



## Flora of the *cangas* of the Serra dos Carajás, Pará, Brazil: history, study area and methodology

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### Abstract

Back in 1960 researchers from the Museu Paraense Emílio Goeldi (MPEG) began to study the Serra dos Carajás, resulting in an important series of collections, giving interesting insights in the local flora. During the last decades, intensification of expeditions to the FLONA Carajás was driven by the discovery of a high number of endemic species, coupled with mining pressure in the area. The project “Flora das *cangas* da Serra dos Carajás” was established in 2014 through the collaboration between MPEG and Vale Institute of Technology – Sustainable Development (ITVDS), which aimed to record systematically the knowledge of the flora associated with the *cangas* of the Serra dos Carajás. Nearly fifteen thousand exsiccatae currently held at several herbaria (MG, BHCB, HCJS, INPA, IAN, NY and RB) served as the base for the compilation of this flora that includes, so far, 151 families including bryophytes, ferns and seed plants. Here we present a short history of the botanical studies carried out in the region, as well as the characterization of the study area and the methodology followed by this project. This introductory chapter heads the first volume of the Flora of the *cangas* of the Serra de Carajás, presenting the first 55 plant families, four of bryophytes (two of mosses and two liverworts), two of lycophytes, eight of ferns, one gymnosperm and 40 families angiosperms, treating 139 genera and 248 species.

**Key words:** Amazon, *campos rupestres*, floristics, ironstone savannas, taxonomy.

### Resumo

No final da década de 1960, pesquisadores do Museu Paraense Emílio Goeldi (MPEG) iniciaram as coletas botânicas na Serra dos Carajás, resultando em um expressivo acervo e interessantes descobertas sobre a flora local, marcada por endemismos e pressão por atividades mineradoras. Em 2014, foi estabelecido o projeto “Flora das *cangas* da Serra dos Carajás” através da cooperação entre o MPEG e o Instituto Tecnológico Vale de Desenvolvimento Sustentável (ITVDS), visando especialmente a elaboração da flora das *cangas* da FLONA Carajás. Um acervo de cerca de quinze mil exsicatas, depositadas principalmente nos herbários MG e BHCB além de HCJS, INPA, IAN, NY e RB constitui a base para o desenvolvimento da flora. Até o momento, a flora inclui 151 famílias de angiospermas, gimnospermas, licófitas e samambaias e briófitas (musgos e hepáticas). Neste trabalho apresentamos um breve histórico dos estudos botânicos na região, caracterização da área de estudo, e procedimentos metodológicos adotados no desenvolvimento do projeto. Também, constitui a introdução para o volume 1 da Flora das *cangas* de Carajás composto por 55 famílias, sendo quatro de briófitas, duas de licófitas, oito de samambaias, uma de gimnospermas e 40 de angiospermas, incluindo 139 gêneros e 248 espécies.

**Palavras-chave:** Amazônia, campos ferruginosos, campos rupestres, florística, taxonomia.

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## Introduction

The Amazon Biome in northern South America occupies approximately 6 million square kilometers, including areas of nine different countries, and with its largest extent within Brazil (ter Steege *et al.* 2013). Represented predominantly by forest formations, this biome also includes open vegetation, such as savannas, *campinaranas* and *campos rupestres* (Pires & Prance 1985), isolated and scattered throughout the forest matrix.

The sheer extension, difficult access and relatively recent history of scientific investigation of the Amazon result in it being the less known of the Brazilian biomes (BFG 2015). The gaps in scientific knowledge throughout the biome are a result of sparse collecting effort, with less than 0.18 herbarium specimens collected by square kilometer in northern Brazil (BFG 2015; Nic Lughadha & Morim 2015). Nonetheless, several new taxa were recently described following specific efforts carried out in isolation, such as the survey of the Parque Estadual do Cristalino, in northern Mato Grosso (*e.g.*, Vanderplank & Zappi 2011; Frisby & Hind 2014), the Serra do Aracá (*e.g.*, Grant *et al.* 2006; Michelangeli & Goldenberg 2014) and the Reserva Ducke, in Amazonas (*e.g.*, Lombardi 2007; Boeira *et al.* 2012; Souza *et al.* 2015), Serra do Cachimbo (Harley 2013) and the Serra dos Carajás, in the state of Pará (*e.g.*, Dittrich *et al.* 2014; Salino *et al.* 2014; Salas *et al.* 2015; Araujo & Chautems 2015; Almeda *et al.* 2016; Pereira *et al.* 2016; Nunes *et al.* 2016).

The Serra dos Carajás is a mountain range located in the southeastern region of the state of Pará, with characteristic rugged terrain culminating in isolated ferruginous rock plateaux. This area is rich in mineral resources, being also known as Mineral Province of Carajás, and includes parts of the municipalities of São Felix do Xingu, Ourilândia do Norte, Curianópolis, Eldorado dos Carajás, Parauapebas, Canaã dos Carajás and Água Azul do Norte, the three last ones part of a formerly larger municipality of Marabá (Silva 2006).

The ferruginous outcrops were first discovered by *United States Steel* geologists in 1967. As well as world scale iron deposits, the site includes manganese, nickel, lateritic and sulphide nickel, copper-gold and others, highlighting the region of Serra dos Carajás as one of the largest mineral provinces of the world (Freitas 1986; Santos 1986). Between 1960 and 1980, the region received intense migratory flow made easier by

the construction of the Belém-Brasília Highway (BR-222) that passes Marabá. Population growth was also driven by the building of the Tucuruí hydroelectric plant (around 260 km from Marabá), by the discovery of gold in Serra Pelada and by the implantation of the Ferro Carajás project, later absorbed by the daring Programa Grande Carajás (Silva 2006).

Created in February 1998, the Floresta Nacional de Carajás (FLONA de Carajás) was the first protected area created locally. FLONAs, or National Forests, are a conservation category that involves sustainable use of resources. Other conservation initiatives were added to the surrounding area of the FLONA de Carajás, and this is nowadays known as the Carajás Mosaic, that includes also the Floresta Nacional de Itacaiúnas, Floresta Nacional do Tapirapé-Aquiri, Reserva Biológica de Tapirapé, Área de Proteção Ambiental do Igarapé Gelado and Terra Indígena Xicrin do Catetê, totalling 12,000 km<sup>2</sup> (STCP 2016). This mosaic is important for the protection of the Amazon rainforest in southern Pará and some of the areas include open *canga* formation forming ferriferous outcrops, where rupicolous or aquatic vegetation can be found. Such formations represent around 5% of the area of the FLONA de Carajás and are directly associated with the local iron deposits (STCP 2016). Such *canga* formations house a specialized flora that is characterized by adaptations to this peculiar environment and the presence of several endemic species.

The Brazilian environmental law determines that the project proposals pertaining mineral exploitation support the conservation of the biota and environmental services associated to a given area, while producing the smallest possible environmental impact. Environmentally licensing processes involving conservation units of sustainable use require detailed diagnostic studies and evaluation of the potential impacts to be analysed by the responsible organisation. While tackling a major gap in botanical knowledge, the systematic, authoritative knowledge of the flora in the FLONA de Carajás is fundamental to provide subsidies to different types of studies ranging from endangered, rare, endemic species or for the utilization of native species in the recovery of degraded areas or to determine and set aside areas for conservation.

The need to improve and systematize the knowledge of the flora of the *cangas* at the Serra dos Carajás has resulted in the creation of the “Flora das

*cangas* da Serra dos Carajás, Pará, Brasil” project, a cooperation between the Museu Paraense Emílio Goeldi (MPEG) and the Vale Institute of Technology – Sustainable Development (ITVDS). This project is supported by over 74 taxonomic botanists from Brazil and other countries. The present work lays out the history of botanical studies in the region, characterizes the study area and the methodology used to prepare and publish the family monographs, as well as providing a list of the botanical families currently recorded for the area, including genera and species numbers for the families published within the first volume of the flora.

### Botanical studies at the Serra dos Carajás over the years

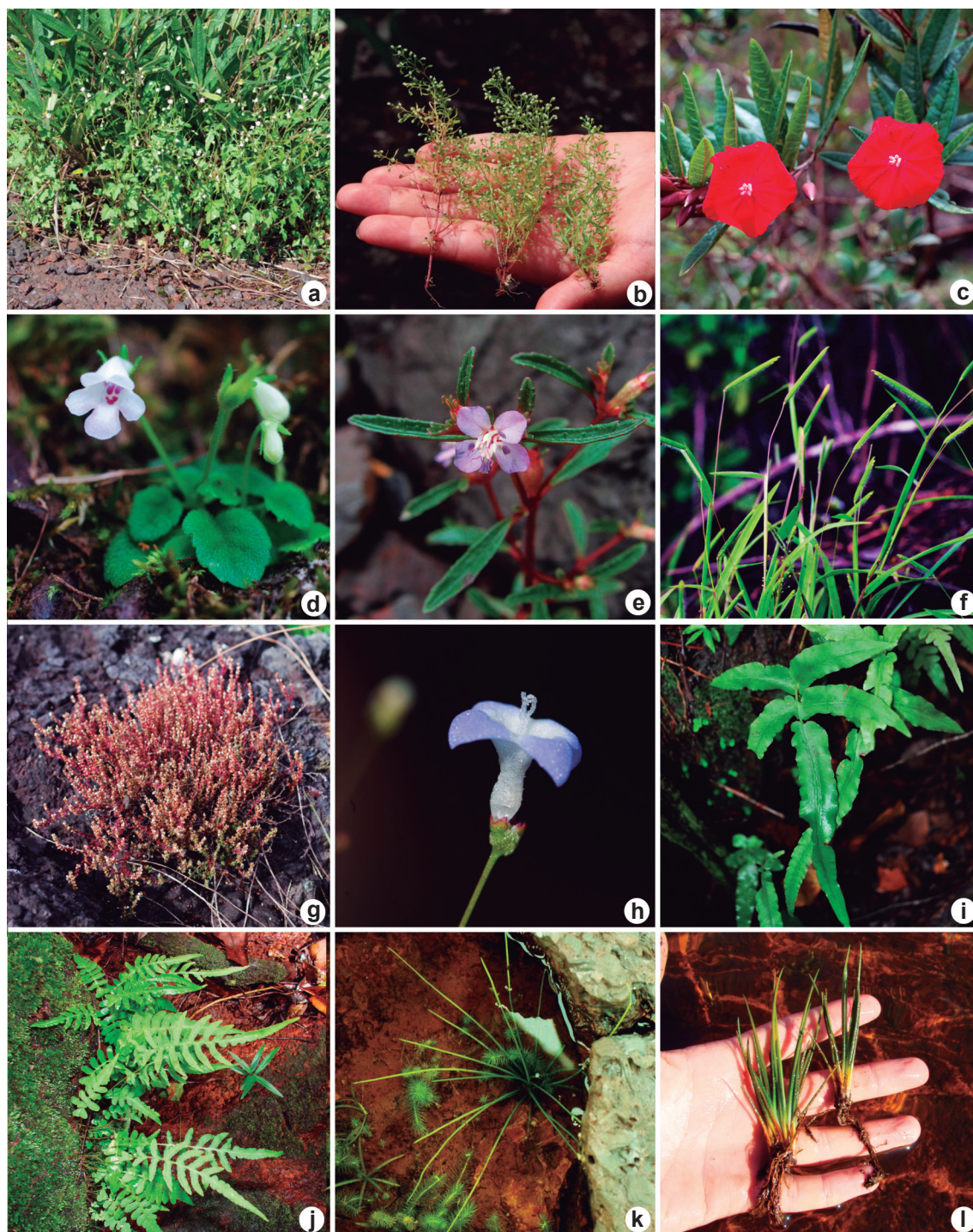
Botanical investigation of the Serra dos Carajás is relatively recent, with the pioneer studies dating back to 1969, when botanist Paulo Bezerra Cavalcante (MPEG) carried out his first expedition to the region to collect plant samples. His records set the base for the discovery and description of new genera and species (see Fig. 1a-l), such as *Monogereion carajensis* G.M. Barroso & R.M. King (Fig. 1a) (Barroso & King 1971), *Parapiqueria cavalcantei* R.M. King & H. Rob. (Fig. 1b) and *Cavalcantia glomerata* (G.M. Barroso & R.M. King) R.M. King & H. Rob. (King & Robinson 1980a; King & Robinson 1980b), in the Asteraceae, *Ipomoea cavalcantei* D. Austin (Fig. 1c) and *I. carajasensis* D. Austin (Austin 1981), Convolvulaceae, *Centrosema carajasense* P. Cavalcante (Cavalcante 1970), in the Fabaceae and *Perama carajensis* J.H.Kirkbr. (Fig. 1b) (Kirkbride 1980), in the Rubiaceae.

The following years saw botanical collections intensify with researchers from MPEG supported by the Companhia Vale do Rio Doce mining company. The publication of the first inventory of plants for the *canga* vegetation in Carajás (Secco & Mesquita 1983) was the first stepping stone for a series of diverse studies, such as floristic (Silva *et al.* 1986a, 1986b; Secco & Lobo 1988; Silva 1991; Lisboa & Ilkiu-Borges 1996), plant ecology (Silva *et al.* 1987; Salomão *et al.* 1988; Silva & Rosa 1989; Silva *et al.* 1996) and phytogeography (Porto & Silva 1989; Cleef & Silva 1994). Within this context, the study by Silva (1991), listed 58 families, 145 genera and 232 species occurring in *canga* vegetation. From this list, around 31% of the taxa were either identified to generic level or were still to be confirmed. A large part of the voucher material for these studies, including several type-

specimens, was deposited in the herbarium MG, at the MPEG. Some new species were described, such as *Ipomoea marabaensis* Austin & Secco (Convolvulaceae) (Austin & Secco 1988) e *Alchornea fluviatilis* Secco (Euphorbiaceae) (Secco 1993). During this period, monographic studies of the rupicolous flora of the Serra dos Carajás were carried out by researchers at the MPEG, focussing on taxa occurring in the *canga* in that region. Treatments were published about the Fabaceae (Silva 1993) and some genera of Poaceae: *Axonopus* (Bastos 1991), *Ichnanthus* (Bastos 1993), *Mesosetum* and *Thrasya* (today included within *Paspalum*) (Bastos 1992).

From the end of the year 2007, consultants, lecturers and students from the BHCb herbarium at the Universidade Federal de Minas Gerais developed studies of the *cangas* at Carajás in order to prepare environmental impact reports within the FLONA de Carajás. Resulting floristic and phytosociological analyses of this vegetation increased the collections to approximately 5,000 samples, this time deposited in the BHCb herbarium. Duplicates were incorporated in other important Brazilian herbaria (MG, IAN and RB), increasing the holdings from Carajás housed within these institutions. These studies were the basis for the discovery and description of another series of new taxa, many of them considered endemic for this region, such as: *Blechnum areolatum* V.A.O. Dittrich & Salino and *B. longipilosum* V.A.O. Dittrich & Salino (Fig. 1i, Blechnaceae) (Dittrich *et al.* 2012); *Isoetes cangae* J.B.S. Pereira, Salino & Stützel (Fig. 1k) and *I. serracarajensis* J.B.S. Pereira, Salino & Stützel (Fig. 1l, Isoetaceae) (Pereira *et al.* 2016), *Borreria elaiosulcata* E.L. Cabral & L.M. Miguel and *B. carajasensis* E.L. Cabral & L.M. Miguel (Rubiaceae) (Cabral *et al.* 2012); *Philodendron carajasense* E.G. Gonç. & A.J. Arruda (Araceae) (Gonçalves & Arruda 2013); *Sinningia minima* A.O. Araujo & Chautems (Fig. 1d - Gesneriaceae) (Araújo & Chautems 2015), as well as *Carajasia cangae* R.M.Salas, E.L. Cabral & Dessein (Fig. 1g, Rubiaceae) (Salas *et al.* 2015) and *Brasilianthus carajasensis* Almeda & Michelangeli (Fig. 1e, Melastomataceae) (Almeda *et al.* 2016), two new monospecific genera. Even though new taxa were described, the bulk of the Carajás collections remained in herbaria, awaiting to be studied in systematically and in detail.

Researchers from MPEG obtained in 2014 a grant from Brazil’s research council, CNPq to elaborate the Flora de Carajás as a medium/long term



**Figure 1** – Some vascular plant species considered endemic to the Serra dos Carajás – a. *Monogereion carajensis*; b. *Parapiqueria cavalcantei*; c. *Ipomoea cavalcantei*; d. *Sinningia minima*; e. *Brasilianthus carajasensis*; f. *Paspalum carajasense*; g. *Carajasia cangae*; h. *Perama carajensis*; i. *Blechnum areolatum*; j. *Blechnum longipilosum*; k. *Isoetes cangae*; l. *Isoetes serracarajensis* (Photos: a-c, e-h, j Pedro Viana; d, l. Nara Mota; i, k. André Arruda).

project and in parallel, MPEG and ITV formed an agreement in order to restart the systematic studies for the project “Flora of the *cangas* of the Serra dos Carajás” as a public-private partnership that would speed up the development of results. This new project aims to publish the total flora in at least two volumes, including bryophytes (mosses and liverworts), ferns and lycophytes and seed plants that occur on the *cangas* of the region. It includes the compilation of all representative collections of the flora of the study area in an authenticated database, including also new collections that are currently underway. The current floristic studies have made it obvious that, as well as the monographic treatments of the families, the richness and composition of the flora of the *cangas* of the Serra dos Carajás have to be reassessed. An updated list of endemic, rare and threatened taxa found within this region, based on the authenticated flora, is not yet available and is indispensable to develop in depth studies with these species, especially aiming at their conservation.

### Serra dos Carajás: physical characterization

The Serra dos Carajás consists in a group of sharp ranges lined up in the W-NW and E-SE direction, limited to the east by the Araguaia-Tocantins rivers, to the west by the Xingu river, to the north by the Serra do Bacajá and the Serra dos Gradaús to the south (Hirata *et al.* 1982). According to Hasui *et al.* (1984), based on the geotectonic model for South America, this region, also referred to as the Mineral Province of Carajás is situated in the Brazilian Central Shield, in the southeastern area of the Amazon Craton.

Ab'Saber (1986) states that the supergenic events recorded in southern Pará date back to the processes of levelling of the region since the pre-Cretaceous period, due to the flattening of uplifted pre-cambrian terrain, creating plains that suffered further uplifting and dissections and a series of surfaces with discontinuous levelling.

Such process is considered the main factor responsible for the formation of expressive lateritic covering in the area, leading to the expressive iron enrichment from the ferriferous banded rocks, which were either itabirites or jaspelites. Within this context, the plateaux of the Serra dos Carajás and the adjacent upland are supported in part by a dendritic laterite covering (*cangas*), that is constituted essentially by relictual fragments of hematite/magnetite, an evidence that the origin of such covering was caused by the weathering of the

banded ferriferous formations (Beisiegel *et al.* 1973). The structure and texture of these dendritic lateritic crusts is linked to the erosive processes that occurred during the levelling, representing the former summit surface (Maurity & Kotschoubey 1995).

Within southern Pará, the Serra dos Carajás stands up in the landscape with altitudes between 500 and 700 m, with slightly flattened summits and less frequent occurrence of hilly mounds and sharp ranges. The studies that defined the Ferriferous District of Carajás (Resende & Barbosa 1972) sectorized the Serra dos Carajás in four main groups of ranges: Serra Norte (plateaux N1 to N9); Serra Sul (plateaux S1 to S45); Serra Leste (plateaux SL1 to SL3) and Serra de São Félix (plateaux SF1 to SF3). Some of the plateaux received specific denominations, such as the Serra da Bocaina and the Serra do Tarzan, both found within Serra Sul (Mota *et al.* 2015). The present study area included the plateaux found in the municipalities of Canaã dos Carajás and Parauapebas (Serra Norte and Serra Sul, including Serra da Bocaina and Serra do Tarzan) (Fig 2).

The regional climate matches Aw type defined by Köppen (Alvares *et al.* 2013), marked by high annual rainfall and a clearly defined period of drought. The rainfall fits within a unimodal cycle, with rainy summer that starts in October, reaches maximum precipitation between January and March and finishes in May, followed by a dry winter. The yearly rainfall recorded in the region (2,033 mm) is extremely high, distributed in an average of 140 rainy days, with ¾ of the annual precipitation during the three rainiest months. Monthly temperatures vary between 25.1° C and 26.3° C, with absolute minimum around 15.6° C and 18.3° C recorded between July and October, and the maximum between 34.3° C and 38.1° C, during any of the remaining months.

Humidity remains high throughout the year with a monthly relative mean between 76.8 and 88.5 %. Monthly insolation reaches its maximum between June and August when it averages around 200 hours.

### *Canga* vegetation in the Serra dos Carajás

The Carajás region comprises open vegetation growing on rocks within a forest matrix more typical of the Amazon Rainforest Biome. The forests in the area vary between evergreen and seasonal with varying degrees of deciduousness, many of them with an abundance of lianas and climbing plants.

Over the ferruginous plateaux a rich mosaic of mostly open vegetation types is found directly associated with the rocky substrate. Rizzini (1979) was the first to characterize the vegetation type that grows over ferruginous rocks at the Serra dos Carajás and in the Quadrilátero Ferrífero, in Minas Gerais, as *canga*, a terminology also adopted by Secco & Mesquita (1983) in their study of the Serra Norte vegetation of Carajás. Some authors (Silva *et al.* 1986a, 1986b; Silva & Rosa 1990; Silva 1991) used the term *campo rupestre*, more frequently associated with the vegetation found over quartzitic and sandstone outcrops of the Espinhaço Mountain Range of Minas Gerais (Giulietti *et al.* 1997), found at altitudes of around 1,000 m and higher. Porto & Silva (1989) proposed the name *savana metalófila* to make reference to the potential heavy metal tolerance and retention capacity of the plant species found within this habitat. The present work will refer to the vegetation associated to ferruginous rocks in the Serra dos Carajás as *canga*.

The varied types of vegetation (Fig. 3) found associated with the *cangas* in Carajás include rupicolous vegetation associated to exposed rocks; grassy fields and savannas, that occur where the rocky substrate is more fragmented; hygrophilous vegetation associated to streams and lagoons that may be perennial or seasonal; and forest copses with deciduous or semideciduous forest associated to areas with higher accumulation of organic matter over the ferruginous substrate. In all the variations it is noticeable that the physiognomy of the *canga* is strongly seasonal, with several herbaceous annual, ephemeral species that are present during the rainy season, and a trend to leaf-loss of the shrubby and tree component during the dry period.

Mota *et al.* (2015) describe and classify in great detail the varied physiognomies of the *cangas* at the Serra dos Carajás, taking into account the soil characteristics, presence of predominant species and in relation to the association with water bodies. These classes were organized within three large groups, of which the first two are subdivided: ferruginous rupicolous vegetation (shrubby rupicolous vegetation, *campo rupestre* over shielded *canga*, *campo rupestre* over nodular *canga*, low forest); hydromorphic vegetation (swampy fields, temporary lagoons, perennial lagoons, temporary streams, *buritizais* and *buritiranais*, swampy forest); and finally forest associated to the ferruginous ranges.

## Project methodology and monograph organization

The “Flora of the *cangas* of the Serra dos Carajás” project has been designed to span between January 2015 and December 2017, with the objective to prepare and publish the taxonomic monographs for all plant families that belong to the flora of the *canga* of the Serra dos Carajás in the municipalities of Parauapebas and Canaã dos Carajás (Fig. 2). The Flora aims to cover all Embryophyta or land plants (bryophytes, ferns, lycophytes and seed plants), including all native and/or naturalized species in the area. The species included were only the ones recorded for the *canga* (*sensu* Mota *et al.* 2015), occurring in open fields, savannas, forests or as aquatic plants.

Basis for the floristic treatments, the holdings of MG and BHC herbaria concentrate large quantity of samples collected in *cangas* of Carajás. Materials from the study area were separated by family and made available by loan to collaborating taxonomists responsible for monographs. Specimens from Carajás may also be found in other herbaria (HCJS, IAN, INPA, K, MBM, NY and RB) and they were examined by the authors of the monographs whenever possible. When necessary, additional material from other herbaria will be examined and included in the monographs.

A plan of monthly botanical collections was established from March 2015, focussing on *canga* formations at the Serra dos Carajás, in order to add to the available body of information subsidising the taxonomic treatments, and also providing data of the phenology and distribution of the species throughout the area, obtaining images of several aspects of the live plants, as well as targeted sampling for micromorphology and molecular studies. The main set of collections is to be deposited at the MG herbarium and duplicates are sent to collaborating specialists and to other herbaria. These activities are carried out by researchers, technicians, students and scholars from MPEG and ITVDS.

Taxonomic treatments for all botanical families with species occurring within the outlined area will be published as separate articles. These follow the general rules for the present journal, with added formatting intended to make the articles uniformly informative and comparable. Each monograph includes a short characterization of the family and genus/genera, identification keys, species description in alphabetic order, illustrative plate(s) with diagnostic characters (line drawings and photographs), selected material list (one per *canga* plateau), comments regarding geographic distribution, taxonomy and morphology

of the species, and finally a list of exsiccatae containing all analysed specimens. Distribution data are provided by Brazilian state and follow what is stated either in BFG (2015), Flora do Brasil 2020 (under construction) or from any other specialized literature (referenced within the monograph). Distribution data per plateau within the studied area were based exclusively in the herbarium records available.

For mosses and liverworts the classification systems respectively follow Goffinet *et al.* (2009) and Crandall-Stotler *et al.* (2009). Fern and lycophyte studies follow PPF I (2006) and angiosperm family classification follows APG IV (2016).

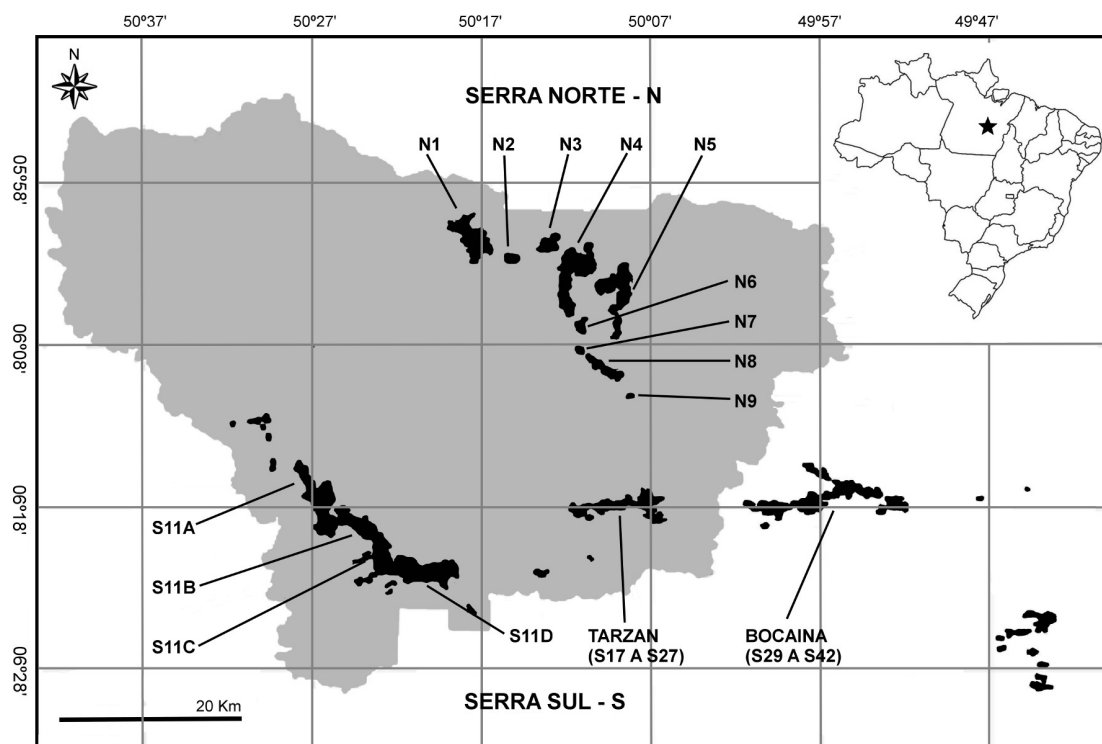
Monographs will be published in special numbers of *Rodriguésia*, with this being the first volume, and the other(s) forecast for publication by December 2017.

### General data regarding Carajás botanical collections

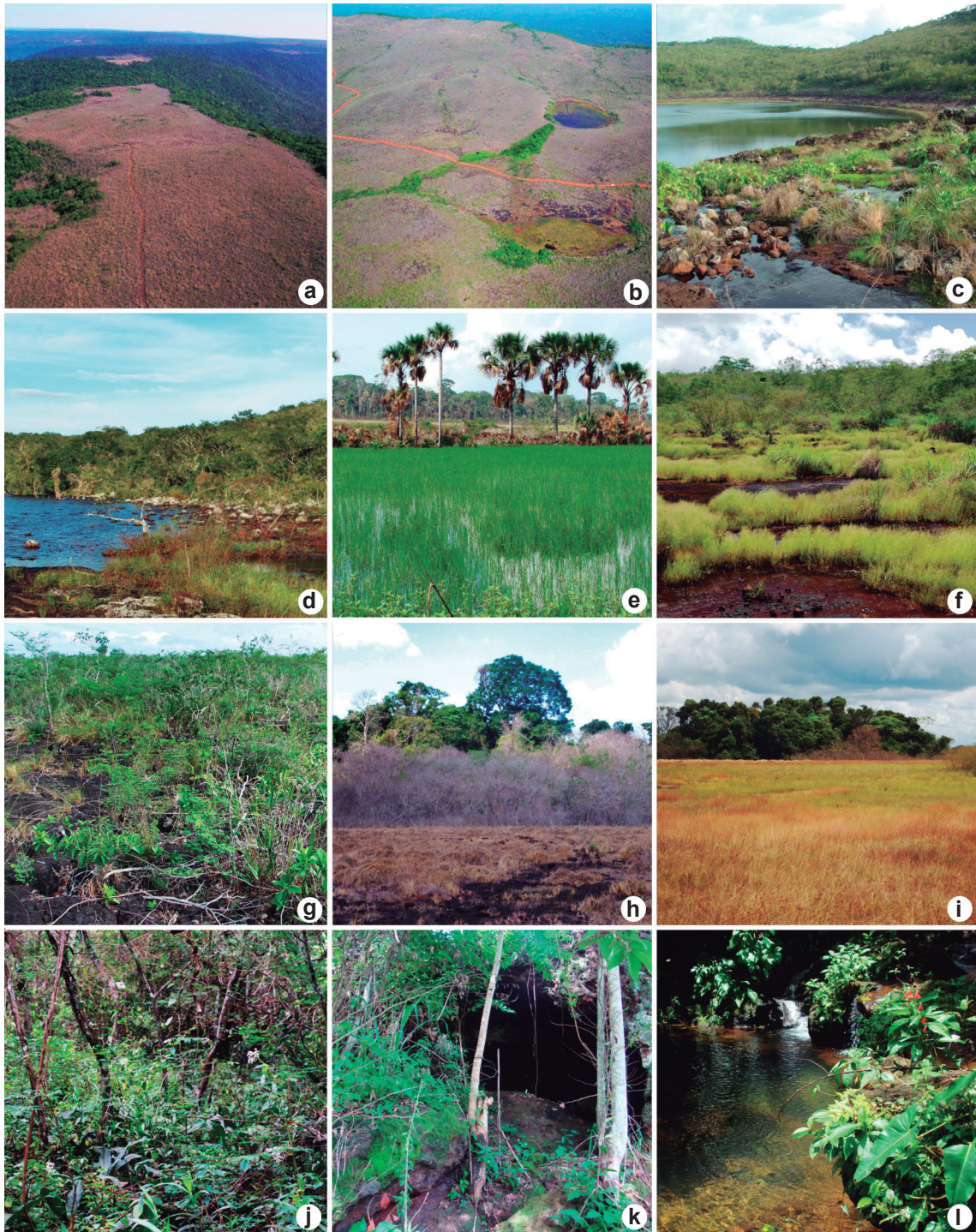
The consolidation of the data scattered throughout eight herbaria that hold collections from Carajás, including *canga* and forest areas, was an important first step towards the start of

this project. The MG and BHCB herbaria alone count with approximately 13 thousand specimens, and adding the data from HCJS, IAN, INPA, K, MBM, NY and RB the total number overtook 15 thousand specimens. After spelling and taxonomic data cleaning, the resulting list has around 2,300 species names. Within the *canga*, 571 species were found, divided between five lycophytes, 62 ferns, one Gymnosperm and 503 Angiosperms. New collections carried out during the project also contribute to the growth of the database that is also being updated and authoritatively authenticated by collaborating specialists that study the material to prepare the floristic treatments.

Recent collections in the FLONA de Carajás were carried March-May, July, September-October and December 2015 and from February to September 2016. Other areas within the state of Pará have been targeted to increase knowledge regarding distribution, and the number of numbered specimens collected is around 3,000 of all studied groups, gathered with three to five duplicates. All collected material is included in the database that now records 8,800 samples only for MG herbarium. Over 50%



**Figure 2** – Location of the Serra dos Carajás (star), FLONA de Carajás boundary (grey) and main outcrop/*canga* plateaus (black) within the study area.



**Figure 3** – Different environments associated to the *canga* at the Serra dos Carajás – a-b. aerial pictures of ferruginous outcrops at Serra Sul; c-d. rock-dwelling vegetation at lagoon edge, Serra Sul; e. swampy fields with *Mauritia flexuosa* (Arecaceae); f. abundance of *Trichantheicum rivale* (Poaceae), an annual grass, over rocky substrate during the rainy season; g. rock-dwelling shrubby vegetation over *canga*; h. rock-dwelling vegetation and transition to forest copse during the dry season; i. open fields and forest copse during the rainy season; j. understory vegetation inside a forest copse; k. vegetation associated to a cave entrance in the *canga*; l. riverine vegetation over ferruginous rocks (Photos: a-b. Leonardo Vianna; c,d,f,h,j. Pedro Viana; e,i,k. Nara Mota).



of the recent collections have had molecular leaf samples that formed the basis for the ITVDS DNA bank, that prioritises molecular barcoding of the genera from the *cangas* of Carajás, amongst other ecological and evolutive approaches, and to aid identification of specimens from the area.

The bryophyte collections (mosses and liverworts) comprise 1,600 samples, of which 347 were collected on *canga* specifically for the present project, and a large collection of 1,253 samples that were deposited in MG herbarium, of which 188 were annotated as growing on *canga* vegetation by diverse collectors. Studies published until the moment have been mostly focused on the mosses (13 families and 27 genera), while only a few liverworts (two families and two genera) were recorded in the *canga* (Lisboa & Ilkiu-Borges 1996; Moraes & Lisboa 2006). The present volume brings two moss families including three genera and four species, and two liverwort families, with two genera and two species out of the total of 20 families foreseen for the bryophyte treatments (Tab. 1).

The main set of ferns and lycophytes is housed at BHCB and counts with around 900 samples, while in all herbaria they add up 1,300 specimens distributed in 22 families and 64 genera represented in all vegetation types of the FLONA de Carajás. In the *cangas* of Carajás, 20 families, 37 genera and around 67 species were recorded. Among these, 10 families, 24 genera and 32 species appear in volume 1 of this Flora (Tab. 1).

There are currently 151 families of Angiosperms recorded for the FLONA de Carajás. Our database includes 503 species, but we estimate that at least 111 families and at least 600 species will be recorded for the *cangas* of the FLONA de Carajás. This volume presents 40 of these families comprising 119 genera and 220 species, including species rich families such as Cyperaceae and Asteraceae (Tab. 1).

### Final considerations

Detailed study of the flora of the *cangas* of Carajás will provide the baseline information to establish conservation actions for the entire biota that occurs in the ferruginous formations in Pará state. In terms of its representation, we estimate that, when this project is concluded, the flora of the *canga* vegetation may represent around 10% of the total of 7,071 species found in the whole state (BFG 2015; Pinheiro & Peralta 2015; Prado *et al.* 2015).

The present study aims to show the importance of biological collections and the crucial role of plant taxonomists in accurately naming and describing biodiversity to organize a regional flora. It also contributes towards the dissemination of correct and authenticated information through the systematization of information and the rescue and updating of past records. This endeavour will substitute outdated or inaccurate lists of the species present in the region, and make possible the use of such information for varied purposes. The initiative to prepare a Flora of the *cangas* of Carajás has also catalysed the development of other on-going studies, mainly involving the distribution of the species currently considered threatened, endemic and rare, and also of the invasive species. Such flagship species are also being studied from the point of view of their phenology, interactions and ecosystem services, as well as from their molecular identity and population dynamics. Such studies aim to improve our understanding of their ecological and evolutive role.

During the last thirty years many floristic lists were published in Brazil either based on a complete set of species or dealing with certain life-forms (trees, epiphytes). Such efforts aided the preparation of the first complete list of the Brazilian flora (Forzza *et al.* 2010; 2012; BFG 2015) since the historic publication of the Flora Brasiliensis. Complete lists (often representing the basis for regional or state floras, many of them still on-going) are historically concentrated in the East of Brazil (BFG 2015), with only few examples, such as Ribeiro *et al.* (1999), focusing on the northern region and the Amazon Rainforest.

Descriptive, detailed knowledge presented by flora writing is needed to differentiate plant species found in this country, the richest flora registered in the world, that comprises around 10% of the plants of the planet (BFG 2015; Zappi *et al.* 2015). The Flora do Brasil 2020 project (Flora do Brasil 2020 under construction) brings together over 700 contributors who are preparing and on-line flora aiming to meet Target 1 of the Global Strategy for Plant Conservation, signed by the Brazilian government. The biggest challenge for these researchers is the gap due to poor, scattered knowledge of the Amazon Rainforest Biome. Diverse traditional regional floras, such as the Flora da Serra do Cipó (Giulietti *et al.* 1987; Pirani *et al.* 2015), of the Pico das Almas (Stannard 1995) and Grão Mogol (Pirani *et al.* 2003), and also state floras, such as the Flora

**Tabela 1** – List of gymnosperm, ferns, lycophytes and bryophytes families recorded from the *cangas* of the Serra dos Carajás. Author(s) and number of genera and species are attributed only to monographs published in this volume; families currently under preparation are marked with \*.

Family	Author(s)	Genera	Species
Gimnospermas			
Gnetaceae	Nara Mota & Ana Maria Giulietti	1	1
	Total de táxons tratados no volume 1	1	1
Licófitas e samambaias			
Anemiaceae*			
Aspleniaceae	Ingridy Moura, André Arruda & Alexandre Salino	1	4
Blechnaceae*			
Cyatheaceae	Alexandre Salino & André Arruda	1	1
Dennstaedtiaceae	Alexandre Salino & André Arruda	1	1
Dryopteridaceae	Ingridy Moura & Alexandre Salino	4	4
Hymenophyllaceae*			
Isoetaceae*			
Lindsaeaceae*			
Lomariopsidaceae*			
Lycopodiaceae	Alexandre Salino & André Arruda	1	1
Lygodiaceae	Alexandre Salino & André Arruda	1	1
Oleandraceae	Alexandre Salino & André Arruda	1	1
Ophioglossaceae*			
Polypodiaceae*			
Pteridaceae	Ingridy Moura & Alexandre Salino	9	10
Schizaeaceae*			
Selaginellaceae	Luiz A. Góes-Neto, Julieta Pallos & Alexandre Salino	1	2
Tectariaceae*			
Thelypteridaceae	Luíza Moura, André Arruda & Alexandre Salino	4	7
	Total de táxons tratados no volume 1	24	32
Briófitas (Musgos e Hepáticas)			
Bartramiaceae	Fúvio Oliveira da Silva & Anna Luiza Ilkiu-Borges	1	2
Bryaceae*			
Calymperaceae*			
Calypogeiaceae	Anna Luiza Ilkiu-Borges & Fúvio Oliveira da Silva	1	1
Cephaloziellaceae*			
Fissidentaceae*			
Frullaniaceae*			
Hypnaceae*			
Lejeuneaceae*			
Lepidoziaceae	Anna Luiza Ilkiu-Borges & Fúvio Oliveira da Silva	1	1
Leucobryaceae*			

Family	Author(s)	Genera	Species
Lophocoleaceae*			
Orthotrichaceae*			
Pilotrichaceae*			
Plagiochilaceae*			
Potiaceae*			
Pterobryaceae*			
Sematophyllaceae*			
Stereophyllaceae	Fúvio Oliveira da Silva & Anna Luiza Ilkiu-Borges	2	2
Thuidiaceae*			
Total of taxa treated in volume 1		5	6

Ilustrada Catarinense (Reitz 1965, FIC 2016), Flora de São Paulo (Wanderley *et al.* 2001-2016), Bahia (Giulietti *et al.* 2006), Sergipe (Prata *et al.* 2013, 2015) and Distrito Federal (Cavacanti & Ramos 2001), provide the baseline knowledge that enables the botanical community to deliver the huge task of organizing, differentiating and describing all plant species found in Brazil. Such floristic treatments are concentrated in the Cerrado, Caatinga and Mata Atlântica Biomes. On the other hand, less than half of the monographs that represent the only regional flora attempted in the Brazilian Amazon, the Flora da Reserva Ducke (Hopkins 2005), have been published. The state of Pará does not yet count with regional, detailed, descriptive, wide reaching Floras. The present project is forecast to last for three years and have wide taxonomic reach, showcasing a public-private partnership and representing a collaborative and efficient work model to organize the flora of a little known region. It is important to note the importance of considering all pre-existing herbarium records for the success of the project. This and other similar studies, involving intense fieldwork in the Amazon, are strategic to start filling the gap.

Based on the current knowledge of Brazilian plant diversity, the Amazon has the highest proportion of tree-species in relation to other life-forms (herbs, shrubs, lianas), with 1:2 in comparison to 1:4 in the Atlantic Rainforest (BFG 2015). The lack of knowledge regarding the varied and diverse open areas found within the Amazon (*campinaranas*, savannas, *campos rupestres*, inselbergs, *cangas*) probably provides the bias towards low proportion of herbaceous species referred for the Amazonian flora (BFG 2015).

Results such as the ones obtained thus far for the Serra dos Carajás, with predominance of shrubby and herbaceous species, do not comply with the 1:2 pattern. When the present project is finalized, a complete species list from the *cangas* of the Serra dos Carajás will enable the comparison of this flora with other rock outcrop areas within the Amazon such as the Parque Estadual do Cristalino (Zappi *et al.* 2011) and the Serra do Aracá (Prance & Johnson 1992). It will also be important to use these data to perform a wider comparison between *cangas* and campos rupestres in the Amazon and elsewhere in the country. We expect it to be an encouragement for the development of new inventories in areas where the flora is still unexplored.

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**Table 2** – List of angiosperm families recorded from the *cangas* of the Serra dos Carajás. Author(s) and number of genera and species are attributed only to monographs published in this volume; families currently under preparation are marked with \*.

<b>Family</b>	<b>Author(s)</b>	<b>Genera</b>	<b>Species</b>
Alismataceae	Climbiê Hall & André Gil	2	2
Acanthaceae*			
Alstroemeriaceae	Ana Kelly Koch	1	1
Amaranthaceae*			
Anacardiaceae*			
Annonaceae	Adriana Lobão	2	2
Apocynaceae*			
Araceae*			
Arecaceae*			
Aristolochiaceae*			
Asteraceae	Ana Paula Cruz, João Ubiratan dos Santos & Pedro Viana	26	34
Balanophoraceae	Julia Meirelles	2	2
Begoniaceae	Ludovic Kollmann	1	4
Bignoniaceae*			
Bromeliaceae	Raquel Monteiro & Rafaela Forzza	7	12
Burmanniaceae	Ana Maria Giulietti	1	2
Burseraceae*			
Cabombaceae	Carla Lima & André Gil	1	2
Cactaceae*			
Calophyllaceae	Lucas Marinho & André Amorim	1	1
Caryocaraceae	Clebiana Nunes & André Gil	1	1
Caryophyllaceae*			
Celastraceae	Júlio Lombardi	4	4
Ceratophyllaceae*			
Chrysobalanaceae*			
Cleomaceae*			
Clusiaceae*			
Combretaceae*			
Commelinaceae	Lidyanne Aona, Grênivel Costa & Maria do Carmo Amaral	5	9
Connaraceae*			
Convolvulaceae	Rosângela Simão-Bianchini, Liziane Vasconcelos & Mayara Pastore	8	17
Cordiaceae*			
Costaceae*			
Cucurbitaceae	Vera Klein, Climbiê Hall & André Gil	4	6
Cyperaceae	Clebiana Nunes, André Gil & Maria de Nazaré Bastos	12	45

Family	Author(s)	Genera	Species
Dilleniaceae*			
Dioscoriaceae*			
Eriocaulaceae*			
Erythroxylaceae*			
Euphorbiaceae*			
Fabaceae*			
Gentianaceae*			
Gesneriaceae*			
Haloragaceae*			
Heliconiaceae*			
Humiriaceae*			
Hydrocharitaceae	Climbiê Hall & André Gil	2	2
Hypericaceae*			
Iridaceae	Rafaella Damasceno & André Gil	1	1
Lacistemataceae	Lucas Marinho & André Amorim	1	1
Lamiaceae	Raymond Harley	8	16
Lauraceae*			
Lentibulariaceae*			
Linderniaceae	Andre Vitto Scatinga & Nara Mota	1	3
Loganiaceae	Daniela Zappi & Robberson Setúbal	2	4
Loranthaceae*			
Lythraceae	Taciana Cavalcanti, Marlon Facco & Laiana Brauner	1	3
Malpighiaceae*			
Malvaceae*			
Marantaceae*			
Marcgraviaceae*			
Mayacaceae	Nara Mota & Ana Kelly Koch	1	3
Melastomataceae*			
Menispermaceae*			
Menyanthaceae	Ana Maria Giulietti	1	1
Metteniusaceae	Ana Paula Cruz & Pedro Viana	1	1
Moraceae*			
Myrtaceae*			
Nyctaginaceae*			
Nymphaeaceae*			
Ochnaceae*			
Olacaceae*			
Onagraceae*			
Opiliaceae*			
Orchidaceae*			

<b>Family</b>	<b>Author(s)</b>	<b>Genera</b>	<b>Species</b>
Orobanchaceae*			
Oxalidaceae*			
Passifloraceae	Anna Kelly Koch & Anna Luiza Ilkiu-Borges	1	4
Peraceae*			
Phyllanthaceae	Ricardo Secco & João Silveira	1	5
Phytolaccaceae	Julia Meirelles	1	1
Picramniaceae	José Rubens Pirani & Marcelo Devecchi	1	2
Piperaceae*			
Plantaginaceae*			
Poaceae*			
Podostemaceae*			
Polygalaceae	José Floriano Pastore & João Silveira	4	6
Polygonaceae*			
Pontederiaceae	Danilo Souza & Ana Maria Giulietti	1	2
Portulacaceae*			
Primulaceae*			
Proteaceae	Climbiê Hall	1	1
Ranunculaceae	Ana Maria Giulietti & Carla Lima	1	1
Rubiaceae*			
Rutaceae*			
Salicaceae*			
Santalaceae*			
Sapindaceae*			
Sapotaceae*			
Simaroubaceae	Marcelo Devecchi & José Rubens Pirani	2	3
Smilacaceae*			
Solanaceae*			
Styracaceae	Pedro Viana & Nara Mota	1	2
Thymelaeaceae	Nara Mota & Ana Maria Giulietti	1	1
Trigoniaceae*			
Turneraceae*			
Urticaceae	André Gaglioti, Renata Almeida-Scabbia & Sérgio Romaniuc Neto	5	7
Velloziaceae*			
Verbenaceae*			
Vitaceae	Julio Lombardi	1	4
Vochysiaceae*			
Xyridaceae	Nara Mota & Maria das Graças Wanderley	1	2
Total of taxa treated in volume 1		119	220

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