



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.

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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 (Salihaj, 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 21° 01' 58" South and longitude 44° 45' 28" West, in an altitude of 952 m above the sea level. The region presents a mosaic of phytophysionomies, since the Minas Gerais State is an ecotone area (transitional areas between phytophysionomies) *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 19°C (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.

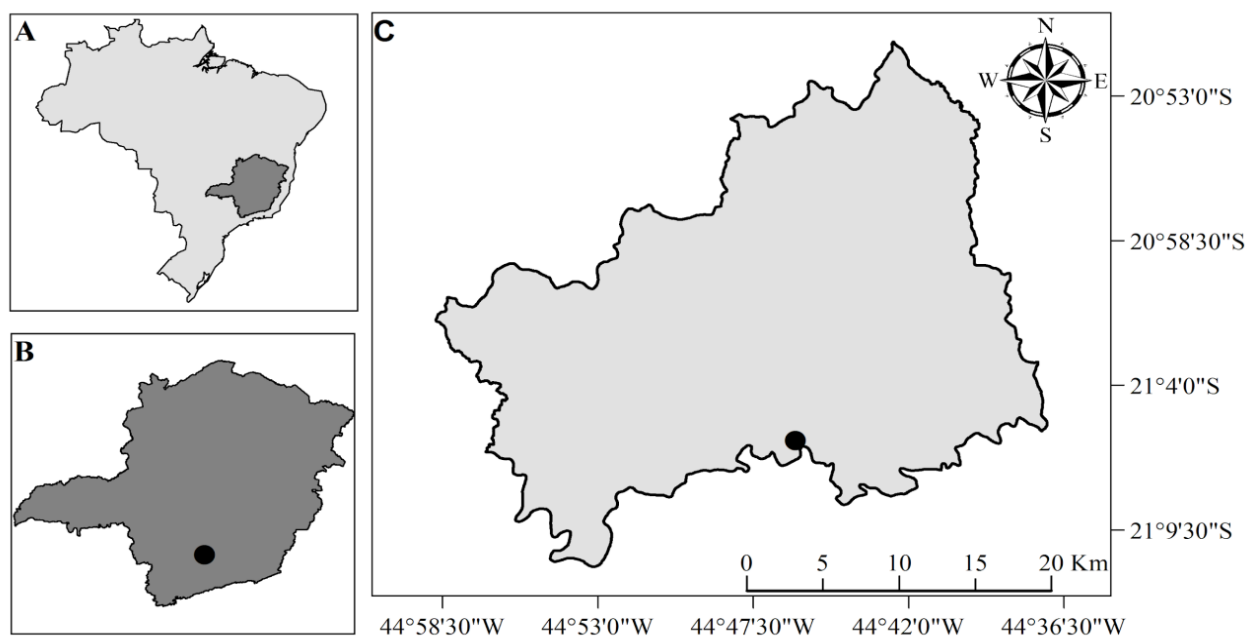


Figure 1. Map and coordinates of a serpentine soil area and the associated flora at Bom Sucesso municipality, Minas Gerais State, Brazil. A) Map of Brazil. B) Map from Minas Gerais State. C) Sampling area at Bom Sucesso municipality. The black dot in figures B and C represent where this study was carried,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

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), Re flora 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 (11.38%) 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 *Miconia* 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			
<i>Astronium fraxinifolium</i> Schott	Low concern	No	No
<i>Lithrea molleoides</i> (Vell.) Engl.	Not evaluated	No	No
<i>Schinus terebinthifolius</i> Raddi	Not evaluated	No	No
<i>Tapirira guianensis</i> Aubl.	Not evaluated	No	No
<i>Tapirira obtusa</i> (Benth.) J.D.Mitch.	Not evaluated	No	No
Annonaceae			
<i>Annona cacans</i> Warm.	Low concern	No	No
<i>Annona cornifolia</i> A.St.-Hil.	Not evaluated	No	No
<i>Annona emarginata</i> (Schltdl.) H.Rainer	Low concern	No	No
<i>Annona neolaurifolia</i> H.Rainer	Not evaluated	Not evaluated	No
<i>Annona sylvatica</i> A.St.-Hil.	Not evaluated	Yes	No
<i>Duguetia furfuracea</i> (A.St.-Hil.) Saff.	Not evaluated	Yes	No
<i>Duguetia lanceolata</i> A.St.-Hil.	Low concern	Yes	No
<i>Guatteria australis</i> A.St.-Hil.	Low concern	Yes	No
<i>Xylopia brasiliensis</i> Spreng.	Near Threatened	Yes	No
<i>Xylopia sericea</i> A.St.-Hil.	Not evaluated	No	No
Apocynaceae			
<i>Aspidosperma australe</i> Müll.Arg.	Low concern	No	No
<i>Aspidosperma cylindrocarpon</i> Müll.Arg.	Low concern	No	No
<i>Aspidosperma</i> sp.	Not evaluated	Not evaluated	No
<i>Aspidosperma spruceanum</i> Benth. ex Müll.Arg.	Low concern	Yes	No
<i>Aspidosperma tomentosum</i> Mart. & Zucc.	Low concern	Yes	No
Aquifoliaceae			
<i>Ilex cerasifolia</i> Reissek	Not evaluated	Yes	No
<i>Ilex conocarpa</i> Reissek	Not evaluated	Yes	No
Araliaceae			
<i>Dendropanax cuneatus</i> (DC.) Decne. & Planch.	Low concern	No	No
<i>Schefflera macrocarpa</i> (Cham. & Schltdl.) Frodin	Not evaluated	Yes	No
Arecaceae			
<i>Syagrus flexuosa</i> (Mart.) Becc.	Not evaluated	No	No
<i>Syagrus romanzoffiana</i> (Cham.) Glassman	Low concern	Yes	No
Asteraceae			
<i>Baccharis brachylaenoides</i> DC.	Not evaluated	Not evaluated	No
<i>Baccharis dentata</i> (Vell.) G.M.Barroso	Not evaluated	No	No
<i>Eremanthus erythropappus</i> (DC.) MacLeish	Not evaluated	Yes	No
<i>Gochnatia paniculata</i> (Less.) Cabrera	Not evaluated	Not evaluated	No
<i>Gochnatia polymorpha</i> (Less.) Cabrera	Low concern	Not evaluated	No
<i>Piptocarpha macropoda</i> (DC.) Baker	Not evaluated	Yes	No
<i>Vernonanthura divaricata</i> (Spreng.) H.Rob.	Not evaluated	No	No
<i>Vernonanthura fagifolia</i> (Gardner) H.Rob.	Vulnerável	Yes	No

Botanical Families/Species	Conservation Status (IUCN)	Endemic Species of Brazil	Protected by Law
Bignoniaceae			
<i>Cybistax antisiphilitica</i> (Mart.) Mart.	Not evaluated	No	No
<i>Handroanthus aureus</i> Mattos	Not evaluated	Not evaluated	No
<i>Handroanthus ochraceus</i> (Cham.) Mattos	Not evaluated	No	No
<i>Handroanthus serratifolius</i> (Vahl) S.O.Grose	Not evaluated	No	No
<i>Jacaranda caroba</i> (Vell.) DC.	Not evaluated	Yes	No
<i>Jacaranda macrantha</i> Cham.	Low concern	Yes	No
Boraginaceae			
<i>Cordia sellowiana</i> Cham.	Not evaluated	Yes	No
<i>Cordia trichotoma</i> (Vell.) Arrab. ex Steud.	Not evaluated	No	No
Bursceraceae			
<i>Protium spruceanum</i> (Benth.) Engl.	Not evaluated	No	No
<i>Protium widgrenii</i> Engl.	Not evaluated	Yes	No
<i>Trattinnickia ferruginea</i> Kuhlm.	Endangered	Yes	Yes
Calophyllaceae			
<i>Calophyllum brasiliense</i> Cambess.	Not evaluated	No	No
<i>Kielmeyera coriacea</i> Mart. & Zucc.	Not evaluated	No	No
<i>Kielmeyera speciosa</i> A.St.-Hil.	Not evaluated	Yes	No
Cannabaceae			
<i>Celtis brasiliensis</i> (Gardner) Planch.	Not evaluated	No	No
<i>Trema micrantha</i> (L.) Blume	Not evaluated	No	No
Cardiopteridaceae			
<i>Citronella paniculata</i> (Mart.) R.A.Howard	Not evaluated	No	No
Caryocaraceae			
<i>Caryocar brasiliense</i> Cambess.	Low concern	No	No
Celastraceae			
<i>Monteverdia evonymoides</i> (Reissek) Biral	Not evaluated	No	No
<i>Maytenus gonoclada</i> Mart.	Not evaluated	No	No
<i>Plenckia populnea</i> Reissek	Not evaluated	No	No
<i>Salacia elliptica</i> (Mart. ex Schult.) G.Don	Not evaluated	No	No
Chrysobalanaceae			
<i>Hirtella glandulosa</i> Spreng.	Not evaluated	No	No
Clethraceae			
<i>Clethra scabra</i> Pers.	Low concern	No	No
Clusiaceae			
<i>Garcinia brasiliensis</i> Mart.	Not evaluated	Yes	No
Combretaceae			
<i>Terminalia argentea</i> Mart.	Low concern	No	No
<i>Terminalia glabrescens</i> Mart.	Not evaluated	No	No
Cunoniaceae			
<i>Lamanonia ternata</i> Vell.	Not evaluated	Yes	No
Dilleniaceae			
<i>Curatella americana</i> L.	Not evaluated	No	No
<i>Davilla rugosa</i> Poir.	Not evaluated	No	No
Ebenaceae			
<i>Diospyros burchellii</i> Hiern	Not evaluated	Not evaluated	No
Erythroxylaceae			
<i>Erythroxylum citrifolium</i> A.St.-Hil.	Not evaluated	No	No
<i>Erythroxylum cuneifolium</i> (Mart.) O.E.Schulz	Not evaluated	No	No
<i>Erythroxylum deciduum</i> A.St.-Hil.	Not evaluated	No	No
<i>Erythroxylum pelleterianum</i> A.St.-Hil.	Low concern	No	No
<i>Erythroxylum suberosum</i> A.St.-Hil.	Not evaluated	No	No
<i>Erythroxylum tortuosum</i> Mart.	Not evaluated	No	No
Euphorbiaceae			
<i>Croton floribundus</i> Spreng.	Not evaluated	No	No
<i>Pera glabrata</i> (Schott) Baill.	Not evaluated	No	No
<i>Sebastiania brasiliensis</i> Spreng.	Not evaluated	No	No
Fabaceae			
<i>Albizia polycephala</i> (Benth.) Killip ex Record	Not evaluated	Yes	No
<i>Andira anthelmia</i> (Vell.) Benth.	Not evaluated	Yes	No
<i>Andira fraxinifolia</i> Benth.	Not evaluated	Yes	No
<i>Bauhinia rufa</i> (Bong.) Steud.	Not evaluated	No	No
<i>Bowdichia virgilioides</i> Kunth	Near Threatened	No	No
<i>Copaifera langsdorffii</i> Desf.	Not evaluated	No	No
<i>Copaifera magnifolia</i> Dwyer	Not evaluated	Yes	No
<i>Dalbergia miscolobium</i> Benth.	Not evaluated	Yes	No
<i>Dalbergia villosa</i> (Benth.) Benth.	Not evaluated	No	No
<i>Enterolobium gummiferum</i> (Mart.) J.F.Macbr.	Not evaluated	Yes	No
<i>Hymenaea courbaril</i> L.	Low concern	No	No
<i>Hymenaea stigonocarpa</i> Mart. ex Hayne	Not evaluated	No	No

Botanical Families/Species	Conservation Status (IUCN)	Endemic Species of Brazil	Protected by Law
<i>Inga vera</i> Willd.	Not evaluated	No	No
<i>Leptolobium dasyarpum</i> Vogel	Not evaluated	No	No
<i>Leptolobium elegans</i> Vogel	Not evaluated	No	No
<i>Leucochloron incuriale</i> (Vell.) Barneby & J.W.Grimes	Not evaluated	Yes	No
<i>Machaerium hirtum</i> (Vell.) Stellfeld	Not evaluated	No	No
<i>Machaerium nyctitans</i> (Vell.) Benth.	Low concern	No	No
<i>Machaerium villosum</i> Vogel	Low concern	No	No
<i>Ormosia fastigiata</i> Tul.	Not evaluated	Yes	No
<i>Piptadenia gonoacantha</i> (Mart.) J.F.Macbr.	Low concern	No	No
<i>Platypodium elegans</i> Vogel	Not evaluated	No	No
<i>Senna aversiflora</i> (Herbert) H.S.Irwin & Barneby	Not evaluated	Yes	No
<i>Senna macranthera</i> (DC. ex Collad.) H.S.Irwin & Barneby	Not evaluated	No	No
<i>Senna multijuga</i> (Rich.) H.S.Irwin & Barneby	Not evaluated	No	No
<i>Stryphnodendron adstringens</i> (Mart.) Cov.	Low concern	Yes	No
<i>Stryphnodendron obovatum</i> Benth.	Not evaluated	Not evaluated	No
<i>Stryphnodendron ochionianum</i> E.M.O.Martins	Not evaluated	Yes	No
<i>Tachigali denudata</i> (Vogel) Oliveira-Filho	Near Threatened	Yes	No
<i>Tachigali rugosa</i> (Mart. ex Benth.) Zarucchi & Pipoly	Near Threatened	Yes	No
<i>Vatairea macrocarpa</i> (Benth.) Ducke	Not evaluated	No	No
Hypericaceae			
<i>Vismia guianensis</i> (Aubl.) Choisy	Not evaluated	No	No
Lacistemaceae			
<i>Lacistema hasslerianum</i> Chodat	Not evaluated	No	No
Lamiaceae			
<i>Aegiphila lhotzkiana</i> Cham.	Not evaluated	Not evaluated	No
<i>Hyptidendron asperrimum</i> (Spreng.) Harley	Low concern	Yes	No
<i>Hyptidendron canum</i> (Pohl ex Benth.) Harley	Not evaluated	No	No
<i>Hyptidendron</i> sp.	Not evaluated	Not evaluated	Not evaluated
<i>Vitex megapotamica</i> (Spreng.) Moldenke	Not evaluated	No	No
<i>Vitex polygama</i> Cham.	Not evaluated	Yes	No
Lauraceae			
<i>Aniba canelilla</i> (Kunth) Mez	Not evaluated	Yes	No
<i>Aniba firmula</i> (Nees & Mart.) Mez	Not evaluated	Yes	No
<i>Endlicheria paniculata</i> (Spreng.) J.F.Macbr.	Not evaluated	No	No
<i>Nectandra grandiflora</i> Nees	Low concern	Yes	No
<i>Nectandra megapotamica</i> (Spreng.) Mez	Not evaluated	No	No
<i>Nectandra nitidula</i> Ness	Not evaluated	Yes	No
<i>Nectandra oppositifolia</i> Ness	Not evaluated	No	No
<i>Ocotea corymbosa</i> (Meisn.) Mez	Not evaluated	No	No
<i>Ocotea odorifera</i> (Vell.) Rohwer	Endangered	Yes	Yes
<i>Ocotea pulchella</i> (Nees & Mart.) Mez	Low concern	No	No
<i>Persea major</i> (Meisn.) L.E.Kopp	Not evaluated	Yes	No
Lecythidaceae			
<i>Cariniana estrellensis</i> (Raddi) Kuntze	Not evaluated	No	No
Lythraceae			
<i>Lafoensia pacari</i> A.St.-Hil.	Low concern	No	No
Malpighiaceae			
<i>Byrsonima coccolobifolia</i> Kunth	Low concern	No	No
<i>Byrsonima intermedia</i> A.Juss.	Not evaluated	Yes	No
<i>Byrsonima sericea</i> DC.	Not evaluated	No	No
<i>Byrsonima verbascifolia</i> (L.) DC.	Not evaluated	No	No
<i>Heteropterys byrsonimifolia</i> A.Juss.	Not evaluated	Yes	No
Malvaceae			
<i>Eriotheca candolleana</i> (K.Schum.) A.Robyns	Not evaluated	Yes	No
<i>Luehea candicans</i> Mart. & Zucc.	Low concern	No	No
<i>Luehea divaricata</i> Mart.	Not evaluated	No	No
<i>Luehea grandiflora</i> Mart. & Zucc.	Not evaluated	No	No
<i>Luehea paniculata</i> Mart. & Zucc.	Not evaluated	No	No
<i>Pseudobombax grandiflorum</i> (Cav.) A.Robyns	Low concern	Yes	No
<i>Pseudobombax longiflorum</i> (Mart. & Zucc.) A.Robyns	Not evaluated	No	No
<i>Pseudobombax tomentosum</i> (Mart.) A.Robyns	Low concern	No	No
Melastomataceae			
<i>Miconia albicans</i> (Sw.) Triana	Not evaluated	No	No
<i>Miconia burchellii</i> Triana	Not evaluated	Yes	No
<i>Miconia pepericarpa</i> DC.	Not evaluated	Yes	No
<i>Miconia sellowiana</i> Naudin	Not evaluated	Yes	No
<i>Miconia trianae</i> Cogn.	Not evaluated	Yes	No
<i>Miconia tristis</i> Spring	Not evaluated	No	No
<i>Miconia willdenowii</i> Klotzsch ex Naudin	Low concern	Yes	No
<i>Pleroma candolleianum</i> (Mart. ex DC.) Triana	Not evaluated	Yes	No
<i>Tibouchina estrellensis</i> (Raddi) Cogn.	Not evaluated	Yes	No

Botanical Families/Species	Conservation Status (IUCN)	Endemic Species of Brazil	Protected by Law
<i>Pleroma fissinervium</i> Schrank et Mart. ex DC.	Not evaluated	Yes	No
<i>Pleroma fothersgillii</i> (Schrank et Mat. ex DC.) Triana	Not evaluated	Yes	No
<i>Pleroma granulatum</i> (Desr.) D. Don	Not evaluated	Yes	No
Meliaceae			
<i>Cabrlea canjerana</i> (Vell.) Mart.	Not evaluated	No	No
<i>Cedrela fissilis</i> Vell.	Vulnerável	No	No
<i>Trichilia pallens</i> C.DC.	Low concern	Yes	No
Monimiaceae			
<i>Mollinedia argyrogyna</i> Perkins	Low concern	Yes	No
Moraceae			
<i>Brosimum gaudichaudii</i> Trécul	Not evaluated	No	No
<i>Ficus pertusa</i> L.f.	Not evaluated	No	No
<i>Ficus adhatodifolia</i> Schott ex Spreng.	Not evaluated	No	No
<i>Maclura tinctoria</i> (L.) D.Don ex Steud.	Not evaluated	No	No
Myrtaceae			
<i>Blepharocalyx salicifolius</i> (Kunth) O.Berg	Low concern	No	No
<i>Calyptanthus clusiiifolia</i> O.Berg	Not evaluated	No	No
<i>Campomanesia guazumifolia</i> (Cambess.) O.Berg	Not evaluated	No	No
<i>Campomanesia velutina</i> (Cambess.) O.Berg	Not evaluated	Yes	No
<i>Campomanesia xanthocarpa</i> (Mart.) O.Berg	Low concern	No	No
<i>Eugenia bimarginata</i> DC.	Not evaluated	No	No
<i>Eugenia discolorans</i> C.Wright	Not evaluated	Not evaluated	No
<i>Eugenia florida</i> DC.	Low concern	Yes	No
<i>Eugenia hiemalis</i> Cambess.	Low concern	No	No
<i>Eugenia sonderiana</i> O.Berg	Not evaluated	Yes	No
<i>Eugenia verticillata</i> (Vell.) Angely	Not evaluated	Yes	No
<i>Eugenia discolorans</i> C. Wright & Sauvalle	Not evaluated	Not evaluated	No
<i>Myrceugenia miersiana</i> (Gardner) D.Legrand & Kausel	Low concern	Yes	No
<i>Myrcia guianensis</i> (Aubl.) DC.	Low concern	No	No
<i>Myrcia hebetata</i> DC.	Not evaluated	Yes	No
<i>Myrcia multiflora</i> (Lam.) DC.	Not evaluated	No	No
<i>Myrcia obovata</i> (O.Berg) Nied.	Low concern	Yes	No
<i>Myrcia subcordata</i> DC.	Not evaluated	Yes	No
<i>Myrcia retorta</i> Cambess.	Not evaluated	Yes	No
<i>Myrcia splendens</i> (Sw.) DC.	Not evaluated	Yes	No
<i>Myrcia tomentosa</i> (Aubl.) DC.	Not evaluated	No	No
<i>Myrcia variabilis</i> DC.	Low concern	Yes	No
<i>Myrcia venulosa</i> DC.	Low concern	Yes	No
<i>Pimenta pseudocaryophyllus</i> (Gomes) Landrum	Not evaluated	Yes	No
<i>Plinia cauliflora</i> (Mart.) Kausel	Not evaluated	Yes	No
<i>Psidium rufum</i> Mart. ex DC.	Not evaluated	Yes	No
<i>Siphoneugenia densiflora</i> O.Berg	Low concern	Yes	No
<i>Siphoneugenia widgreniana</i> O.Berg	Low concern	Not evaluated	No
Nyctaginaceae			
<i>Guapira opposita</i> (Vell.) Reitz	Not evaluated	No	No
Ochnaceae			
<i>Ouratea castaneifolia</i> (DC.) Engl.	Not evaluated	No	No
Pentaphylacaceae			
<i>Ternstroemia brasiliensis</i> Cambess.	Low concern	Yes	No
Phyllanthaceae			
<i>Hieronyma alchorneoides</i> Allemão	Not evaluated	Not evaluated	No
Piperaceae			
<i>Piper gaudichaudianum</i> Kunth	Not evaluated	No	No
Polygonaceae			
<i>Ruprechtia laxiflora</i> Meisn.	Not evaluated	No	No
Primulaceae			
<i>Myrsine coriacea</i> (Sw.) R.Br. ex Roem. & Schult.	Not evaluated	No	No
<i>Myrsine gardneriana</i> A.DC.	Not evaluated	No	No
<i>Myrsine guianensis</i> (Aubl.) Kuntze	Not evaluated	No	No
<i>Myrsine lineata</i> (Mez) Imkhan.	Not evaluated	Yes	No
<i>Myrsine umbellata</i> Mart.	Not evaluated	No	No
Proteaceae			
<i>Euplassa rufa</i> (Loes.) Sleumer	Not evaluated	Yes	No
<i>Roupala montana</i> Aubl.	Not evaluated	No	No
Rubiaceae			
<i>Amaioua guianensis</i> Aubl.	Not evaluated	No	No
<i>Amaioua intermedia</i> Mart. ex Schult. & Schult.f.	Not evaluated	No	No
<i>Chomelia sericea</i> Müll.Arg.	Not evaluated	Yes	No
<i>Cordia concolor</i> (Cham.) Kuntze	Not evaluated	No	No
<i>Cordia sessilis</i> (Vell.) Kuntze	Not evaluated	No	No

Botanical Families/Species	Conservation Status (IUCN)	Endemic Species of Brazil	Protected by Law
<i>Faramea latifolia</i> (Cham. & Schltdl.) DC.	Not evaluated	Yes	No
<i>Guettarda uruguayensis</i> Cham. & Schltdl.	Not evaluated	No	No
<i>Guettarda viburnoides</i> Cham. & Schltdl.	Not evaluated	Yes	No
<i>Ixora brevifolia</i> Benth.	Not evaluated	Not evaluated	No
<i>Machaonia brasiliensis</i> (Hoffmans. ex Humb.) Cham. & Schltdl.	Not evaluated	No	No
<i>Rudgea viburnoides</i> (Cham.) Benth.	Not evaluated	No	No
Rutaceae			
<i>Zanthoxylum caribaeum</i> Lam.	Not evaluated	No	No
<i>Zanthoxylum fagara</i> (L.) Sarg.	Not evaluated	No	No
<i>Zanthoxylum rhoifolium</i> Lam.	Not evaluated	No	No
<i>Zanthoxylum riedelianum</i> Engl.	Not evaluated	No	No
Salicaceae			
<i>Casearia arborea</i> (Rich.) Urb.	Not evaluated	No	No
<i>Casearia decandra</i> Jacq.	Not evaluated	Yes	No
<i>Casearia lasiophylla</i> Eichler	Low concern	Yes	No
<i>Casearia sylvestris</i> Sw.	Not evaluated	No	No
Sapindaceae			
<i>Allophylus edulis</i> (A.St.-Hil. et al.) Hieron. ex Niederl.	Not evaluated	No	No
<i>Cupania zanthoxyloides</i> Radlk.	Not evaluated	Yes	No
<i>Matayba guianensis</i> Aubl.	Not evaluated	No	No
Sapotaceae			
<i>Chrysophyllum marginatum</i> (Hook. & Arn.) Radlk.	Not evaluated	No	No
<i>Pouteria gardneri</i> (Mart. & Miq.) Bachni	Not evaluated	No	No
Siparunaceae			
<i>Siparuna brasiliensis</i> (Spreng.) A.DC.	Low concern	Yes	No
<i>Siparuna guianensis</i> Aubl.	Not evaluated	No	No
Smilacaceae			
<i>Smilax brasiliensis</i> Spreng.	Not evaluated	Yes	No
Solanaceae			
<i>Cestrum axillare</i> Vell.	Not evaluated	No	No
<i>Solanum bullatum</i> Vell.	Low concern	Yes	No
<i>Solanum cernuum</i> Vell.	Not evaluated	Yes	No
<i>Solanum lycocarpum</i> A.St.-Hil.	Not evaluated	No	No
Styracaceae			
<i>Styrax camporum</i> Pohl	Not evaluated	No	No
<i>Styrax ferrugineus</i> Nees & Mart.	Not evaluated	No	No
<i>Styrax latifolius</i> Pohl	Not evaluated	Yes	No
<i>Styrax pohlilii</i> A.DC.	Not evaluated	No	No
Symplocaceae			
<i>Symplocos pubescens</i> Klotzsch ex Benth.	Not evaluated	No	No
<i>Symplocos</i> sp.	Not evaluated	No	No
Thymelacaceae			
<i>Daphnopsis coriacea</i> Taub.	Not evaluated	Yes	No
Urticaceae			
<i>Cecropia pachystachya</i> Trécul	Not evaluated	No	No
Verbenaceae			
<i>Aloysia virgata</i> (Ruiz & Pav.) A.Juss.	Not evaluated	No	No
Vochysiaceae			
<i>Qualea grandiflora</i> Mart.	Not evaluated	No	No
<i>Qualea multiflora</i> Mart.	Not evaluated	No	No
<i>Vochysia magnifica</i> Warm.	Not evaluated	Yes	No
<i>Vochysia rufa</i> Mart.	Not evaluated	Yes	No
<i>Vochysia thyrsoides</i> Pohl	Not evaluated	Yes	No
<i>Vochysia tucanorum</i> Mart.	Not evaluated	No	No
Zygophyllaceae			
<i>Kallstroemia minor</i> 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.

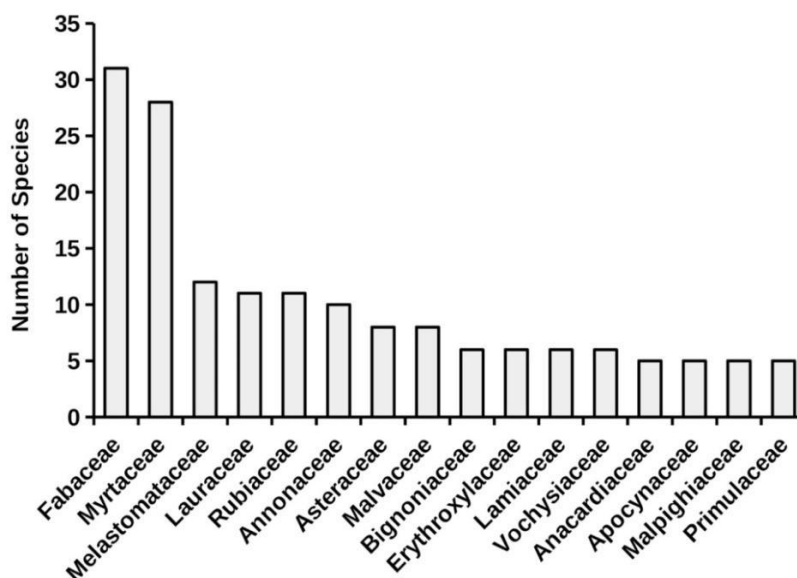


Figure 2. Most representative families (> than 5 species) in a serpentine soil area in Bom Sucesso, Minas Gerais State, Brazil.

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, Kobaiissi, 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 dam 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 potential 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 refuge to those species providing a specific habitat for the vegetation.

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