Cerrado rupestre</i> as a vegetation type belonging to <i>Cerrado stricto sensu</i> occurring on litholic neosoils. Knowledge about the shrubs and trees of this sub-type is very limited. A few woody species have high structural importance and are adapted to rocky environments, leading to the peculiar floristics of these vegetation types.	Serra de Caldas Novas (GO)
13. Pinto <i>et al.</i>	2011	2	Rupestrial environments of the Cerrado may include <i>campo rupestre</i> , <i>cerrado rupestre</i> and dry forest (<i>mata seca</i>). The former two grow over similar rocky substrate however have different physiognomies (<i>campo rupestre</i> are open formations with less than 5% of tree cover while the <i>cerrado rupestre</i> is a savanna with 5 – 70% tree cover). The floristic composition is different and they present a typical flora with a high level of endemism.	10 sites in the Cerrado Biome (GO).
14. Maracahipes <i>et al.</i>	2011	1	Floristic composition and the structure of a savanna on rocky soil (<i>cerrado rupestre</i>) woody vegetation (including monocots and lianas) in the Cerrado-Amazon Forest ecotone. Cerrado rupestre as important refugia for flora and fauna considering the rapid transformation of the habitat.	Bacaba Municipal Park, Nova Xavantina (MT).
15. Lenza <i>et al.</i>	2011	1	The woody vegetation of a <i>cerrado rupestre</i> area was compared with areas of <i>cerrado stricto sensu</i> , revealing low floristic similarity between them and highlighting the floristic particularities of the <i>cerrado rupestre</i> .	Alto Paraíso de Goiás, Chapada dos Veadeiros (GO)
16. Gomes <i>et al.</i>	2011	1	Vegetation richness, floristic composition and structure of woody plants of rocky cerrado (<i>cerrado rupestre</i>) typical cerrado were compared. The basal area per plot was higher in <i>cerrado rupestre</i> , density per plot, height and mean diameter of individuals did not differ between both physiognomies, suggesting that the shallow soil and rock outcrops did not limit the establishment and development of the woody flora in <i>cerrado rupestre</i> .	Eastern Mato Grosso (MT)
17. Moura <i>et al.</i>	2011	2	The generic term <i>rock outcrop</i> may define environments from different origin on rocks of any composition, independent of their vegetation matrix. Woody component of cerrado <i>stricto sensu</i> on rock outcrops is known as <i>cerrado rupestre</i> . These environments may be described as extreme, and distribution restricted and endemic species are common therein.	Cerrado Biome.

18. Santos <i>et al.</i>	2012	1	The <i>Cerrado rupestre</i> is a type of savanna characterized by vegetation associated with rocky outcrops, one of the eleven vegetation types found throughout the Cerrado biome. The size of woody species populations distinguishes the areas under investigation. Initiatives and actions for the conservation of the Cerrado biome should consider not only the size of protected areas but also the populations to be protected, especially woody species on rocky outcrops.	Brazilian Central Plateau (GO)
19. Lemos <i>et al.</i>	2013	1	Compared floristic composition, richness, species diversity and structure of the woody component in pairs of typical Cerrado and rock outcrop Cerrado (<i>cerrado rupestre</i>) in two localities.	Natividade and Palmas (TO)
20. Mews <i>et al.</i>	2014	3	Savannas in steep areas with shallow, rocky soils have been considered as future biodiversity refuges. Adjacent savanna sites differ in the size of woody species populations, but not in species occurrence or diversity. Savannas on distinct substrates should be considered to improve decision-making and conservation initiatives when expanding or creating new Cerrado conservation units.	Cerrado in Central Brazil (GO).
21. Pinto <i>et al.</i>	2015	3	Phytosociology in the <i>Cerrado Rupestre</i> : conventional parameters applied and less-used analyses	Cerrado Biome
22. Schaefer <i>et al.</i>	2016	2	Rupestrian savanna (<i>cerrado rupestre</i>) as an open formation on metapelitic o metarenitic rocks, with high silt contents, and deeper soils, included in the Rupestrian Grasslands Complex (RGC). Rock outcrops are not common, only where resistant rock cores remain. The physiognomy varies from open grassy savanna to typical savanna (<i>cerrado stricto sensu</i>).	Sempre-Vivas National Park (MG)
23. Abadia <i>et al.</i>	2017	2	<i>Cerrado rupestre</i> on hilly slopes, with relatively shallow interspersed with rocky soils (<i>cerrado rupestre</i>) and Cerrado on flat terrain with deep soils have similar species composition. However, <i>cerrado rupestre</i> is more heterogeneous in species and soil composition.	Nova Xavantina and Ribeirão Cascalheira (MT)

24. Rocha & Pinto	2021	1	<i>Cerrado rupestre</i> as a refuge for the vegetation of the Brazilian Savanna on rock outcrops, an environment considered restrictive. The woody vegetation dynamics of these formations over time includes disturbance, fires and cattle grazing that promote changes in vegetation structure but not on its diversity. Continuing disturbances are likely to compromise their resilience.	Pireneus State Park (GO)
25. Pereira & Fernandes	2022	1	<i>Cerrado rupestre</i> as the rarest and least known Cerrado subdivision, occurring in rock outcrops, mainly above 800 m a.s.l., often together with <i>campo rupestre</i> , a grassland phytophysiology with which it is often confused. Characterized by species typical of savanna and grasslands of the Cerrado, but also by restricted species from different microhabitats such as cracks, fissures and exposed rocks, providing a high degree of endemism, with several threatened species.	Espinhaço Mountains, Central Plateau in Goiás, and the Carajás Mountains (MG, BA, GO, PA).
26. Pereira <i>et al.</i>	2022	1	Pollination and dispersal syndromes of five fragments of <i>cerrado rupestre</i> immersed in an agricultural landscape, on a continuous crust of canga (iron ore deposits). Biotic syndromes predominate in the community, especially melittophily and zoochory, highlighting the functionality and availability of resources in the community, as well as providing information for the conservation, management, and restoration of natural environments.	Paranaíba River, western Minas Gerais.
27. Souza <i>et al.</i>	2023	1	Local environmental conditions and spatiality influence the floristic variation of woody vegetation and ecological strategies in cerrado sites on three substrate types: deep soil at high altitude typical cerrado, deep quartzitic sandy soil at low elevation cerrado and rupestrian cerrado (<i>cerrado rupestre</i>) with rock outcrops at high elevation. Local ecological factors and processes drive species distribution and variations in vegetation, even at the local scale, must be considered to conserve biodiversity effectively.	Serra do Cipó, MG

Discussion

“Campo rupestre” as a well-established term

In searches using a single term, “*campo rupestre*” appears in 76% of the results obtained in the Web of Science search (2025), while the English equivalent, “rupestrian grasslands,” which first appeared in the literature published in 2005 (Coelho *et al.*, 2005), is present in 24% of the results. For the same search on Google Scholar (2025), the percentage of results containing “*campo rupestre*” is even higher (85%), with only 15% of searches using “rupestrian grasslands.” In both databases, these terms prevail over “rocky fields”, which can be used to describe vegetation associated with a variety of rocky outcrops worldwide, such as in China (Liu *et al.* 2015; Lu *et al.* 2024), in Japan (Uda, 2010; Hara, 2014), and in Turkey (Sari & Acar, 2016; Acar *et al.* 2025). Consequently, the term “*campo rupestre*” has been used consistently and more frequently in recent research to refer to high-altitude ecosystems or vegetation types associated with rocky substrates of quartzite, sandstone, or iron ore in Brazil, demonstrating that there is no need to translate the term, as this increases the likelihood of confusion. This is consistent with other terms used to describe certain ecosystems around the world that do not require translation, such as “*fynbos*,” popularized to describe South African vegetation influenced by the Mediterranean climate (Mucina, 2018; Bruda & Daniel, 2025), the *pantepui* in the Guiana Highlands (Rull *et al.* 2019; Barbosa-Silva *et al.* 2020), or the high-altitude Andean *puna* (Halbritter *et al.* 2024).

Geographic distribution of the *campo rupestre*

Of particular note is the non-zonal nature of *campo rupestre* (Alves & Kolbek 2010, and various subsequent authors), as the *campo rupestre* raising as islands from the zonal vegetation of, primarily, two Brazilian biomes (the Cerrado and the Caatinga). About 90% of known *campos rupestres* are recorded in the states of Minas Gerais and Bahia, where most of the research was conducted, while the *campo rupestre* in the states of Goiás (and Tocantins), previously highlighted by Eiten (1978) and Harley (1995), was less well-known two decades ago (Ribeiro & Walter 2008).

According to the Web of Science (2025) search results obtained here, this disparity persists to this day, with over 95% of published studies referring to the states of Minas Gerais and Bahia. The multiplicity of regional expressions and meanings for types of rock vegetation reflects the diversity of Brazilian lithobiomes (Azevedo *et al.* 2024), which dates back to the

history of their exploration in the 19th century. By the end of the 20th century, a certain consensus had emerged in the scientific literature that *campo rupestre* referred to high-altitude vegetation found above 900 m on quartzite, sandstone, or iron ore substrates, exemplified by an area of recognized biogeographic importance in the Serra do Espinhaço (Harley, 1995; Giuliatti & Pirani, 1997). At the turn of the 21st century, this region had two *campo rupestre* provinces, in accordance with the International Code of Area Nomenclature (ICAN) (Morrone 2018), recognized based on high diversity and endemism (Colli-Silva *et al.* 2019, Vasconcelos *et al.* 2020): one in Bahia (Chapada Diamantina province) and another in Minas Gerais (Espinhaço Meridional province). While the Chapada Diamantina province is located within the Caatinga domain (Moro *et al.* 2024), the Espinhaço Meridional province lies between the Cerrado to the north and west and the Atlantic Forest to the south and east. Despite the existence of significant areas of *campo rupestre* in the Central Plateau (western Minas Gerais, Goiás, and Tocantins, e.g. Serra Geral in GO/TO, Chapada dos Veadeiros in GO) (Schaefer *et al.* 2016), these were considered by some authors to be atypical cases in relation to the eastern mountains (Alves & Kolbek, 2010) and were not recognized as a phytogeographic region by (Colli-Silva *et al.* 2019). This is likely because the areas of Bahia and Minas Gerais have a much higher density of collections, introducing a certain bias in the analyses, leading to their immediate recognition to the detriment of less collected areas.

The *campo rupestre* on *canga*, or iron ore, refers mainly to the Iron Quadrangle, south of the Serra do Espinhaço, in Minas Gerais (Messias *et al.* 2012; Carmo & Jacobi, 2013), such as the Iron Quadrangle District of the Southern Espinhaço province (*sensu* Colli-Silva *et al.* 2019); and in the Amazon, such as the Serra dos Carajás, in the state of Pará (Mota *et al.* 2018; Giuliatti *et al.* 2019). From a floristic perspective, however, experts point to few connections between the Amazonian *campo rupestre* and those of eastern Brazil (Zappi *et al.* 2019).

Some authors also include the *tepui* mountains in the Northern Amazon (Rull *et al.* 2019) as elements of the *campo rupestre* (Schaefer *et al.* 2016). In broader considerations, some authors point to evidence of the *campo rupestre* in more than ten Brazilian states not mentioned previously (e.g. Miola *et al.* 2021 – see Table 2).

The existence of the *campo rupestre*, identified in the savanna of the Bolivian highlands (Parker & Rocha, 1991), was cited in the last decade by Barbosa & Fernandes (2016), who propose that the *campo rupestre* is not an exclusively Brazilian ecosystem. More recent

debates suggest that this ‘ancient complex of rocky grasslands’ may be very extensive, extending as far as the *tepui* of Mount Roraima and the granitic-gneissic highlands of the Serra dos Órgãos (Rio de Janeiro) (Schaefer *et al.* 2016).

The *campo rupestre* as a *Peinobiome*

It is estimated that the *campo rupestre*, as conceived by Giulietti & Pirani (1997), accounts for nearly 15% of Brazil’s native terrestrial plants, occupying less than one percent of the country’s territory (Zappi *et al.* 2017). An impressive 39% of these species are endemic to this ecosystem (Flora & Funga of Brazil, 2025). The situation of *campo rupestre* on rocky and dystrophic soils, at altitudes where sunlight, winds, and temperature variation can be extreme, may qualify it as a *peinobiome* (H. Walter & Lamberti, 1986; Mucina, 2018), a type of azonal biome characterized by pedological conditions, transcending traditional biogeographic subdivisions (domain or province). There has been research on the putative *campo rupestre* below the conservative threshold of 900 m a.s.l., on sandy substrates (Oliveira *et al.* 2018) and iron ore (*canga*) (Mota *et al.* 2018; Lima *et al.* 2019; Souza-Filho *et al.* 2019). The disjunctions in the southern part of the state of Minas Gerais (Ibitipoca State Park) are physiognomically similar but differ floristically from the central area of the Serra do Espinhaço (Forzza *et al.* 2013).

The multiplicity of edaphic and climatic factors influencing the formation of these ecosystems, as well as the synergy of environmental filters and interactions among species associated with high biodiversity and vital ecosystem services, have been highlighted (Mucina, 2018; Miola *et al.* 2021). Given the growing evidence of high biodiversity and endemism in the *campo rupestre*, such factors have been considered a notable characteristic of these high-altitude rupestrian ecosystems (Silveira *et al.*, 2016), with some authors viewing them as more inclusive and establishing connections with other regions and biomes (Schaefer *et al.* 2016). However, unsupervised cluster analysis of different geosystems or lithobiomes using floristic evidence clarified that some of the groups included in this broad *peinobiome* are clearly recognizable by a combination of geology and altitude and are represented by their unique floras (Azevedo *et al.* 2024). In this study, the *campo rupestre* of the Serra do Espinhaço emerges as a group distinct from other lithobiomes, and the granitic-gneiss outcrops are identified either as *inselbergs* (lower elevations) or as *campo de altitude* (in the higher elevations of the Serra da Mantiqueira and the Serra do Mar).

OCBIL Theory: Museums or Cradles?

The association of the “*campo rupestre*” in the broad sense with the OCBIL (Old Climatically-buffered Infertile Landscape) theory (Hopper, 2009) was first established by Silveira in 2016 (F. A. O. Silveira *et al.* 2016; S. Hopper *et al.* 2016) and followed by other researchers (Morellato & Silveira, 2018; Fiorini *et al.*, 2019), who added a fourth region to the three initial OCBIL regions (the Southwest Australian Floristic Region, the Great Cape Floristic Region in South Africa, and the Pantepui in the Guiana Highlands of South America), due to the association of their geologically ancient landscapes, dystrophic soils, and supposedly relatively stable climatic conditions. Advances on the seven initial predictions of the OCBIL theory (Hopper, 2009) were published a few years later (Silveira *et al.* 2021). This multifaceted theory, however, assumed climatic stability as part of the set of variables for the establishment of OCBIL; however, there is clear evidence of climatic fluctuations affecting the *campo rupestre* during glacial cycles, as suggested by Pacifico *et al.* (2020) for Melastomataceae, Bonatelli *et al.* (2014) for Cactaceae and Simon *et al.* (2009) for *Mimosa* and Microliceae. Although the first premise of the theory states that plant species in the OCBIL should exhibit reduced dispersibility, the most representative plant lineages in open *campo rupestre* vegetation, such as Poales and Asterales, which account for the largest percentage of species, are, for the most part, dispersed over long distances by anemochory (Zappi *et al.* 2017). The second premise is the marked persistence of ancient lineages in these environments; however, it seems clear that most plant species in the *campo rupestre* are evolving rapidly, regardless of lineage age, supporting the cradle theory rather than the museum theory (Vasconcelos *et al.* 2020; Padilha *et al.* 2025). Furthermore, Vasconcelos *et al.* (2020) suggest that radiations and diversification rates may be similar in age for both recent and ancient elevations, and that the geological age of an environment may be a confounding factor in estimating the age of a biota.

Vegetation mosaic vs. well-defined phytophysiology

The concept of *campo rupestre* as a vegetation mosaic proposed by Giulietti *et al.* (1987) was adopted at the turn of the 21st century by many authors (e.g. Alves & Kolbek, 2010; Pugliesi & Rapini, 2015; Barbosa & Fernandes, 2016; Castro *et al.* 2016; Silveira *et al.* 2016; Zappi *et al.* 2017; Alcantara *et al.* 2018). The general perception of these authors is that there are multiple determining factors for the establishment of this vegetation, such as paleohistory, geomorphology, nitrogen cycle, substrate type, altitude, topography, and microclimate.

Following this line of thought, Zappi *et al.* (2014, 2017) distinguished phytophysiognomies within an area of the *campo rupestre* province of Minas Gerais (Serra do Cipó), classifying open vegetation types into four *field* types (*sujo*, *pedregoso*, *arenoso*, *brejoso*), *crystalline rock* outcrops (*afloramentos de rocha cristalina*) and water course margin (*beira de córrego*). This classification effectively avoided the use of the term *campo rupestre* to describe a single phytophysiognomy.

Other restrictive uses have emerged in the literature. The *campo rupestre stricto sensu* was defined by Silveira *et al.* (2016) as a mosaic of grasslands and associated vegetation on rocky outcrops. Ribeiro & Walter (1998, 2008), who consider the *campo rupestre* as a specific phytophysiognomy of grassland (“campestre”) similar in structure to the *campo sujo*, but distinguished by its substrate (rocky soil) and the high number of endemic species found in this high-altitude vegetation (above 900 m a.s.l.), under the influence of constant winds and extreme climatic conditions, such as high temperature range and very distinct seasonality, characteristic of the Cerrado. Some authors mention the somewhat controversial use of the term “*rupestre*” (rock-dwelling or *rupestrian*) in these high-altitude areas with rocky substrate (Walter, 2006; Pinto *et al.* 2009, Pereira & Fernandes, 2022). Ribeiro & Walter (2008) also note that the *campo rupestre* encompasses a complex of vegetation that includes micro-reliefs with typical species, occupying stretches of rocky outcrops. However, the definition by Ribeiro & Walter (2008) excludes a series of vegetation types that are included in the mosaic complex of the *campo rupestre* or in a broader sense, such as the *campo limpo*, *campo sujo*, *campo brejoso*, the *vegetation on rock outcrops* (all open vegetation or grassland types), as identified by Eiten (1993), as well as the *cerrado rupestre* and other *cerrado stricto sensu* types (savannic types) and the riverine and montane forest types. In Alves *et al.* (2014) attempt to circumscribe the *campo rupestre*, they used the term ‘rocky montane savanas’ in the title, and the implication of defining this vegetation as a *savanna* would refer to the earlier discussion (Schimper, 1890) of savannas as intermediate features between fields and deserts, in a way relegating the more significant open grassy areas (grasslands), which harbor the majority of the endemisms found in this type of vegetation.

Cerrado Rupestre, a savanna vegetation type

The term “*Cerrado Rupestre*” is generally understood as a savanna vegetation type, and some authors extend its occurrence to other South American countries where the Cerrado domain extends, such as Bolivia (Barbosa & Fernandes, 2016; Pivello *et al.* 2025). The

cerrado rupestre is not necessarily associated with high-altitude zones (Moura *et al.* 2011), being determined by geomorphology; it occurs on lithic or rocky substrates, mainly on sloping terrain and with a higher density of tree species, between 5% and 20% - in contrast to the *campo rupestre*, which is often associated with elevations above 900 m and, according to Ribeiro & Walter (2008), has less than 5% tree species. It is considered one of the least understood Cerrado landscapes (e.g. Pinto *et al.* 2009; Moura *et al.* 2010; Pereira & Fernandes, 2022), and is frequently observed on the steep slopes of cliffs, between the lowland Cerrado and the *campo rupestre* at the top of the plateaus (Ribeiro & Walter 2008; Zappi *et al.* 2014). It has been highlighted as fundamental for ecosystem services (Pinto *et al.* 2011, Pereira & Fernandes 2022) and, due to its edaphic and topographic characteristics, the *cerrado rupestre* occupies a unique position, acting as a barrier against unchecked agricultural expansion on flat terrain (Nascimento & Sano, 2010). It has been considered a biodiversity refuge, contributing to the conservation of local species (Moura *et al.* 2011, Arcela, 2019), since this landscape exhibits high species richness and diversity (Maracahipes *et al.* 2011) and is important for endemic species of flora and fauna.

Conclusion

We analyzed the evolution of various definitions applied to the flora, geomorphology, and ecological characteristics of the *cerrado rupestre* and the *campo rupestre*. While the *cerrado rupestre* has an established definition as a savannic phytophysiology determined by soil composition, the presence of rock outcrops, and local topography—appearing mainly in studies conducted in Goiás, Tocantins and Mato Grosso—the *campo rupestre* presents more varied definitions, defined either by floristic or by phytophysiological attributes. In this sense, considering the results of this research and the indications from discussions still underway in both scientific forums and the socio-environmental sphere, we reiterate the use of the expressions in Portuguese – *campo rupestre* and *cerrado rupestre* – to refer to the vegetation and ecosystems at altitude on rocky outcrops, recorded and identified in various vegetation mosaics in the highlands of Brazil, occurring mainly in the Cerrado, Caatinga and Amazon, as well as in numerous ecotonal fragments between these biomes. A possible suggestion/recommendation is to use the term "*mosaico de campo rupestre*" ("*campo rupestre* mosaic") for the extensive mosaic of vegetation found above a certain altitude (approximately between 900 and 1,200 m above sea level) in shallow soils with rocky outcrops, as considered by Giulietti, Pirani, Fernandes, and Overbeck, among other authors.

The term *campo rupestre* in isolation, or as we suggest, "*campo rupestre stricto sensu*", should be applied to a specific phytophysognomy associated with open vegetation (herbaceous-subshrubby), according to Ribeiro & Walter (2008), mainly in the Cerrado, Caatinga, and their ecotones, which presents a unique endemic flora (Eiten 1972). Studies related to these high-altitude rupestrian mosaics, encompass areas located in the Serra do Espinhaço and Chapada Diamantina, currently indicated as phytogeographic provinces, and establish that the geology of these high plains, which dates back millions of years before the formation of the Cerrado domain, supports a landscape in which most speciation events date from the Pleistocene (Vasconcelos *et al.* 2020). The high-altitude islands of the *campos rupestres*, inserted in different domains and sometimes occurring at atypical altitudes, highlight the azonal character of such ecosystems (for example, Alves & Kolbek 2010). In short, the recommendation anchored in the present research is the use of the expression "*campo rupestre* mosaic" to refer to the *lato sensu* character of these high-altitude ecosystems, reserving the simple expression *campo(s) rupestre(s)* for the *stricto sensu* application of open phytophysognomies found at altitude and on rocky outcrops, in shallow and dystrophic soils, especially in the Cerrado and Caatinga.

Relative to *cerrado rupestre*, its identification as a phytophysognomy of the Cerrado biome is considered consensual, but it is important to emphasize that, occurring at altitude, mainly in the Cerrado, this phytophysognomy is frequently associated with the *campo rupestre*, thus being able to integrate the vegetation complex that we are calling here the "*mosaico de campo rupestre*." The stabilization of this understanding and the use of defined terms to refer to the *mosaic of campo rupestre*, as well as the *campo rupestre* and the *cerrado rupestre* as phytophysognomies, would greatly facilitate intercommunication between the various agents involved in the recording, research, conservation and protection of these ecosystems, and would benefit the understanding and practical and legal streamlining in the assignment of conservation priorities for them, given their very high relevance as biodiversity hotspots and a source of essential ecosystem services.

Regarding the proposal to recognize the *campo rupestre* as a biome, the difficulty arises in defining what a biome is and the need to clarify the term to facilitate communication among scientists worldwide. However, scientific discussions on terminology do not address the urgent need to implement legal protection for the threatened biodiversity sheltered by *campos rupestres* and *cerrados rupestres*. Basic research, combined with ecological programs and

robust conservation policies, remains necessary to underpin and consolidate effective environmental and informational public policies, prioritizing the protection of these unique environments.

The Cerrado biome is represented by many types of vegetation; however, the bias in historical knowledge that privileges forest environments to the detriment of savannas and grasslands has led to much less recognition and attention given to the herbaceous and subshrubby strata of open areas, compared to the woody component. In Brazil, environmental policies protecting native vegetation have suffered systematic dismantling in recent years, carried out by political and economic interests that are staunch defenders of profit at any cost for agribusiness, mining, and many types of predatory exploitation. Non-forest areas are the most attacked in the fallacious narrative that, "by preserving the standing forests," the "rest" has no value and can be easily replaced. This "rest" is precisely the grasslands, savannas, and some of these open features to which we refer here. The herbaceous and subshrubby components of the *campo rupestre* and *cerrado rupestre* in the highlands of the Central Plateau of Brazil, in Goiás and the Federal District, require greater attention in terms of conservation and floristic research, establishing their importance in terms of endemism, floristic affinities, and their high environmental value within the Cerrado and Brazilian ecosystems as a whole.



Figure 4. Area of *cerrado rupestre* vegetation extending from seasonally flooded *campo rupestre*: the density of trees and shrubs is usually one of the indicators of the transition between the two phytophysiognomies in the Cerrado. EEUnB, DF, March 2025 (photo: Rosa Cartagenes).

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Supplementary material S1 - Boolean Research Tables (see appendix at the end of dissertation)

CHAPTER 2. FLORA OF ROCK OUTCROP VEGETATION ENCLAVES IN THE CERRADO CORE REGION

Abstract

Considered the most biodiverse savanna in the world, the Cerrado includes a wealth of vegetation types distinguished by the density and height/presence of trees over varied geomorphologies. Among these, the *campo rupestre* (CaR) and *cerrado rupestre* (CeR), both associated with rock outcrops, are among the least known habitats in terms of floristic studies in Central Brazil. Aiming to increase the knowledge of the flora associated with rock outcrops in this region, we carried out field research at the Água Limpa Ecological Station (FAL), Distrito Federal, Brazil, preparing a checklist of vascular plants found in CaR and CeR locations and investigating the floristic relationship between these and that of other rocky and non-rocky vegetation types described for the region. Species were categorized regarding distribution, life-form, endemism and IUCN threat categories. The resulting list included 230 species, of which 165 were recorded for CaR and 153 in CeR. A matrix with 624 species combining our list with published work from four selected sites has shown that 38.8% of species occurred exclusively in the rock outcrop vegetation sites. Plant species life form composition differed significantly among the sites, with herbaceous species overrepresented in *campo limpo úmido* and underrepresented in *cerrado stricto sensu*, where tree species were overrepresented. Rock outcrop vegetation areas had similar life-form class distribution patterns. Although geographically close, the vegetation types compared in this study had low floristic similarity, and rock outcrop vegetation sites shared only 10% of species, with the most similar being CaR and CeR from FAL. Despite the proximity between selected sites, each rock outcrop area examined harbours a rich and distinct flora, forming a mosaic of plant communities shaped by local soil and microhabitat conditions, highlighting the importance of conserving rock outcrop vegetation across multiple spatial scales, including both local and regional levels.

Keywords: *Campo rupestre*, *Cerrado rupestre*, Distrito Federal, Fazenda Água Limpa, herbaceous-shrubby layer, floristics

Resumo

Considerada a savana mais biodiversa do mundo, o Cerrado apresenta ampla diversidade de tipos de vegetação, que se distinguem pela densidade, altura e presença de árvores sobre variadas geomorfologias. Entre esses, o Campo Rupestre (CaR) e o Cerrado Rupestre (CeR), ambos associados a afloramentos rochosos, estão entre os habitats menos conhecidos em termos de estudos florísticos no Brasil Central. Visando ampliar o conhecimento sobre a flora associada a afloramentos rochosos nesta região, realizamos pesquisa de campo na Estação Ecológica da UnB - Fazenda Água Limpa (FAL), Distrito Federal, elaborando uma lista de espécies de plantas vasculares encontradas em áreas de CaR e CeR e investigando a relação florística entre essas espécies e a de outros tipos de vegetação, sobre afloramentos rochosos ou não, descritos para a região. As espécies foram categorizadas quanto à distribuição, forma de vida, endemismo e categorias de ameaça da IUCN. A lista resultante incluiu 230 espécies, das quais 165 foram registradas para o CaR e 153 para o CeR. Uma matriz com 624 espécies, combinando nossa lista com trabalhos publicados de quatro outros locais na região, mostrou que 38,8% das espécies ocorreram exclusivamente sobre afloramentos rochosos. A composição das formas de vida das espécies vegetais diferiu significativamente entre os locais, com espécies herbáceas sobrerrepresentadas no campo limpo úmido e sub-representadas no cerrado *stricto sensu*, onde as espécies arbóreas foram sobrerrepresentadas. As áreas de vegetação em afloramentos rochosos apresentaram padrões de distribuição de classes de formas de vida semelhantes. Embora geograficamente próximos, os tipos de vegetação comparados neste estudo apresentaram baixa similaridade florística, e os afloramentos rochosos compartilharam apenas 10% das espécies, sendo os mais semelhantes CaR e CeR da FAL. Apesar da proximidade entre os locais selecionados, cada afloramento rochoso examinado abriga uma flora rica e distinta, formando um mosaico de comunidades vegetais moldadas pelas condições locais do solo e do microhabitat, destacando a importância da conservação da vegetação em afloramentos rochosos em múltiplas escalas espaciais, incluindo níveis locais e regionais.

Palavras-Chave: Campo rupestre, Cerrado rupestre, Distrito Federal, Fazenda Água Limpa, estrato herbáceo-arbustivo, florística.

Introduction

Known as the most biodiverse savanna in the world, the Cerrado is a biodiversity hotspot currently under serious threat from rampant agrobusiness (Myers *et al.* 2000; Klink & Machado 2005; Strassburg *et al.* 2019; Siqueira *et al.* 2021). Mostly occurring in the central region of Brazil, over a gradient of 20 degrees of latitude (5°S to 25°S) and 20 degrees of longitude (40°W a 60°W), it houses nearly 13,000 species of vascular plants (Flora and Funga of Brazil 2026) distributed through a vegetation mosaic that includes grasslands, savannas and forests, with habitats distinguished mainly by the density and height/presence of trees, distributed in areas with different altitudes, soil depth and drainage, presence of rocks or stones and association with water courses (Ribeiro & Walter 2008).

The *cerrado stricto sensu* is the most common savanna vegetation type in the biome. It is characterized by low trees, typically 2-4 m tall, generally with twisted and gnarled trunks, along with shrubs distributed through a continuous grassy layer. Two vegetation types associated with rock outcrops (also referred to as rupestrian) are listed for the biome. The *cerrado rupestre* (CeR) is a sub-type of *cerrado* with tree cover that varies between 5% and 20%, occurring in acidic, shallow soils among rock outcrops, mostly over inclined terrain (Eiten 1978; Ribeiro & Walter 2008), found at the edge of cerrado plateaus. As a plant physiognomy, the *campo rupestre* (CaR) is found under similar substrate conditions, however it is classified as a grassland and occurs at higher altitudes (above 900 m a.s.l.), and with high density of often endemic herbaceous species (Ribeiro and Walter 2008). The concept used here for CaR as a grassland plant physiognomy follows Ribeiro and Walter (2008), and differs from the broader definition used by other authors, that view *campo rupestre* as a complex vegetation mosaic sometimes including savannas and forests (Giulietti and Pirani 1988, 1997; Harley 1995). The Brazilian Central-Western CaR has been flagged as an endemic rich vegetation (Eiten 1992; Harley 1995; Fernandes 2016), however, it has not been acknowledged as a biogeographic province (Colli-Silva *et al.* 2019), possibly because of the less complete sets of collections from this area.

In the last four decades, the development of agrobusiness methods to exploit the acidic soils of the Cerrado has led to an estimated loss of approximately 50% of its native vegetation cover (Alencar *et al.* 2022). While the shallow, rocky soils associated with the edges of the plateaus make these areas difficult for mechanized agriculture, such areas represent important refugia for native vegetation. Additionally, species distribution models show that, under a climate change scenario, Cerrado areas below 743–798 m a.s.l. are

projected to be under higher species extinction risk, while higher ground might sustain the migration of species from lower areas (Silva *et al.* 2024). The Distrito Federal, found within the core area of the Cerrado, has already lost around 47% of its native vegetation (Neves *et al.* 2017). Vegetation types such as CaR and CeR are poorly documented in the region, having been detected both in protected areas and in areas under intense human pressure (Amaral *et al.* 2006; Chacon *et al.* 2014; Neves *et al.* 2021; Barbosa *et al.* 2023).

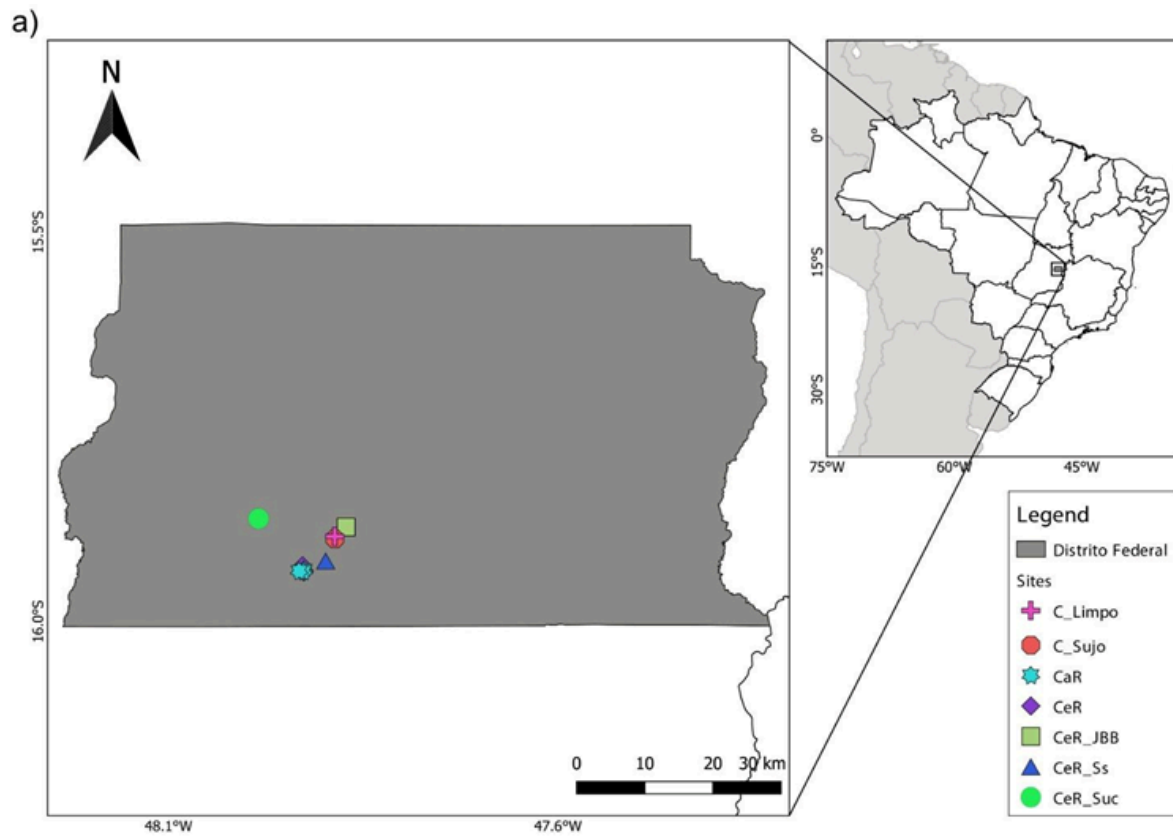
Open vegetation types have been neglected despite their high richness, endemism and ecosystem services provision (Zappi *et al.* 2017; Bonanomi *et al.* 2019, Overbeck *et al.* 2022). The objective of this work is to record and document the flora of rock outcrop vegetation in a core area of the Cerrado, located in the Distrito Federal at the Água Limpa Ecological Station (FAL), a site listed in the UNESCO Man and the Biosphere Programme (MAB) as a priority area for conservation of global biodiversity. We prepared a checklist of vascular plants found in CaR and CeR spots in the area and investigated the floristic relationship between their flora and that of other rocky and non-rocky vegetation types described for the region. Each species has been categorized regarding its distribution, life-form, endemism and IUCN threat categories. Our objective is to increase the knowledge regarding the flora associated with rock outcrops in the central region of the Cerrado, including possible new records for the FAL.

Material and methods

Study Area

The study was carried out at the Ecological Station of the University of Brasília – Fazenda Água Limpa Ecological Station – (FAL), Distrito Federal, Brazil (47°59'02.23" to 47°53'16.15"W and 15°58'32.77" to 15°58'56.84"S) (Fig. 1), located within the Gama-Cabeça de Veado Environmental Protection Area (Decree – 9417 – 21th April 1986). Half of the 4,340 ha area of FAL is protected under Brazil's National System of Nature Conservation Units (SNUC), namely the Area of Relevant Ecological Interest of Capetinga and Taquara. FAL has borders with the Ecological Station of the Botanical Garden of Brasília (JBB) and the Ecological Reserve of the Brazilian Institute of Geography and Statistics (RECOR-IBGE). Together, these areas represent approximately 10,000 ha of preserved land. The climate in the region is seasonal tropical Köppen Aw, characterized by wet summers (November to April) and dry winters between May and October (Alvares *et al.* 2013). The mean annual precipitation is approximately 1,500 mm, and the average maximum and

minimum temperatures are 28.5 °C and 12.0 °C, respectively (Munhoz & Felfili 2007). The altitude varies between 760 and 1.342 m (Felfili *et al.* 2002).



b)



c)



Figure 1. a) Map showing Distrito Federal in Central Plateau of Brazil, and the sites studied in the Água Limpa Ecological Station (FAL; CaR, CeR, C-Limpo, C-Sujo, CER-ss), Fazenda Sucupira (CeR-Suc) and Brasília Botanical Garden (CeR-JBB) Brasília - Federal District, Brazil. **b)** *cerrado rupestre* (CeR) at FAL and **c)** *campo rupestre* (CaR) at FAL. Map: Eliel de Jesus Amaral; photos: Rosa Cartagenes.

The areas of CaR and CeR were selected for FAL using literature citations for these vegetation types (eg. Felfili *et al.* 2002) and botanical collections available at SpeciesLink platform (<https://specieslink.net/>). Saxicolous plants such as *Lychnophora* spp. (Asteraceae), *Stenodon suberosus* Naudin (Melastomataceae), *Barbacenia* spp. and *Vellozia variabilis* (Velloziaceae) were used as indicators of CeR and CaR (CNC Flora 2026). We also considered the presence of specific fauna (Leal & Cartagenes 2021), such as *Phyllomedusa oreades* Brandão, 2002, an endemic tree frog from rivers and streams in rock outcrop environments (Brandão & Álvares 2009, Cândido *et al.* 2024) and *Calomys expulsus* Lund, 1841, a rodent typical from rocky areas (Santos & Henriques 2010) in the selection of the study sites.

Field expeditions to locate areas with shallow, stony soil were carried out at FAL, resulting in the selection of three CeR (15°58'05.5"S, 47°57'01.4"W; 15°58'29.4"S, 47°56'53.8"W and 15°58'35.7"S, 47°56'54.7"W) and three CaR (15°58'24.8"S, 47°56'54.6"W; 15°58'33.6"S, 47°56'56.1"W and 15°58'32.0"S, 47°57'17.7"W) sites (Fig. 1).

Data collection

All fertile vascular plants were sampled using a walking survey method (Filgueiras *et al.* 1994), with collections over 12 non-consecutive months, between December 2023 and July 2025. Field collections were performed by a team of three people aiming to cover an area of approx. one ha (100 × 100 m), spending an average of two hours 45 minutes per site during each collection event. Specimen identification used specialized literature, comparison with online databases (Flora & Funga of Brazil 2026, SpeciesLink platform - <https://specieslink.net/>), and consulting specialists when necessary. For the species list, vascular plant family circumscriptions followed Angiosperm Phylogeny Group (APG IV 2016), and taxonomic concepts and spelling were based on Flora & Funga of Brazil (2026).

The listed species were categorized into plant life form groups (herbs, subshrubs, shrubs, climbers, trees and dracenoids) based on the classifications proposed by Dansereau (1951). Palms were included in the dracenoid class, together with Velloziaceae. Geographic distribution was consulted in Flora & Funga of Brazil (2026) complemented with specimens

identified by specialists in virtual herbaria (<https://specieslink.net/>, Flora & Funga of Brazil 2026), classified according to their narrowest distribution as follows: a) wide distribution, species occurring beyond Brazil; b) Brazilian endemic; c) Cerrado endemic; d) Goiás and Distrito Federal endemic; and e) restricted to the Distrito Federal. Threat categories follow the Brazilian Red List at CNC Flora (2026). A comparison with the last species list produced for FAL (Felfili *et al.* 2004) enabled us to list the new records for the area. All plant collections were deposited at the Herbarium of the Universidade de Brasília (UB).

Data analysis

The species list compiled for CeR and CaR was compared with surveys from other cerrado vegetation types near the study area, including *campo sujo* (shrubby grassland), *campo limpo úmido* (wet grassland), and *cerrado stricto sensu* also sampled at FAL, as well as two areas of CeR: one at Fazenda Sucupira (EMBRAPA) and another at the Ecological Station of the Brasília Botanical Garden (Table 1, Fig. 1). *Campo limpo úmido* occurs on hydromorphic soils that are mostly permanently waterlogged, with very low woody cover (<1%) and only sparse shrubs and subshrubs. Similarly, *campo sujo* has low tree cover (<5%) compared to *cerrado stricto sensu* (20–70%) (Ribeiro & Walter 2008). To avoid duplication of species between areas due to synonyms and nomenclatural discrepancies, we checked all botanical names using the package ‘florabr’ (Trindade 2024). The similarity between the areas was measured by the Jaccard index using the *vegdist* function of the *vegan* package in R (Oksanen *et al.* 2022).

To evaluate differences between plant life form composition among vegetation types (sites), we used a chi-square test of independence based on the number of species per life-form category. Rare categories (climbers and dracenoids) were pooled (as others) to meet test assumptions. Standardized residuals were used to identify deviations from expected frequencies in each area. A chord diagram to compare the floristic links between the four rock outcrop sites (Car, CeR, CeR-JBB and CeR-Suc – Table 1) was prepared using the *circlize* package in R software (Gu *et al.* 2014). The analyses were performed in R version 4.5.1 (R Core Team 2025).

Table 1. Cerrado vegetation types compared in the present study. Code = Site codes; N = number of vascular plant species used in the comparison matrix.

Code	Site	Vegetation Type	N	Number of unique species	References
Cer_JBB	Brasília Botanical Garden Station	<i>cerrado rupestre</i>	110	38	Chacon <i>et al.</i> (2015)
c_limpo	Água Limpa Ecological Station	<i>campo limpo</i> <i>úmido</i>	126	64	Souza <i>et al.</i> (2021)
c_sujo	Água Limpa Ecological Station	<i>campo sujo</i>	193	66	Souza <i>et al.</i> (2021)
cerrado_ss	Água Limpa Ecological Station	<i>cerrado stricto</i> <i>sensu</i>	165	69	Almeida <i>et al.</i> (2014)
CeR-Suc	Sucupira Farm	<i>cerrado rupestre</i>	135	49	Vale <i>et al.</i> (2007)
CeR	Água Limpa Ecological Station	<i>cerrado rupestre</i>	148	26	Present study
CaR	Água Limpa Ecological Station	<i>campo rupestre</i>	162	42	Present study

Results

Rock outcrop vascular flora of FAL

A total of 230 species distributed in 129 genera and 47 families were collected in the CeR and CaR at FAL (Table 2). From these, 165 species were recorded for CaR and 153 in CeR. The families with higher species richness were Asteraceae (29 spp.), Poaceae (26 spp.), Cyperaceae (20 spp.), Melastomataceae (19 spp.), Fabaceae (18 spp.), and Rubiaceae (11 spp.). The genera with more species were *Rhynchospora* (Cyperaceae), with 12 species, *Microlicia* (Melastomataceae, eight spp.), *Paspalum* (Poaceae, six spp.), and *Diplusodon* (Lythraceae), *Lessingianthus* (Asteraceae), *Mimosa* (Fabaceae), and *Xyris* (Xyridaceae) with five species each. Only three specimens were determined to generic level. Velloziaceae species (*Barbacenia flavida*, *Vellozia pumila* and *V. variabilis*; Fig. 2) and Asteraceae genus *Lychnophora* (Fig. 2) were recorded for all CeR and CaR sites at FAL. Regarding the species

listed by Felfili *et al.* (2004), we found 43 new occurrences at FAL. More than half of the sampled species have wide occurrence, with 37 Brazilian endemic and 94 widely distributed (Table 2). Ninety-three species are endemic to the Brazilian Cerrado. We recorded 14 species endemics to Goiás and Distrito Federal (e.g. *Mimosa speciosissima* and *Stenodon suberosus*; Fig. 2e), including one species restricted to the Distrito Federal (*Lychnophora planaltina*). Four new records were made for the Distrito Federal: *Dyckia marnierlapostollei* (Bromeliaceae) (Fig. 2); *Rhynchospora loefgrenii* (Cyperaceae); *Dalechampia francisceana* (Euphorbiaceae), and *Microlicia neogracilis* (Melastomataceae) (Table 2). Four species are listed as endangered (EN): *Ctenodon graminoides* (Fabaceae); *Diplusodon capitalensis* (Lythraceae); *Lessingianthus eitenii* (Asteraceae); and *Senega franchetii* (Polygalaceae). Invasive species *Aristida adscensionis* (Poaceae) was removed from comparative analyses.

Floristic similarity between rupestrian and non-rupestrian sites in the region

Of the total species included in the analyses (624 species) from FAL CeR and CaR and from the other four selected sites, 242 species (38.8%) occurred exclusively in all rock outcrop vegetation sites, among these, 107 (17.1%) species were recorded only in the CeR and CaR sites at FAL, of which 44 found in CeR and 26 in CaR. The rock outcrop vegetation sites shared 24 species, five of which occurred at all four rupestrian sites (*Lychnophora ericoides*, *Odontadenia lutea*, *Rhynchospora elatior*, *Stenodon suberosus*, and *Vochysia pumila*; Fig. 2d). FAL sites of CeR and CaR were more similar floristically and formed a group associated with *cerrado rupestre* areas, with this rock outcrop flora being distinct from the other evaluated vegetation types (Fig. 3).



Figure 2. Representative species of *cerrado rupestre* (CeR) and *campo rupestre* (CaR) at FAL, **a** *Chresta scapigera* (Less.) Gardner (CeR & CaR); **b** *Bulbostylis paradoxa* (Spreng.) Lindm. (CaR); **c** *Actinocephalus bongardii* (A.St.-Hil.) Sano (CaR); **d** *Vochysia pumila* Pohl (CaR & CeR); **e** *Stenodon suberosus* Naudin (CeR & CaR) **f** *Habenaria lavrensis* Hoehne (CaR); **g** *Kielmeyera rubriflora* Cambess (CeR); **h** *Dyckia marnierlapostollei* [L.B.Sm.](#) (CeR & CaR); **i** *Xyris savanensis* Miq. (CaR & CeR); **j** *Lychnophora ericoides* Mart. (CaR & CeR); **k** *Paspalum lanciflorum* Nees ex Steud. (CaR & CeR) and *Justicia lanstykii* Rizzini (CaR & CeR). Photos: CBR Munhoz, JAVS Rabello & RCC Cartagenes.

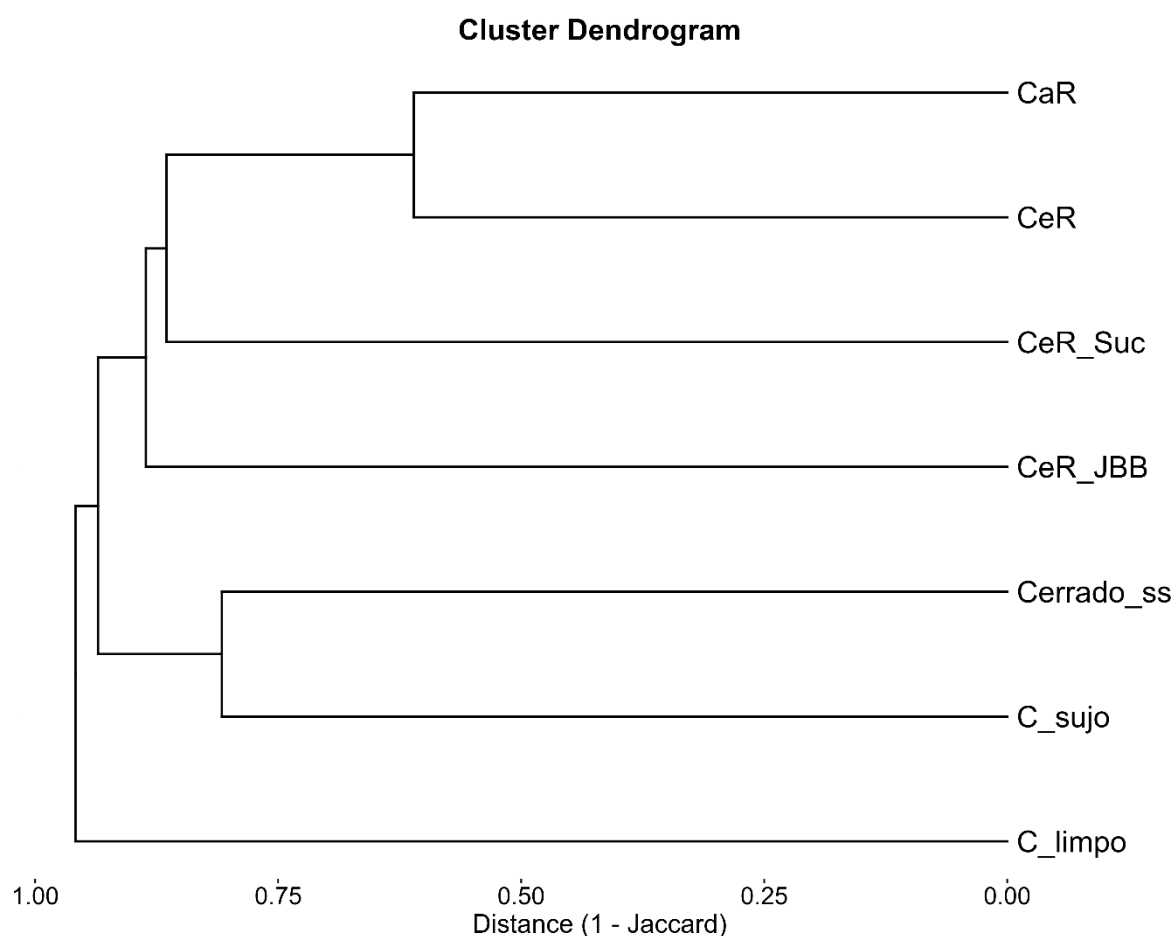


Figure 3. Dendrogram displaying a cluster analysis based on the Jaccard similarity index. Site acronyms are provided in Table 1.

Plant species life forms composition differed significantly among areas ($X^2 = 216.09$, $p < 0.001$). Herbaceous species were overrepresented in *campo limpo úmido* (standardized residual = 9.26) and underrepresented in *cerrado stricto sensu* (-5.56), and CeR-S (-3.83). Tree species were highly overrepresented in *cerrado stricto sensu* (9.78) and underrepresented in open areas such as *campo limpo úmido* (-3.66), *campo sujo* (-2.96), CaR (-2.50) and CeR-JBB (-2.36). Overall, the life-form composition of the rock outcrop vegetation areas (CaR, CeR, CeR-Suc, and CeR-JBB) showed similar class distribution patterns (Fig. 4). Further analysis of species share between the four rock outcrop vegetation sites studied (CaR, CeR, CeR-Suc, and CeR-JBB) highlights a higher proportion of shared species between CaR and CeR, while the other two sites have a much smaller overlap (Fig. 5).

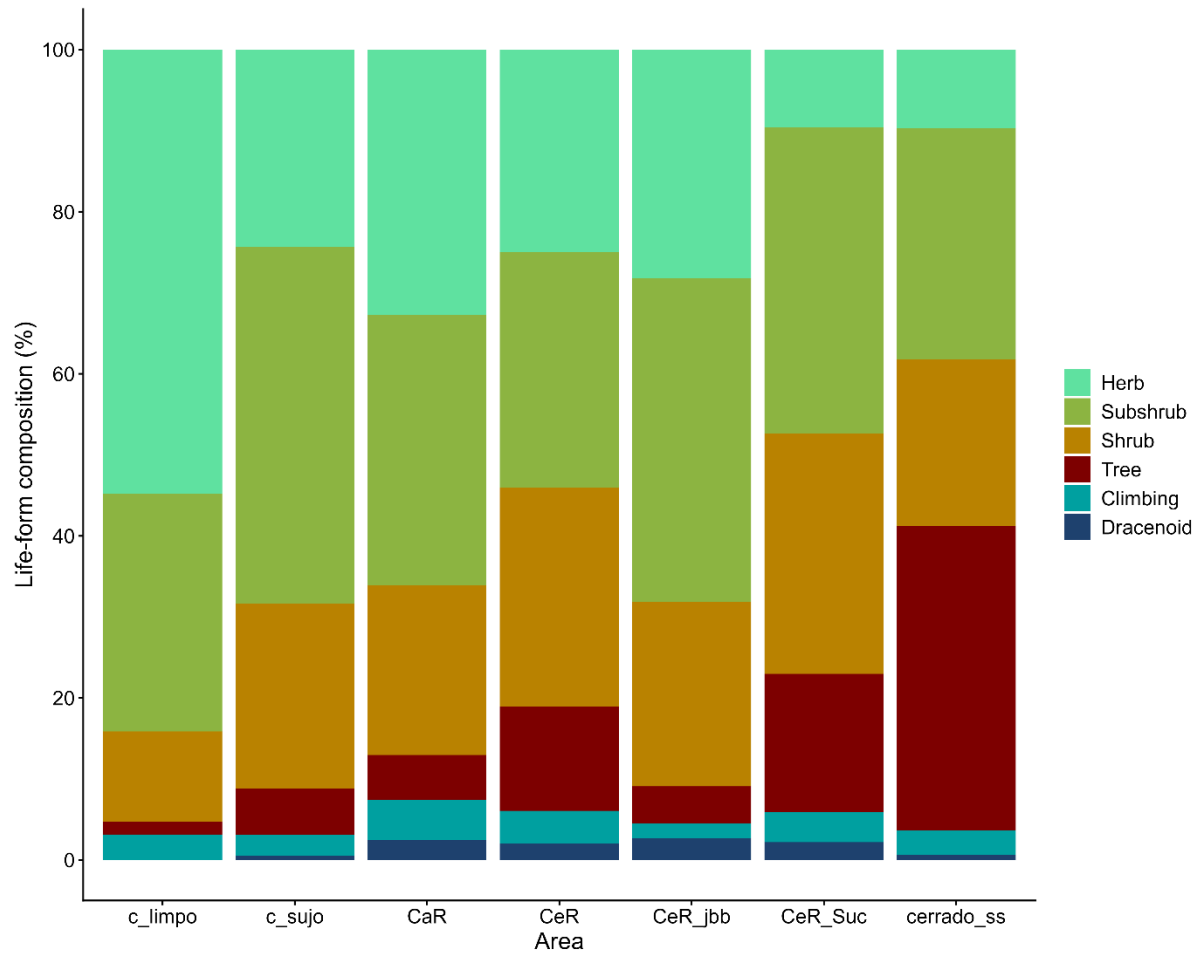


Figure 4. Species percentage per life form class in the different vegetation types and in study localities and compared sites. Site acronyms are provided in Table 1.

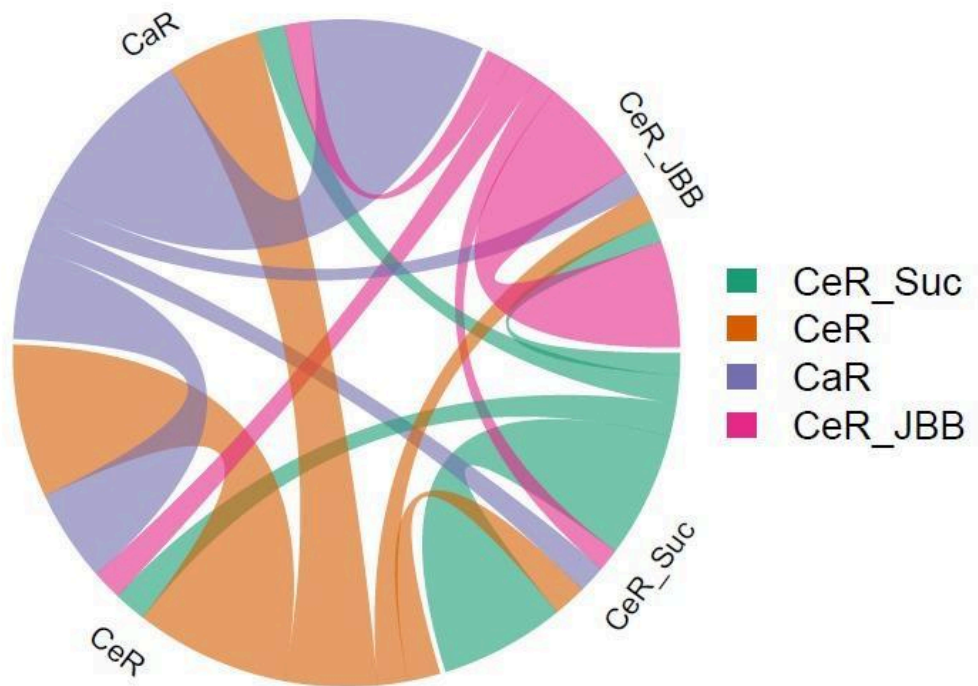


Figure 5. Chord diagram comparing species share between the four rock outcrop sites. Site acronyms are provided in Table 1.

Discussion

The rock outcrop vegetation areas at FAL have high species richness that includes many taxa commonly reported for these vegetation types, such as Asteraceae, Bromeliaceae, Eriocaulaceae, Melastomataceae, and Xyridaceae species (Ribeiro & Walter 2008; Alves *et al.* 2014; Schaefer *et al.* 2016). Some species recorded in the CaR and CeR areas at FAL are associated with rock outcrops, such as *Barbacenia flavida*, an herb typical of rocky substrates and found in *campo rupestre* vegetation in the states of Goiás and Minas Gerais, including the Serra da Canastra National Park, as well as in the Distrito Federal. *Lagenocarpus rigidus*, considered common in rock outcrop ecosystems (Mucina 2018; Cunha-Blum *et al.* 2025), was also recorded. Several species (*Barbacenia flavida*, *Lepidaploa rufogrisea*, *Lychnophora ericoides*, *Lychnophora planaltina*, *Mandevilla myriophylla*, *Microlicia polystemma* and *Xyris asperula*) are exclusive from *campo rupestre* vegetation (Flora & Funga of Brazil 2026). *Microlicia consimilis*, *Stenodon suberosus*, and *Vellozia variabilis*, which are typical to rock outcrop vegetation (Harley 1995; Flora & Funga do Brasil 2025).

In this study, we expanded the knowledge of the FAL flora, increasing the number of recorded species by 19%, including endemics species to Goiás and the Distrito Federal. The discovery of a new population of *Lychnophora planaltina*, an endemic species of the *campo rupestre* of the Distrito Federal at FAL is important, as this species was previously known from a highly restricted population surrounded by the urban matrix of Brasília (Loeuille *et al.* 2022), and further highlights the importance of protected Cerrado areas for biodiversity conservation. Beyond the boundaries of the FAL, the first record of *Dyckia marnierlapostollei* for the Distrito Federal also underscores the relevance of floristic surveys in documenting regional biodiversity. This species is known from Minas Gerais and Goiás, occurring in *campo rupestre* and previously recorded from only three localities: *Serra do Óculos* (MG), *Cocalzinho de Goiás*, and *Serra dos Cristais* (GO) (<https://specieslink.net/>). Given the geographic separation among known sites, the species are likely to occur in other rocky areas, reinforcing the importance of non-tree floristic surveys.

In terms of threat categories, the record of only four species as endangered (EN) according to the Brazilian Red List (CNC Flora 2026) in the FAL CeR and CaR sites may be underestimated. The vast majority of species in the FAL list (78%) have not been evaluated (NE), and this includes other 23 species with restricted distribution, occurring only in Goiás and the Distrito Federal. Considering the rapid land use conversion in the Cerrado region (Neves *et al.* 2017; Strassburg *et al.* 2017; Alencar *et al.* 2020), the populations of some of these species are almost certainly being affected by habitat loss. Using an automated conservation status assessment, Pompeu (2022) estimated that 53–86% of endemic Cerrado species are threatened with extinction, highlighting the serious threat situation that affects many species that are fortunately protected at the FAL site.

Although geographically close, the vegetation types compared in this study had low floristic similarity. In fact, rock outcrop vegetation sites shared only 10% of species, with the most similar being CaR and CeR from FAL. The marked distinctiveness of the *campo limpo úmido* is likely driven by water saturation, which acts as an environmental filter, limiting the establishment of certain species and favoring those adapted to high-moisture conditions (Xavier *et al.* 2019). On the other hand, shallow, rocky, and nutrient-poor soils harbouring rock outcrop vegetation favour species adapted to drier conditions and with more diverse growth habits. Nevertheless, each rock outcrop area examined, despite their proximity, harbours a rich and distinct flora, forming a mosaic of plant communities shaped by local soil and microhabitat conditions (Santos *et al.* 2012; Le Stradic *et al.* 2015). This finding

highlights the importance of conserving rock outcrop vegetation across multiple spatial scales, including both local and regional levels.

The four rock outcrop vegetation sites analyzed had low floristic similarity, however they contained similar proportions of herbs, shrubs, and subshrubs. Shrubs and herbs are the most representative life forms in outcrop vegetation (Messias *et al.* 2011; Cunha-Blum *et al.* 2025), and shrub-rich families such as Asteraceae, Melastomataceae, and Fabaceae are consistently among the most species-rich groups in this vegetation (Cunha-Blum *et al.* 2025). For the herbaceous stratum, the family with the highest species richness was Poaceae (19), followed by Cyperaceae (10). The floristic comparison of our samples of CaR and CeR vegetation in FAL (Fig. 5) revealed moderate distinction between these vegetation types, with an overlap of 88 species (i.e. 38.2%), and uniqueness of 34% for CaR and 28.2% for CeR, contributing useful information to the questions raised by Walter (2006) about the (then) still poorly known floristic identity of CaR according to the definition of Ribeiro & Walter (1998). However, while comparing the life-forms between all rock outcrop sites (Table 4) the concept of CeR as a vegetation with more tree-species does not agree with the life-form composition found at the CeR-JBB, and this may be an artefact of sampling (it is possible CaR is also represented in the site but has not been discriminated). In recent work on herbaceous-shrub flora (2025), Mercadante *et al.* state that the Brasília Botanical Garden Ecological Station presents several phytophysiognomies characteristic of the Cerrado, such as *cerrado sensu stricto*, gallery forest, rupestrian field (i.e., *campo rupestre*), “*campo sujo*”, “*campo limpo úmido*”, “*vereda*”, “*cerradão*” and small patches of “*murundus*”.

Finally, the differences between these four rupestrian sites were not found to be significant. In the *campo limpo úmido*, herbs predominated largely due to the high occurrence of Poaceae and Cyperaceae species; these families are among the richest in wet open grassland ecosystems of the Cerrado (Amorim & Batalha 2007; Munhoz *et al.* 2008; Bijos *et al.* 2017). As expected, tree species were more representative in the *cerrado stricto sensu* (Ribeiro & Walter 2008).

Conclusion

Although climate change models suggest that higher-altitude Cerrado areas, where the rock outcrop vegetation is common may support the upslope migration of species from lower elevations (Silva *et al.* 2024), it remains unclear how competitive interactions will unfold between these migrants and the species already established in these rocky environments. Therefore, all types of native vegetation should be conserved, with priority given to

establishing protected areas in the Cerrado that safeguard sites harboring the highest diversity of herbaceous and subshrub species (Amaral *et al.* 2017). Despite the limitation of the study, restricted to a few sites at FAL and additional nearby localities, our results showed that, at a local scale, adjacent vegetation types within the Cerrado differ markedly in species composition and life forms. The species composition of each vegetation type of the Cerrado (alpha diversity) is fundamental to maintain the high plant diversity observed across the region. Consequently, each patch of native vegetation is crucial for the conservation of the biome, which is under heavy threat from accelerated land clearing and transformation (Sano *et al.* 2019).

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Table 2. Vascular plant species from *Cerrado rupestre* (CeR) and *Campo rupestre* (CaR) at Água Limpa Ecological Station, Distrito Federal, Brazil. Life form, distribution and voucher information for each species. Collector: Cartagenes, RCC. *Species categorized as EN according to CNC Flora (2026).

Family/Species	Ce R	Ca R	Life form	Distributio n	Vouche r
Acanthaceae					
<i>Justicia lanstyakii</i> Rizzini	1	1	Subshrub	Cerrado	RC 680
<i>Justicia sarothroides</i> Lindau	1		Subshrub	GO+DF	RC 211
<i>Ruellia hapalotricha</i> Lindau	1	1	Subshrub	Cerrado	RC 91
Anemiaceae					
<i>Anemia millefolia</i> (Gardner) C.Presl		1	Herb	Cerrado	RC 28
<i>Anemia mynsseniana</i> Mickel	1	1	Herb	Cerrado	RC 26
Apiaceae					
<i>Eryngium brasiliense</i> Constance	1		Herb	Cerrado	RC 190
Apocynaceae					
<i>Mandevilla myriophylla</i> (Taub. ex Ule)					
Woodson		1	Subshrub	Cerrado	RC 386
<i>Odontadenia lutea</i> (Vell.) Markgr.	1	1	Subshrub	Wid	RC 544
<i>Oxypetalum erectum</i> Mart.		1	Subshrub	Wid	RC 540
Araliaceae					
<i>Didymopanax macrocarpus</i> (Cham. & Schltld.) Seem.	1		Tree	Cerrado	RC 109
Arecaceae					
<i>Syagrus comosa</i> (Mart.) Mart.	1		Dracenoid	Wid	RC 256
<i>Syagrus glazioviana</i> (Dammer) Becc.		1	Dracenoid	Cerrado	RC 795
Asteraceae					
<i>Achyrocline satureioides</i> (Lam.) DC.	1	1	Subshrub	Wid	RC 212
<i>Ageratum fastigiatum</i> (Gardner) R.M.King & H.Rob.	1	1	Subshrub	Wid	RC 144
<i>Aldama bracteata</i> (Gardner) E.E.Schill. & Panero	1	1	Subshrub	Cerrado	RC 547
<i>Baccharis linearifolia</i> (Lam.) Pers.		1	Subshrub	Wid	RC 298
<i>Baccharis retusa</i> DC.	1	1	Shrub	Brazil	RC 802
<i>Calea fruticosa</i> (Gardner) Urbatsch, Zlotzky & Pruski	1		Shrub	Cerrado	RC 204

Family/Species	Ce R	Ca R	Life form	Distributio n	Vouche r
<i>Calea quadrifolia</i> Pruski & Urbatsch		1	Subshrub	Cerrado	RC 528
<i>Calea sickii</i> (G.M.Barroso) Urbatsch et al.	1	1	Subshrub	GO+DF	RC 535
<i>Chresta scapigera</i> (Less.) Gardner	1	1	Subshrub	Cerrado	RC 696
<i>Chrysolaena simplex</i> (Less.) Dematt.		1	Subshrub	Wid	GS 3
<i>Dimerostemma vestitum</i> (Baker) S.F.Blake		1	Subshrub	Cerrado	RC 466
<i>Disynaphia spathulata</i> (Hook. & Arn.) R.M.King & H.Rob.		1	Subshrub	Brazil	RC 488
<i>Echinocoryne</i> sp.	1	1	Subshrub	n.a.	RC 791
<i>Eremanthus glomerulatus</i> Less.	1		Tree	Cerrado	RC 232
<i>Eremanthus goyazensis</i> (Gardner) Sch.Bip.	1	1	Tree	Cerrado	RC 789
<i>Eremanthus mollis</i> Sch.Bip.	1	1	Shrub	Cerrado	RC 7
<i>Lepidaploa aurea</i> (Mart. ex DC.) H.Rob.	1	1	Shrub	Brazil	RC 534
<i>Lepidaploa rufogrisea</i> (A.St.-Hil.) H.Rob.	1	1	Shrub	Cerrado	RC 523
<i>Lessingianthus buddleiifolius</i> (Mart. ex DC.) H.Rob.		1	Subshrub	Cerrado	RC 500
<i>Lessingianthus eitenii</i> (H.Rob.) H.Rob.*	1	1	Subshrub	GO+DF	RC 532
<i>Lessingianthus elegans</i> (Gardner) H.Rob.	1	1	Shrub	Cerrado	RC 143
<i>Lessingianthus floccosus</i> (Gardner) H.Rob.	1		Shrub	Cerrado	RC 763
<i>Lessingianthus ligulifolius</i> (Mart. ex DC.) H.Rob.	1	1	Subshrub	Wid	RC 533
<i>Lychnophora ericoides</i> Mart.	1	1	Shrub	Brazil	RC 253
<i>Lychnophora planaltina</i> Semir ex Loeuille, Bringel & Faria	1		Shrub	DF	RC 88
<i>Praxelis capillaris</i> (DC.) Sch.Bip.		1	Subshrub	Cerrado	RC 553
<i>Richterago discoidea</i> (Less.) Kuntze	1	1	Subshrub	Cerrado	RC 467
<i>Stenocephalum megapotamicum</i> (Spreng.) Sch.Bip.		1	Subshrub	Wid	RC 14
<i>Trichogonia salviifolia</i> Gardner		1	Subshrub	Wid	RC 487
Bignoniaceae					
<i>Handroanthus coronatus</i> (Proença & Farias) Farias	1		Tree	Cerrado	RC 751
<i>Jacaranda ulei</i> Bureau & K.Schum.	1		Shrub	Cerrado	RC 218
Bromeliaceae					

Family/Species	Ce R	Ca R	Life form	Distributio n	Vouche r
<i>Dyckia marnierlapostollei</i> L.B.Sm.	1		Herb	Cerrado	DZ 681
Calophyllaceae					
<i>Kielmeyera rubriflora</i> Cambess.	1		Shrub	Wid	RC 121
Celastraceae					
<i>Salacia crassifolia</i> (Mart. ex Schult.) G.Don	1		Tree	Wid	RC 263
Convolvulaceae					
<i>Distimake tomentosus</i> (Choisy) Petrongari & Sim.-Bianch.	1	1	Cliber	Cerrado	RC 104
<i>Ipomoea pinifolia</i> Meisn.	1	1	Cliber	Cerrado	RC 55
Cyperaceae					
<i>Bulbostylis hirtella</i> (Schrad.) Urb.		1	Herb	Wid	RC 685
<i>Bulbostylis jacobinae</i> (Steud.) Lindm.	1	1	Herb	Brazil	RC 3
<i>Bulbostylis loefgrenii</i> (Boeckeler) Prata & M.G.López		1	Herb	Brazil	RC 365
<i>Bulbostylis paradoxa</i> (Spreng.) Lindm.		1	Herb	Wid	RC 31
<i>Lagenocarpus rigidus</i> Nees	1	1	Herb	Wid	RC 313
<i>Lagenocarpus verticillatus</i> (Spreng.) T.Koyama & Maguire	1	1	Herb	Brazil	RC 783
<i>Rhynchospora albiceps</i> Kunth	1		Herb	Wid	RC 266
<i>Rhynchospora armerioides</i> J.Presl & C.Presl	1	1	Herb	Wid	RC 539
<i>Rhynchospora barbata</i> (Vahl) Kunth		1	Herb	Wid	RC 387
<i>Rhynchospora consanguinea</i> (Kunth) Boeckeler	1	1	Herb	Wid	RC 343
<i>Rhynchospora elatior</i> Kunth	1	1	Herb	Brazil	RC 613
<i>Rhynchospora exaltata</i> Kunth	1		Herb	Wid	RC 766
<i>Rhynchospora globosa</i> (Kunth) Roem. & Schult.		1	Herb	Wid	RC 411
<i>Rhynchospora loefgrenii</i> Boeckeler	1		Herb	Wid	RC 131
<i>Rhynchospora nervosa</i> (Vahl) Boeckeler	1		Herb	Brazil	RC 364
<i>Rhynchospora patuligluma</i> C.B.Clarke ex Lindm.	1	1	Herb	Cerrado	RC 12
<i>Rhynchospora pilosa</i> Boeckeler	1	1	Herb	Brazil	RC 494
<i>Rhynchospora</i> sp.	1		herb	n.a.	RC 349

Family/Species	Ce R	Ca R	Life form	Distributio n	Vouche r
<i>Scleria leptostachya</i> Kunth	1		Herb	Wid	RC 228
<i>Scleria tenella</i> Kunth		1	Herb	Wid	RC 681
Dilleniaceae					
<i>Davilla elliptica</i> A.St.-Hil.	1	1	Tree	Wid	RC 182
Droseraceae					
<i>Drosera communis</i> A.St.-Hil.		1	Herb	Wid	RC 393
Eriocaulaceae					
<i>Actinocephalus bongardii</i> (A.St.-Hil.) Sano		1	Herb	Brazil	RC 284
<i>Coracoralina chiquitensis</i> (Herzog) Andrino	1	1	Herb	Wid	RC 551
<i>Floralia elongata</i> (Bong.) Andrino	1	1	Herb	Cerrado	RC 275
<i>Syngonanthus davidsei</i> Huft.		1	Herb	Wid	RC 616
<i>Syngonanthus nitens</i> Ruhland		1	Herb	Wid	RC 381
Erythroxylaceae					
<i>Erythroxylum campestre</i> A.St.-Hil.		1	Shrub	Wid	RC 464
Euphorbiaceae					
<i>Croton campestris</i> A.St.-Hil.		1	Subshrub	Wid	RC 458
<i>Croton goyazensis</i> Müll.Arg.	1		Subshrub	Brazil	RC 145
<i>Dalechampia caperonioides</i> Baill.		1	Subshrub	Cerrado	JP 308
<i>Dalechampia francisceana</i> Baill.	1	1	Subshrub	Brazil	RC 54
Fabaceae					
<i>Bowdichia virgilioides</i> Kunth	1		Tree	Wid	RC 206
<i>Calliandra dysantha</i> Benth.	1	1	Shrub	Wid	RC 125
<i>Chamaecrista decumbens</i> (Benth.) H.S.Irwin & Barneby	1		Subshrub	Cerrado	RC 122
<i>Chamaecrista orbiculata</i> (Benth.) H.S.Irwin & Barneby	1		Shrub	Wid	RC 127
<i>Chamaecrista planaltoana</i> (Harms) H.S.Irwin & Barneby	1	1	Subshrub	Cerrado	RC 792
<i>Ctenodon graminoides</i> (G.P.Lewis) D.B.O.S.Cardoso & H.C.Lima*	1		Subshrub	GO+DF	RC 153
<i>Dalbergia miscolobium</i> Benth.		1	Tree	Cerrado	RC 814
<i>Eriosema glaziovii</i> Harms	1	1	Subshrub	Cerrado	RC 13
<i>Mimosa clausenii</i> Benth.	1	1	Shrub	Cerrado	RC 247

Family/Species	Ce R	Ca R	Life form	Distributio n	Vouche r
<i>Mimosa lanuginosa</i> Glaz. ex Burkart	1	1	Subshrub	GO+DF	RC 315
<i>Mimosa radula</i> Benth.	1		Shrub	Cerrado	RC 636
<i>Mimosa somnians</i> Humb. & Bonpl. ex Willd.	1		Shrub	Wid	RC 617
<i>Mimosa speciosissima</i> Taub.	1	1	Subshrub	GO+DF	RC 286
<i>Periandra mediterranea</i> (Vell.) Taub.	1	1	Shrub	Wid	RC 123
<i>Stylosanthes capitata</i> Vogel		1	Subshrub	Wid	RC 677
<i>Stylosanthes guianensis</i> (Aubl.) Sw.	1		Subshrub	Wid	RC 124
<i>Stylosanthes macrocephala</i> M.B.Ferreira & Sousa Costa	1		Subshrub	Brazil	RC 595
<i>Tachigali subvelutina</i> (Benth.) Oliveira-Filho		1	Tree	Wid	RC 788
Gentianaceae					
<i>Schultesia gracilis</i> Mart.		1	Herb	Brazil	RC 537
Iridaceae					
<i>Pseudotrimezia juncifolia</i> (Klatt) Lovo & A.Gil		1	Herb	Brazil	RC 489
Lamiaceae					
<i>Cyanocephalus taciannae</i> (Harley) Harley & J.F.B.Pastore	1	1	Subshrub	GO+DF	RC 526
<i>Hypenia macrantha</i> (A.St.-Hil. ex Benth.) Harley	1	1	Subshrub	Brazil	RC 811
<i>Hyptis hilarii</i> Benth.	1		Shrub	GO+DF	RC 112
<i>Hyptis saxatilis</i> A.St.-Hil. ex Benth.	1	1	Shrub	Cerrado	RC 741
<i>Hyptis villosa</i> Pohl ex Benth.		1	Subshrub	Wid	RC 545
Lentibulariaceae					
<i>Utricularia subulata</i> L.		1	Herb	Wid	RC 555
Loranthaceae					
<i>Passovia ovata</i> (Pohl ex DC.) Tiegh.	1	1	Mistletoe/ climb	Brazil	RC 491
<i>Struthanthus flexicaulis</i> (Mart.) Mart.	1		Mistletoe/ climb	Brazil	RC 199
<i>Struthanthus polyrhizus</i> (Mart.) Mart.		1	Mistletoe/ climb	Brazil	RC 10
Lythraceae					

Family/Species	Ce R	Ca R	Life form	Distributio n	Vouche r
<i>Cuphea acicularis</i> Koehne	1	1	Subshrub	Cerrado	RC 585
<i>Cuphea filiformis</i> T.B.Cavalc. & S.A.Graham		1	Subshrub	Cerrado	RC 283
<i>Cuphea spermacoce</i> A.St.-Hil.		1	Subshrub	Cerrado	RC 24
<i>Diplusodon capitalensis</i> T.B.Cavalc.*		1	Shrub	GO+DF	RC 775
<i>Diplusodon oblongus</i> Pohl		1	Shrub	Cerrado	RC 665
<i>Diplusodon rosmarinifolius</i> A.St.-Hil.	1	1	Shrub	Cerrado	RC 92
<i>Diplusodon sessiliflorus</i> Koehne	1	1	Shrub	Cerrado	RC 106
<i>Diplusodon villosus</i> Pohl	1		Shrub	Cerrado	RC 606
Malpighiaceae					
<i>Banisteriopsis campestris</i> (A.Juss.) Little	1	1	Shrub	Brazil	RC 453
<i>Banisteriopsis latifolia</i> (A.Juss.) B.Gates	1		Shrub	Cerrado	RC 726
<i>Banisteriopsis malifolia</i> (Nees & Mart.) B.Gates	1		Subshrub	Brazil	RC 609
<i>Banisteriopsis stellaris</i> (Griseb.) B.Gates	1	1	Climb	Brazil	RC 684
<i>Byrsonima pachyphylla</i> A.Juss.	1	1	Tree	Wid	RC 455
<i>Byrsonima viminifolia</i> A.Juss.	1	1	Tree	Cerrado	RC 730
<i>Camarea hirsuta</i> A.St.-Hil.	1	1	Subshrub	Cerrado	RC 546
<i>Heteropterys campestris</i> A.Juss.	1	1	Climb	Wid	RC 591
<i>Peixotoa goiana</i> C.E.Anderson	1		Subshrub	Cerrado	RC 114
<i>Pterandra pyroidea</i> A.Juss.	1		Subshrub	Cerrado	RC 244
Malvaceae					
<i>Helicteres andersonii</i> Cristóbal	1		Shrub	Cerrado	RC 142
<i>Pavonia grandiflora</i> A.St.-Hil.	1		Shrub	Brazil	RC 712
Melastomataceae					
<i>Cambessedesia espora</i> (A.St.-Hil. ex Bonpl.) DC.	1		Subshrub	Cerrado	RC 103
<i>Cambessedesia hilariana</i> (Kunth) DC.		1	Subshrub	Cerrado	RC 306
<i>Chaetogastra parviflora</i> (Cogn.) P.J.F.Guim. & Michelang.	1		Subshrub	Cerrado	RC 98
<i>Miconia albicans</i> (Sw.) Triana	1	1	Shrub	Wid	RC 196
<i>Miconia ferruginata</i> DC.	1	1	Shrub	Wid	RC 62
<i>Miconia minutiflora</i> (Bonpl.) DC.	1		Tree	Wid	RC 99
<i>Microlicia acuminata</i> Naudin		1	Subshrub	Cerrado	RC 691

Family/Species	Ce R	Ca R	Life form	Distributio n	Vouche r
<i>Microlicia consimilis</i> Wurdack	1	1	Subshrub	GO+DF	RC 672
<i>Microlicia hirsuta</i> (DC.) R.Romero, Versiane & Woodgyer		1	Subshrub	Brazil	RC 282
<i>Microlicia neogracilis</i> Versiane & R.Romero		1	Subshrub	GO+DF	R 3065
<i>Microlicia polystemma</i> Naudin	1	1	Subshrub	Cerrado	RC 569
<i>Microlicia ramosa</i> Pilg.		1	Subshrub	Cerrado	RC 561
<i>Microlicia serpyllifolia</i> D.Don	1	1	Subshrub	Brazil	RC 471
<i>Microlicia suberosa</i> (Naudin) Versiani & R.Romero		1	Subshrub	GO+DF	RC 690
<i>Ossaea congestiflora</i> (Naudin) Cogn.		1	Shrub	Cerrado	RC 475
<i>Pleroma candolleanum</i> (Mart. ex DC.) Triana	1		Tree	Cerrado	RC 101
<i>Pleroma stenocarpum</i> (Schränk et Mart. ex DC.) Triana	1	1	Tree	Wid	RC 97
<i>Stenodon suberosus</i> Naudin	1	1	Shrub	GO+DF	RC 357
<i>Tibouchina aegopogon</i> (Naudin) Cogn.	1	1	Shrub	Cerrado	RC 524
Myrtaceae					
<i>Eugenia langsdorffii</i> O.Berg	1	1	Shrub	Cerrado	RC 105
<i>Eugenia puniceifolia</i> (Kunth) DC.	1		Shrub	Brazil	RC 719
<i>Myrcia goyazensis</i> Cambess.		1	Shrub	Brazil	RC 290
<i>Myrcia nivea</i> Cambess.	1		Shrub	Cerrado	RC 340
<i>Myrcia pinifolia</i> Cambess.	1	1	Shrub	Cerrado	RC 316
<i>Myrcia tomentosa</i> (Aubl.) DC.	1		Shrub	Wid	RC 230
<i>Psidium firmum</i> O.Berg	1	1	Shrub	Brazil	RC 5
Ochnaceae					
<i>Ouratea floribunda</i> (A.St.-Hil.) Engl.		1	Shrub	Cerrado	RC 465
<i>Ouratea salicifolia</i> (A.St.-Hil. & Tul.) Engl.	1		Tree	Brazil	RC 243
<i>Sauvagesia erecta</i> L.		1	Subshrub	Wid	JP 321
<i>Sauvagesia racemosa</i> A.St.-Hil.		1	Subshrub	Wid	JP 318
Orchidaceae					
<i>Cyrtopodium eugenii</i> Rchb.f.	1		Herb	Wid	RC 733
<i>Habenaria armata</i> Rchb.f.		1	Herb	Wid	JP 326
<i>Habenaria imbricata</i> Lindl.		1	Herb	Brazil	JP 323
<i>Habenaria lavrensis</i> Hoehne		1	Herb	Cerrado	RC 49

Family/Species	Ce R	Ca R	Life form	Distributio n	Vouche r
<i>Habenaria secundiflora</i> Barb.Rodr.	1	1	Herb	Wid	RC 702
Oxalidaceae					
<i>Oxalis densifolia</i> Mart. & Zucc. ex Zucc.	1		Herb	Brazil	RC 642
Poaceae					
<i>Agenium leptocladum</i> (Hack.) Clayton		1	Herb	Wid	RO3304
<i>Andropogon leucostachyus</i> Kunth		1	Herb	Wid	RC 384
<i>Aristida adscensionis</i> L.	1	1	Herb	Invasive	RC 201
<i>Aristida gibbosa</i> (Nees) Kunth	1	1	Herb	Wid	RC 784
<i>Aristida recurvata</i> Kunth	1	1	Herb	Wid	RC 147
<i>Aristida setifolia</i> Kunth	1		Herb	Wid	RC 139
<i>Axonopus aureus</i> P. Beauv.	1		Herb	Wid	RC 149
<i>Axonopus brasiliensis</i> (Spreng.) Kuhlm.		1	Herb	Wid	RC 150
<i>Axonopus pressus</i> (Nees ex Steud.) Parodi	1		Herb	Wid	RC 641
<i>Echinolaena inflexa</i> (Poir.) Chase	1	1	Herb	Wid	RC 198
<i>Homolepis longispicula</i> (Döll) Chase		1	Herb	Cerrado	RC 502
<i>Ichnanthus inconstans</i> (Trin. ex Nees) Döll		1	Herb	Wid	RC 307
<i>Mesosetum loliiforme</i> (Hochst.) Chase		1	Herb	Wid	RC 79
<i>Otachyrium seminudum</i> Hack. ex Send. & Soderstr.		1	Herb	Cerrado	RC 510
<i>Panicum campestre</i> Nees ex Trin.	1		Herb	Brazil	RC 240
<i>Panicum olyroides</i> Kunth	1		Herb	Wid	RC 180
<i>Paspalum carinatum</i> Humb. & Bonpl. ex Flüggé	1		Herb	Wid	RC 589
<i>Paspalum eucomum</i> Nees ex Trin.	1		Herb	Cerrado	RC 136
<i>Paspalum glaziovii</i> (A.G.Burm.) S.Denham		1	Herb	Cerrado	RC 25
<i>Paspalum lanciflorum</i> Nees ex Steud.	1	1	Herb	Wid	RC 134
<i>Paspalum polyphyllum</i> Nees		1	Herb	Wid	RC 818
<i>Paspalum</i> sp.	1		herb	n.a.	RC 137
<i>Paspalum trichostomum</i> Hack.	1	1	Herb	Cerrado	RC 135
<i>Schizachyrium sanguineum</i> (Retz.) Alston	1	1	Herb	Wid	RC 146
<i>Trachypogon spicatus</i> (L.f.) Kuntze	1	1	Herb	Wid	RC 242
<i>Trichanthecium wettsteinii</i> (Hack.) Zuloaga & Morrone	1	1	Herb	Brazil	RC 611

Family/Species	Ce R	Ca R	Life form	Distributio n	Vouche r
Polygalaceae					
<i>Monnina exalata</i> A.W.Benn.		1	Herb	Cerrado	RC 2
<i>Senega atropurpurea</i> (A.St.-Hil. & Moq.) J.F.B.Pastore		1	Herb	Cerrado	RC 794
<i>Senega franchetii</i> (Chodat) J.F.B.Pastore*		1	Herb	Cerrado	RC 479
<i>Senega galioides</i> (Poir.) J.F.B.Pastore		1	Herb	Wid	RC 542
Primulaceae					
<i>Myrsine umbellata</i> Mart.	1		Tree	Wid	RC 246
Proteaceae					
<i>Roupala montana</i> Aubl.	1		Tree	Wid	RC 603
Rubiaceae					
<i>Alibertia edulis</i> (Rich.) A.Rich.	1		Shrub	Wid	RC 115
<i>Borreria capitata</i> (Ruiz & Pav.) DC.	1	1	Subshrub	Wid	RC 93
<i>Borreria poaya</i> (A.St.-Hil.) DC.	1		Subshrub	Wid	RC 116
<i>Borreria tenella</i> (Kunth) Cham. & Schltdl.	1	1	Subshrub	Wid	RC 662
<i>Chomelia ribesioides</i> Benth. ex A.Gray	1	1	Shrub	Wid	RC 470
<i>Coccocypselum aureum</i> (Spreng.) Cham. & Schltdl.		1	Subshrub	Wid	RC 675
<i>Coccocypselum lanceolatum</i> (Ruiz & Pav.) Pers.		1	Subshrub	Wid	RC 673
<i>Palicourea officinalis</i> Mart.		1	Shrub	Cerrado	RC 486
<i>Palicourea rigida</i> Kunth		1	Shrub	Wid	RC 521
<i>Psyllocarpus phyllocephalus</i> K.Schum.		1	Subshrub	Cerrado	JP 322
<i>Sabicea brasiliensis</i> Wernham	1	1	Shrub	Wid	RC 481
Salicaceae					
<i>Casearia arborea</i> (Rich.) Urb.		1	Tree	Wid	RC 454
<i>Casearia grandiflora</i> Cambess.	1	1	Tree	Wid	RC 647
<i>Casearia sylvestris</i> Sw.	1		Tree	Wid	RC 233
Sapindaceae					
<i>Serjania reticulata</i> Cambess.		1	Climb	Wid	RC 661
Sapotaceae					
<i>Pouteria ramiflora</i> (Mart.) Radlk.	1		Tree	Wid	RC 96
Smilacaceae					

Family/Species	Ce R	Ca R	Life form	Distributio n	Vouche r
<i>Smilax brasiliensis</i> Spreng.		1	Climber	Cerrado	RC 22
Solanaceae					
<i>Solanum subumbellatum</i> Vell.		1	Shrub	Brazil	RC 480
Turneraceae					
<i>Turnera lamiifolia</i> Cambess.	1		Subshrub	Cerrado	RC 207
Velloziaceae					
<i>Barbacenia flavida</i> Goethart & Henrard		1	Dracenoid	Cerrado	RC 295
<i>Vellozia pumila</i> Goethart & Henrard	1	1	Dracenoid	Cerrado	RC 270
<i>Vellozia variabilis</i> Mart. ex Schult. & Schult.f.	1	1	Dracenoid	Wid	RC 259
Verbenaceae					
<i>Lippia lacunosa</i> Mart. & Schauer	1	1	Shrub	Wid	RC 234
Vochysiaceae					
<i>Qualea multiflora</i> Mart.	1		Tree	Wid	RC 610
<i>Qualea parviflora</i> Mart.	1		Tree	Wid	RC 130
<i>Salvertia convallariodora</i> A.St.-Hil.	1		Tree	Wid	RC 129
<i>Vochysia elliptica</i> Mart.	1	1	Tree	Brazil	RC 128
<i>Vochysia pumila</i> Pohl	1	1	Shrub	Cerrado	RC 17
Xyridaceae					
<i>Xyris asperula</i> Mart.		1	Herb	Cerrado	RC 77
<i>Xyris hymenachne</i> Mart.	1	1	Herb	Wid	RC 567
<i>Xyris savanensis</i> Miq.	1	1	Herb	Wid	RC 549
<i>Xyris tenella</i> Kunth		1	Herb	Wid	RC 407
<i>Xyris tortula</i> Mart.	1	1	Herb	Brazil	RC 559

Supplementary material S1 - Boolean Research Tables (main)

<https://www.webofscience.com/wos/woscc/summary/69ef1235-f411-4b65-a819-e408d60b65df-01a6b76886/relevance/1>

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