Unveiling neotropical serpentine flora: a list of Brazilian tree species in an iron saturated environment in Bom Sucesso, Minas Gerais

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ABSTRACT. Serpentine soils are those holding at least of 70% iron-magnesium compounds, which make life intolerable for many species. Although plant’s adaptation to environmental toughness is widely studied in tropics, virtually nothing is known about Brazilian serpentine flora. Our aim was to bring up and characterize the serpentine flora in Bom Sucesso, Minas Gerais state, Brazil. We performed expeditions utilizing rapid survey sampling method to identify the arboreal compound in the area. Plants within circumference at breast high (CBH) up to 15,7 cm were included in our study. A specialist identified all the individuals to species level. We found 246 species located in 59 botanical families. Fabaceae, Myrtaceae and Melastomataceae were the most representative families in the area. Serpentine areas usually present a few species capable to survive to adverse conditions, contrasting the high number found in our study. To our knowledge, this is the first floristic survey in serpentine areas in the neotropics, reinforcing the need for more studies about plant diversity in those areas. It seems that serpentinites is not the key factor influencing plant diversity in the neotropics. The high diversity found in our study strengthens serpentine areas as a place for conservation concern.

Keywords: ultramafic vegetation; trace elements; heavy metals; serpentine soil.

Introduction

Serpentine soils are those holding 70% or more iron-magnesium compounds, leading to rocky soils with many degrees of nutritional imbalance, containing high concentrations of weathered ultramafic rocks (Salihjaj, Bani, & Echevarria, 2016). They are drifted from ultramafic rocks, shaping environments with low capacity to hold water, nutrient deficit and plenty of toxic materials such as nickel, chrome, magnesium and iron (Anacker, 2014). Although there some areas of serpentine soils in South America, they are scares around the globe, with the majority of them found in the Circum-pacific margin and Mediterranean Sea (Hseu, Zehetner, Fujii, Watanabe, & Nakao 2018), leading to a large gap of knowledge and only a few floristic surveys in Brazil and Central America (Almeda & Martins, 2015). Iron (Fe) and Magnesium (Mg) are known as trace elements because they are found at very small concentrations on plants, and when at higher concentrations, their presence can lead to leaf death, necrotic brown spotting on leaves, chlorosis, cellular damage, permutagenic damage, DNA strand breaks and DNA base modifications (Nagajyoti, Lee, & Sreekanth, 2010). Heavy metals are known to interfere directly on the physiological processes of the plants, playing an important role in the redox reactions, being an integral part of enzymes, interfering in CO2 fixation, nutrient absorption, gaseous exchange and respiration (Nagajyoti et al., 2010). Altogether, those physical and chemical characteristics make serpentine soils a harsh environment for plants, hosting a reduced flora when compared to the neighboring areas (Brady, Kruckeberg, & Bradshaw Jr., 2005).

Serpentine plants need to endure harsh environmental conditions, and therefore understanding the ecological species that survive in those places is an important part of the serpentine problem (Kazakou et al., 2010). They are also known for the presence of extremely specialized habitats that hosts ‘islands’ of biodiversity and endemic flora (Chiarucci & Baker, 2007). In the tropics, flora associated with serpentine
soil is a topic of concern for scientists (Cano, Cano-Ortiz, Del Río, Ramirez, & Ruiz, 2014), but despite the high endemism rates found on those places, floristic surveys exclusive from these locals on South America are scarce (Almeda & Martins, 2015).

Iron rich environments figure among the most threatened and less studied places in State Minas Gerais (Jacobi & Carmo, 2008). The state endured resource exploitation for livestock farming, wood harvest and anthropic fire, reducing its vegetation to a few. Mining in Brazil (from licenses to search for the ore to extractions) quadrupled between 2000 to 2009, reaching a 698.000 km² area in national territory (Jacobi, Carmo, & Campos, 2011). Despite all the measures that are being taken to preserve Brazilian biodiversity, few are those that intend to conserve mineral rich environments (Jacobi et al., 2011).

Due the high threaten to forest fragments and the advances on the mining industry in soils with high concentration of heavy metals (Hseu & Iizuka, 2013), it’s urgent to understand vegetation distribution in serpentine environments and utilize those studies to help recover disturbed areas. Our study’s aim was to characterize flora in a serpentine area in Bom Sucesso, Minas Gerais State, Brazil, by producing a species list that can further be used on conservation projects.

Material and methods

Study area

We conducted this study in Minas Gerais State, Bom Sucesso municipality in an area known as Morro das Almas, located between the coordinates 21º 01’ 58” South and longitude 44º 45’ 28” West, in an altitude of 952 m above the sea level. The region presents a mosaic of phytophysiognomies, since the Minas Gerais State is an ecotone area (transitional areas between phytophysiognomies) Instituto Brasileiro de Geografia e Estatística (IBGE, 2012) with the main vegetation types belonging to the Cerrado (Brazilian savannah) and Mata Atlântica Domain IBGE (2013). Climate in the region is usually marked by two well defined seasons - wet and rainy summers, with dry cold winters IBGE (2013). The mean annual precipitation is 1776 mm concentrated in the months of October to March and mean temperature of 19ºC (Figure 1). The area was previously studied by the Departamento de Ciências do Solo (Department of Soil Science) from Universidade Federal de Lavras, where they investigated the geology of the area and found that the flora from that locality stands upon soils holding high saturation of iron oxide (Fe₂O₃ on 72.33%), characterizing serpentine soils Araujo, Pedroso, Amaral, and Zinn (2014). Local landscape is surrounded by natural fields - a mosaic of Altitude and rocky fields), in which is usual the presence of livestock grazing.

![Figure 1. Map and coordinates of a serpentine soil area and the associated flora at Bom Sucesso municipality, Minas Gerais State, Brazil. A) Map of Brazil. B) Map from Minas Gerais State. C) Sampling area at Bom Sucesso municipality. The black dot in figures B and C represent where this study was carried, at Morro das Almas, Bom Sucesso, Minas Gerais, Brazil.](image-url)
Floristic survey

We performed the floristic survey utilizing the rapid survey sampling method. This method consists in walking through an area and identifying the arboreal species, making a presence/absence list. When the same species appears several times in the same area, we continue to walk to try to find new species. Our sampling was complete when we covered the whole area of the Morro das Almas hill. We covered a 352 ha area and identified some species in the field. Species were sampled and identified by a dendrology specialist (Prof. Rubens Santos, from UFLA), since most of the species were not flourish. The plants which the specialist could not identify in the field were collected and checked using the Brazilian Flora Group (BFG, 2015) virtual herbarium. Plants were identified by using their vegetative characteristics and their names were checked in The Plant List (2018), Reflora 2015 virtual herbarium.

Results

We recorded 249 arboreal species, located in 61 botanical families (Table 1). The most representative family in this study was Fabaceae, holding 31 species, an equivalent to 12.60% of the total richness in the community, followed by Myrtaceae with 33 species (11.58%) and Melastomataceae with 12 species (4.87%) (Figure 2). Those families hold 10.37% of the total floristic richness. Copaifera L. and Bowdichia Kunth were the most representative genera in Fabaceae, followed by Myrcia and Eugenia in Myrtaceae and Tibouchina in Melastomataceae. Myrcia splendens, Pera glabrata and Ocotea pulchella were commonly found in all the area.

Table 1. List of the species from a neotropical serpentine site in Bom Sucesso, Minas Gerais State, Brazil.

| Botanical Families/Species | Conservation Status (IUCN) | Endemic Species of Brazil | Protected by Law |
|----------------------------|----------------------------|---------------------------|-----------------|
| Anacardiaceae               |                            |                           |                 |
| Astronium fraxinifolium Schott | Low concern             | No                         | No              |
| Lithra molleoides (Vell.) Engl. | Not evaluated         | No                         | No              |
| Schinus terethiifolius Raddi | Not evaluated            | No                         | No              |
| Tapirira guianensis Aubl.   | Not evaluated            | No                         | No              |
| Tapirira obtusa (Benth.) J.D.Mitch. | Not evaluated     | No                         | No              |
| Annonaceae                  |                            |                           |                 |
| Annona caranu Warm.         | Low concern              | No                         | No              |
| Annona coriifolia A.St.-Hil. | Not evaluated          | No                         | No              |
| Annona emarginata (Schldl.) H.Rainer | Low concern      | No                         | No              |
| Annona nemaurofis H.Ramer   | Not evaluated            | Not evaluated              | No              |
| Annona sylvatica A.St.-Hil. | Not evaluated            | Yes                        | No              |
| Duguetia furfuracea (A.St.-Hil.) Saff. | Not evaluated | Yes                        | No              |
| Duguetia lancelata A.St.-Hil. | Low concern           | Yes                        | No              |
| Guattaria auranti A.St.-Hil. | Low concern            | Yes                        | No              |
| Xylopia brasiliensis Spreng. | Near Threatened         | Yes                        | No              |
| Xylopia sericea A.St.-Hil.  | Not evaluated            | No                         | No              |
| Apocynaceae                 |                            |                           |                 |
| Aspidosperma austral Müll.Arg. | Low concern         | No                         | No              |
| Aspidosperma cylindracea Müll.Arg. | Low concern     | No                         | No              |
| Aspidosperma sp.            | Not evaluated            | Not evaluated              | No              |
| Aspidosperma soppauaum Benth. ex Müll.Arg. | Low concern  | Yes                        | No              |
| Aspidosperma tomentous Mart. & Zucc. | Low concern  | Yes                        | No              |
| Aquifoliaceae               |                            |                           |                 |
| Ilex cerasifolia Reissek    | Not evaluated            | Yes                        | No              |
| Ilex conoarpa Reissek       | Not evaluated            | Yes                        | No              |
| Araliaceae                  |                            |                           |                 |
| Denophanax cuneatus (DC.) Decne. & Planch. | Low concern   | No                         | No              |
| Schefflera macrocarpa (Cham. & Schldl.) Frodin | Not evaluated | Yes                        | No              |
| Arecaceae                   |                            |                           |                 |
| Syagrus flexuosa (Mart.) Becc. | Not evaluated         | No                         | No              |
| Syagrus romanzoffiana (Cham.) Glassman | Low concern | Yes                        | No              |
| Asteraceae                  |                            |                           |                 |
| Baccharis brachylophoides DC. | Not evaluated         | Not evaluated              | No              |
| Baccharis dentata (Vell.) G.M.Barroso | Not evaluated | No                         | No              |
| Eriemanthius erythrophysus (DC.) MacLeish | Not evaluated | Yes                        | No              |
| Geonatica paniculata (Less.) Cabrera | Not evaluated | Not evaluated              | No              |
| Geonatica polymophu (Less.) Cabrera | Low concern     | Not evaluated              | No              |
| Piptocarpa macropoda (DC.) Baker | Not evaluated     | Yes                        | No              |
| Vernonanthura divaricata (Spreng.) H.Rob. | Not evaluated | No                         | No              |
| Vernonanthura laxifolia (Gardner) H.Rob. | Vulnerável         | Yes                        | No              |
| Botanical Families/Species | Conservation Status (IUCN) | Endemic Species of Brazil | Protected by Law |
|---------------------------|----------------------------|---------------------------|-----------------|
| Bignoniaceae              |                            |                           |                 |
| Cybistax antisiphilitica  | Not evaluated             | No                        | No              |
| Handroanthus aureus       | Not evaluated             | No                        | No              |
| Handroanthus odreacei     | Not evaluated             | No                        | No              |
| Handroanthus serratifolius| Not evaluated             | Yes                       | No              |
| Jacaranda caroba          | Not evaluated             | Yes                       | No              |
| Jacaranda marantana       | Low concern               | Yes                       | Yes             |
| Boraginaceae              |                            |                           |                 |
| Cordia sellowiana         | Not evaluated             | Yes                       | No              |
| Cordia trichotoma         | Not evaluated             | No                        | No              |
| Borreria                  |                            |                           |                 |
| Protium spruceanum        | Not evaluated             | No                        | No              |
| Protium vulgaris          | Not evaluated             | Yes                       | No              |
| Tractiniopsis farrigina   | Endangered               | Yes                       | Yes             |
| Calophyllaceae            |                            |                           |                 |
| Calophyllum brasiliense   | Not evaluated             | No                        | No              |
| Kidneyrea cornea          | Not evaluated             | No                        | No              |
| Kidneyrea speciosa        | Not evaluated             | Yes                       | No              |
| Burseraceae               |                            |                           |                 |
| Protium spruceanum        | Not evaluated             | No                        | No              |
| Protium widgrenii         | Not evaluated             | Yes                       | No              |
| Uramphus                  | Not evaluated             | Yes                       | Yes             |
| Trattinnickia             |                            |                           |                 |
| Citronella paniculata     | Not evaluated             | No                        | No              |
| Caryocaraceae             |                            |                           |                 |
| Caryocar brasiliense      | Not evaluated             | No                        | No              |
| Celastraceae              |                            |                           |                 |
| Monteverdia evonymodes    | Not evaluated             | No                        | No              |
| Myrtus gorumala           | Not evaluated             | No                        | No              |
| Pimoketra popula           | Not evaluated             | No                        | No              |
| Salacia elliptica         | Not evaluated             | No                        | No              |
| Chrysobalanaceae          |                            |                           |                 |
| Hirtella glandulosa       | Not evaluated             | No                        | No              |
| Clusiaceae                |                            |                           |                 |
| Gavatsia brasiliensis     | Not evaluated             | Yes                       | No              |
| Clusiaceae                |                            |                           |                 |
| Terminalia argentea       | Not evaluated             | No                        | No              |
| Terminalia floribundus    | Low concern               | No                        | No              |
| Cunoniaceae               |                            |                           |                 |
| Lamanonia ternata         | Not evaluated             | Yes                       | No              |
| Fabaceae                  |                            |                           |                 |
| Albizia polyphylla        | Not evaluated             | Yes                       | No              |
| Andira anethelina         | Not evaluated             | Yes                       | No              |
| Andira fassianofloia      | Not evaluated             | Yes                       | No              |
| Banbahia rafa             | Not evaluated             | Yes                       | No              |
| Bregida virgilioides      | Near Threatened           | No                        | No              |
| Copaifera longifolia      | Not evaluated             | No                        | No              |
| Copaifera magnificolia    | Not evaluated             | Yes                       | No              |
| Dalbergia micabellum      | Not evaluated             | Yes                       | Yes             |
| Dalbergia villosa         | Not evaluated             | No                        | No              |
| Entroebium gummiforum     | Not evaluated             | Yes                       | No              |
| Hymenaea courbaril        | Low concern               | No                        | No              |
| Hymenaea stigonacarpa     | Not evaluated             | No                        | No              |

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| Botanical Families/Species | Conservation Status (IUCN) | Endemic Species of Brazil | Protected by Law |
|---------------------------|---------------------------|--------------------------|----------------|
| Inga vera Willd.          | Not evaluated             | No                       | No             |
| Leptolobium dasyxarpum Vogel | Not evaluated             | No                       | No             |
| Leptolobium elegans Vogel | Not evaluated             | No                       | No             |
| Leucaena inaurea (Vell.) Barneby & J.W. Grimes | Not evaluated             | Yes                      | No             |
| Maclurita hirtum (Vell.) Stellfeld | Not evaluated             | No                       | No             |
| Maclurita nitiana (Vell.) Benth. | Low concern              | No                       | No             |
| Maclurita villosa Vogel | Low concern               | No                       | No             |
| Ormosia fastigiatu Tul.    | Not evaluated             | Yes                      | No             |
| Piptadenia gossanathra (Mart.) J.F.Macbr. | Low concern              | No                       | No             |
| Platypodium elegans Vogel | Not evaluated             | No                       | No             |
| Sena averfordae (Herbert) H.S.Irwin & Barneby | Not evaluated             | Yes                      | No             |
| Sena macrocarpa (DC. ex Collad.) H.S.Irwin & Barneby | Not evaluated             | No                       | No             |
| Sena multijuga (Risch.) H.S.Irwin & Barneby | Not evaluated             | No                       | No             |
| Stryphnodendron alstroemers (Mart.) Cov. | Low concern               | No                       | No             |
| Stryphnodendron obtusum Benth. | Not evaluated             | No                       | No             |
| Stryphnodendron ochianum E.M.O.Martins | Not evaluated             | Yes                      | No             |
| Tachigali demidata (Vogel) Oliveira-Filho | Near Threatened           | Yes                      | No             |
| Tachigali nguea (Mart. ex Benth.) Zarucchi & Popoly | Near Threatened           | Yes                      | No             |
| Vatairea macrocarpa (Benth.) Ducke | Not evaluated             | No                       | No             |
|Hypericaceae               |                          |                          |                |
| Viania guianensis (Aubl.) Choisy | Not evaluated             | No                       | No             |
| Laticeraceae               | Laticena hadenianum Choisy | Not evaluated             | No             |
| Lamiaceae                  |                            |                          |                |
| Aegiphila huetziana Cham.  | Not evaluated             | No                       | No             |
| Hypericum tubulatum (Spreng.) (Mart.) Cov. | Not evaluated             | No                       | No             |
| Hyptidendron canum (Pohl ex Benth.) Harley | Low concern              | Yes                      | No             |
| Hyptidendron sp.           | Not evaluated             | No                       | No             |
| Vitex megapotamica (Spreng.) Moldenke | Not evaluated             | No                       | No             |
| Vitex pohyana Cham.        | Not evaluated             | Yes                      | No             |
| Lauraceae                  |                            |                          |                |
| Aniba castanilla (Kunth) Mez. | Not evaluated             | Yes                      | No             |
| Aniba forbesi (Nees & Mart.) Mez. | Not evaluated             | Yes                      | No             |
| Endlicheria paniculata (Spreng.) J.F.Macbr. | Not evaluated             | No                       | No             |
| Nestandra grandiflora Nees | Low concern               | Yes                      | No             |
| Nestandra megapotamica (Spreng.) Mez. | Not evaluated             | No                       | No             |
| Nestandra nitidula Ness   | Not evaluated             | Yes                      | No             |
| Nestandra oppositifolia Ness | Not evaluated             | No                       | No             |
| Ocotella corymbosa (Meisn.) Mez. | Not evaluated             | No                       | No             |
| Ocotella odorifera (Vell.) Rohwer | Endangered              | Yes                      | Yes            |
| Ocotella pulchella (Nees & Mart.) Mez. | Low concern              | No                       | No             |
| Persea major (Meisn.) L.E.Kopp | Not evaluated             | Yes                      | No             |
| Lecythidaceae              |                            |                          |                |
| Carniana estrellensis (Raddi) Kunthze | Not evaluated             | No                       | No             |
| Lythraceae                 |                            |                          |                |
| Lathyrus parvus A.St.-Hil. | Low concern               | No                       | No             |
| Malpighiaceae              |                            |                          |                |
| Byrsonima coccolobifolia Kunth | Low concern               | No                       | No             |
| Byronima intermedia A.Juss. | Not evaluated             | Yes                      | No             |
| Byronima irticata DC.      | Not evaluated             | No                       | No             |
| Byronima verbascifolia (L.) DC. | Not evaluated             | No                       | No             |
| Heteropitys byronimifolia A.Juss. | Not evaluated             | No                       | No             |
| Malvaceae                  |                            |                          |                |
| Eriotheca candollea (K.Schum.) A.Robyns | Not evaluated             | Yes                      | No             |
| Luehea candida Mart. & Zucc. | Low concern               | No                       | No             |
| Luehea divaricata Mart.    | Not evaluated             | No                       | No             |
| Luehea grandiflora Mart. & Zucc. | Not evaluated             | No                       | No             |
| Luehea paniculata Mart. & Zucc. | Not evaluated             | No                       | No             |
| Pseudobombax grandiflorum (Cav.) A.Robyns | Low concern               | Yes                      | No             |
| Pseudobombax longiflorum (Mart. & Zucc.) A.Robyns | Not evaluated             | No                       | No             |
| Pseudobombax tenerrimus (Mart.) A.Robyns | Low concern               | No                       | No             |
| Melastomataceae            |                            |                          |                |
| Miconia albicans (Sw.) Triana | Not evaluated             | Yes                      | No             |
| Miconia birchellii Triana | Not evaluated             | Yes                      | No             |
| Miconia pepcapa DC.        | Not evaluated             | Yes                      | No             |
| Miconia zollowiana Naudin | Not evaluated             | Yes                      | No             |
| Miconia trianae Cogn.      | Not evaluated             | Yes                      | No             |
| Miconia tristis Spring     | Not evaluated             | Yes                      | No             |
| Miconia villosenovii Klotzsch ex Naudin | Low concern              | Yes                      | No             |
| Pleroma candolleaunum (Mart. ex DC.) Triana | Not evaluated             | Yes                      | No             |
| Tibouchina estrellensis (Raddi) Cogn. | Not evaluated             | Yes                      | No             |
| Botanical Families/Species | Conservation Status (IUCN) | Endemic Species of Brazil | Protected by Law |
|---------------------------|-----------------------------|---------------------------|-----------------|
| *Pleroma fis sewerium* Schrank et Mart. ex DC. | Not evaluated | Yes | No |
| *Pleroma fothergillii* (Schrank et Mart. ex DC.) Triana | Not evaluated | Yes | No |
| *Pleroma guinahockum* (Desr.) D. Don | Not evaluated | Yes | No |
| Meliaceae | | | |
| *Cabralea canjerana* (Vell.) Mart. | Not evaluated | No | No |
| *Cedrela fusilis* Vell. | Vulnerável | No | No |
| *Tridilia pallens* C.D.C. | Low concern | Yes | No |
| Monimiaceae | | | |
| *Mollinedia argyrogyna* Perkins | Low concern | Yes | No |
| Moraceae | | | |
| *Brosimum gandichandii* Trécule | Not evaluated | No | No |
| *Ficus pertusa* L.F. | Not evaluated | No | No |
| *Ficus adhatodifolia* Schott ex Spreng. | Not evaluated | No | No |
| *Madura tintoria* (L.) D.Don ex Steud. | Not evaluated | No | No |
| Myrtaceae | | | |
| *Blepharocalyx salicifolius* (Kunth) O.Berg | Low concern | No | No |
| *Calyptranthes chuifiofa* O.Berg | Not evaluated | No | No |
| *Campomanesia guazumifolia* (Camassa) O.Berg | Not evaluated | No | No |
| *Campomanesia retuina* (Camassa) O.Berg | Not evaluated | Yes | No |
| *Campomanesia xanthocarpa* (Mart) O.Berg | Low concern | No | No |
| *Eugenia bimarginata* DC. | Not evaluated | No | No |
| *Eugenia discolobus* C.Wright | Not evaluated | No | No |
| *Eugenia floríaca* DC. | Low concern | Yes | No |
| *Eugenia hiemalis* Camp. | Low concern | No | No |
| *Eugenia sonderiana* O.Berg | Not evaluated | Yes | No |
| *Eugenia verticillata* (Vell.) Am. | Not evaluated | No | No |
| *Eugenia discolobus* C. Wright & Sauvalle | Not evaluated | No | No |
| *Myrcenaia miestiana* (Gardner) D.Legrand & Kausel | Low concern | Yes | No |
| *Myrcia guianensis* (Aubl.) DC. | Low concern | No | No |
| *Myrcia hebeptalae* DC. | Not evaluated | Yes | No |
| *Myrcia multiforma* (Lam.) DC. | Not evaluated | No | No |
| *Myrcia obovata* (O.Berg) Nied. | Low concern | Yes | No |
| *Myrcia subcordata* DC. | Not evaluated | Yes | No |
| *Myrcia retorta* Camp. | Not evaluated | Yes | No |
| *Myrcia splendidus* (Sw.) DC. | Not evaluated | No | No |
| *Myrcia tontumosa* (Aubl.) DC. | Not evaluated | No | No |
| *Myrcia variabilis* DC. | Low concern | Yes | No |
| *Myrsinaeum* DC. | Low concern | Yes | No |
| *Pimenta pseudocarpophylla* (Gomes) Landrum | Not evaluated | Yes | No |
| *Plinia caffra* (Mart.) Kausel | Not evaluated | Yes | No |
| *Pitulium ruifum* Mart. ex DC. | Not evaluated | Yes | No |
| *Siphondra densifora* O.Berg | Low concern | Yes | No |
| *Siphondra unigrensa* O.Berg | Low concern | Not evaluated | No |
| Nyctaginaceae | | | |
| *Guinaea opposita* (Vell.) Reitz | Not evaluated | No | No |
| Ochnaceae | | | |
| *Ouratea costanerfella* (DC.) Engl. | Not evaluated | No | No |
| Pentaphylacaceae | | | |
| *Termesia brasiliens* (Camassa) | Low concern | Yes | No |
| Phyllanthaceae | | | |
| *Hieronyma alfordoides* Allemão | Not evaluated | Not evaluated | No |
| Piperaceae | | | |
| *Piper gandichandianum* Kunth | Not evaluated | No | No |
| Polygonaceae | | | |
| *Ruprechtia lassaltina* Meisn. | Not evaluated | No | No |
| Primulaceae | | | |
| *Myrten coriaceae* (Sw.) R.Br. ex Roem. & Schult. | Not evaluated | No | No |
| *Myrten gardneriana* A.DC. | Not evaluated | No | No |
| *Myrten guianensis* (Aubl.) Kuntze | Not evaluated | No | No |
| *Myrten lineata* (Mez) Imkhan. | Not evaluated | Yes | No |
| *Myrten umbellata* Mart. | Not evaluated | No | No |
| Proteaceae | | | |
| *Euplassa nfe* (Loes.) Sleumer | Not evaluated | Yes | No |
| *Rouala montana* Aubl. | Not evaluated | No | No |
| Rubiaceae | | | |
| *Amasua guianensis* Aubl. | Not evaluated | No | No |
| *Amaeia intermedia* Mart. ex Schult. & Schult.f. | Not evaluated | No | No |
| *Chomera arica* Miüß.Arg. | Not evaluated | Yes | No |
| *Cordera concol* (Cham.) Kuntze | Not evaluated | No | No |
| *Cordera scuoli* (Vell.) Kuntze | Not evaluated | No | No |
| Botanical Families/Species                | Conservation Status (IUCN) | Endemic Species of Brazil | Protected by Law |
|-------------------------------------------|-----------------------------|---------------------------|------------------|
| *Faramea latifolia* (Cham. & Schltdl.) DC. | Not evaluated               | Yes                       | No               |
| *Guettarda arungensis* Cham. & Schltdl.   | Not evaluated               | No                        | No               |
| *Guettarda rubrinoidea* Cham. & Schltdl.  | Not evaluated               | Yes                       | No               |
| *Iora bifoliosa* Benth.                   | Not evaluated               |                           | No               |
| *Macaronesia brasiensis* (Hoffm. ex Ham.) Cham. & Schltdl. | Not evaluated | No | No |
| *Rudgea rubrinoidea* (Cham.) Bent.        | Not evaluated               | No                        | No               |
| **Rutaceae**                              |                             |                           |                  |
| *Zanthoxylum caribaeum* Lam.              | Not evaluated               | No                        | No               |
| *Zanthoxylum fagara* (L.) Sarg.           | Not evaluated               | No                        | No               |
| *Zanthoxylum rhoifolium* Lam.             | Not evaluated               | No                        | No               |
| *Zanthoxylum riedelianum* Engl.           | Not evaluated               | No                        | No               |
| **Salicaceae**                            |                             |                           |                  |
| *Casaria arborescens* (Rich.) Urb.        | Not evaluated               | No                        | No               |
| *Casaria deandreae* Jacq.                 | Not evaluated               | Yes                       | No               |
| *Casaria lasiophylla* Eichler             | Low concern                 | Yes                       | No               |
| *Casaria sylvestris* Sw.                  | Not evaluated               | No                        | No               |
| **Sapindaceae**                           |                             |                           |                  |
| *Allophylus edulis* (A.St.-Hil. et al.) Hieron. ex Niederl. | Not evaluated | No | No |
| *Capena zanthoxyloides* Radlk.            | Not evaluated               | No                        | No               |
| **Sapotaceae**                            |                             |                           |                  |
| *Chrysophyllum marginatum* (Hook. & Arn.) Radlk. | Not evaluated | No | No |
| *Pouteria gardneri* (Mart. & Miq.) Baehni | Not evaluated               | No                        | No               |
| **Siparunaceae**                          |                             |                           |                  |
| *Siparuna brasiliensis* (Spreng.) A.DC.  | Low concern                 | Yes                       | No               |
| *Siparuna guianensis* Aubl.               | Not evaluated               | No                        | No               |
| **Smilacaceae**                           |                             |                           |                  |
| *Similes insulizensis* Spreng.            | Not evaluated               | Yes                       | No               |
| **Solanaceae**                            |                             |                           |                  |
| *Cestrum axillare* Vell.                  | Not evaluated               | No                        | No               |
| *Solanum bulbatum* Vell.                  | Low concern                 | Yes                       | No               |
| *Solanum cernuum* Vell.                   | Not evaluated               | Yes                       | No               |
| *Solanum lyrbarum* A.St.-Hil.             | Not evaluated               | No                        | No               |
| **Styracaceae**                           |                             |                           |                  |
| *Styax camporum* Pohl                     | Not evaluated               | No                        | No               |
| *Styax ferrugineus* Nees & Mart.          | Not evaluated               | No                        | No               |
| *Styax latifolius* Pohl                   | Not evaluated               | Yes                       | No               |
| *Styax pohlii* A.DC.                      | Not evaluated               | No                        | No               |
| **Symplocaceae**                          |                             |                           |                  |
| *Symphoecus pulcher* Klotzsch ex Benth.  | Not evaluated               | No                        | No               |
| *Symphoecus sp.*                         | Not evaluated               | No                        | No               |
| **Thymelaceae**                           |                             |                           |                  |
| *Daphnopsis coryacea* Taub.               | Not evaluated               | Yes                       | No               |
| **Urticaceae**                            |                             |                           |                  |
| *Cecropia pachystachya* Trécule            | Not evaluated               | No                        | No               |
| **Verbenaceae**                           |                             |                           |                  |
| *Aloysia virgata* (Ruiz & Pav.) A.Juss.   | Not evaluated               | No                        | No               |
| **Vochysiaceae**                          |                             |                           |                  |
| *Qualea grandiflora* Mart.                | Not evaluated               | No                        | No               |
| *Qualea multiflora* Mart.                 | Not evaluated               | No                        | No               |
| *Vochysia magnifica* Warm.                | Not evaluated               | Yes                       | No               |
| *Vochysia rufa* Mart.                     | Not evaluated               | Yes                       | No               |
| *Vochysia thyroides* Pohl                 | Not evaluated               | Yes                       | No               |
| *Vochysia tucanorum* Mart.                | Not evaluated               | No                        | No               |
| **Zygophyllaceae**                        |                             |                           |                  |
| *Kallstroemia minor* Hook.f.              | Not evaluated               | Not evaluated             | No               |

From the 249 species recorded in our study, 91 are native from Brazil. Four of the species are recorded as Near Threatened, two are Vulnerable and two are Endangered according to the IUCN Red List (International Union for Conservation of Nature [IUCN], 2019).

**Discussion**

Serpentine environments provide peculiar conditions, resulting in a strong selective pressure, specialized flora to adverse conditions and holding many degrees of soil toxicity and endemism (Cano et al., 2014). Due to the many degrees of nutritional imbalance and inhospitable physicochemical conditions on
soils, it is usual to find a depauperate flora on serpentine areas (Branco & Ree, 2010). In some surveys regarding flora associated to serpentine soils in the tropics, it is usual to find a low number of species (Cano et al., 2014), counterpointing the high species number found in our survey. The highest species number found for the Americas in a serpentine soil area was 219 species in Dominican Republic (Cano et al., 2014) and recently 135 species in Philippines (Sarmiento, 2018), reinforcing the importance of the Morro das Almas area as one of the most diverse serpentine areas from the Tropics.

The amount of species found in our study points to the existence of some kind of adaptation by the plants present in Morro das Almas, making explicit that despite the stress caused by toxic metals in soil, vegetation might present morphological and anatomical adaptations to deal with those effects. Despite the proposal that serpentine soils are limiting factors to vegetation diversification, in our study it doesn't seem to be the key factor influencing this community's plurality, as the high species number can evidence. Fabaceae, Myrtaceae and Melastomataceae, the families with higher species richness, also characterize the neighboring region flora (Guimarães, Almeida, Carneiro, Souza, & Siqueira, 2012; Terra et al., 2018), foregrounding its adaptive power facing edaphic variations.

Fabaceae is frequently associated with nodule systems that benefit not only the plants from this family, but also induces changes in the soil fertility, nitrogen fixation and enhances the variability of microbes (Saad, Kobaissi, Amiaud, Ruelle, & Benizri, 2018), characteristics that might explain the higher representativeness of this family in our study. It is also possible that the soil microbes found in the area might be highly adapted to the excess of toxic heavy metals, as the soil microbes activity can affect the fertility, carbon storages and growth patterns from the plants (Malik et al., 2018).

From the 249 species recorded, two (Trattinnickia ferruginea and Ocotea odorifera) are classified as endangered according to the IUCN Red List (IUCN, 2019) and protected by the Brazilian law as priority for the conservation in the country (Brasil, 2008). The fact that we could found species that are protected by law at Morro das Almas reinforces the need to pay better care for this area. Morro das Almas hill has already been studied by MMX Mineração e Metálicos S.A., a company from the Eike Batista group, as a possible location to exploit minerals, but the business didn’t continue due to the fact that the company experienced a bankrupt. The fact that a mining company already had the license to exploit this region makes the need to study this place urgent. Since the State of Minas Gerais is already dealing with a series of environmental contamination due to the disrupts of the damn in Mariana and Brumadinho that killed two important rivers for the state (Rio Doce and Rio Paraopeba), it is vital to study and comprehend the flora from places with natural excess of heavy metal, using them as potencial phytoremediators and vegetation management projects for areas impacted by ore extractions (Ali, Kahn, & Sajad, 2013).

As our results demonstrate from the high number of species found on the area, it seems that the presence of serpentine soil is not enough to restrict the local flora biodiversity, which reinforces that there...
might be some anatomical and physiological adaptations on the plants from the studied community to deal with the environmental adversity provided by the high levels of iron–magnesium compounds found on the local soil. As those soils are only found in less than 1% of the Earth’s exposed surface (Vithanage, Rajapaksha, Oze, Rajakaruna, & Dissanayake, 2014), further investigations on the area might explore the biochemical, ecological and resistance to stress aspect of the plants (Echevarria et al., 2018) to help understand the functioning aspect of this single community. Investigating the relationships between the plants from serpentine areas and the soil might assist on phytostabilization projects, as it’s been successfully used in other countries (Boisson et al., 2018; Mizuno, Nakahara, Fujimori, & Yoshida, 2018).

Conclusion

Species substitution and environmental heterogeneity found in this study reinforce serpentine environments importance to conservation as they act as refugee to those species providing a specific habitat for the vegetation.

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