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THE CACTACEAE FAMILY IN *INSELBERGS* OF THE SUGARLOAF LAND, SOUTHEASTERN BRAZIL

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Abstract: Isolated monoliths of granite and/or gneissic rock that rise abruptly from the surrounding landscape are known as *inselbergs*. Dome-shaped *inselbergs* are common throughout the Atlantic Forest in southeastern Brazil, a region known as the Of the Sugarloaf Land (SL). This study aimed to provide a comprehensive list of species from the Cactaceae family that occur in sugarloaf *inselbergs* in the SL, discuss the conservation status of these species, and provide brief ecological descriptions. Information from online databases, own sampling and data from previously published studies were used. We compiled a total of 17 species of Cactaceae, belonging to eight genera. Among the catalogued species, one is listed as threatened with extinction, one has data deficiencies, six are in less worrying categories and nine have not been assessed.

Keywords: Rock outcrops, cacti, Atlantic Forest, *inselbergs*, rupicolous plants

INTRODUCTION

Brazil has the greatest diversity of seed plants in the world (BFG 2018). Surprisingly, inventories in well-studied areas, such as the Atlantic Forest in southeastern Brazil, continue to record new species for science (Sobral & Stehmann 2009). This is especially true for underexplored habitats such as *inselbergs* (Barthlott & Porembski 2000), isolated monoliths in the landscape of granite and/or gneissic rock.

In recent decades, several new species from+ different families have been identified in these locations (Kollmann & Fontana 2010, Leme et al. 2010a, Leme et al. 2010b, Gonçalves & de Paula 2016).

Inselbergs are common features in many landscapes around the world (Hopper et al. 2016), being especially biodiverse in southeastern Brazil, the central highlands of Madagascar, and southwestern Australia

(Porembski 2007). They are characterized by extreme soil and microclimatic conditions, which leads to the ecological isolation of these formations in relation to the surrounding matrix and their similarity to islands (Porembski et al. 2000).

In the Atlantic Forest, *inselbergs* are characteristic elements of the landscape, occurring in large numbers and varying in size, altitude and degree of isolation (Safford & Martinelli 2000). The term “Sugarloaf” is associated with low-altitude, isolated, dome-shaped *inselbergs* present in the Atlantic Forest of southeastern Brazil (Ab’Sáber 1967). The region that concentrates these outcrops is called the Sugarloaf Land (SL); de Paula et al. 2016).

Literature on the flora and vegetation of *inselbergs* is scarce and data on their ecological characteristics are mainly descriptive. Despite the lack of detailed knowledge about Brazilian *inselbergs*, previous regional studies suggest a high floristic richness (eg Meirelles et al. 1999, Caiafa & Silva 2005; de Paula et al. 2016, 2020).

The Cactaceae family is widely represented in rocky outcrops, where several species exhibit remarkable adaptations to extreme environmental conditions, such as water scarcity and high sun exposure (Taylor & Zappi 2004). In addition to their ecological importance, cacti have great landscaping and ornamental potential, being valued in gardens and collections for their beauty and resistance. However, these plants face significant threats due to illegal extraction and mining (Martinelli et al. 2007), which results in the destruction of their natural habitat.

Considering the lack of research and the rapid destruction of these unique formations, this study presents a list of Cactaceae species that occur in *inselbergs*, of the “sugar loaf” type, present in the Atlantic Forest of southeastern Brazil.

The aim of this work is to provide comprehensive and up-to-date information about the species, including their life forms and conservation status, as well as illustrating the diversity of Cactaceae in these rock formations.

MATERIAL AND METHODS

The study area covers lowland *inselbergs* in the states of Rio de Janeiro, Espírito Santo, southern Bahia and eastern Minas Gerais, that is, present in the Sugarloaf Land (de Paula et al. 2016, 2020).

First, the list of angiosperms presents in the SL inventory (de Paula et al. 2020) was extracted, from which species from the Cactaceae family were filtered. As a next step, species sampled by the author were added, that is, species that, until now, had not been documented in de Paula et al. (2020). Species were also added based on available literature, such as floristic inventories, original species descriptions and ecological studies. Sampling was restricted to Cactaceae species that occur on islands of vegetation (Porembski et al. 2000), for example: isolated patches of vegetation of various shapes and sizes, delimited by exposed rock or directly sitting on exposed rock (de Paula et al. 2017).

The final list was composed of native plants and only includes vouchers identified at the species level, based on the List of Species of Flora and Funga of Brazil (2024). The correction and updating of names were performed using the function in the flora package (Carvalho 2017) for the R software environment (R Core Team 2016), which compares the names in the list with those in Flora and Funga of Brazil, 2024). Families and genera follow the Flora and Funga of Brazil (2024) and are listed in alphabetical order. Herbarium acronyms follow Thiers (2020). The vouchers were carefully chosen from specimens collected on vegetation islands of lowland *inselbergs*. Links have been added to

vouchers with images available in Jabot-JBRJ (2020) and in ReFlora - Virtual Herbarium 2020, which can be continuously updated in relation to taxonomic changes. Information on life forms was obtained for each species, based on the Flora and Funga of Brazil (2024).

To assign conservation status, information from the National Flora Conservation Center was used (<http://www.cncflora.jbrj.gov.br/portal>), which provides a continually updated list of threatened plant species in the country (MMA 2022).

RESULTS

A total of 17 species of Cactaceae were compiled, belonging to eight genera (Table 1; Figure 1). Link to the vouchers for the cataloged species are present in Table 2. The richest genera were *Coleocephalocereus* (five spp.) and *Rhipsalis* (four spp.) (Figure 2). Among the cataloged species, one is listed as endangered (CR, critically endangered; *Rhipsalis cereoides*), one has data deficiencies, six are in categories of least concern and nine have not been assessed (Table 1). The most predominant life form is the shrub (nine spp.); (Figure 3).



Figure 1: Species of Cactaceae in the Of the Sugarloaf Land, present in the Atlantic Forest domain in Southeast Brazil. From left to right, in line 1: *Pilosocereus brasiliensis*, *Coleocephalocereus fluminensis*, *Cereus fernambucensis*; in line 2: *Coleocephalocereus buxbaumianus*, *Rhipsalis cereoides*.

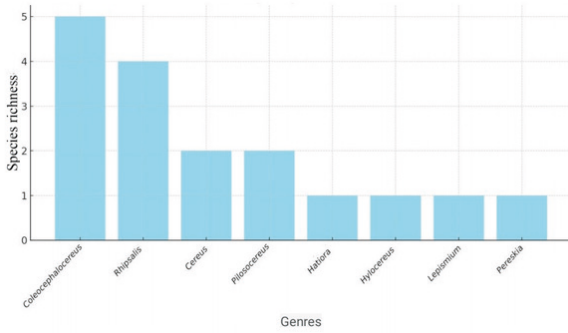


Figure 2: Richness of Cactaceae species by genus.

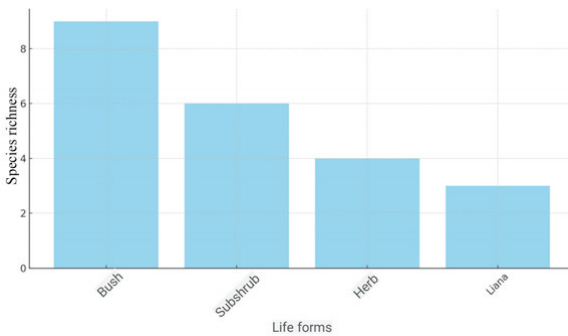


Figure 3: Richness of Cactaceae species by life form.

DISCUSSION

This study reveals the diversity of Cactaceae species in the *inselbergs* of the region known as the Sugarloaf Land (de Paula et al. 2020). Several groups of plants, including Bromeliaceae (for example: *Alcantarea* spp., de Paula et al. 2016) and Orchidaceae (for example: *Pseudolaelia* spp.; Menini-Neto & Forzza 2013), also diversified in the sugar loaves of this central area. These findings suggest that historical factors, combined with long-term isolation and climatic conditions (de Paula et al. 2021), may have influenced the pattern of high plant diversity in these *inselbergs*.

The Cactaceae family, which has an endemic distribution in the Americas (except *Rhipsalis baccifera*), is associated with a variety of xerophilic environments, soil textures, solar irradiance and altitudes (Taylor & Zappi 2004). There are three main centers of diversity for this family: the Andes, the Caatinga and the Atlantic Forest (Barthlott

et al. 2015). In the Atlantic Forest, the richest genera described are *Rhipsalis*, *Schlumbergera*, *Lepismium* and *Pilosocereus* (Barthlott et al. 2015). But especially the genera *Cereus*, *Coleocephalocereus* and *Pilosocereus* occur in rocky outcrops in the Caatinga and Atlantic Forest (Barthlott et al. 2015). Cactaceae is a charismatic group of plants and an example of recent radiation (Arakaki et al. 2011), presenting a remarkable diversity in growth forms (Hunt et al. 2006). In *inselbergs*, the cacti not only accumulate water, but also have spines (modified leaves) and trichome-like spikes at the base of the stem, adapting to avoid overheating when directly on the rock, as is typical of *Coleocephalocereus* species (Paula et al. 2017).

Cactaceae, together with Bromeliaceae and Orchidaceae, occur both on the slopes and in the flatter parts of the outcrops, forming mats that play an important role in the plant communities of the *inselbergs*. These plant mats facilitate the succession process by creating a substrate that increases water availability and provides mechanical support, allowing the development of other plants. It is common to find different species of Araceae, Apocynaceae, Euphorbiaceae, Gesneriaceae, ferns, among others, coexisting in these carpets (Porembski 2007, de Paula et al. 2015). However, it is still unclear to what extent different mat formers compete with each other or whether they have specific habitat preferences.

A common phenomenon in these outcrops is the occurrence of polymorphic species (de Paula et al. 2020, 2021). Many *inselberg* taxa have been described as exhibiting extensive intraspecific variation between and within populations, especially monocots such as *Anthurium*, *Philodendron* (Araceae), *Alcantarea*, *Encholirium*, *Pitcairnia* (Bromeliaceae), *Pseudolaelia* (Orchidaceae), *Barbacenia* and *Vellozia* (Velloziaceae), but also eudicots, such as *Pleroma* (Melastomataceae)

and *Coleocephalocereus* (Cactaceae) (Mello-Silva 2004, Taylor & Zappi 2004, Hmeljevski et al. 2017, de Paula et al. 2017, Menini-Neto et al. 2019). The spatial and ecological isolation of these outcrops, due to their embeddedness in the surrounding forest, is considered responsible for the high levels of genetic differentiation among populations, including *Alcantarea* (Barbará et al. 2007), *Encholirium* (Hmeljevski et al. 2015, Hmeljevski et al., 2017) and *Pitcairnia* (Palma-Silva et al. 2011). This morphological variability is frequently reported in adaptive radiation events (Palma-Silva et al. 2011).

In many tropical and subtropical regions, threats to *inselberg* biodiversity are growing rapidly (Porembski et al. 2016). In addition to the removal of low-lying vegetation in areas surrounding *inselbergs*, which facilitates biological invasion, these outcrops face specific threats such as mining and unsustainable harvesting of attractive flora species (Martinelli 2007). The vulnerability of *inselberg* plant communities is exacerbated

by soil removal, as their species generally have reduced growth rates and low dispersal capacity (Hopper et al. 2016). Consequently, the ability of these communities to persist and recover after disturbances is very low, increasing the opportunity for invasive organisms.

Given the low coverage of protected areas that may only encompass a small portion of the range of Cactaceae species, it is urgently necessary to assess and recognize semiarid and arid lands in the Neotropics (Barthlott et al., 2015), such as *inselbergs*, to ensure the protection of their species. This study, by compiling the diversity of Cactaceae in the Of the Sugarloaf Land and highlighting their threats, contributes to the planning of more effective conservation strategies. Future studies must focus on evaluating the degree of endemism of the family in granite outcrops, the number of species with disjunct and small distributions, the IUCN threat criteria and whether these species are in protected areas.

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Family	Species	Author	Origin	Threat Category	Life forms	Source	Habitat	Reference or voucher
Cactaceae	<i>Cereus hildmannianus</i>	K. Schum.	Native	AT	Bush	FAN	SAW	Pena and Alves-Araújo 2017
Cactaceae	<i>Cereus fernambucensis</i>	Lem.	Native	AT	Bush	F, C	SAW	de Paula, LFA 1047 (RB)
Cactaceae	<i>Coleocephalocereus braunii</i>	Diers & Esteves	Native	AT	Bush; Subshrub	F, EC	SAW	Cardoso, WC 406 (VIES)
Cactaceae	<i>Coleocephalocereus buxbaumianus</i>	Building	Native	AT	Bush	F, C	SAW	Mauad, LP 373 (RB)
Cactaceae	<i>Coleocephalocereus decumbens</i>	Ritter	Native	AT	Bush; Subshrub	F, C	SAW	de Paula, LFA 906 (RB)
Cactaceae	<i>Coleocephalocereus fluminensis</i>	(Miq.) Backeb.	Native	AT	Bush	F, C	SAW	de Paula, LFA 1037 (RB)
Cactaceae	<i>Coleocephalocereus pluricostatus</i>	Buining & Brederoo	Native	AT	Bush; Subshrub	F, C	SAW	de Paula, LFA 990 (RB)
Cactaceae	<i>Hattoria cylindrica</i>	Britton & Rose	Native	DD	Herb	EC	VI, S	Zorzanelli, JPF 1087 (RB)
Cactaceae	<i>Hylocereus setaceus</i>	(Salm-Dyck) R.Bauer	Native	L.C.	Liana	F, C	SAW	de Paula, LFA 908 (RB)
Cactaceae	<i>Lepismium cruciform</i>	(Vell.) Miq.	Native	L.C.	Herb	F, C	VI, S	Kollmann, L. 11388 (RB)
Cactaceae	<i>Pereskia aculeata</i>	Mill.	Native	L.C.	Liana	F, C	VI, S	by Paula. LFA 1067 (RB)
Cactaceae	<i>Pilosocereus arrabidaei</i>	(Lem.) Byles & Rowley	Native	L.C.	Bush	F, EC	SAW	Barros, AAM 2300 (RB)
Cactaceae	<i>Pilosocereus brasiliensis</i>	(Britton & Rose) Backeb.	Native	NT	Bush; Liana	F, C	SAW	de Paula, LFA 1075 (RB)
Cactaceae	<i>Rhipsalis floccosa</i>	Salm-Dyck ex Pfeiff.	Native	L.C.	Herb; Subshrub	A	SAW	Pena and Alves-Araújo 2017
Cactaceae	<i>Rhipsalis cereoides</i>	(Backeb. & Voll) Backeb.	Native	CR	Herb	FAN	SAW	Meirelles et al. 1999
Cactaceae	<i>Rhipsalis grandiflora</i>	Haw.	Native	AT	Subshrub	EC	VI, S	Carauta, JPP 3353 (RB)
Cactaceae	<i>Rhipsalis triangularis</i>	Werderm.	Native	AT	Subshrub	W	SAW	Braga, JMA 3357 (RB)

Table 1. List of Cactaceae occurring in lowland *inselbergs* in the Atlantic Forest, southeastern Brazil. Origin and forms of life: following Flora and Funga of Brazil (2024) (<http://floradobrasil.jbrj.gov.br/>); Threat category: following the National Flora Conservation Center (<http://www.cncflora.jbrj.gov.br/portal/>); DD = Data Deficient, NT = Near Threatened, VU = Vulnerable, CR = Critically Endangered, EN = Endangered, LC = Least Concern, NE = Not Assessed. Source: indicates where the information that the species occurs in lowland *inselbergs* was obtained; F: when the species was listed on the Flora and Funga of Brazil (2024) website as occurring in “Rocky outcrop vegetation” (and confirmed to occur in lowland *inselbergs*); A: when the species was found in previously published articles (in this case the article reference is provided); C: when the species was collected by the author of this article; EC: when the species was sampled by an extra collector and vouchers were found in online databases (JABOT-JBRJ, www.jbrj.gov.br/jabot/; Reflora-Herbário Virtual, <http://reflora.jbrj.gov.br/reflora/herbarioVirtual/>). Habitat: indicates whether the species occurs on islands of vegetation (VI; elliptical patches of vegetation surrounded by exposed rock) and scrube (S; arboreal-shrub vegetation surrounding the *inselberg*). References or voucher: indicates vouchers with the respective herbarium acronym according to Thiers (<http://sweetgum.nybg.org/ih/>, continually updated) when the source is C or EC; if the source is A, the article reference was provided.

Family	Species	Author	Reference or voucher	Link to voucher
Cactaceae	<i>Cereus hildmannianus</i>	K. Schum.	Pena and Alves-Araújo 2017	
Cactaceae	<i>Cereus fernambucensis</i>	Lem.	de Paula, LFA 1047 (RB)	http://jabot.jbrj.gov.br/v3/consulta.php?edtcodbarras=1157446&chkboxherbario[]=RB
Cactaceae	<i>Coleocephalocereus braunii</i>	Diers & Esteves	Cardoso, WC 406 (VIES)	http://jabot.jbrj.gov.br/v3/consulta.php?edtcodbarras=048708&chkboxherbario[]=RB
Cactaceae	<i>Coleocephalocereus buxbaumianus</i>	Building	Mauad, LP 373 (RB)	http://jabot.jbrj.gov.br/v3/consulta.php?edtcodbarras=1115621&chkboxherbario[]=RB
Cactaceae	<i>Coleocephalocereus decumbens</i>	Ritter	de Paula, LFA 906 (RB)	http://jabot.jbrj.gov.br/v3/consulta.php?edtcodbarras=1115716&chkboxherbario[]=RB
Cactaceae	<i>Coleocephalocereus fluminensis</i>	(Miq.) Backeb.	de Paula, LFA 1037 (RB)	http://jabot.jbrj.gov.br/v3/consulta.php?edtcodbarras=1157436&chkboxherbario[]=RB
Cactaceae	<i>Coleocephalocereus pluricostatus</i>	Buining & Brederoo	de Paula, LFA 990 (RB)	http://jabot.jbrj.gov.br/v3/consulta.php?edtcodbarras=1115458&chkboxherbario[]=RB
Cactaceae	<i>Hatiora cylindrica</i>	Britton & Rose	Zorzanelli, JPF 1087 (RB)	http://jabot.jbrj.gov.br/v3/consulta.php?edtcodbarras=R-B01097481&chkboxherbario[]=RB
Cactaceae	<i>Hylocereus setaceus</i>	(Salm-Dyck) R.Bauer	de Paula, LFA 908 (RB)	http://jabot.jbrj.gov.br/v3/consulta.php?edtcodbarras=1115718&chkboxherbario[]=RB
Cactaceae	<i>Lepismium cruciform</i>	(Vell.) Miq.	Kollmann, L. 11388 (RB)	http://jabot.jbrj.gov.br/v3/consulta.php?edtcodbarras=557382&chkboxherbario[]=RB
Cactaceae	<i>Pereskia aculeata</i>	Mill.	by Paula, LFA 1067 (RB)	http://jabot.jbrj.gov.br/v3/consulta.php?edtcodbarras=1157466&chkboxherbario[]=RB
Cactaceae	<i>Pilosocereus arrabidaei</i>	(Lem.) Byles & Rowley	Barros, AAM 2300 (RB)	http://jabot.jbrj.gov.br/v3/consulta.php?edtcodbarras=R-B00534956&chkboxherbario[]=RB
Cactaceae	<i>Pilosocereus brasiliensis</i>	(Britton & Rose) Backeb.	de Paula, LFA 1075 (RB)	http://jabot.jbrj.gov.br/v3/consulta.php?edtcodbarras=1115485&chkboxherbario[]=RB
Cactaceae	<i>Rhipsalis floccosa</i>	Salm-Dyck ex Pfeiff.	Pena and Alves-Araújo 2017	
Cactaceae	<i>Rhipsalis cereoides</i>	(Backeb. & Voll) Backeb.	Meirelles et al. 1999	
Cactaceae	<i>Rhipsalis grandiflora</i>	Haw.	Carauta, JPP 3353 (RB)	http://jabot.jbrj.gov.br/v3/consulta.php?edtcodbarras=64703&chkboxherbario[]=RB
Cactaceae	<i>Rhipsalis triangularis</i>	Werderm.	Braga, JMA 3357 (RB)	http://jabot.jbrj.gov.br/v3/consulta.php?edtcodbarras=R-B00685288&chkboxherbario[]=RB

Table 2. List of Cactaceae species occurring in lowland *inselbergs* in the Atlantic Forest, southeastern Brazil. The link to the online image of the respective voucher is provided; the links are from JABOT-JBRJ and Reflora-Herbário Virtual.