Phanerogamic flora and phytogeography of the Cloud Dwarf Forests of Ibitipoca State Park, Minas Gerais, Brazil

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Abstract:
This study was developed in Ibitipoca State Park (ISP), a mountainous massif that stands out in the Serra da Mantiqueira, in the Southeastern Region of Brazil. The vegetation is represented by a phytophysionomic mosaic where areas of campos rupestres interspersed with cloud dwarf forests predominate, at altitudes of 1100 to 1700 m.s.m. The cloud dwarf forests exist in narrow altitude belts on the mountain peaks, immersed in a layer of clouds. They form a peculiar landscape high in the mountains by the short stature of the arboreal elements and richness of lichens and bryophytes, which develop under constant condensation of humidity, low temperatures, and frequent winds. The objective of the present work was to determine the floristic composition and phytogeography of the cloud dwarf forests of ISP. Twelve monthly campaigns were conducted to collect botanical material during the years 2014 and 2015. The collected material was deposited in the collection of the CESJ Herbarium. A total of 372 species, 209 genera, and 73 families of phanerogams were found. The richest families were Orchidaceae (84 spp.), Asteraceae (39 spp.), and Melastomataceae (21 spp). The genera with the greatest wealth were Leandra (09 spp.), Epidendrum (09 spp.), Pleurothallis (09 spp.), Mikania (07 spp.), and Miconia (07 spp). The arboreal habit was predominant with 103 species (27.7%), followed by 83 shrubs (22.3%), 82 epiphytic herbs (22%), 80 terrestrial herbs (21.5%), and 23 lianas (6.5%). The floristic composition presents elements typical of altitude vegetation, including species of campos rupestres and high epiphytes richness, especially of the families Orchidaceae and Bromeliaceae. The genera with tropical distribution represent 86.5%, whereas the temperate elements represent 13.5% of the total. The cloud dwarf forests presented similarity, at the family and gender levels, with the upper montane forests of the Andes, besides phytogeographic characteristics that allow to associate them to a transition environment between the campos rupestres and the upper montane forests of the Southeast Region of Brazil.

Keywords: Atlantic Forest, cloud forest, conservation, dense ombrophylous forest, Serra da Mantiqueira.

Flora fanerogâmica e fitogeografia das Nanoflorestas Nebulares do Parque Estadual do Ibitipoca, Minas Gerais, Brasil

Resumo: Este estudo foi desenvolvido no Parque Estadual do Ibitipoca (PEIB), um maciço montanhoso que se destaca na Serra da Mantiqueira, na Região Sudeste do Brasil. A vegetação é representada por um mosaico fitofisionômico onde predominam áreas de campos rupestres entremeadas às Nanoflorestas Nebulares, em altitudes de 1100 a 1700 m.s.m. As Nanoflorestas Nebulares ocorrem em cinturões de altitude estreitos, nos picos de montanhas, imersas na camada de nuvens. Formam uma paisagem peculiar no alto das montanhas, pela baixa estatura dos elementos arbóreos e riqueza de líquens e briófitas, que se desenvolvem sob constante condensação de umidade, baixas temperaturas e ventos frequentes. O presente trabalho teve como objetivo conhecer a composição florística e fitogeográfica das Nanoflorestas Nebulares do PEIB. Foram realizadas 12 campanhas mensais para coleta de material botânico, durante os anos de 2014 e 2015. O material coletado foi depositado na coleção do Herbário CESJ. Foram encontradas 372 espécies, 209 gêneros e 73 famílias de fanerógamas. As famílias de maior riqueza foram Orchidaceae (84 spp.), Asteraceae (39 spp.) e Melastomataceae (21 spp). Os gêneros com maior riqueza
The regions of tropical mountains are considered of great importance for the conservation of natural resources, presenting high biological diversity and a high index of endemism, propitiated by the variety of environments associated with biotic and abiotic factors that provide places favorable to speciation (Martinelli 2007). These regions represent refuges and corridors for regional and continental migrations, and often have richer plant diversity than the adjacent lowlands (Martinelli 2007). Nevertheless, little is known about the ecology, biogeography, and natural history of these formations, which have unique physiognomic characteristics (Körner 1999).

The upper montane vegetation in the Southeastern Region of Brazil is constituted by a vegetative mosaic composed by forest and field formations, which vary according to the geographic region and the altitude gradients (Oliveira-Filho 2009). Changes in floristic composition related to altitudinal gradients are strongly influenced by local environmental variables, since different altimetric heights have different temperature conditions, air humidity, water availability, exposure to winds, and classes of depth and soil drainage (Rhakeb 2005, Grytnes & McCain 2007, Slik et al. 2010). The increase in altitude and topographic irregularity in mountainous environments can decisively influence the heterogeneity of landscapes, interfering in the circulation of masses of air and exposure to the sun rays (Webster 1995). The influence of altitude on species diversification is complex. It is believed that the decrease in atmospheric pressure and temperature, as well as the increase in wind speed and solar radiation, may be related to high plant diversity (Körner 1999, Rhakeb 2005).

The Serra da Mantiqueira is one of the largest and most important mountain chains in the Southeastern Region of Brazil (Almeida & Carneiro 1998). It houses more than half of the endangered species of the fauna of Minas Gerais, with an expressive endemism of plant species (Costa & Herrmann 2006). It extends from the Caldas Plateau and the Campos do Jordão Plateau in the south of Minas Gerais, a border with São Paulo, to the Plateau of Caparão, on the border between Minas Gerais and Espírito Santo, with an approximate area of 13,176 km² (Moreira & Canelier 1977, Almeida & Carneiro 1998). These mountain ranges have rocks dating from the Pre-Cambrian period and later shaped by large archways in the Late Cretaceous (Teixeira & Cordani 2007). The Serra da Mantiqueira was part of a large crystalline plateau, and in the Triassic period this plateau underwent a process of bending and fracturing. After extensive erosive work and geological processes during the quaternary period, this plateau became massive, with isolated points and deep valleys (Meireles et al. 2014).

In regions of occurrence of nebular forests, there are areas with climatic and topographic conditions favorable to the regular formation of fogs. These areas present well-developed natural forests that, because they remain frequently enveloped in fog and clouds, are generally called cloud forests (Bruijnzel et al. 2010). These forests account for only 2.5% of the total area of tropical forests in the world, with an overall surface area of approximately 380,000 km² (Bubb et al. 2004). In Brazil, they are represented mainly by the montane and upper montane rainforests along the Serra do Mar in the states of Santa Catarina, Paraná, São Paulo, and Rio de Janeiro, in small stretches of the Serra da Mantiqueira de Minas Gerais, and still high in the plateaus and mountains of the Amazon, such as Pico da Neblina and Monte Roraima (Oliveira-Filho 2009; Bertoncello et al. 2009). These forests are responsible for hidden precipitation, that is, additional water entry into the ecosystem through the fog, by interception of water through the treetops and subsequent drainage to the forest floor (Arcova 2013). Thus, for these localities, the abstraction of water from the atmosphere constitutes an important process of the hydrological cycle of the hydrographic basins (Bruijnzel et al. 2010, Arcova 2013).

The forests of Serra da Mantiqueira are still little known, and their floristic composition and richness have been described in some places by Oliveira-Filho & Fontes (2000), França & Stehmann (2004), Meireles et al. (2008), Valente et al. (2011), Salimena et al. (2013), Meireles et al. (2014), Santiago et. al. (2018), Oliveira-Filho et al. (2013), and Pompeu et al. (2014), among others. Nevertheless, the great environmental heterogeneity presented by this mountain chain has not been sufficiently detailed (Martinelli 2007). Among the least known forest formations are the cloud dwarf forests (sensu Oliveira-Filho et al. 2013).

The aspects that involve the cloud dwarf forests are related to the fact of their immersion in the cloud layer and to the local hydrological cycle (Oliveira-Filho & Fontes 2000). They occur in narrow altitude belts, in ridges of mountainous relief, or in mountain peaks, with a distribution of species similar to archipelagos (Vázquez-García 1995). The abundance, diversity, and distribution of cloud dwarf forest species are determined by global and regional climatic processes that operate on the phylogenetic lines observed over time on a geographic scale (Brown et al. 1996). The geographic distribution of the taxa is unique, being determined by their autecological characteristics, geoclimatic barriers, climatic changes, and historical ecological processes (Brown et al. 1996). The discontinuous distribution of the altitude massifs of the Serra da Mantiqueira promotes
the isolation of the cloud dwarf forests and the species that compose them, being able to restrict gene flow and to prevent the connectivity between the different populations. This process favors the occurrence of species and local endemism (Safford 1999). The species that occur in cloud dwarf forests tolerate adverse conditions such as freezing night temperatures, high temperatures during the day, frost, climatic seasonality, and physical changes such as high light intensity and low atmospheric pressure (Oliveira-Filho & Fontes 2000), with the presence of haze (Bruijnzeel et al. 2010). In addition, it is important to note that the dwarf forests are more likely to be found in high-altitude areas.

Seeking to broaden the knowledge about the altitude formations of the Serra da Mantiqueira, this study was developed with the objective of determining the floristic composition of the cloud dwarf forests of Ibitipoca State Park (ISP) and the contribution of the tropical and temperate distribution elements in this phytophysiognomy.

Material and Methods

1. Study area

ISP is located in Minas Gerais, between the municipalities of Lima Duarte, Bias Fortes, and Santa Rita do Ibitipoca, at coordinates 21°40’-21°44’S and 43°52’-43°55’W and covers an area of 1,488 ha. The region’s climate is classified as Cwb, according to Köppen (1948), with dry winters and rainy and mild summers. The Serra do Ibitipoca has relief formed by high escarpments or hills, with variable altitudes between 1100 m and 1784 m (Rodela & Tarifa 2002) (Figure 1).

ISP is one of the many areas of rocky outcropping in Southeastern Brazil, where there are Proterozoic metamatic rocks of the Andrelândia Group, mainly quartzites and schists, which are on a basement formed of orthogneisses and migmattes belonging to the Mantiqueira Group (Nummer 1991, Corrêa Neto & Baptista Filho 1997). Soils are acidic, alkaline, dystrophic, kaolinitic, and shallow, with little water retention capacity, and support a mosaic of complex vegetation (Dias et al. 2002).

The predominant landscape in ISP is represented by savannas and prairies, described in the literature as campos rupestres, and most of the forest cover is cloud dwarf forests that cover about 226 ha or 15.6% of the surface of the park (Oliveira-Filho et al. 2013). The distribution of most cloud dwarf forests in ISP appears to be closely related to the local drainage network, housed in depressions in the ground and in the bottom of valleys, where there is high deposition of sediment and water (Oliveira-Filho et al. 2013). The identification and recognition of the vegetative types of ISP in this work follow the proposal of Oliveira-Filho et al. (2013) (Figure 2).

2. Floristic composition

In order to evaluate the floristic composition of the cloud dwarf forests of ISP, 12 field campaigns were carried out to collect botanical material, from September 2014 to September 2015, lasting three days each, in different areas of cloud dwarf forests distributed in varying altimetric heights, between 1100 and 1700 m.s.m. The collection was performed by traversing trails inside the dwarf forests, seeking to cover as much of the area as possible, following the method of walking (Filgueiras et al. 1994). The classification of the species habit followed Gonçalves & Lorenzi (2007).

The collected material was herborized according to the techniques of Mori et al. (1989) and deposited in the collection of the CESJ Herbarium of the Federal University of Juiz de Fora (acronym according to Thiers 2016), where it was identified with the help of specialized literature and comparison with the collection of ISP already deposited in the collection, in addition to consulting specialists. The names of the angiosperm families followed the system proposed by APG IV (2016). The synonymy, the spelling and the authorship of the names of the species were conferred through Flora do Brasil 2020 (under construction). Materials deposited in the collections of the herbariums CESJ, BHCB, ESAL, and RB (acronyms according to Thiers 2016) from botanical works in ISP for more than 40 years were included in the floristic listing.

3. Phytogeography

For the phytogeography analyses, the genera were classified into seven phytogeographic groups delimited based on their current centers of diversity cited by Safford (2007). The groups are: Austral-Antarctic - from temperate regions of the Southern hemisphere; Holistic - center of diversity in temperate Northern hemisphere; Generalized Tempering; Cosmopolitan - worldwide distribution; Tropical Species - at least 5% of species on a second continent; Neotropical; and Endemic to Brazil. The geographic distribution of the species was based on the literature and on specialized sites, such as speciesLink (CRIA 2001), w3Tropicos (MBG 2014), and BFG (2015).

Results

1. Floristic composition

A total of 372 species were recorded, distributed in 209 genera and 73 families of phanerogams, with only one species, Podocarpus sellowii Klotzsch (Podocarpaceae), representative of the group of gymnosperms. Of the total specimens, 337 were identified at a specific level, the remaining 28 at the gender level, and seven at the family level (Table 1).

The richest families are Orchidaceae (84 spp.), Asteraceae (39 spp.), Melastomataceae (21 spp.), Bromeliaceae (20 spp.), Myrtaceae (18 spp.), and Rubiaceae (17 spp) (Figure 3).

The genera with the greatest richness were Epidendrum (nine spp.), Leandra (nine spp.), Pleurothallis (nine spp.), Mikania (seven spp.), Micoria (seven spp.), Tillandsia (six spp.), Solanum (six spp.), and Myrcia (six spp.) (Figure 4).

Among the 372 species found, 103 are arboreal (27.7%), 83 shrub (22.3%), 82 epiphytic herbs (22%), 80 terrestrial herbs (21.5%), and 23 lianas (6.5%). Among the tree species, the families Myrtaceae with 17 species and Melastomataceae with 14, with greater richness, stand out. Among the shrubs, the greatest wealth is of the family Asteraceae with 21 spp., followed by Rubiaceae (eight) and Melastomataceae (seven). The terrestrial herbaceous habit was highlighted among the Orchidaceae families with 23 species, Asteraceae with nine, and Bromeliaceae with eight. Epiphytic species predominated in the Orchidaceae family, with 61 species. Among the lianas, the most representative family was Asteraceae with six species, followed by Apocynaceae and Smilacaceae with four each.
Figure 1. Geographic location of Ibitipoca State Park, Serra da Mantiqueira, Southeastern Brazil, with emphasis on its phytophysiognomies (adapted from Oliveira-Filho et al. 2013).

Among the species found in the cloud dwarf forests of ISP, seven have some degree of extinction threat: Octomeria wawrae, Ocotea odorifera, and Vriesea penduliflora classified as “endangered”; Hindsia ibitipocensis as “critically endangered” (CR); and Baccharis lychnophora, Schlumbergera opuntioides, and Sinningia tuberosa as “vulnerable” (VU) (Martinelli & Morais 2013).

2. Phytogeography

The genera with a tropical diversity center represent 86.5% of the total, distributed among 126 neotropical (60%), 45 large tropical (21.5%), and 10 endemic genera of Brazil (5%). The genus with a diversity center in temperate regions corresponded to 13.5% of the total, distributed among seven genera austral-antarctic (3.5%), one of holarian origin (0.5%), two of large temperate origin (1%), and 17 (8.5%) cosmopolitan (Table 2).

Discussion

1. Floristic composition

In the cloud dwarf forests of ISP is the presence of a dense understory, where the arboreal individuals branch to a low height. The floristic profile presents typical characteristics of forest formations of altitude. However, it also presents characteristic species of fields and savannas (Oliveira-Filho et al. 2013). The cloud dwarf forests of ISP present a canopy of about 10 meters, with few emergent trees such as Eugenia brasiliensis, Cupania zanthoxyloides, and Solanum mauritianum. Just below the sub-forest, at about five meters, we can find species such as Agarista pulchella, Leandra melastomoides, Leandra aurea, Myrcia splendens, and the palm tree Geonoma schottiana, which has a large fruit production that serves as food for the local fauna (Oliveira-Filho et al. 2013). Soils, derived from quartzite, are generally shallow and poor in minerals, but the feedback from litter decomposition can sustain medium-sized vegetation (Oliveira-Filho et al. 2013).
Figure 2. A-B. Phytophysiognomies of Ibitipoca State Park; C-D. Details of cloud dwarf forests border, highlighting the transition environments; E-F. Details of inside cloud dwarf forests, Ibitipoca State Park, Minas Gerais, Brazil.
Table 1. Composition of the phanerogamic flora of the cloud dwarf forests of Ibitipoca State Park, Serra da Mantiqueira, Southeastern Brazil. The species are listed by family and in alphabetical order, accompanied by the habit (Tr - tree, Sh - shrub, Li - liana, Th - terrestrial herb, Eh - epiphytic herb) and the testimonial material that is deposited in the herbariums CESJ, BHCB, ESAL, and RB.

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<th>Voucher</th>
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<td>Justicia sp1</td>
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<td>Langsdorffia hypogaea Mart.</td>
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<td>Begonia angulata Vell.</td>
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<td>Begonia rafii Thunb.</td>
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<td>Fridericia speciosa Mart.</td>
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<td>Handroanthus albus (Cham.) Mattos.</td>
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<td>Aechmea aiuruocensis Leme</td>
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<td>Billbergia alfonsioannis Reitz</td>
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<td>Billbergia distachia (Vell.) Mez</td>
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<td>Nidularium ferdinandocoburgii Wawra</td>
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<td><em>Vriesea friburgerensis</em> Mez</td>
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<td><em>Vriesea heterostachys</em> (Baker) L.B.Sm.</td>
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<td><em>Vriesea longicaulis</em> (Baker) Mez</td>
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*Caetaceae*

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<td><em>Lepismium houlettianum</em> (Lem.) Barthlott</td>
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<td><em>Rhipsalis floccosa</em> Salm-Dyck ex Pfeiff.</td>
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<td><em>Rhipsalis juengeri</em> Barthlott &amp; N.P.Taylor</td>
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<td><em>Rhipsalis pulchra</em> Loefgr.</td>
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<td><em>Schlumbergera opuntioides</em> (Loefgr. &amp; Dusén) D.R. Hunt</td>
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<td><em>Tovomitopsis paniculata</em> (Spreng.) Planch. &amp; Triana</td>
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<td><em>Dichorisandra hexandra</em> (Aubl.) C.B.Clarke</td>
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<td><em>Tripogandra diuretica</em> (Mart.) Handlos</td>
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| Peperomia galoides Kunth | Th | B.Moreira 272 |
| Peperomia mandioccana Miq. | Eh | S.G.Furtado 302 |
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</tr>
<tr>
<td>Setaria sp1</td>
<td>Th</td>
<td>B. Moreira 154</td>
</tr>
<tr>
<td><strong>Podocarpaceae</strong></td>
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<td></td>
</tr>
<tr>
<td><em>Podocarpus sellowii</em> Klotzsch</td>
<td>Tr</td>
<td>Fontes 064</td>
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<tr>
<td><strong>Polygalaceae</strong></td>
<td></td>
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<tr>
<td><em>Caamenesca oxyphylla</em> (DC.) J.F.B. Pastore</td>
<td>Sh</td>
<td>B. Moreira 006</td>
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<tr>
<td><em>Polygala paniculata</em> L.</td>
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<tr>
<td><strong>Primulaceae</strong></td>
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<tr>
<td><em>Myrsine coriacea</em> (Sw.) R. Br. ex Roem. &amp; Schult.</td>
<td>Tr</td>
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<td><em>Myrsine ferruginea</em> (Ruiz &amp; Pav.) Spreng.</td>
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</tr>
<tr>
<td><em>Myrsine lancifolia</em> Mart.</td>
<td>Tr</td>
<td>Fontes 151</td>
</tr>
<tr>
<td><em>Myrsine umbellata</em> Mart.</td>
<td>Tr</td>
<td>Fontes 127</td>
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<tr>
<td><strong>Proteaceae</strong></td>
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<tr>
<td><em>Roupala longepetiolata</em> Pohl</td>
<td>Tr</td>
<td>Fontes 138</td>
</tr>
<tr>
<td><em>Roupala montana</em> Aubl.</td>
<td>Tr</td>
<td>B. Moreira 305</td>
</tr>
<tr>
<td><em>Roupala rhombifolia</em> Mart.</td>
<td>Tr</td>
<td>Fontes 164</td>
</tr>
<tr>
<td><strong>Rhamnaceae</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Rhamnus sphaerosperma</em> Sw.</td>
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</tr>
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<td><strong>Rubiaceae</strong></td>
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<td></td>
</tr>
<tr>
<td><em>Amaioua intermedia</em> Mart. ex Schult. &amp; Schult.f.</td>
<td>Sh</td>
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</tr>
<tr>
<td><em>Borreria capitata</em> (Ruiz &amp; Pav.) DC.</td>
<td>Th</td>
<td>B. Moreira 224</td>
</tr>
<tr>
<td><em>Borreria sp1</em></td>
<td>Th</td>
<td>B. Moreira 313</td>
</tr>
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<td><em>Coccocypselum condalia</em> (Ruiz &amp; Pav.) Pers.</td>
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<td><em>Coccocypselum erythrocephalum</em> Cham. &amp; Schltdl.</td>
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</tr>
<tr>
<td><em>Coccocypselum lanceolatum</em> (Ruiz &amp; Pav.) Pers.</td>
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</tr>
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<td><em>Cordiera concolor</em> (Cham.) Kuntze</td>
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<td>B. Moreira 086</td>
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<tr>
<td><em>Cordiera elliptica</em> (Cham.) Kuntze</td>
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<td><em>Hillia parasitica</em> Jacq.</td>
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</tr>
<tr>
<td><em>Hindia ibitipocensis</em> Di Maio</td>
<td>Sh</td>
<td>B. Moreira 064</td>
</tr>
<tr>
<td><em>Palicourea marcgravii</em> A.St.-Hil.</td>
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<td>B. Moreira 119</td>
</tr>
<tr>
<td><em>Posoqueria acutifolia</em> Mart.</td>
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<td>B. Moreira 178</td>
</tr>
<tr>
<td><em>Psychotria leiocarpa</em> Cham. &amp; Schltdl.</td>
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<tr>
<td><em>Psychotria ruellifolia</em> (Cham. &amp; Schltdl.) Müll.Arg.</td>
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<tr>
<td><em>Psychotria stachyoides</em> Benth.</td>
<td>Sh</td>
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<tr>
<td><em>Psychotria vellosiana</em> Benth.</td>
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<td><em>Rudgea sessilis</em> (Vell.) Müll.Arg.</td>
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<td><strong>Rutaceae</strong></td>
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<td><em>Dictyoloma vandellianum</em> A. Juss.</td>
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<td><em>Esenbeckia grandiflora</em> Mart.</td>
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<td>B. Moreira 297</td>
</tr>
<tr>
<td><em>Zanthoxylum rhoifolium</em> Lam.</td>
<td>Tr</td>
<td>Fontes 154</td>
</tr>
<tr>
<td><strong>Sabiaceae</strong></td>
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<td></td>
</tr>
<tr>
<td><em>Meliosma sellowii</em> Urb.</td>
<td>Tr</td>
<td>Fontes 166</td>
</tr>
<tr>
<td><strong>Santalaceae</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Phoradendron sp1</em></td>
<td>Th</td>
<td>B. Moreira 128</td>
</tr>
<tr>
<td><em>Phoradendron sp2</em></td>
<td>Th</td>
<td>B. Moreira 353</td>
</tr>
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Continued Table 1.

<table>
<thead>
<tr>
<th>Family/Species</th>
<th>Habit</th>
<th>Voucher</th>
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<tr>
<td><strong>Sapindaceae</strong></td>
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<tr>
<td><em>Cupania vernalis</em> Cambess.</td>
<td>Tr</td>
<td>B.Moreira 018</td>
</tr>
<tr>
<td><em>Cupania zanthoxyloides</em> Cambess.</td>
<td>Tr</td>
<td>B.Moreira 268</td>
</tr>
<tr>
<td><em>Matayba cristae</em> Reitz</td>
<td>Tr</td>
<td>Fontes 167</td>
</tr>
<tr>
<td><em>Matayba guianensis</em> (Aubl.) Radlk.</td>
<td>Tr</td>
<td>B.Moreira 008</td>
</tr>
<tr>
<td><em>Matayba marginata</em> Radlk.</td>
<td>Tr</td>
<td>B.Moreira 009</td>
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<td>Sapindaceae sp1</td>
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<td>B.Moreira 105</td>
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<td><strong>Smilacaceae</strong></td>
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<tr>
<td><em>Smilax elastica</em> Griseb.</td>
<td>Li</td>
<td>B.Moreira 217</td>
</tr>
<tr>
<td><em>Smilax staminea</em> Griseb.</td>
<td>Li</td>
<td>B.Moreira 379</td>
</tr>
<tr>
<td><em>Smilax stenophylla</em> A.DC.</td>
<td>Li</td>
<td>B.Moreira 359</td>
</tr>
<tr>
<td><em>Smilax sp1</em> Li</td>
<td>Li</td>
<td>B.Moreira 259</td>
</tr>
<tr>
<td><strong>Solanaceae</strong></td>
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<tr>
<td><em>Aureliana velutina</em> Sendtn.</td>
<td>Tr</td>
<td>B.Moreira 085</td>
</tr>
<tr>
<td><em>Brunfelsia brasiliensis</em> (Spreng.) L.B.Sm. &amp; Downs</td>
<td>Sh</td>
<td>B.Moreira 110</td>
</tr>
<tr>
<td><em>Dysoxylum viridiflorum</em> (Sims) Miers</td>
<td>Sh</td>
<td>B.Moreira 274</td>
</tr>
<tr>
<td><em>Solanum americanum</em> Mill.</td>
<td>Th</td>
<td>B.Moreira 250</td>
</tr>
<tr>
<td><em>Solanum didymum</em> Dunal</td>
<td>Sh</td>
<td>B.Moreira 254</td>
</tr>
<tr>
<td><em>Solanum kriegeri</em> Giacomini &amp; Stehmann</td>
<td>Th</td>
<td>B.Moreira 063</td>
</tr>
<tr>
<td><em>Solanum mauritianum</em> Scop.</td>
<td>Tr</td>
<td>B.Moreira 278</td>
</tr>
<tr>
<td><em>Solanum swartzianum</em> Roem. &amp; Schult.</td>
<td>Tr</td>
<td>B.Moreira 180</td>
</tr>
<tr>
<td><em>Solanum sp1</em> Sh</td>
<td>Sh</td>
<td>B.Moreira 090</td>
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<td>Solanaceae sp1</td>
<td>Sh</td>
<td>B.Moreira 085</td>
</tr>
<tr>
<td>Solanaceae sp2</td>
<td>Tr</td>
<td>B.Moreira 098</td>
</tr>
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<td></td>
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<tr>
<td><em>Symplocos celastrinea</em> Mart.</td>
<td>Tr</td>
<td>B.Moreira 248</td>
</tr>
<tr>
<td><strong>Theaceae</strong></td>
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<td></td>
</tr>
<tr>
<td><em>Laplacea fruticosa</em> (Schrad.) Kobuski</td>
<td>Sh</td>
<td>B.Moreira 023</td>
</tr>
<tr>
<td><strong>Urticaceae</strong></td>
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<td></td>
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<tr>
<td><em>Cecropia glaziovii</em> Snethl.</td>
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<td>B.Moreira 311</td>
</tr>
<tr>
<td><strong>Verbenaceae</strong></td>
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<td></td>
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<tr>
<td><em>Lantana fucata</em> Lindl.</td>
<td>Sh</td>
<td>B.Moreira 169</td>
</tr>
<tr>
<td><em>Verbena litoralis</em> Kunth</td>
<td>Th</td>
<td>B.Moreira 080</td>
</tr>
<tr>
<td><strong>Violaceae</strong></td>
<td></td>
<td></td>
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<tr>
<td><em>Anchietea pyrifolia</em> (Mart.) G.Don</td>
<td>Li</td>
<td>B.Moreira 073</td>
</tr>
<tr>
<td><strong>Vochysiaceae</strong></td>
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<td></td>
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<tr>
<td><em>Qualea cordata</em> (Mart.) Spreng.</td>
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<td>B.Moreira 095</td>
</tr>
<tr>
<td><em>Vochysia tucanorum</em> Mart.</td>
<td>Tr</td>
<td>B.Moreira 133</td>
</tr>
<tr>
<td><strong>Winteraceae</strong></td>
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<td></td>
</tr>
<tr>
<td><em>Drimys brasiliensis</em> Miers</td>
<td>Tr</td>
<td>B.Moreira 329</td>
</tr>
</tbody>
</table>
The Asteraceae, Rubiaceae, and Melastomataceae families were noted for their richness in the shrub strata of the cloud dwarf forests. The high Asteraceae richness probably is associated to its diversity of habits, with species occupying different strata of the vegetation. In cloud forests located in regions of altitude in the South Region of Brazil, Asteraceae also presents high representativeness, although in Brazil, it presents greater richness in regions of rupestrian fields (Falkenberg 2003, Borges et al. 2010). Melastomataceae and Rubiaceae were also highlighted in studies in the Serra da Mantiqueira and Serra Negra (MG), due to the high richness of the shrub taxa (Salimena et al. 2013, Meireles et al. 2014). The genera Baccharis, Psychotria, Leandra, and Pleroma (three species each) were the most representative among the shrubs. These data are in agreement with Mocochinski & Scheer (2008) and Meireles et al. (2014), who found Leandra and Pleroma as shrub genera with high richness and a representative number of endemic species in high montane formations.

Terrestrial herbs are the main components of the ISP cloud dwarf forests’ sub-forest, especially in humid and shady places, and are mainly represented by species of the Asteraceae and Orchidaceae families, understory plants of the genera Coccocypselum and Anthurium, as well as species of the family Commelinaceae, such as Dichorisandra hexandra and Commelina obliqua. The herbaceous earth species contribute to the floristic increase of forest areas and to the composition of the soil, because they have a shorter life cycle than species of arboreal habit (Martins-Ramos et al. 2011). In the present study, the terrestrial herbs correspond to about 21.5% of the total species, a value close to that obtained for the shrub species (22.3%). Pereira-Silva et al. (2007), Meireles et al. (2014), and Santiago et al. (2018), in studies carried out in different regions of the Serra da Mantiqueira, recorded Asteraceae as the family with the highest species richness. The high richness of this family in the terrestrial herbaceous stratum can be related to the direct contact of the cloud dwarf forests with the adjacent altitude fields, which facilitates the establishment of Asteraceae species in these areas (Pillar et al. 2009). The family is one of the most diverse in global terms and can be found in all types of habitats around the world (Judd et al. 2009).

Among the lianas, the Chusquea and Mikania genera are well distributed throughout the study area. Bamboos of the genus Chusquea are frequent in the cloud dwarf forests of ISP and generally form clusters near the areas of greater humidity, bordering the rivers and streams. Chusquea and Mikania occur preferentially in Atlantic South Atlantic formations (Safford 2007, Meireles et al. 2014).

The cloud dwarf forests have a high epiphytic rate, especially the families Orchidaceae and Bromeliaceae, which occupy diverse forest strata and collaborate for the high index of epiphytic species in a forest formation, besides the abundant presence of lichens that occupy the trunks of the trees, shrubs, and soil (Furtado 2016). In the present study, a high rate of epiphytic species was observed (22% of the species sampled). These species can often be considered typical of cloud forests and may correspond to about 25% of the species sampled (Benzing 1998). Furtado (2016) has compiled a list of vascular epiphytes occurring in the cloud forests of ISP, composed of 222 species distributed in 81 genera and 22 families, of which Orchidaceae is the richest (85 spp.), corresponding to 28% of the vascular flora formation. Both the absolute number of species and the epiphytic quotient observed by Furtado (2016) correspond to one of the greatest diversities already sampled in studies of this nature in the Brazilian Atlantic Forest.
Cloud Dwarf Forests of Ibitipoca State Park

Table 2. Phytogeographic groups of the genera represented in cloud dwarf forests of Ibitipoca State Park, Serra da Mantiqueira, Southeastern Brazil.

<table>
<thead>
<tr>
<th>Phytogeographic groups</th>
<th>Genera (nº)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperate</td>
<td></td>
</tr>
<tr>
<td>Austral-antarctic</td>
<td></td>
</tr>
<tr>
<td>Drimys, Fuchsia, Griselinia, Myrceugenia, Podocarpus, Polygala, Weinmannia</td>
<td>7</td>
</tr>
<tr>
<td>Holartic</td>
<td></td>
</tr>
<tr>
<td>Rhamnus</td>
<td>1</td>
</tr>
<tr>
<td>Large temperate</td>
<td></td>
</tr>
<tr>
<td>Senecio, Dendrophorobium</td>
<td>2</td>
</tr>
<tr>
<td>Cosmopolitan</td>
<td></td>
</tr>
<tr>
<td>Bidens, Boreria, Brickellia, Caemembea Cerastium, Commelina, Crepis, Ficus, Galactia, Ilex, Ipomoea, Malaxis, Opilimesmus, Rhynchospora, Solanum, Setaria, Taraxacum, Verbesina</td>
<td>18</td>
</tr>
<tr>
<td>Tropical</td>
<td></td>
</tr>
<tr>
<td>Endemic of Brazil</td>
<td></td>
</tr>
<tr>
<td>Eremanthus, Grobya, Nematanthus, Trembleya, Aosa, Dyssochroma, Gomesa, Periandrea, Vanhouttea, Wittrockia</td>
<td>10</td>
</tr>
<tr>
<td>Neotropical</td>
<td></td>
</tr>
<tr>
<td>Large tropical</td>
<td></td>
</tr>
<tr>
<td>Abutilon, Achyrocline, Agarista, Ageratum, Alternanthera, Andropogon, Aspilia, Begonia, Bulbophyllum, Chamaecrista, Clethra, Cordia, Erythroxylum, Eugenia, Gocnnatia, Habenaria, Hypis, Justicia, Lantana, Meliosma, Mendoncia, Mikania, Mimosina, Myrsine, Ocotia, Ouratea, Paepalanthes, Pawonia, Peperomia, Polystachya, Psychotria, Rhipsalis, Rudgea Sacoila, Sauvagesia, Schefflera, Scleria, Senna, Similax, Symlocos, Trichilia, Tripogandra, Triumphetta, Vitex, Zanthoxylum.</td>
<td>45</td>
</tr>
</tbody>
</table>

In view of the above, it is possible to assume that the epiphytes play an important role in the cycles of the cloud dwarf forests. They also act in the local water cycle, since they interfere in the capture, storage, and slow release of water (Richardson et al. 2000). It is estimated that in some areas epiphytes can store about 3,000 liters/ha and provide water, nesting, and feeding materials for a wide range of animal species, from invertebrates to primates (Richardson et al. 2000). These factors alone justify the importance of the presence of epiphytes for the ecosystem as a whole.

The floristic profile of the ISP cloud dwarf forests presents floristic similarities at the family and genera levels with the Andes highland forests, also presenting characteristics that allow them to be associated with a transition environment between the rupestrian and highland forests, also presenting characteristics that allow them to be associated with a transition environment between the rupestrian and highland forests, with a height of around 17 m, with emergent trees reaching 30 m, while the cloud dwarf forests have a canopy of about 10 m, with few emergent trees, reaching up to 16 m (Olveira-Filho et al., 2013).

In general, the richness of the plant community of the cloud dwarf forests of ISP reinforces its importance for local, demonstrating that relatively small areas are also relevant for preservation and that even conservation units should improve strategies for maintaining biodiversity (Drummond et al. 2005).

2. Phytoecography

The studies that seek to understand the geographic distribution of the species present in the cloud dwarf forests are of fundamental importance, since they allow to subsidize strategies of conservation and environmental restoration, and help in the prediction of the impacts of future climate changes on the natural vegetation. In this study, we classified the genera in seven phytogeographic groups delimited based on their current centers of diversity cited in Safford (2007). Among the Austral-Antarctic genera, Drimys, Fuchsia, Polygala, and Weinmannia the “Mata Baixa” and only eight species common to the two habitats, indicating that they are two forest physiognomy very distinct. Menino (2013), in a study performed in the same sample area as Fontes (1997), found Psychotria suterella, Aspidosperma australis and Psychotria vellosiana as the species of high VI. Among these, only Psychotria vellosiana was sampled in the cloud dwarf forests, reinforcing the heterogeneity among the forest physiognomies. PEIB cloud forests are characterized by canopy rich in clearings, with a height of around 17 m, with emergent trees reaching 30 m, while the cloud dwarf forests have a canopy of about 10 m, with few emergent trees, reaching up to 16 m (Olveira-Filho et al., 2013).

In general, the richness of the plant community of the cloud dwarf forests of ISP reinforces its importance for local, demonstrating that relatively small areas are also relevant for preservation and that even conservation units should improve strategies for maintaining biodiversity (Drummond et al. 2005).
have few Atlantic representatives, whereas *Myrsine* is richer to the east of Brazil, with species indicative of the high montane forests under cold and humid climates (Meireles et al. 2008). These genera were part of a past flora dispersed among Australia, Antarctica, and South America (Brade 1956).

As representative of the Holartic floristic element, only the genus *Rhamnus* was found in the cloud dwarf forests of ISP. The presence of Holartic elements in the Neotropical flora has been associated with the proximity between North and South America during the Cretaceous, continental, and volcanic island arches in the Central American region, long-distance dispersal events during the Cenozoic, and the formation of the Isthmus of Panama and elevation of the northern Andes between the Miocene and the Pliocene, about 3.5 million years ago. According to Brade (1956), the Holartic element went from North America to South America using the mountain chain of the Andes as a migration bridge and later advanced to the east of the continent towards Serra da Mantiqueira and Serra do Mar.

According to Safford (2007), the flora of the Andes and the highest points of the Brazilian mountain ranges form a group of species tropical, temperate, and cosmopolitan origin that have developed in these places through long periods of environmental changes and migrations. Safford (2007) reports that during the drought periods of the Tertiary, the Atlantic mountain ranges served as a refuge for species adapted to cold and humidity, especially the Austral-Antarctic taxa, and that during long periods of colder weather a greater contact occurred between the plant formations of east and west of South America, thus favoring colonization of the tropical Atlantic forests by Andean elements. This contact may have occurred several times, and the Atlantic rainforests may have been an important source for the colonization of the new mountainous environments developed late in the northern Andes (Safford 2007).

In ISP, the temperate floristic component is represented by the genera *Senecio* and *Dendrophorum*, whereas the cosmopolitan elements are represented by the genera *Bidentes*, *Borreria*, *Brickellia*, *Caemembeca*, *Cerastium*, *Commerlinia*, *Crepis*, *Ficus*, *Galactia*, *Ilex*, *Ipomoea*, *Malaxis*, *Opilismenus*, *Rhychnospora*, *Solaneum*, *Setaria*, *Taranuncul*, and *Verbesina*. Temperate taxa, mainly Holartics, are more common in regions with a high annual temperature than in the Brazilian mountains, due to a series of geographic and historical factors, lower altitudes, and the more limited area of the mountains in Brazil. Safford (2007) suggests that many temperate and cosmopolitan species first arrived in Southern Brazil by migrating through favorable habitats, rather than dispersing over long distances.

Among the ten endemic genera of Brazil, the family Gesneriaceae, represented by the *Nematanthus* and *Vanhouettea*, stands out. The genera *Nematanthus* is endemic in South and Southeast of Brazil, except for one species that reaches the south of Bahia (Chauvet 1988). *Vanhouettea* has species distributed in the states of Espírito Santo, Minas Gerais and Rio de Janeiro (Chauvet 2002). The other endemic genera are *Eremanthus*, *Trembleya*, *Aosa*, *Dyssochroma*, *Gomesia* (sensu stricto), *Grobya*, *Periandra* and *Wittrockia*, which present very common species in high altitude vegetation formations in the Atlantic Forest. Among these, *Eremanthus*, *Periandra* and *Trembleya*, present a greater richness in *campos rupestres*, with some species present in altitude fields and inside the cloud dwarf forests (Giulietti & Pirani 1988).

About 60% of the genera found are Neotropical, and among them, *Cabralea*, *Leandra*, *Miconia*, *Mollinedia*, *Myrcia*, *Myrciaria*, *Roupala*, *Siphoneugena*, *Pleroma*, and *Vernonanthura* can present species of montane forests that tolerate adverse altitude conditions (Oliveira-Filho & Fontes 2000, Meireles et al. 2014). Among the Neotropical genera, some are commonly found in the Andes mountains, such as *Baccharis* and *Chasquea*, besides being of great importance in the floristic composition of the montane vegetation of the Southeastern and Southern Region of Brazil (Brade 1956, Safford 1999, Meireles et al. 2014).

The *Hindisia* genus is richest in the mountains of eastern Brazil, and in this study the species *Hindisia ibitipocensis*, considered to be endangered, is recorded only for a small part of the Serra da Mantiqueira, represented by ISP. (Di Maio 1996, Oliveira et al. 2013). Broad tropical genera accounted for 24%, with predominance of the Asteraceae and Malvaceae families, in which attributes such as long dispersal distances, large fruit production, and seed dormancy are common, helping to increase their distributions (Lorenzi 2008).

Due to the historical process of land occupation, characterized mainly by the exploitation of timber species, forest fragmentation, and expansion of agricultural and livestock activities, the original forest areas of the Serra da Mantiqueira were drastically reduced (Almeida & Carneiro 1998, Drummond et al. 2005). In this way, conservation of the remaining forests is fundamental, since besides presenting high residual diversity, they perform environmental services, such as the sequestration of atmospheric carbon dioxide, soil protection, maintenance of the hydrological cycle, and protection of watercourses (Pounds et al. 1999). It is important to point out that the cloud dwarf forests contribute with additional water provision to the water systems, through the capture of condensed water in the clouds. Therefore, conservation of these forests will contribute to the continuous production of water in the springs, which will benefit the production of drinking water and water quality for future generations (Oliveira-Filho et al. 2004). Further studies on the biodiversity of cloud dwarf forests are needed to support the development of public policies aimed at protecting these areas, especially given their great fragility in the face of global climate change (IPCC 2014).

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Author Contributions

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Conflicts of interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

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