Phytosociological and Environmental Analysis of a Rocky Outcrop Located in Caldas County, Minas Gerais State, Brazil

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ABSTRACT – The Atlantic Forest and Cerrado are domains of Brazil. We should pay more attention to the lesser assessed points in these biomes, as well as to their rocky outcrops. These sites are under great anthropogenic pressure due to the mineral exploitation present. This results in environmental degradation and loss of species that have not yet been studied. In the present study we aimed to characterize the structure and composition of a rocky outcrop in order to provide aids for the creation of protected areas and on the adoption of management techniques in areas degraded by mining activities. In total, we surveyed vegetation and environmental conditions in 10 plots (50 x 2m) allocated in the Environmental Protection Area of Pedra Branca Ecological Sanctuary, MG. We found 60 species distributed within 30 families and 52 genera, and diversity of 2.83 nats/ind. The most important family was Orchidaceae, which was followed by Poaceae, Polypodiaceae, Bromeliaceae and Piperace. The most important species were *Cyperus coriifolius, Brasiliorchis picta, Tibouchina heteromalla, Paspalum notatum* and *Aechmea distichantha*. The area has a higher Shannon diversity index (H') than other quartzite outcrops.

Keywords: Granite; inselberg; pedra branca; rocky-outcrop; xerophyte-vegetation.

Análise Fitossociológica e Ambiental de um Afloramento Rochoso Localizado no Município de Caldas, Minas Gerais, Brasil

RESUMO – A Mata Atlântica e o Cerrado são biomas considerados como *hotspots* de diversidade existentes no Brasil. Apesar de haver uma série de estudos nesses biomas, ainda restam vários pontos pouco avaliados; por exemplo, os afloramentos rochosos. Esses locais estão sob grande pressão antropogênica devido às suas composições mineralógicas. O objetivo do presente estudo foi caracterizar a estrutura e composição de um afloramento rochoso no município de Caldas e, assim, planejar estudos sobre a criação de áreas protegidas e a adoção de técnicas de manejo em áreas degradadas pelas atividades de mineração. O estudo foi realizado na Área de Proteção Ambiental do Santuário Ecológico de Pedra Branca, MG. No total, foram alocadas 10 parcelas (50 x 2m) onde a vegetação e as condições ambientais foram inventariadas. Foram encontradas 60 espécies, distribuídas em 30 famílias e 52 gêneros e diversidade de Shannon de 2,83 nats/ind. A família mais relevante foi Orchidaceae, seguida por Poaceae, Polypodiaceae, Bromeliaceae e Piperace. As espécies mais importantes foram *Cyperus coriifolius, Brasiliorchis picta, Tibouchina heteromalla, Paspalum notatum e Aechmea distichantha*. A área possui maior índice de diversidade de Shannon (H') do que outros afloramentos de quartzito.

Palavras-chave: Granito; inselberg; pedra branca; afloramento rochoso; vegetação xerofítica.

Análisis Fitosociológico y Ambiental de un Afloramiento Rocoso Ubicado en el Condado de Caldas, Estado de Minas Gerais, Brasil

RESUMEN – El Bosque Atlántico y el Cerrado son biomas considerados puntos críticos de diversidad en Brasil. Aunque hay varios estudios en estos biomas, todavía hay algunos puntos mal evaluados, como los afloramientos rocosos. Estos sitios están bajo una gran presión debido a sus composiciones mineralógicas y la falta de investigación. El objetivo del presente estudio fue caracterizar la estructura y composición de un afloramiento rocoso en el municipio de Caldas y, por lo tanto, planificar estudios sobre la creación de áreas protegidas y la adopción de técnicas de manejo en áreas degradadas por las actividades mineras. El estudio se llevó a cabo en el Área de Protección Ambiental del Santuario Ecológico Pedra Branca, MG. En total, se asignaron 10 parcelas (50 x 2m) donde se inventariaron la vegetación y las condiciones ambientales. Encontramos 60 especies distribuidas en 30 familias y 52 géneros y diversidad de Shannon de 2.83 nats/ind. La familia más importante fue Orchidaceae, seguida de Poaceae, Polypodiaceae, Bromeliaceae y Piperace. Las especies más importantes fueron *Cyperus coriifolius, Brasiliorchis picta, Tibouchina heteromalla, Paspalum notatum* y *Aechmea distichantha*. El área tiene un índice de diversidad de Shannon (H') más alto que otros afloramientos de cuarcita.

Palabras clave: Granito; inselberg; piedra blanca; afloramiento rochoso; vegetación xerofítica.

Introduction

The Atlantic Forest is one of the most threatened biomes on Earth, being considered one of the world biodiversity hotspots given its exceptionally high levels of diversity and endemism (Myers *et al*. 2000). Despite being relatively well-studied as compared to other biomes in Brazil, much of its area remains poorly known, such as the rocky outcrops. These outcrops harbor a peculiar vegetation that develops under adverse soil, temperature and humidity conditions (Giuliettiet *et al*. 1997). According to Ab'Saber (2003), these environments can be nominated as relict or vegetation refuges. Yet, according to Groger & Barthlott (1996), they can be Xeric Islands, where a species or plant community is surrounded by several sections of other ecosystems or phytophysiognomies.

In Poços de Caldas region, species are adapted to physiological, morphological and reproductive conditions, and their communities have great structural and floristic peculiarities (Porembski *et al*. 1997, Gibson *et al*. 2012). The soil in these locations also has peculiarities, in addition to toxic elements that influence current plant communities (Siefert *et al*. 2012; Vleminckx *et al*. 2015). The soils are mainly made up of Cambisols and Neossols (Moraes & Jiménez-Rueda 2008) and have reduced nutritional levels due to the sources of origin. In addition, it exhibits low levels of exchangeable bases and base saturation. (Fernandes *et al*. 2003).

Due to their great mineralogical potential, rocky outcrops have been exploited since colonial period in Brazil, experiencing exponential increase in anthropic pressure in the last century (IBRAM 2003). Thus, many species have suffered drastic reduction in their *habitat* (Pinto *et al*. 2004). These losses led to real genetic-erosion risk, even to species extinction, mainly in tropical biomes (Pinto *et al*. 2004). Landscape conservation is of paramount importance for the maintenance of ecological processes and ecosystem biodiversity (Salles *et al*. 2019).

Meirelles (1996), Porembski *et al*. (1998) and Safford & Martinelli (2000) highlighted that works on floristic composition and ecological characteristics of Brazilian granitoid rocky florals are rare in the specialized literature. Knowledge on rocky outcrop-associated vegetation provided by phytosociological surveys is a source of conservation support (Felfili *et al*. 1993, Castro 1994, Scarano 2007). It also provides important information for the assessment of anthropogenic impacts, for the creation of protected areas, and for the adoption of management techniques (Felfili & Silva Júnior 2001).

The aims of the present study were to carry out a phytosociological analysis of a model area based on meteorological data collected throughout

the study period, as well as to analyze humidity variation and the chemical composition of the used substrates. Studies similar to the current one can highlight the importance of conserving these sites due to the environmental issues Brazil has been going through because of the weakening of environmental laws.

Material and Methods

The study was carried out in the Environmental Protection Area APA Sanctuary Ecological of Pedra Branca (APAPB), which is located in Southwestern Caldas County, Southern Minas Gerais State (Figure 1). According to Köppen's classification, the climate in the region is of the Cwb type, subtropical in altitude, with mild and rainy summers and dry winters. Two types of soil are found in the area: 1. Regolithic Neosol, which only occurs in areas associated with mixed slopes that present materials from the basement rock – found in the highest parts of the area –; and 2. Haplic Cambisol, which is considered an underdeveloped soil that accounts for characteristics of the original material that presents restrictions to agricultural land-use (Moraes 2008).
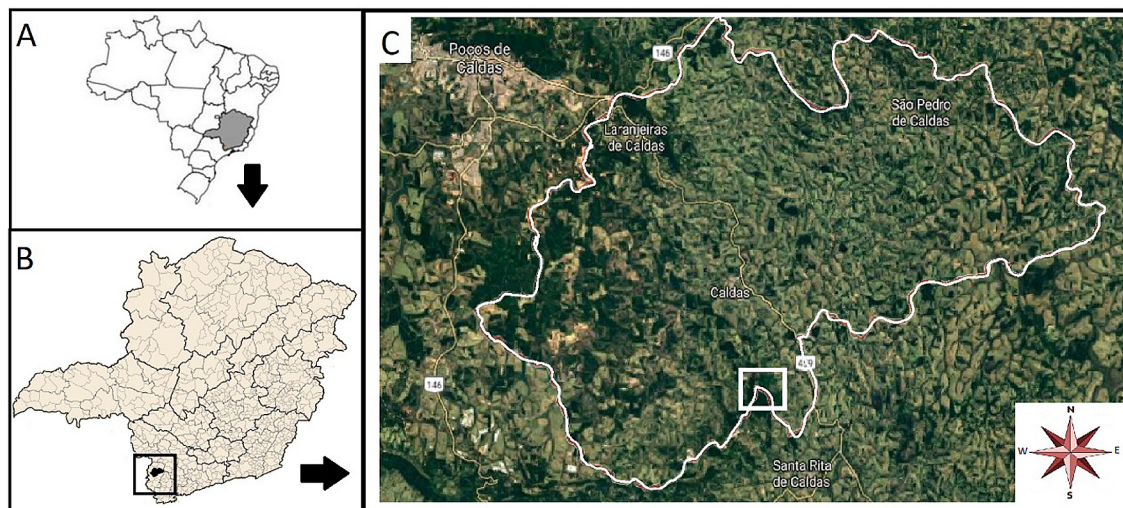

Figure 1 – Map of the study area showing the Ecological Sanctuary of Pedra Branca and the Municipal Biological Reserve of Serra da Pedra Branca in "C". Photo by João Paulo de Lima Braga.

According to Conforti *et al.* (2007), the following phytophysiognomies form the vegetative mosaic at APAPB: Altitude field and high elevation grasslands According to Elias *et al.* (2009) the area is covered by forest remnants, that corresponded to 13.6% (it comprised the phytophysiognomies and rock outcrops) (7.8%) and to the anthropic area (78.6%). Rocky outcrop areas accounting for 7.8% of the total APA area are considered ecological refuges (IBGE 2012) and the harbor for endangered species.

According to rainfall data for the region January 2016 was the rainiest month, it recorded rainfall index of 276.46mm. April was the driest month, it presented an index of 0.44mm.

February presented the highest mean temperature (20.22 °C) and June showed the lowest one (13.59 °C). There were at least 3 large frosts with negative temperatures in June 2016. Vegetation is historically subject to significant drought periods from April to September in the APAPB region.

In total, 10 plots (50m x 2m) were established within APAPB in order to sample vegetation cover on outcrops in natural areas – the total sample area was of 0.1ha. Plots were perpendicular to the base ridge direction of the outcrop – they were spaced 50m from each other (Figures 2a and 2b). Finally, subplots (1m²) were subdivided every 10cm (Figure 3), – 100m² were sampled per plot, and it totaled 1000m² of inventories.
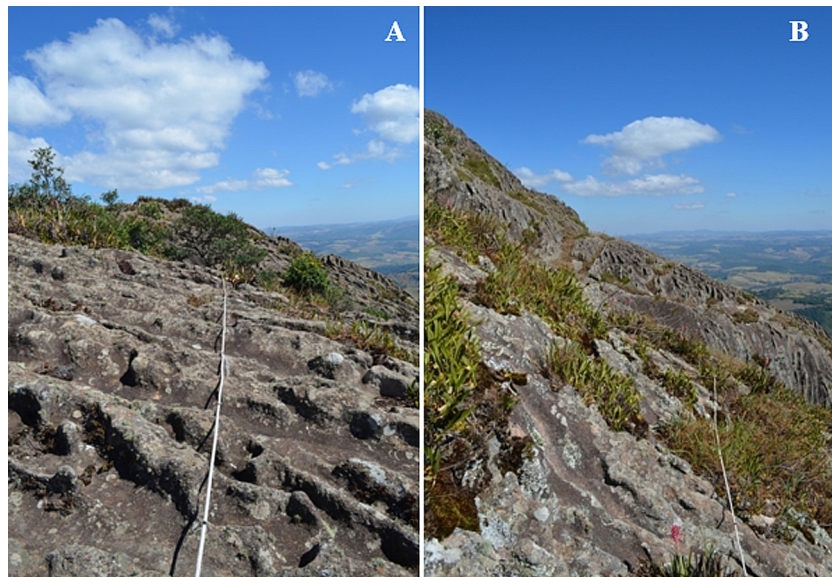
Figure 2 – Image of the allocation of plots in the outcrop. A: Exposed rock; B: Native vegetation. APA Pedra Branca Ecological Sanctuary, Caldas, MG. 2016. Photo by João Paulo de Lima Braga.

Figure 3 – Subdivision (0.1 x 0.1m) of the one m² subplots. APA Pedra Branca Ecological Sanctuary, Caldas, MG. 2016. Photo by João Paulo de Lima Braga.

Phytosociological parameters 'frequency' (absolute and relative) and 'dominance' (absolute and relative) were calculated. Their values were used to calculate the Coverage Value (VC) of each species found in the site (Brower *et al*. 1998). Other authors have adopted this procedure in structural works about vegetation presenting the same vegetative characteristics (Menezes & Araujo 1999, Assumpção & Nascimento 2000, Cordeiro 2005, Carvalho & Sá 2011, Araujo *et al*. 2016). Only two relative parameters (frequency, coverage) were used to calculate VC – the final sum was equal to 200% (Carvalho & Sá 2011). The species of exotic grasses found in the area were not quantified at the time to determine the structural analysis. These species were taken into consideration in further

analysis, they were quantified and categorized. Outcrop coverage rates of these same plots were estimated by considering the following categories: Rock, Native Vegetation, Dominated by exotic, Briophyte and Lichens.

The botanical material was collected, herborized and deposited in the Herbário Anders Fredrik Regnell (AR) of the Fundação Jardim Botânico de Poços de Caldas – duplicates were deposited in the Herbário do Instituto de Pesquisas Jardim Botânico do Rio de Janeiro (RB). Taxonomic identification was carried out through consultation in the specialized literature and through comparisons with herbarium material. Angiosperm Phylogeny Group III (APG III 2009) was adopted for the taxonomic classification of angiosperm families.

For comparison of nutrient contents, as well as pH and organic matter, samples of the substrates were collected monthly which at the end of the evaluation period formed a composite sample. Concomitantly, a compost sample was collected in the area where the plots of the phytosociological study were installed. The samples were sent to the Soil Laboratory of ESALQ/USP in Piracicaba, SP. The samples of the substrates were also used to quantify the humidity.

Results and Discussion

Structural analysis of the area

Sixty species, distributed into 30 families and 52 genera, were found in the APAPB. Orchidaceae (12 spp.) was the richest family with 12 species, followed by Poaceae (7 spp.), Polypodiaceae (5 spp.), Bromeliaceae (3 spp.) and Piperace (3 spp.). It represents an addition of four species compared to previous surveys carried out in the same area (Rezende 2013). The predominance of species with herbaceous and shrubby habit, occurring in altitude fields, follows a pattern commonly observed in similar environments, in which vegetation is dominated by shrubs and small trees with several species of Poaceae, Orchidaceae, Bromeliaceae, and ferns (Safford 1999). The richest families found in this area are often cited as being the most representative in the predominantly rural areas of Minas Gerais (Giulietti *et al.* 1997, Pirani *et al.* 2003, Leoni & Tinte 2004, Alves & Kolbek 2009, Salimena *et al.* 2013). Orchidaceae is the richest family in the Atlantic Forest, and it is often referred as the most representative in highlands or rupestrian fields, such as Serra do Brigadeiro State Park (PESB) (Leoni & Tinte 2004, Caiafa & Silva 2005), Ibitipoca Estadual Park (PEI) (Menini-Neto *et al.* 2007) and Serra Negra (Abreu *et al.* 2011).

Cyperus coriifolius Boeckeler, *Brasiliorchis picta* (Hook.) RBSinger, *Tibouchina heteromalla* D. Don (D. Don), *Paspalum notatum* Flüggé, *A. distichantha* Lem., *Octomeria crassifolia* Lindl., *Doryopteris ornithopus* (Hook. and Baker) J.Sm. and *Axonopus* sp (Table 1) were the species presenting the highest values of importance (VC). These eight species have prevailed in the APAPB, recording VCs higher than 10 and occupying approximately 63% of it. In total, 18 species, whose VC ranged from 1 and 10 (31.4% of VC), were intermediate. The 35 species considered rare presented VC lower than one and together they represent 5.7% of the total.

Table 1 – Species sampled in the rock outcrop of Rebio da Pedra Branca, Caldas, Minas Gerais. Phytosociological parameters: NP = number of plots with occurrence of the species; FR = relative frequency (%); RC = relative coverage (%) and CV = cover value. Species ordered from CV. Caldas, MG. 2016.

Specie	Botanical Family	NP	FR	CR	VC
Cyperus coriifolius Boeckeler	Cyperaceae	195	9.92	15.8	25.76
Brasiliorchis picta (Hook.) R.B.Singer et al.	Orchidaceae	96	4.88	14.2	19.14
Pleroma heteromalla D. Don (D. Don)	Melastomataceae	200	10.17	8.63	18.80
Paspalum notatum Flüggé	Poaceae	78	3.96	10.9	14.89
Aechmea distichantha Lem.	Bromeliaceae	99	5.03	9.71	14.75
Octomeria crassifolia Lindl.	Orchidaceae	80	4.07	7.27	11.34

Doryopteris ornithopus (Hook. & Baker) J.Sm.	Pteridaceae	151	7.68	2.91	10.60
Axonopus sp.	Poaceae	76	3.86	6.58	10.45
Peperomia galioides Kunth	Piperaceae	124	6.31	2.87	9.18
Eupatoriopsis hoffmanniana Hieron.	Asteraceae	112	5.70	1.71	7.41
Scleria sp.	Cyperaceae	83	4.22	2.47	6.70
Alstroemeria variegata M.C.Assis	Alstroemeriaceae	104	5.29	1.30	6.59
Asplenium serra Langsd. & Fisch.	Aspleniaceae	74	3.77	1.64	5.40
Sinningia striata (Fritsch) Chautems	Gesneriaceae	89	4.53	0.84	5.37
Schizachyrium sp.	Poaceae	28	1.43	2.07	3.50
Croton hemiargyreus Müll.Arg.	Euphorbiaceae	32	1.63	1.68	3.30
Mandevilla venulosa (Müll.Arg.) Woodson	Apocynaceae	35	1.78	0.85	2.64
Epidendrum secundum Jacq.	Orchidaceae	22	1.12	1.00	2.12
Bulbophyllum rupicolum Barb.Rodr.	Orchidaceae	27	1.37	0.24	1.61
Sinningia magnifica (Otto & A.Dietr.) Wiehler	Gesneriaceae	23	1.17	0.32	1.49
Sisyrinchium vaginatum Spreng.	Iridaceae	18	0.92	0.57	1.49
Microgramma squamulosa (Kaulf.) de la Sota	Polypodiaceae	20	1.02	0.32	1.34
Calydorea campestris (Klatt) Baker	Iridaceae	21	1.07	0.19	1.26
Trichanthecium cyanescens (Nees ex Trin.) Zuloaga & Morrone	Poaceae	6	0.31	0.93	1.24
Philodendron cordatum Kunth ex Schott	Araceae	7	0.36	0.69	1.04
Tillandsia tenuifolia L.	Bromeliaceae	14	0.71	0.31	1.02
Prescottia montana Barb.Rodr.	Orchidaceae	18	0.92	0.03	0.94
Vriesea sceptrum Mez	Bromeliaceae	9	0.46	0.41	0.87
Peperomia oreophila Henschen	Piperaceae	11	0.56	0.21	0.77
Tripogon spicatus (Nees) Ekman	Poaceae	7	0.35	0.33	0.69
Stevia decussata Baker	Asteraceae	12	0.61	0.07	0.68
Zygopetalum triste Barb.Rodr.	Orchidaceae	5	0.25	0.34	0.59
Rhipsalis floccosa Salm-Dyck ex Pfeiff.	Cactaceae	3	0.15	0.45	0.59
Bulbophyllum epiphytum Barb.Rodr.	Orchidaceae	9	0.45	0.08	0.53
Myrcia obovata (O.Berg) Nied.	Myrtaceae	2	0.10	0.42	0.52
Bulbophyllum exaltatum Lindl.	Orchidaceae	8	0.40	0.08	0.49
Pecluma sp.	Polypodiaceae	5	0.25	0.19	0.44
Pleopeltis pleopeltidis (Fée) de la Sota	Polypodiaceae	7	0.35	0.08	0.44
Commelina erecta L.	Coomelinaceae	5	0.25	0.15	0.41
Dioscorea sp.	Dioscoreaceae	7	0.35	0.05	0.41
Ipomoea regnellii Meisn.	Convolvulaceae	6	0.30	0.09	0.40
Elaphoglossum burchellii (Baker) C.Chr.	Dryopteridaceae	7	0.35	0.02	0.37
Doryopteris crenulans (Fée) Christ	Pteridaceae	3	0.15	0.12	0.27
Bifrenaria harrisoniae (Hook.) Rchb.f.	Orchidaceae	3	0.15	0.07	0.22
Hyptis sp.	Lamiaceae	2	0.10	0.08	0.18

Handroanthus albus (Cham.) Mattos	Bignoniaceae	3	0.15	0.01	0.16
Phlegmariurus regnellii (Maxon) B.Øllg.	Lycopodiaceae	3	0.15	0.01	0.16
Andropogon bicornis L.	Poaceae	1	0.05	0.10	0.15
Alternanthera brasiliana (L.) Kuntze	Amaranthaceae	2	0.10	0.05	0.15
Melpomene sp.	Polypodiaceae	2	0.10	0.04	0.14
Anemia villosa Humb. & Bonpl. ex Willd.	Anemiaceae	2	0.10	0.03	0.13
Chloris sp.	Poaceae	1	0.05	0.05	0.10
Habenaria caldensis Kraenzl.	Orchidaceae	1	0.05	0.03	0.08
Elaphoglossum itatiayense Rosenst.	Dryopteridaceae	1	0.05	0.03	0.07
Peperomia tetraphylla (G.Forst.) Hook. & Arn.	Piperaceae	1	0.05	0.02	0.06
Asplenium praemorsum Sw.	Aspleniaceae	1	0.05	0.01	0.06
Gomesa varicosa (Lindl.) M.W.Chase & N.H.Williams	Orchidaceae	1	0.05	0.01	0.06
Borreria sp.	Rubiaceae	1	0.05	0.01	0.05
Epidendrum avicula Lindl.	Orchidaceae	1	0.05	0.00	0.05
Serpocaulon vacillans (Link) A.R.Sm.	Polypodiaceae	1	0.05	0.01	0.05
		1965	100	100	200

Diversity value was 2.83 nats/ind. and equability was 0.64. Meirelles *et al*. (1999) found 1.74 to 2.96 nats/ind in different granitic outcrops in Rio de Janeiro. The area has Shannon diversity index (H') greater than the quartizitic outcrops in Chapada Diamantina and in Canga Outcrops at Serra do Espinhaço region. Conceição & Giulietti (2002) found 2.79 nats/ind in a quartzitic outcrop in Chapada Diamantina. Our diversity values are comparable with those from other studies carried out in distinct outcrops. According to Rizzini (1979), plant communities in rocky outcrops often show lower species diversity than their surrounding ecosystems. However, due to isolation, they usually present high β diversity (Burke 2003). Based on these results, the herein assessed site has considerable diversity, but we must also take into account the endemism of species found in this type of vegetation.

Most species in APAPB outcrops followed the pattern of rocky outcrops. In APAPB the floristic composition differed due to insulation caused by their exposure to rock lengthens. According to data recorded at the Botanical Garden of Poços de Caldas and field observations, many of these species did not occur in adjacent phytophysiognomies, as observed for species *C. coriifolius, Tibouchina heteromalla, Paspalum notatum, Octomeria crassifolia, Doryopteris ornithopus* and *Axonopus* sp. However, some species, such as *A. distichantha, S. magnifica, A. minarum* and *Philodendron cordatum*, occured in rocky outcrops and in forests surrounding them. The fact that they have species that are not found in adjacent phytophysiognomies reinforces the importance given by Drummond *et al*. (2005), where in their study, they address the need for floristic inventories in the region, recognizing it as an important place for the conservation of the flora of Minas Gerais.

Outcrop coverage rates are as follow: Rock, 59.43% (594.3m²); Native Vegetation, 24.25% (242.5m²); Exotic Species, 6.35% (63.5m²); Bryophytes, 3.72% (37.2m²); and Lichens, 6.25% (62.5m²) – Figure 4.

Although it was possible observing flora representatives of syenitic outcrops in the region, RebioPB presented some signs of environmental degradation. The presence of exotic species, mainly of grasses belonging to genera *Melinis* spp. and *Urochloa* spp. (molasses Grass and Brachiaria, respectively), was worrisome because these species are quite aggressive and compete with the native species for space and resources.
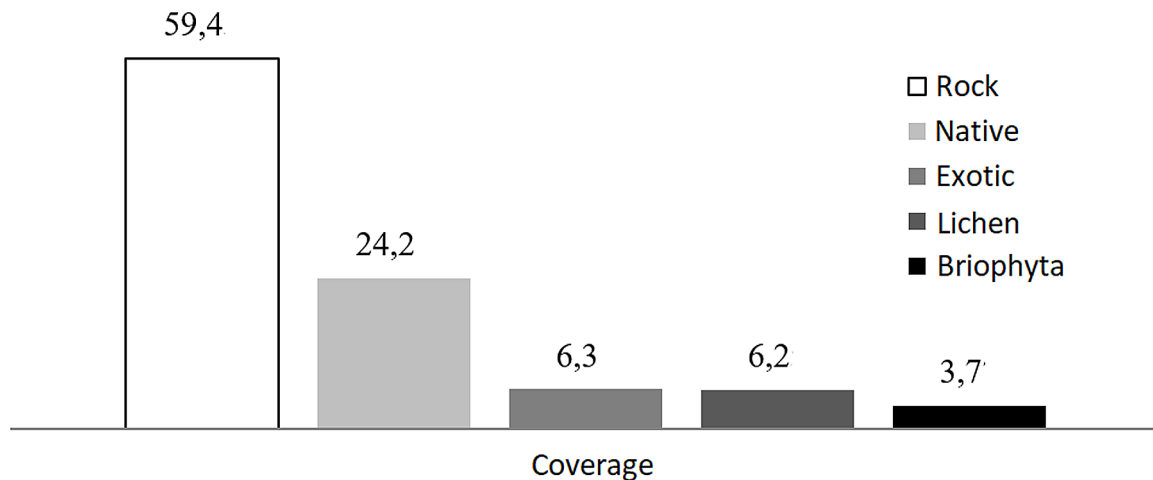
Figure 4 – Graph of the percentage of average coverage of rocky outcrops of the Environmental Protection Area Pedra Branca Ecological Sanctuary.

Chemical analysis of substrates

Both soil in the natural area and substrates used in the plots presented high acidity. Both soils presented very good organic matter content values. Mendonça (2013) considered that soil physical and chemical characteristics in canga outcrops are among the main factors limiting vegetation development. He also observed that soil in these areas is very acid and poor in nutrients, mainly in phosphorus and Magnesium. The "protossol" found in syenitic outcrops at APAPB also followed this pattern; however, it had very good organic matter content. This outcome mostly resulted from vegetation-fragment cycling. This process is of fundamental importance to nutrient supply in order to assure the maintenance of the ecosystem established in there.

Water scarcity is a limiting factor; species that have managed to adapt to this environmental feature survive over time and settle in rocky outcrops. Winter is the dry season, and it often records negative temperatures and frost events. Vegetation responds with vegetative part loss, dormancy of gems and reproductive part loss at this time of the year.

Mean rainfall influenced the survival of all species, except for *A. distichanth*. The highest mortality peaks of *A. minarum, B. picta* and *S. magnifica* were recorded at the first drought period in April 2016, whereas the mortality peak of *C. coriifolius* occurred in the second drought period, between August and September 2016.

Substrate humidity

Figure 5 shows the mean substrate humidity during the evaluation period – its maximum value was recorded in January 2016. Humidity remained at levels close to 30% in the first drought period (April 2016), it rose in the following two months due to rainfall in May and June. Humidity decreased again after this period and reached its lowest level in September – treatment 01 recorded 12.45%, treatment 02 recorded 4.90% and treatment 03 recorded 2.11%. There was direct association between mean rainfall and substrate humidity. Time variation was statistically similar even when mean substrate humidity values were different.

Final Considerations

It is of utmost importance to maintain vegetation in sienitic outcrops at APAPB due to its environmental importance. Besides presenting a larger number of species than other environments
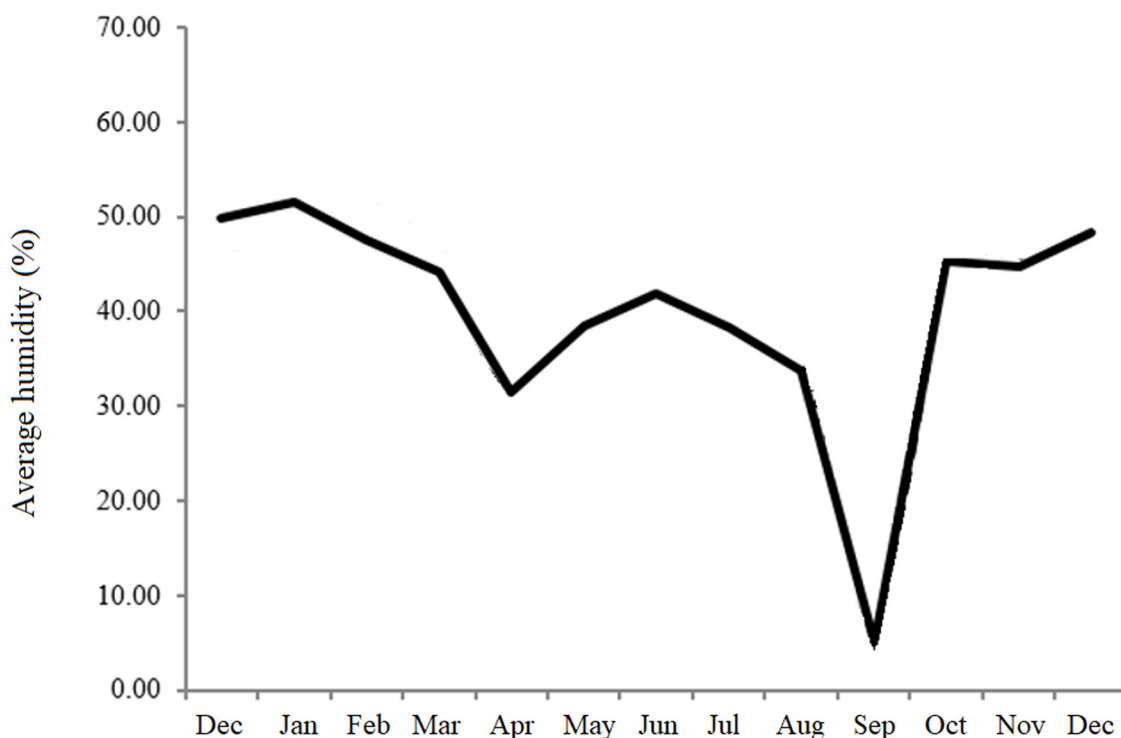
Figure 5 – Average moisture content (%) of the substrate during the study period. Caldas, MG. 2016.

in Brazil, APAPB is home to an endemic species of the rocky outcrops considered critically endangered, namely: *Phlegmariurus regnellii* (Maxon) B.Øllg. (Lycopodiaceae); and to a recently described species that deserves attention, *Alstroemeria variegata* M.C. Assis (Alstroemeriaceae).

The analysis of outcrop cover showed that the largest portion of APAPB is formed by bare rock; it is followed by native vegetation, exotic vegetation, lichens and bryophytes. The existence of exotic species is a worrisome factor because APAPB is a conservation unit. Grasses belonging to genera *Melinis* spp. and *Urochloa* spp. (molasses Grass and Brachiaria, respectively) are aggressive species that compete with native species. Therefore, it is interesting to carry out regular monitoring and, if necessary, to adopt control measures of invasive species.

Further studies on conservation and restoration of areas like "Pedra Branca" are needed, mainly research using a larger number of species in these areas. Many floristic composition studies have been carried out in rocky outcrops in recent years, but little is known about the management of these canga species.

Acknowledgement

Author Contribution Statement

João P. L. Braga did the field work, set the plots, collected data and wrote the first version of the manuscript. Sarah França Andrade assisted in data analysis and helped writing the article. Richieri A. Sartori made the data analysis and helped writing and translating the article.

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