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# THE WOODY VEGETATION OF QUARTZITE SOILS IN A MOUNTAIN LANDSCAPE IN THE ATLANTIC FOREST DOMAIN (SOUTH-EASTERN BRAZIL): STRUCTURE, DIVERSITY AND IMPLICATIONS FOR CONSERVATION

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The Serra Negra belongs to the Mantiqueira mountain complex, Minas Gerais, Brazil. It has a vegetation mosaic dominated by ombrophilous and seasonal forest and grassland formations. Woody physiognomies occur on patches of quartzite soils. The aim of the present study was to investigate the patterns of structure and diversity of woody vegetation on quartzite soils in Serra Negra. Ten plots (20 × 50 m) were randomly placed in patches of woody vegetation on quartzite soils along the landscape. The diameter and height of all woody plants with a diameter of ≥ 3 cm at 30 cm from the soil were measured. The 1899 individuals sampled represented 30 plant families and 68 species. A strong ecological dominance was found, with about 30% of individuals belonging to a single species, *Eremanthus incanus* (Asteraceae). The Shannon diversity index ($H'$) was 2.74 nats/individual and evenness ($J$) 0.65. The two most abundant and ecologically important species in this vegetation type, *Eremanthus incanus* and *Eremanthus erythropappus*, called 'candeias', are exploited in the region, mainly for firewood. This exploitation, combined with other factors (e.g. increased tourism), can pose risks to the conservation of the whole flora of the region.

*Keywords.* Atlantic Forest ecosystems, high-altitude rocky complex, multistemmed individuals, scrub.

## Introduction

Tropical mountains harbour a wide biological diversity, especially with regard to flora (Martinelli, 2007). An important factor governing plant diversity in tropical mountains is the high heterogeneity of environments found in these regions, which leads to the occurrence of species with different adaptations in small areas (Ribeiro *et al.*, 2007). This shows that high beta diversity (Whittaker *et al.*, 2001) is an important component of such systems.

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A characteristic formation occurring in the mountains of south-eastern Brazil is the *campos rupestres* (rocky grasslands). This vegetation occurs on rocky outcrops and shallow soils, on the tops of mountains, associated with quartzites and sandstones (Benites *et al.*, 2007). It consists of a mosaic of vegetation types, ranging from open areas covered by herbaceous vegetation to areas of dense vegetation mainly comprising shrubs and small trees (Benites *et al.*, 2007; Vasconcelos, 2011; Conceição *et al.*, 2016). The Serra Negra, a component of the Mantiqueira mountain complex, has a vegetation mosaic in which patches of rain forest and *campos rupestres* predominate in the landscape. A floristic survey of the Serra Negra region has demonstrated its high species richness on a regional scale, with 1020 phanerogamic species (Salimena *et al.*, 2013), 209 pteridophyte species (Souza *et al.*, 2012) and 93 bryophyte species (Amorim, 2013) catalogued so far. Many of these species are considered rare or endemic, and some are endangered. Species new to science, in the process of description, and new botanical records for the state of Minas Gerais have also been found (Salimena *et al.*, 2013).

The area of occurrence of *campos rupestres* is still a matter of discussion. Most authors agree that *campos rupestres* occur in the south-east of Brazil, principally in the transition between the Cerrado and Atlantic Forest Domains, in the Espinhaço Range, and other isolated areas (Benites *et al.*, 2007; Vasconcelos, 2011; Alves *et al.*, 2014; Fernandes, 2016). However, there is no consensus about the occurrence of *campos rupestres* in areas of the Mantiqueira mountain complex, such as Serra Negra and Ibitipoca, both in Minas Gerais State. Although Salimena *et al.* (2013) considered the open vegetation in Serra Negra to be *campos rupestres* similar to those encountered at Ibitipoca, Alves *et al.* (2014) point out that a woody scrub replaces the open vegetation in most parts of the Serra Negra.

The woody scrub highlighted by Alves *et al.* (2014) in the Serra Negra remains a poorly sampled formation. At present, there is no published work focusing specifically on this formation. Therefore, a specific study on the appropriate methodology for sampling woody plants is necessary. In this paper, we present the first analysis of the structure and diversity of non-forest woody vegetation on quartzite soils in this region of the Mantiqueira mountain complex, Minas Gerais State, Brazil.

## Materials and Methods

### *Study area*

The Serra Negra is located between the municipalities of Rio Preto, Lima Duarte, Santa Barbara do Monte Verde and Olaria, at approximately 21°58′43.95″S, 43°52′16.85″W (Fig. 1), and is part of the Mantiqueira mountain complex (Valente *et al.*, 2011). The elevation is 900–1698 m, mean annual temperature is 19.3°C and annual mean rainfall is 1886 mm (EMATER, 2003). The climate is Cwb, according to Köppen's classification (Peel *et al.*, 2007): humid mesothermal with dry and cold winters, and mild and humid summers.

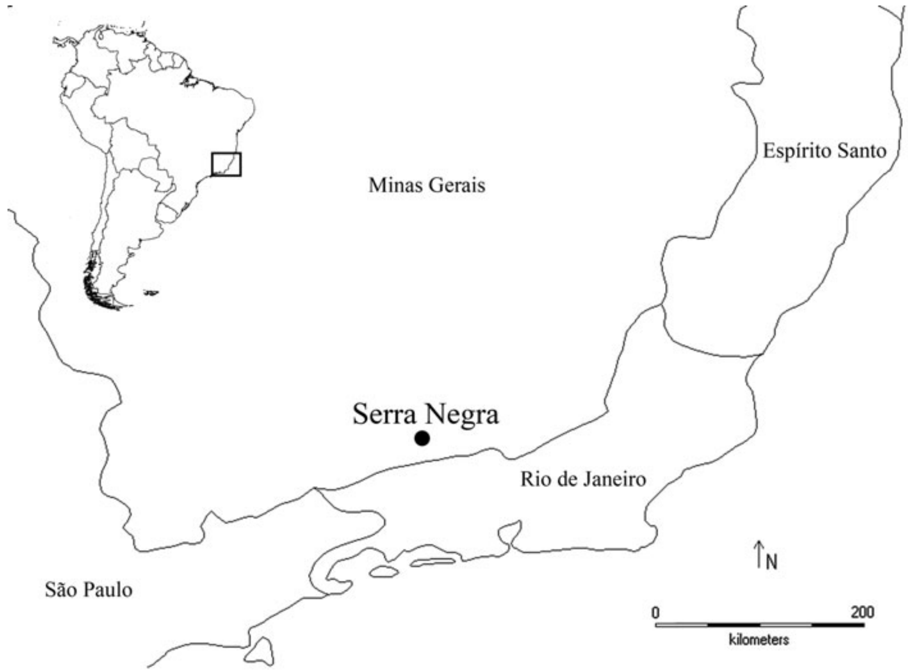


FIG. 1. Location of Serra Negra in the Atlantic Forest Domain, between the municipalities of Rio Preto, Lima Duarte, Santa Barbara do Monte Verde and Olaria, Minas Gerais, in the south-eastern region of Brazil.

The landscape is mountainous, with steep slopes and valleys (Heilbron *et al.*, 2000). The predominant geological formation of the area belongs to the Andrelândia Group, with dystrophic yellow oxisol, in addition to the presence of sand material (quartzite) with low natural fertility (Olszevski *et al.*, 2008; Oliveira & Marques-Neto, 2014). The quartzites occur as two rock types in the region: coarse quartzite, with > 95% of quartz grains ranging from 3 to 8 mm (covering about 28 $km^2$), and impure quartzite, that is, quartz associated with feldspar and traces of muscovite, with grains between 1 and 3 mm (covering about 10 $km^2$) (Uagoda *et al.*, 2011).

The region is within the domain of the Atlantic Forest, with a mosaic of vegetation types consisting of forest, shrub and anthropogenic physiognomies. Forest types are described according to the Brazilian vegetation classification (IBGE, 2012) as Alluvial, Montane and Upper Montane Dense Rain Forests (Valente *et al.*, 2011) and Semideciduous Seasonal Forests. The *campo rupestre* physiognomy occurs mainly on the ridges, associated with quartzites (Salimena *et al.*, 2013). The non-forest woody formations (Fig. 2) that are the target of this study have developed on sandy soils of quartzite origin (coarse quartzite), being distributed across the landscape in patches among other physiognomies. These formations have been described as 'broadleaved

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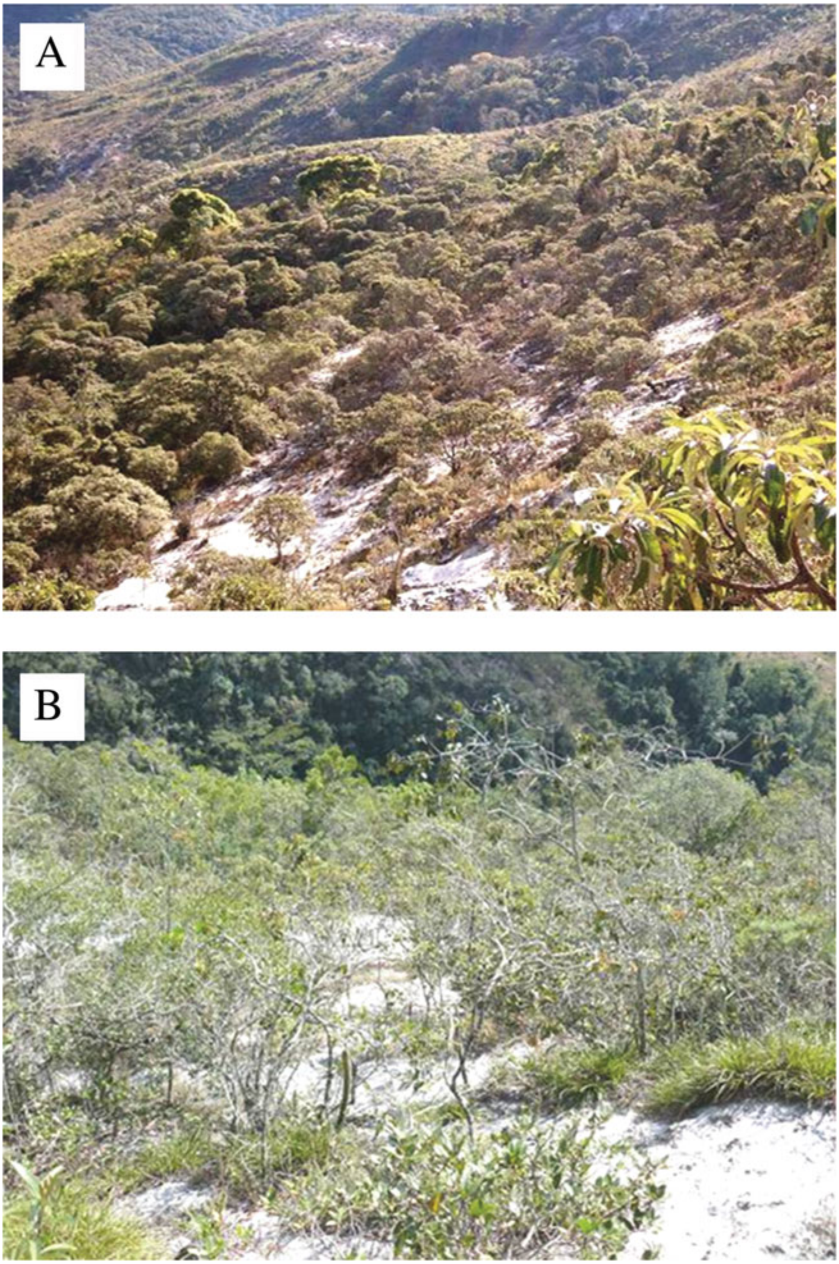


FIG. 2. Woody formations on quartzite soils in Serra Negra, Minas Gerais, Brazil. A, Vegetation mosaic with patches of rain forest and the woody formations occurring on quartzite soils. B, The woody formations that were the target of this study.

scrubs' by Salimena *et al.* (2013) following the classification system proposed by Oliveira-Filho (2009), which also corresponds to 'scrub' according to Eiten (1979).

### *Sampling and data collection*

The sampling methodology was proposed for woody vegetation in grasslands (wood savannas) and rock vegetation types of central and north-eastern Brazil (Felfili *et al.*, 2005). Using the maps provided by Uagoda *et al.* (2011) and satellite images, 10 patches of non-forest woody formations were randomly selected. In each selected patch, a plot of 20 × 50 m was placed in the centre of the area, in order to avoid edge effects. The 10 plots together covered 1 ha. Field data were collected between June and September 2012.

All individuals with a diameter ≥ 3 cm at 30 cm above ground level (diameter at ground height) were measured. The height of these individuals was estimated by comparison with a graduated rod. A digital caliper was used to measure the stem diameter (diameter at ground height). Botanical material was collected for identification at species level. Identification of botanical material was made by reference to the literature, consultation with experts and comparison with material deposited in the herbarium Leopoldo Krieger (CESJ) (code following Thiers, continuously updated) of the Federal University of Juiz de Fora. The names of the species and botanical synonyms were confirmed by consulting the *Flora do Brasil 2020* (Rio de Janeiro Botanical Garden, continuously updated), and the classification of botanical families followed APG III (Angiosperm Phylogeny Group, 2009).

### *Data analysis*

For the structural analysis, the following phytosociological parameters of species were evaluated according to formulas described in Kent & Coker (1992): absolute and relative frequency (*AF* and *RF*, respectively); absolute and relative density (*AD* and *RD*, respectively); absolute and relative dominance (*ADo* and *RDo*, respectively); and importance value (*IV*), calculated as the sum of *RF*, *RD* and *RDo*. To analyse dominance in multistemmed individuals (individuals that had two or more stems branching below 30 cm), we summed the basal areas of each stem (Felfili *et al.*, 2005). The Shannon diversity index ($H'$) was used in the natural logarithmic base (e) to estimate species diversity. By using a logarithmic basis, this index is more suitable for communities in which species abundance is very uneven, balancing the weight of dominant species (Magurran, 2004). The evenness index ($J$) based on $H'$ was used to estimate the community uniformity. The analyses were performed using the PAST software, version 2.08 (Hammer, 2011).

Histograms of diameter distribution for the community were developed. The class intervals were defined by the approximation of Spiegel's formula (Felfili & Resende, 2003), resulting in class intervals of 2 cm. Logarithmic fit, its equation and coefficient

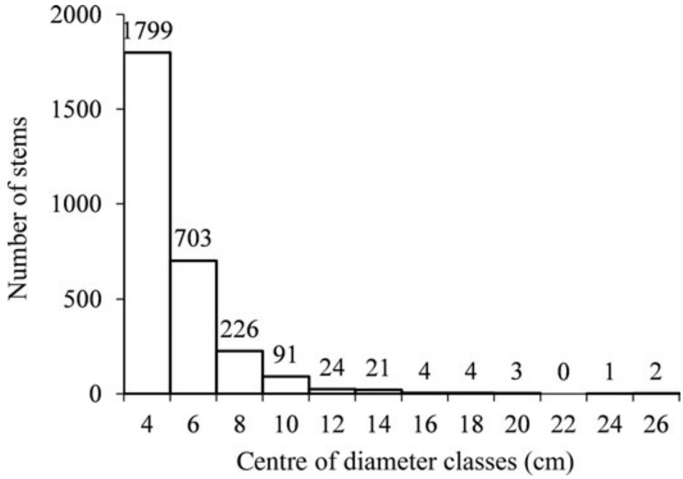


FIG. 3. Frequency distribution in diameter classes of stems in vegetation on quartzite soils in Serra Negra, Rio Preto, Minas Gerais. Logarithmic fit, $R^2 = 0.751$.

of correlation ($R^2$) for each distribution, was determined. A histogram of height distribution for the community was also prepared, using the class interval of 0.5 m.

## RESULTS

### *Richness and diversity*

In total, 1899 individuals were sampled, with a mean of 287.9 ± 50.9 individuals/plot, belonging to 30 families and 68 species (see Appendix). Six taxa were identified to genus level and three to family level; one was not identified. The family with the largest number of species was Myrtaceae (16 species), followed by Asteraceae and Melastomataceae (five species each) and Lauraceae and Primulaceae (four species each). Annonaceae, Ericaceae, Euphorbiaceae, Fabaceae, Hypericaceae, Lamiaceae, Rubiaceae and Sapindaceae had two species each. All other families were represented by a single species. The Shannon diversity index ($H'$) was 2.74 nats/individual, and evenness ($J$) was 0.65.

### *Phytosociology and vegetation structure*

Table 1 shows the phytosociological parameters of the community. As observed in the diversity values ($H'$ and $J$), the results show a community with strong ecological dominance, in which > 50% of *IV* is concentrated only in five species: *Eremanthus incanus* (Less.) Less., *Eremanthus erythropappus* (DC.) MacLeish, *Eugenia modesta* DC., *Byrsonima variabilis* A.Juss. and *Trembleya parviflora* (D.Don) Cogn.

As seen in Figure 3, most individuals are concentrated in the smaller classes of diameter, gradually decreasing in the bigger classes, in a reverse J pattern (logarithmic

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TABLE 1. Phytosociological parameters of species sampled in vegetation on quartzitic soils in Serra Negra, Rio Preto, Minas Gerais*

| Species | *AD* | *ADo* ($m^2$) | *AF* | *RD* (%) | *RDo* (%) | *RF* (%) | *IV* |
|---|---|---|---|---|---|---|---|
| *Eremanthus incanus* | 543 | 2.0454 | 7 | 28.59 | 29.70 | 5.04 | 63.33 |
| *Eremanthus erythropappus* | 203 | 1.3874 | 8 | 10.69 | 20.14 | 5.76 | 36.59 |
| *Eugenia modesta* | 197 | 0.6171 | 7 | 10.37 | 8.96 | 5.04 | 24.37 |
| *Byrsonima variabilis* | 159 | 0.4204 | 6 | 8.37 | 6.10 | 4.32 | 18.79 |
| *Trembleya parviflora* | 113 | 0.3724 | 2 | 5.95 | 5.41 | 1.44 | 12.80 |
| *Pseudobrickellia angustissima* | 85 | 0.2584 | 2 | 4.48 | 3.75 | 1.44 | 9.67 |
| *Aspidosperma olivaceum* | 61 | 0.1141 | 5 | 3.21 | 1.66 | 3.60 | 8.47 |
| *Erythroxylum amplifolium* | 63 | 0.2407 | 2 | 3.32 | 3.49 | 1.44 | 8.25 |
| *Ocotea tristis* | 50 | 0.1153 | 5 | 2.63 | 1.67 | 3.60 | 7.90 |
| *Myrcia pulchra* | 37 | 0.1496 | 4 | 1.95 | 2.17 | 2.88 | 7.00 |
| *Agarista glaberrima* | 48 | 0.1666 | 2 | 2.53 | 2.42 | 1.44 | 6.39 |
| *Myrcia splendens* | 32 | 0.0743 | 5 | 1.69 | 1.08 | 3.60 | 6.36 |
| *Matayba marginata* | 41 | 0.0802 | 4 | 2.16 | 1.16 | 2.88 | 6.20 |
| *Eugenia involucrata* | 21 | 0.0341 | 6 | 1.11 | 0.49 | 4.32 | 5.92 |
| *Ouratea semiserrata* | 20 | 0.0764 | 4 | 1.05 | 1.11 | 2.88 | 5.04 |
| *Clusia criuva* | 21 | 0.0803 | 3 | 1.11 | 1.17 | 2.16 | 4.43 |
| *Myrcia hartwegiana* | 15 | 0.0636 | 3 | 0.79 | 0.92 | 2.16 | 3.87 |
| *Myrsine umbellata* | 15 | 0.0542 | 3 | 0.79 | 0.79 | 2.16 | 3.74 |
| *Blepharocalyx salicifolius* | 29 | 0.0394 | 2 | 1.53 | 0.57 | 1.44 | 3.54 |
| *Tibouchina fissinervia* | 21 | 0.0837 | 1 | 1.11 | 1.22 | 0.72 | 3.04 |
| *Tibouchina estrellensis* | 7 | 0.0174 | 3 | 0.37 | 0.25 | 2.16 | 2.78 |
| *Persea rufotomentosa* | 4 | 0.0303 | 2 | 0.21 | 0.44 | 1.44 | 2.09 |
| *Chamaecrista cathartica* | 6 | 0.0210 | 2 | 0.32 | 0.30 | 1.44 | 2.06 |
| *Ternstroemia brasiliensis* | 6 | 0.0112 | 2 | 0.32 | 0.16 | 1.44 | 1.92 |
| *Lamanonia cuneata* | 9 | 0.0484 | 1 | 0.47 | 0.70 | 0.72 | 1.90 |
| *Maytenus urbaniana* | 4 | 0.0049 | 2 | 0.21 | 0.07 | 1.44 | 1.72 |
| *Guatteria australis* | 2 | 0.0059 | 2 | 0.11 | 0.09 | 1.44 | 1.63 |
| *Myrsine lancifolia* | 2 | 0.0027 | 2 | 0.11 | 0.04 | 1.44 | 1.58 |
| *Myrcia venulosa* | 2 | 0.0016 | 2 | 0.11 | 0.02 | 1.44 | 1.57 |
| *Clethra scabra* | 2 | 0.0015 | 2 | 0.11 | 0.02 | 1.44 | 1.57 |
| *Alchornea triplinervia* | 3 | 0.0427 | 1 | 0.16 | 0.62 | 0.72 | 1.50 |
| *Vismia magnoliifolia* | 7 | 0.0262 | 1 | 0.37 | 0.38 | 0.72 | 1.47 |
| *Myrcia guianensis* | 8 | 0.0150 | 1 | 0.42 | 0.22 | 0.72 | 1.36 |
| *Myrsine gardneriana* | 4 | 0.0174 | 1 | 0.21 | 0.25 | 0.72 | 1.18 |
| *Myrcia mutabilis* | 5 | 0.0123 | 1 | 0.26 | 0.18 | 0.72 | 1.16 |
| *Seguieria* sp. | 1 | 0.0250 | 1 | 0.05 | 0.36 | 0.72 | 1.13 |
| *Macropeplus schwackeanus* | 5 | 0.0097 | 1 | 0.26 | 0.14 | 0.72 | 1.12 |
| *Tapirira obtusa* | 1 | 0.0241 | 1 | 0.05 | 0.35 | 0.72 | 1.12 |
| *Pera glabrata* | 4 | 0.0122 | 1 | 0.21 | 0.18 | 0.72 | 1.11 |
| *Hyptis monticola* | 5 | 0.0049 | 1 | 0.26 | 0.07 | 0.72 | 1.05 |
| *Gaylussacia densa* | 4 | 0.0069 | 1 | 0.21 | 0.10 | 0.72 | 1.03 |
| Undetermined sp. 1 | 2 | 0.0120 | 1 | 0.11 | 0.17 | 0.72 | 1.00 |
| *Eugenia* sp. | 3 | 0.0044 | 1 | 0.16 | 0.06 | 0.72 | 0.94 |
| *Eugenia bimarginata* | 2 | 0.0078 | 1 | 0.11 | 0.11 | 0.72 | 0.94 |
| *Ladenbergia hexandra* | 1 | 0.0080 | 1 | 0.05 | 0.12 | 0.72 | 0.89 |

TABLE 1. (*Continued*)

| Species | *AD* | *ADo* ($m^2$) | *AF* | *RD* (%) | *RDo* (%) | *RF* (%) | *IV* |
|---|---|---|---|---|---|---|---|
| *Calea* sp. | 2 | 0.0019 | 1 | 0.11 | 0.03 | 0.72 | 0.85 |
| *Vismia parviflora* | 2 | 0.0018 | 1 | 0.11 | 0.03 | 0.72 | 0.85 |
| *Eugenia handroana* | 2 | 0.0018 | 1 | 0.11 | 0.03 | 0.72 | 0.85 |
| *Miconia* sp. 1 | 1 | 0.0051 | 1 | 0.05 | 0.07 | 0.72 | 0.85 |
| Fabaceae sp. 1 | 1 | 0.0041 | 1 | 0.05 | 0.06 | 0.72 | 0.83 |
| *Cabralea canjerana* | 1 | 0.0027 | 1 | 0.05 | 0.04 | 0.72 | 0.81 |
| *Xylopia brasiliensis* | 1 | 0.0026 | 1 | 0.05 | 0.04 | 0.72 | 0.81 |
| *Maprounea guianensis* | 1 | 0.0026 | 1 | 0.05 | 0.04 | 0.72 | 0.81 |
| *Pavonia viscosa* | 1 | 0.0021 | 1 | 0.05 | 0.03 | 0.72 | 0.80 |
| *Persea willdenovii* | 1 | 0.0018 | 1 | 0.05 | 0.03 | 0.72 | 0.80 |
| *Remijia ferruginea* | 1 | 0.0017 | 1 | 0.05 | 0.03 | 0.72 | 0.80 |
| *Vitex sellowiana* | 1 | 0.0014 | 1 | 0.05 | 0.02 | 0.72 | 0.79 |
| *Miconia urophylla* | 1 | 0.0013 | 1 | 0.05 | 0.02 | 0.72 | 0.79 |
| *Psidium firmum* | 1 | 0.0012 | 1 | 0.05 | 0.02 | 0.72 | 0.79 |
| *Handroanthus albus* | 1 | 0.0012 | 1 | 0.05 | 0.02 | 0.72 | 0.79 |
| Myrtaceae sp. 1 | 1 | 0.0011 | 1 | 0.05 | 0.02 | 0.72 | 0.79 |
| Lauraceae sp. 1 | 1 | 0.0010 | 1 | 0.05 | 0.01 | 0.72 | 0.79 |
| *Myrsine* sp. 1 | 1 | 0.0009 | 1 | 0.05 | 0.01 | 0.72 | 0.78 |
| *Cupania ludowigii* | 1 | 0.0008 | 1 | 0.05 | 0.01 | 0.72 | 0.78 |
| *Eugenia* sp. 2 | 1 | 0.0008 | 1 | 0.05 | 0.01 | 0.72 | 0.78 |
| *Ilex subcordata* | 1 | 0.0008 | 1 | 0.05 | 0.01 | 0.72 | 0.78 |
| *Verbesina pseudoclaussenii* | 1 | 0.0008 | 1 | 0.05 | 0.01 | 0.72 | 0.78 |
| *Eugenia widgrenii* | 1 | 0.0007 | 1 | 0.05 | 0.01 | 0.72 | 0.78 |
| Total | 1899 | 6.8872 | 139 | 100 | 100 | 100 | 300 |

*Species ordered by decreasing importance value ($IV = RD + RDo + RF$).
*AD*, absolute density; *ADo*, absolute dominance; *AF*, absolute frequency; *RD*, relative density; *RDo*, relative dominance; *RF*, relative frequency.

fit, $y = -608\ln(x) + 1253$; $R^2 = 0.751$). The same pattern was observed when the biomass (sum of basal areas of individuals) was analysed by diameter class, showing that the major fraction of biomass is accumulated in smaller individuals (Fig. 4; logarithmic fit, $y = -0.96\ln(x) + 2.172$; $R^2 = 0.920$).

The distribution of individuals in height classes shows that the community is characterised by a large number of small individuals, with some emergents reaching a maximum height of 6 m (Fig. 5). It is not possible to identify the formation of different strata. Furthermore, the vegetation is not continuous, occurring more densely at some sites and sparsely at others, even at small scales (Fig. 2).

Another important aspect is the large number of multistemmed individuals (Table 2), with about 28% of individuals multistemmed at ground height (30 cm above ground), and 48.5% of species with at least one multistemmed individual. Of the species with highest density (more than 10 individuals), only one, *Tibouchina fissinervia* (Schrank & Mart. ex DC.) Cogn. (species name listed in *Flora do Brasil 2020*, Rio de Janeiro Botanical Garden, continuously updated; *Tibouchina fissinervia* Cogn. in the

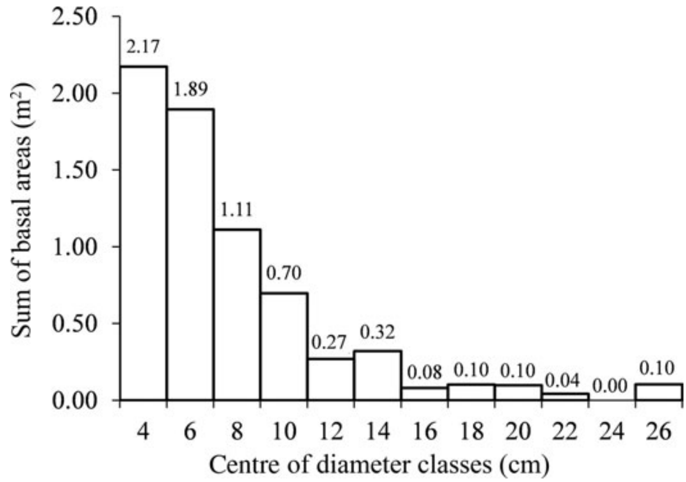


FIG. 4. Sum of basal areas per diameter class for vegetation on quartzite soils in Serra Negra, Rio Preto, Minas Gerais. Logarithmic fit, $R^2 = 0.920$.

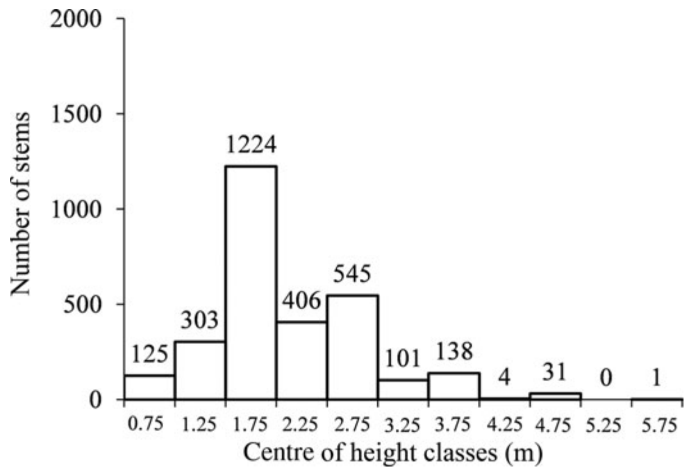


FIG. 5. Frequency distribution in height classes for vegetation on quartzite soils in Serra Negra, Rio Preto, Minas Gerais.

Plant List, 2013–), had no multistemmed individuals. Species with higher *IV* also had a high percentage of multistemmed individuals (Table 2).

## DISCUSSION

### *Richness and diversity*

The composition of most representative families sampled is close to that reported for the general flora of Serra Negra (Salimena *et al.*, 2013), and also approximates the

TABLE 2. Number of individuals, percentage of multistemmed individuals and total stems for the community and principal populations* in vegetation on quartzitic soils in Serra Negra, Rio Preto, Minas Gerais

| Species | No. of individuals | Multistemmed individuals (%) | Total stems |
|---|---|---|---|
| All 68 spp. sampled | 1899 | 28.33 | 2878 |
| *Eremanthus incanus* | 543 | 19.34 | 701 |
| *Eremanthus erythropappus* | 203 | 41.87 | 354 |
| *Eugenia modesta* | 197 | 45.18 | 396 |
| *Byrsonima variabilis* | 159 | 24.53 | 220 |
| *Trembleya parviflora* | 113 | 30.97 | 168 |
| *Pseudobrickellia angustissima* | 85 | 27.06 | 113 |
| *Aspidosperma olivaceum* | 61 | 19.67 | 85 |
| *Erythroxylum amplifolium* | 63 | 47.62 | 123 |
| *Ocotea tristis* | 50 | 34.00 | 81 |
| *Myrcia pulchra* | 37 | 43.24 | 90 |
| *Agarista glaberrima* | 48 | 35.42 | 75 |

*Ordered by decreasing importance value (see Table 1).

composition of forests in the region (Valente *et al.*, 2011). The Myrtaceae, Asteraceae, Melastomataceae, Lauraceae and Primulaceae families are recognised as important in forest formations at altitude in the Atlantic Forest Domain (Oliveira-Filho & Fontes, 2000). Therefore, in general, the floristic composition of woody vegetation on quartzite soils on Serra Negra tends to approach that of other woody formations in the region.

There have been no studies using similar methodology in similar physiognomies in the Atlantic Forest Domain, which prevents a direct comparison with this domain. However, the Shannon diversity and evenness values found were close to those found for the savanna (*cerrado sensu stricto*) area on quartzite soils in Piauí State, northern Brazil ($H'$, 2.75 nats/individual; $J$, 0.70), for which the same sampling methodology was applied (Lindoso *et al.*, 2009). Species richness was also close to that determined by Lima *et al.* (2010) for some areas of rocky 'cerrado' in central Brazil, using the same sampling, although the $H'$ values were slightly higher ($H'$, 3.09–3.65 nats/individual). These comparisons reveal a close structural affinity with the Brazilian savannas vegetation, which deserves future phytogeographical investigation.

### *Phytosociology and vegetation structure*

The community showed a typical reverse J pattern of diameter class distribution. It can be inferred that the community has the potential to maintain its structure over time, with a good stock of young individuals able to occupy the places left by dead ones.

The two species of greatest ecological importance, *Eremanthus incanus* and *E. erythropappus*, which together comprise 33% of *IV*, are commonly known as 'candeias' and occur frequently in the rocky physiognomies of the Cerrado; they also occur in the Atlantic Forest Domain at altitudes above 700 m a.s.l. (Macleish, 1987).

Ecological dominance is common in plant communities in habitats with more severe environmental conditions in the Atlantic Forest Domain (Scarano, 2002). In these environments, locally abundant species often play an important role in the operation and maintenance of communities (Scarano *et al.*, 2001). In the present study, the strong dominance contrasts with the high species richness recorded in the area (Salimena *et al.*, 2013). This is probably the result of limiting environmental factors, such as poor soil (Ribeiro, 2013), favouring species with adaptations to these conditions. Microhabitats in that environment and the proximity to other vegetation types (Menini Neto *et al.*, 2009; Valente *et al.*, 2011) allow the establishment of a large number of local rare species. Some of the species found were among the most important species recorded in forest formations adjacent to the study areas (Valente *et al.*, 2011). Although these species have low densities and frequencies in *campos rupestres*, they are important species in forests in the Serra Negra. According to a study of forest formations at Serra Negra (Valente *et al.*, 2011), *Alchornea triplinervia* (Spreng.) Müll.Arg., for example, is the species with the highest *IV* in the Upper Montane Dense Rain Forest, and the species with the third highest *IV* in the Alluvial Dense Rain Forest; and *Eugenia widgrenii* Sond. ex O.Berg. and *Xylopia brasiliensis* Spreng. are the species with the second and third highest *IV* in the Montane Dense Rain Forest. This sharing of species between different vegetation types in the Serra Negra was also observed by Salimena *et al.* (2013). Sharing of species with forest formations seems to be a frequent pattern in grassland environments of mountains, where forest species tend to occur as occasional elements, showing smaller sizes, and often being more branched, because of limitations imposed by edaphic aspects (Messias *et al.*, 2012; Oliveira-Filho *et al.*, 2013; Valente *et al.*, 2013).

The high percentage of multistemmed individuals shows that the formation of multiple stems is an important process in the structural conformation of this community. In open vegetation, competition for light is not an important factor, therefore plants can show more diverse forms, such as the formation of multistemmed individuals, in response to different selective pressures (Archibald & Bond, 2003). Investment in forming multiple stems occurs at the expense of investment in other processes, especially the allocation of resources to reproduction (Iwasa & Kubo, 1997). Furthermore, multistemmed plants tend to have lower biomass and shorter height than single-stemmed plants, being less competitive in shaded environments (Bond & Midgley, 2001). However, sprouting and regrowth ability may have advantages as a way to recover after disturbances capable of causing loss of above-ground biomass, such as fire, strong winds and stem cut (Bond & Midgley, 2001). Theoretical models show that sprouting is advantageous in situations in which the frequency and intensity of disturbance is intermediate to intense (Iwasa & Kubo, 1997; Bellingham & Sparrow, 2000).

The occurrence of high proportions of multistemmed individuals is not related only to the occurrence of disturbances in the environment. Dunphy *et al.* (2000), studying tropical dry forests in Puerto Rico, found a high proportion of multistemmed individuals and showed that in most cases they showed no signs of having been cut, keeping the main stem intact. Indeed, the model proposed by Bellingham & Sparrow (2000) incorporates productivity of the environment as an important factor in predicting the rate of sprouting. In environments with low productivity, as in cases of low soil fertility, sprouting can be advantageous even without the presence of constant disturbances. Bellingham & Sparrow (2009) found that, in tropical montane forests in Jamaica, the formation of multistemmed individuals is mainly related to low soil fertility. In the present study, it is likely that the high proportion of multistemmed individuals, especially among the most abundant species, is also related to low soil fertility (Olszevski *et al.*, 2008).

*Final considerations and implications for conservation*

The results show that the woody vegetation on quartzite soils of Serra Negra is characterised by the contrast of strong ecological dominance and expressive richness, with elements of adjacent forests. In addition, three sampled species are considered endangered in the Atlantic Forest Domain of Minas Gerais State (Biodiversitas Foundation, 2008); *Pseudobrickellia angustissima* (Spreng. ex Baker) R.M.King & H.Rob. and *Verbesina pseudoclaussenii* D.J.N.Hind (Asteraceae) are considered critically endangered, and *Handroanthus albus* (Cham.) Mattos (Bignoniaceae) is considered vulnerable. According to the Biodiversitas Foundation (2008), which used the criteria of the International Union for Conservation of Nature, these three species are considered endangered mainly because of factors related to their area of occupation and loss of habitat. Martinelli & Moraes (2013) also point out that *Verbesina pseudoclaussenii* is critically endangered in Brazil and is now restricted to the Serra Negra.

The two most abundant species, *Eremanthus incanus* and *E. erythropappus*, have great economic importance in the region because of their highly durable wood, which is used mainly for making fences and for firewood extraction. Information from local residents indicates that they commonly use the wood for making fences and rustic furniture, and as fuel for wood stoves, but still with a low impact on natural populations. In Brazil, the commercial exploitation of 'candeias' for extraction of essential oil, which is used in dermatological products and the cosmetics industry (Bohlmann *et al.*, 1980; Silvério *et al.*, 2008), has been growing. The imminent exploitation of these species for oil extraction may pose an additional risk to the vegetation studied here, because the results show that these species have great ecological importance in the structural conformation of the woody community.

The great heterogeneity of vegetation, with many species of low frequency and locally 'rare', means that a strategy for their effective conservation must include the largest possible area distributed across the landscape. Strategies for flora conservation in the region should focus not only on the rare and endangered species, but also on locally abundant species that are functionally vital in maintaining the plant community (Scarano, 2002) and should also be considered in biodiversity conservation plans (Scarano 2009). Commercial use of woody species, if not performed in a planned way, can also increase soil exposure, which exposes the fragile structure and makes it subject to erosion (Olszevski *et al.*, 2008). Therefore, a greater coordinated effort between the government and the local population is necessary to ensure the conservation and proper use of natural resources in the region.

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## Appendix

The testimony material (Appendix table 1) is deposited in the herbarium Leopoldo Krieger (CESJ) and the Laboratory of Plant Ecology, Department of Botany, Universidade Federal de Juiz de Fora.

Appendix table 1. Species sampled in vegetation on quartzitic soils in Serra Negra, Rio Preto, Minas Gerais, arranged in alphabetical order of family, genus and species, respectively

| Species sampled* | Testimony material |
|---|---|
| Anacardiaceae | |
| *Tapirira obtusa* (Benth.) J.D.Mitch. | *Ribeiro 120* |
| Annonaceae | |
| *Guatteria australis* A.St.-Hil. | *Ribeiro 119* |
| *Xylopia brasiliensis* Spreng. | *Ribeiro 104* |
| Apocynaceae | |
| *Aspidosperma olivaceum* Müll.Arg. | *Ribeiro 245* |
| Aquifoliaceae | |
| *Ilex subcordata* Reissek | *Ribeiro 107* |
| Asteraceae | |
| *Calea* sp. | *Ribeiro 229* |
| *Eremanthus erythropappus* (DC.) MacLeish | *Ribeiro 103* |
| *Eremanthus incanus* (Less.) Less. | *Ribeiro 106* |
| *Pseudobrickellia angustissima* (Spreng. ex Baker) R.M.King & H.Rob. | *Ribeiro 105* |
| *Verbesina pseudoclaussenii* D.J.N.Hind | *Ribeiro 116* |
| Bignoniaceae | |
| *Handroanthus albus* (Cham.) Mattos | *Ribeiro 114* |
| Celastraceae | |
| *Maytenus urbaniana* Loes. | *Ribeiro 124* |
| Clethraceae | |
| *Clethra scabra* Pers. | *Ribeiro 115* |
| Clusiaceae | |
| *Clusia criuva* Cambess. | *Ribeiro 135* |

Appendix table 1. (*Continued*)

| Species sampled* | Testimony material |
|---|---|
| Cunoniaceae | |
| *Lamanonia cuneata* (Cambess.) Kuntze | *Ribeiro 125* |
| Ericaceae | |
| *Agarista glaberrima* (Sleumer) Judd | *Ribeiro 134* |
| *Gaylussacia densa* Cham. | *Ribeiro 132* |
| Erythroxylaceae | |
| *Erythroxylum amplifolium* (Mart.) O.E.Schulz (= *Erythroxylum amplifolium* Baill.) | *Ribeiro 137* |
| Euphorbiaceae | |
| *Alchornea triplinervia* (Spreng.) Müll.Arg. | *Ribeiro 109* |
| *Maprounea guianensis* Aubl. | |
| Fabaceae | |
| *Chamaecrista cathartica* (Mart.) H.S.Irwin & Barneby | *Ribeiro 110* |
| Fabaceae sp. 1 | *Ribeiro 138* |
| Hypericaceae | |
| *Vismia magnoliifolia* Cham. & Schltdl. | *Ribeiro 140* |
| *Vismia parviflora* Cham. & Schltdl. (= *Vismia parviflora* Schltdl. & Cham.) | *Ribeiro 141* |
| Lamiaceae | |
| *Hyptis monticola* Mart. ex Benth. | *Ribeiro 143* |
| *Vitex sellowiana* Cham. | *Ribeiro 144* |
| Lauraceae | |
| Lauraceae sp. 1 | *Ribeiro 121* |
| *Ocotea tristis* (Nees & Mart.) Mez | *Ribeiro 147* |
| *Persea rufotomentosa* Nees & Mart. (= *Persea rufotomentosa* Nees & C.Mart.) | *Ribeiro 145* |
| *Persea willdenovii* Kosterm. | *Ribeiro 126* |
| Malpighiaceae | |
| *Byrsonima variabilis* A.Juss. | *Ribeiro 123* |
| Malvaceae | |
| *Pavonia viscosa* A.St.-Hil. | *Ribeiro 131* |
| Melastomataceae | |
| *Miconia* sp. 1 | *Ribeiro 127* |
| *Miconia urophylla* DC. | *Ribeiro 146* |
| *Tibouchina estrellensis* (Raddi) Cogn. | *Ribeiro 130* |
| *Tibouchina fissinervia* (Schrank & Mart. ex DC.) Cogn. (= *Tibouchina fissinervia Cogn.*) | *Ribeiro 150* |
| *Trembleya parviflora* (D.Don) Cogn. | *Ribeiro 151* |
| Meliaceae | |
| *Cabralea canjerana* (Vell.) Mart. | *Ribeiro 157* |
| Monimiaceae | |
| *Macropeplus schwackeanus* (Perkins) I.Santos & Peixoto | *Ribeiro 158* |
| Myrtaceae | |
| *Blepharocalyx salicifolius* (Kunth) O.Berg | *Ribeiro 152* |
| *Eugenia* sp. 1 | *Ribeiro 159* |
| *Eugenia* sp. 2 | *Ribeiro 156* |

APPENDIX TABLE 1. (*Continued*)

| Species sampled* | Testimony material |
|---|---|
| *Eugenia bimarginata* DC. | |
| *Eugenia modesta* DC. | *Ribeiro 162* |
| *Eugenia handroana* D.Legrand | *Ribeiro 174* |
| *Eugenia involucrata* DC. | *Ribeiro 164* |
| *Eugenia widgrenii* Sond. ex O.Berg | *Ribeiro 175* |
| *Myrcia guianensis* (Aubl.) DC. | *Ribeiro 161* |
| *Myrcia hartwegiana* (O.Berg) Kiaersk. | *Ribeiro 187* |
| *Myrcia mutabilis* (O.Berg) N.Silveira | *Ribeiro 192* |
| *Myrcia pulchra* (O.Berg) Kiaersk. | *Ribeiro 190* |
| *Myrcia splendens* (Sw.) DC. | *Ribeiro 176* |
| *Myrcia venulosa* DC. | *Ribeiro 163* |
| Myrtaceae sp. 1 | *Ribeiro 160* |
| *Psidium firmum* O.Berg | *Ribeiro 179* |
| Ochnaceae | |
| *Ouratea semiserrata* (Mart. & Nees) Engl. | *Ribeiro 177* |
| Pentaphylacaceae | |
| *Ternstroemia brasiliensis* Cambess. | *Ribeiro 167* |
| Peraceae | |
| *Pera glabrata* (Schott) Poepp. ex Baill. | *Ribeiro 166* |
| Phytolaccaceae | |
| *Seguieria* sp. | *Ribeiro 183* |
| Primulaceae | |
| *Myrsine gardneriana* A.DC. | *Ribeiro 195* |
| *Myrsine lancifolia* Mart. | *Ribeiro 184* |
| *Myrsine* sp. 1 | *Ribeiro 165* |
| *Myrsine umbellata* Mart. | *Ribeiro 170* |
| Rubiaceae | |
| *Ladenbergia hexandra* (Pohl) Klotzsch | *Ribeiro 185* |
| *Remijia ferruginea* (A.St.-Hil.) DC. | *Ribeiro 186* |
| Sapindaceae | |
| *Cupania ludowigii* Somner & Ferrucci | *Ribeiro 168* |
| *Matayba marginata* Radlk. | *Ribeiro 173* |
| Undetermined | |
| Undetermined sp. 1 | *Ribeiro 122* |

*Species names are those listed in *Flora do Brasil 2020* (Rio de Janeiro Botanical Garden, continuously updated); Plant List (2013–) names are in parentheses.