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Floristic-structural relationships between Canga ferruginous tree communities and adjacent vegetation types

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ABSTRACT. Our objective was to evaluate the floristic and structural relationships between Canga tree communities and other vegetation types inserted in the physiognomic units set, in order to test the hypothesis that these communities have unique characteristics due to their specific environmental conditions. For this, we compared the structural and floristic attributes of Canga vegetation with adjacent semideciduous seasonal forest, Savanna and ecotone areas, evaluating the similarity in its behavior. Our results demonstrate the existence of distinct relationships among vegetation types in relation to different perspectives, related to macro-scale environmental attributes and to the phytogeographic context. In general, Canga tree vegetation has its structure associated with open vegetation types, such as the Cerrado (Savanna) and its composition associated with forest vegetation types, constituted by a community with specific ecological characteristics. Our results suggest the presence of ferruginous soils as a factor that contributes to environmental and ecological heterogeneity in vegetation matrices.

Keywords: Canga; bounded iron formations; floristic-structural characteristics.

Relações florístico-estruturais entre comunidades arbóreas de canga ferruginosa e tipos vegetacionais adjacentes

RESUMO. Nosso objetivo foi avaliar as relações florísticas e estruturais entre comunidades arbóreas de Canga e outros tipos vegetacionais inseridos no conjunto de unidades fisionômicas para testar a hipótese de que estas comunidades apresentam características singulares devido às suas condições ambientais específicas. Para isso, comparamos atributos estruturais e florísticos deste tipo vegetacional com outras adjacentes tais como floresta estacional semidecídua, Cerrado e áreas ecotonais, avaliando a similaridade em seu comportamento. Nossos resultados demonstram a existência de relações distintas entre os tipos vegetacionais com relação às diferentes perspectivas, relacionadas aos atributos ambientais de macro escala e ao contexto fitogeográfico. No geral, vegetação de canga tem sua estrutura associada a tipos vegetacionais de menor porte como Cerrado e sua composição associada a tipos vegetacionais florestais, consistindo em uma comunidade com características ecológicas específicas. Nossos resultados sugerem a presença de solos ferruginosos como um fator que contribui para a heterogeneidade ambiental e ecológica em matrizes vegetacionais.

Palavras-chave: Canga; Formações ferríferas bandadas; características florístico-estruturais.

Introduction

Environments under soils with iron saturation, so-called 'bounded iron formation', such as Brazilian 'Canga' (Skirycz et al., 2014) and 'African ferrictes' (Porembski, Fischer, & Biedinger, 1997) are commonly associated with high biological diversity and endemism (Jacobi, Carmo, Vincent, & Stehmann, 2007; Gibson, Yates, & Dillon, 2010; Fernandes, Maia, Monteiro, & Condé, 2016). The presence of this factor is reported as influential to the mesofauna (Moras, Gomes, & Tavares, 2015),

underground biology (Ferreira, 2005), avifauna (Pacheco et al., 2007), ecological interactions (Jacobi & Antonini, 2008; Dáttilo et al., 2014), and to vegetation characteristics (Jacobi et al., 2007; Vincent & Meguro, 2008; Gibson et al., 2010; Gibson, Meissner, Markey, & Thompson, 2012). Regarding this last group, the presence of environmental filters associated with iron saturation and microhabitat diversity are factors considered as regulators of plant communities and beta diversity potentiators in ferruginous systems (Porembski et al., 1997; Vilela,

Melo, Costa, Logoeiro, & Varajão, 2004; Jacobi et al., 2007; Vincent & Meguro, 2008).

The presence of ferruginous rock exposed at these sites acts as a restrictive environmental characteristics' driver which are common to rocky outcrops, such as soil absence, high albedo, and high heavy metals' concentration, among others (Jacobi et al., 2007; Skirycz et al., 2014). The absence of a considerable soil layer implies low soil moisture, which impairs the direct use of this resource for physiological processes and nutrient absorption (Skirycz et al., 2014). In addition, rock exposure potentiates the amount of reflected radiation and increases surface temperatures (Skirycz et al., 2014). These factors contribute to the association of ferruginous environments with aridity, even in places of high rainfall (Gibson et al., 2012; Skirycz et al., 2014). In these environments, plant species may present morphological, physiological and reproductive adaptations that allow survival in these places of high environmental hardness and attribute peculiar structural and floristic characteristics to the communities (Porembski et al., 1997; Jacobi et al., 2007; Gibson et al., 2012). Soil attributes such as texture, nutrient availability and presence of toxic elements (such as iron) are considered to have great influence on vegetation, especially on small scales because they are associated to habitat restrictiveness and resource availability (Siefert et al., 2012; Vleminckx et al., 2015; Krishnadas, Kumar, & Comita, 2016). Species composition is mainly affected by habitat restrictiveness associated to the ecological filters, which may control the populations distribution in environmental gradients by determining locations in which the population is able to establish (Hart & Marshall, 2013; Cadotte & Tucker, 2017). The populations structure is conditioned to edaphic factors because they are directly related to water and nutrients availability and consequently to plant growth and development (Pausas & Austin, 2001; & Van Breemen, 2005). Local variation of these edaphic attributes in the landscape context (environmental heterogeneity) may originate, associated to phytogeographic influences, diverse combinations of species with different structural behaviors, thus acting as diversity agent (Hutchings, John, & Wijesinghe, 2003; John et al., 2007).

Some studies approach the ferruginous environments' floristics and structure (Jacobi et al., 2007; Jacobi & Carmo, 2008; Meissner, Owen, & Bayliss, 2009) and their relationships with other plant formations on rocky outcrops (Messias, Leite, Meira Neto, & Kozovits, 2012), however, most of the time with emphasis on the herbaceous-shrub

stratum. The tree stratum is often treated from a phytogeographic perspective at floristic composition level (Jacobi & Carmo, 2008), focusing on the alluvial and ecotone forest formations associated with ferruginous soils (Meyer, Silva, Marco Júnior, & Meira Neto, 2004; Spósito & Stehmann, 2006). Thus, there is a lack of information on floristic and structural aspects related to the iron saturation in tree communities, as well as the connections among these communities and those of adjacent vegetation types present in the same system.

Furthermore, ferruginous environments are globally degraded because of their restricted occurrence and anthropogenic pressure caused by their association with the largest iron ore deposits in the world (Klein, 2005). For the '*Quadrilátero Ferrífero*' region (in the Minas Gerais state, Brazil), this information is even more relevant given its socioeconomic context and degradation associated with the land use history (Mourão & Stehmann, 2007). This region has been explored since the Brazilian colonial period (XVII century) and accounts for most of the Brazilian iron ore production and trade balance (*Instituto Brasileiro de Mineração* [Ibram], 2003). Although recognized as one of the conservation priority areas in the Brazilian Minas Gerais state (Drummond, Martins, Machado, Sebaio, & Antonini, 2005), the *Quadrilátero Ferrífero* region is little covered by integral protection conservation units (Carmo, 2010). Thus, increasing knowledge about these environments is of great importance because of their threatened situation around the world (Klein, 2005).

Therefore, our objective was to evaluate the floristic and structural relationships between Canga tree communities and adjacent units inserted in their set of vegetation types associated to ferruginous soils. We start from the hypothesis that this vegetation type presents singular behavior associated to its specific environmental characteristics.

Material and methods

Study area

The study was conducted at the Serra do Rola Moça State Park (SRMSP) in the municipality of Belo Horizonte, Minas Gerais State, Brazil (20° 3' 7.26" S; 44° 0' 6.85" W) (Figure 1). The climate of the region is Cwa following Köppen classification (Subtropical of cold winter and hot summer) with two defined seasons, one rainy and another typically dry (Ibram, 2003; Brasil, 2007). The average annual rainfall is 1430 mm and the average temperature varies from 18 to 21°C between the two main seasons (Ibram, 2003; Meyer et al., 2004; Brasil,

2007). The altitudes range from 900 to 1450 m and their relief is irregular with variation from mildly undulating hills to very rugged stretches (Brasil, 2007). SRMSP is located on the *Quadrilátero Ferrífero* region in a transition area between the Savanna and Atlantic Forest domains, with occurrence of ferruginous rock stains (Veloso et al., 1992; Brasil, 2007).

Data collection

We allocated 25 sampling units of 400 m² equally divided among five Forest vegetation types found in the SRMSP, five sample unit in each one: Canga (CG) or Ferruginous Savanna, Rock Savanna (RS), Semi-deciduous seasonal forest (SSF), Ecotone between ferruginous Savanna and semideciduous seasonal forest (EFSSF) and Ecotone between rock Savanna and semideciduous seasonal forest (ERSSF). The plots were randomly distributed within the physiognomies, with the condition that they were not contiguous. The CG and RS vegetation types are found in the highest areas of the park, being associated with shallow soils, high insolation and low vegetation. The SSF are located in the valley bottoms and in drainage lines in the form of forest capons in which the humidity is higher and the soils are deeper. Ecotone vegetation types consist of narrow transition bands between the core areas of the mentioned units, being located in intermediate points of the landscape. The adoption of the nomenclature presented for ecotones was based on directly adjacent physiognomies such as Rock Savanna and Semideciduous Forest in the case of EFSSF.

The dimensions of the sample units were 20 x 20 m in the CG, RS and SSF and 40 x 10 m in the EFSSF and ERSSF in order to capture a greater range of the plant physiognomic gradient. The adoption of these sample units dimensions for the ecotonal vegetation types is justified by their arrangement in narrow transitional ranges between physiognomies, which present a small width (< 20 m) irregularly occurring along their length. Such situation impairs the use of standard dimensions (20 x 20 m) and makes it necessary to adopt dimensions that prevent the sampling of core vegetation types. Thus, we decrease in width and increase in length along the ecotonal range, increasing the reach of the sample unit. All environments are submitted to the presence of iron in high concentrations in relation to physiognomically similar areas in other regions, being larger in the ferruginous Savanna, decreasing towards the semideciduous seasonal forest and the rock Savanna, with the ecotone environments in an

intermediate situation (Table 1) (Figure 2) (Brasil, 2007; Schaefer et al., 2015).

Table 1. General characteristics of vegetation type of the Serra do Rola Moça State Park, Minas Gerais State, Brazil.

	CG	RS	ERSSF	EFSSF	SSF
Soil depth	0 - 30 cm	0 - 40 cm	> 1 m	> 1 m	> 1 m
Formation	Open	Open	Closed	Closed	Closed
Lianas and vines	Absent	Absent	Plenty	Plenty	Absent or scarce
Canopy height	5 m	5 m	10 m	10 m	25 m

Note: the presented information is from field observations. RS = Rock Savanna; CG = Ferruginous Savanna; EFSSF = Ecotone between ferruginous Savanna and semi-deciduous seasonal forest; ERSSF = Ecotone between rock Savanna and semi-deciduous seasonal forest; SSF = Semi-deciduous seasonal forest.

Within each sample unit, all tree individuals with circumference at breast height (CBH) ≥ 15.7 cm were measured with measuring tapes and identified at the species level. In cases with more than one stem, the individual was included when the square root of the sum of squares of the circumferences reached the inclusion criterion (Scolforo & Mello, 1997). Identification followed the APG III with the adoption of Souza and Lorenzi (2005) for families. The botanical nomenclature was verified based on the TreeAtlas database (Oliveira-Filho, 2014).

Data analysis

We evaluated the existence of differences among vegetation types in relation to the structural characteristics through three comparisons. First, we compared the density of individuals (ind ha⁻¹) and basal area (m² ha⁻¹) among vegetation types through analysis of variance with 5% significance level and subsequent Tukey test for averages. The data normality and homoscedasticity were tested respectively by Shapiro-Wilk (Royston, 1982) and Levene's Test (Fox, 2008). Second, we compared the specific richness of vegetation types by rarefaction curve, considering different number of individuals measured (Heck, van Belle, & Simberloff, 1975; Soetaert & Heip, 1990), as well as the Shannon diversity index (H') and Pielou's evenness (J') (Brower, Zar, & von Ende, 1998). Finally, we evaluated the structural pattern of dominance by comparing phytosociological behavior of vegetation types, suggested as being the relationship between the phytosociological importance value (IV) (Mueller-Dombois & Ellenberg, 1974) and accumulated phytosociological importance value (AIV). The phytosociological importance value refers to a measure obtained for each species of a community and consists on the sum of the values of relative density, relative dominance and relative frequency (Mueller-Dombois & Ellenberg, 1974). The relationship between IV and AIV seeks to provide information about how occurs the ranking of the ecological importance of species in the community (Mueller-Dombois & Ellenberg, 1974).

The floristic dissimilarity among the vegetation types was evaluated by obtaining the number of shared species and Jaccard similarity coefficients (1-J) (Jaccard, 1908, Real & Vargas, 1996) among vegetation types. Then, we performed a permutational multivariate analysis of variance (Permanova) (Clarke, 1993) at 0.05 significance level in order to test if ferruginous Savanna differs

floristically from the others vegetation types based on coefficients. Finally, we performed a detrended correspondence analysis (DCA) (ter Braak, 1995) to evaluate indirectly the existence of gradients based on the abundance of species in the sample units. The analyses were performed through the software R Studio v. 3.3.1 (R Core Team, 2016) and the 'Vegan' package (Oksanen, 2011).

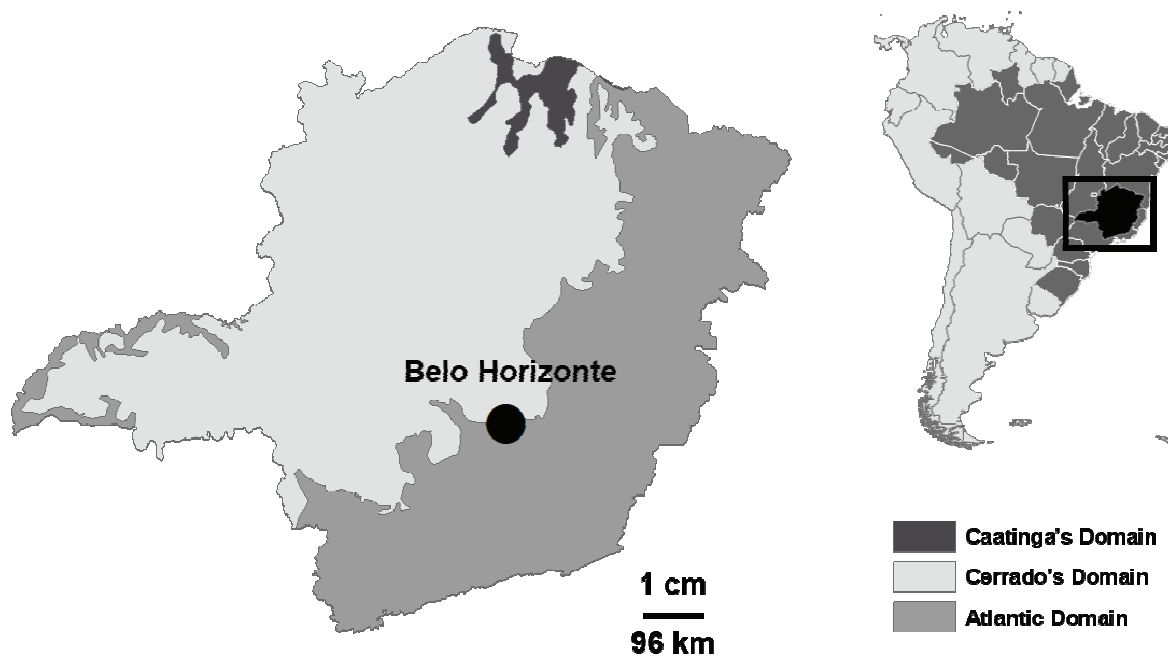


Figure 1. Location of the city of Belo Horizonte in the state of Minas Gerais, Brazil, South America, in relation to the phytogeographic domains of the state of Minas Gerais.

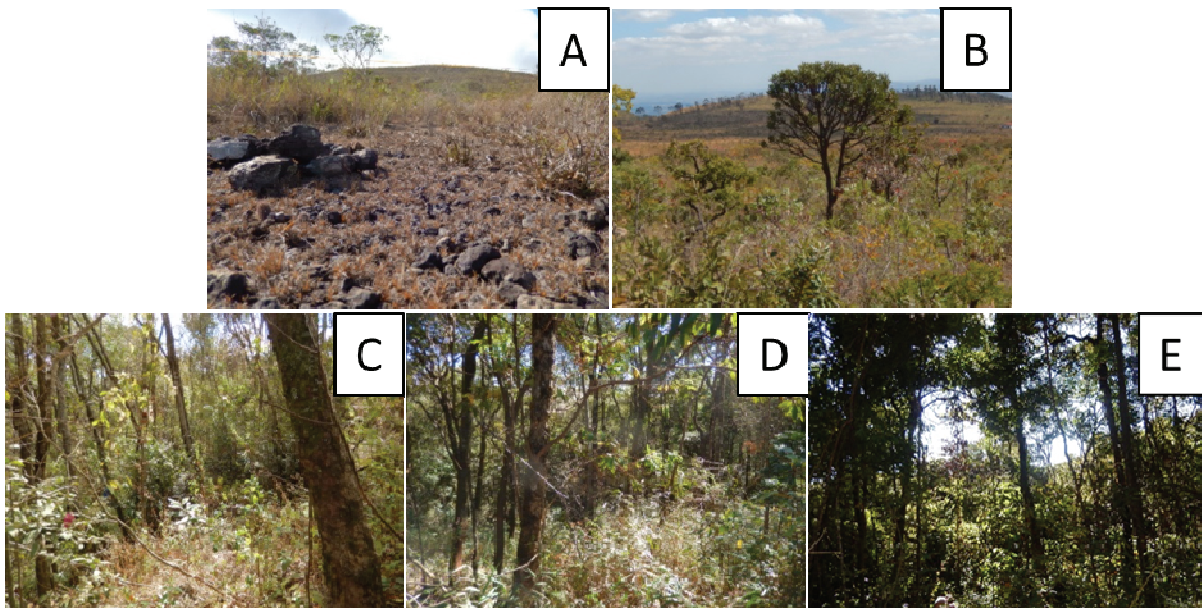


Figure 2. Studied vegetation types. A) Canga; B) Rock Savanna; C) Ecotone between Ferruginous Savanna and Semi-deciduous seasonal forest; D) Ecotone between semi-deciduous seasonal forest and rock Savanna; E) Semi-deciduous seasonal forest.

Results and discussion

The vegetation types demonstrated different density ($F = 25.77$, $gl = 24$ and $p < 0.01$), basal area (F test = 66.97, $gl = 24$ and $p < 0.01$), richness estimated by rarefaction (Figure 3), Shannon diversity index (H'), and Pielou's evenness (J') (Table 2). CG, however, showed structural characteristics similar to those of RS and different from the other vegetation types, according to the comparisons among pairs. The ecotones (EFSSF and ERSSF) showed structural behavior similar to each other and different from SSF.

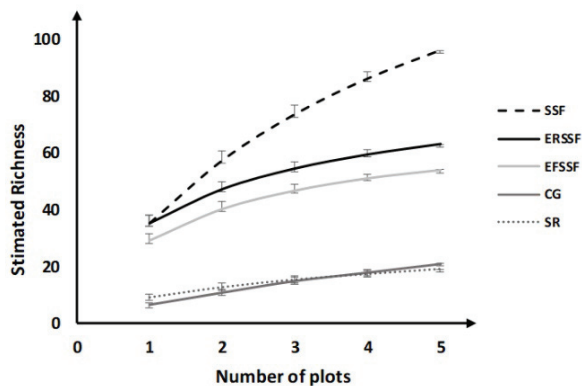


Figure 3. Average curve of rarefaction of species for the five vegetation types sampled from the SRMSP, Belo Horizonte, Minas Gerais State, Brazil. Note: RS = Rock Savanna; CG = Ferruginous Savanna; EFSSF = Ecotone between ferruginous Savanna and semi-deciduous seasonal forest; ERSSF = Ecotone between rock Savanna and semi-deciduous seasonal forest; SSF = Semi-deciduous seasonal forest.

In relation to the ecological dominance, CG presented an intermediate behavior between ecotones (EFSSF and ERSSF) and RS, with higher concentration of IV. Ecotones (EFSSF and ERSSF) presented similar dominance patterns with each other and were different from SSF, with the lowest IV concentration in the system (Figure 4), explained by the magnitude of variation of IV. Thus, three structurally different groups were formed: one with EFSSF and ERSSF, another with isolated SSF and the last with CG and RS, which differed from the others and not from each other.

In relation to floristics, the vegetation types showed different compositions among themselves (F model = 5.9, $gl = 24$, $p < 0.001$), with a maximum sharing of 30 species between EFSSF and ERSSF and minimum of zero species between RS and EFSSF (Table 3). In general, the system showed high floristic dissimilarity, with an average index value (1-Jaccard value) of 0.89 ± 0.03 . In addition, most species are restricted to one vegetation type,

with no species occurring widely in all vegetation types (Appendix 1). CG showed a high relative sharing of species with the EFSSF, ERSSF and SSF but not with RS, sharing only one species. DCA resulted in eigenvalues of 0.98 for axis 1 to 0.59 and for axis 2, which sets long-range scenario of high replacement species for both directions (ter Braak, 1995) (Figure 5).

Table 2. Density, basal area, richness, and diversity indexes for the five sampled environments of the Serra do Rola Moça State Park, Belo Horizonte, Minas Gerais State, Brazil.

	D	G	S	H'	J'
SSF	1325 ± 60.4 B	47.1 ± 1.5 A	96	4.1	0.89
ERSSF	2355 ± 60.1 A	29.1 ± 1.4 B	63	3.4	0.83
EFSSF	1720 ± 122.9 AB	19.6 ± 0.8 B	54	3.3	0.83
CG	345 ± 66.1 C	2.4 ± 0.5 C	21	2.7	0.87
RS	415 ± 44.5 C	3.1 ± 0.3 C	19	2.4	0.82

Note: D = Average density of individuals (ind ha^{-1}) and their average standard error; G = basal area ($\text{m}^2 \text{ha}^{-1}$) and their standard deviation; S = number of species; H' = Shannon-Wiener index (ind nat^{-1}); J' = Pielou's evenness; RS = Rock Savanna; CG = Ferruginous Savanna; EFSSF = Ecotone between ferruginous Savanna and semi-deciduous seasonal forest; ERSSF = Ecotone between rock Savanna and semi-deciduous seasonal forest; SSF = Semi-deciduous seasonal forest. For D and G, values followed by the same letters do not differ statistically by the Tukey test at 5% significance level.

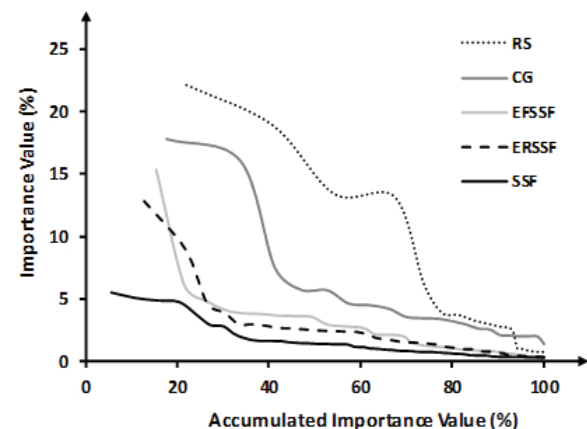


Figure 4. Relation between IV and AIV for the five vegetation types sampled from the SRMSP, Belo Horizonte, Minas Gerais State, Brazil. Note: RS = Rock Savanna; CG = Ferruginous Savanna; EFSSF = Ecotone between ferruginous Savanna and semi-deciduous seasonal forest; ERSSF = Ecotone between rock Savanna and semi-deciduous seasonal forest; SSF = Semi-deciduous seasonal forest.

In relation to axis 1, the units were ordered in two floristically distinct clusters, one in the extreme right, corresponding to SR vegetation type; and another at the right end with CG, EFSSF, ERSSF, and SSF vegetation types. Regarding axis 2, there are: high similarity between ERSSF and EFSSF, agglomerated in the upper part of the axis; CG with a differentiated composition from the others, with sample units agglomerated in the lower part of the axis; SSF present along large part of the gradient, but with greater similarity with the cluster formed by the sampling units of ERSSF and EFSSF.

Thus, the vegetation types are floristically distinguished in a group containing the sampling units of EFSSF, ERSSF, SSF, and CG; and another with the RS sampling units. In the first one, EFSSF and ERSSF form a unique system and SSF and CG environments present themselves individually, however, more similar to each other than to the SR environment. Thus, GC has a composition more similar to EFCG, ERSSF, and SSF vegetation types in relation to SR.

Table 3. Dissimilarity by Jaccard similarity coefficients (1-Jaccard Value) (upper right portion) and amount of shared species (lower left portion) for the vegetation types sampled in the SRMSP, Belo Horizonte, Minas Gerais State, Brazil.

	RS	CG	EFSSF	ERSSF	SSF
RS	*	0.97	0.99	1	0.99
CG	1	*	0.73	0.8	0.94
EFSSF	1	16	*	0.65	0.92
ERSSF	0	14	30	*	0.91
SSF	1	6	11	13	*

Note: RS = Rock Savanna; CG = Ferruginous Savanna; EFSSF = Ecotone between ferruginous Savanna and semi-deciduous seasonal forest; ERSSF = Ecotone between rock Savanna and semi-deciduous seasonal forest; SSF = Semi-deciduous seasonal forest.

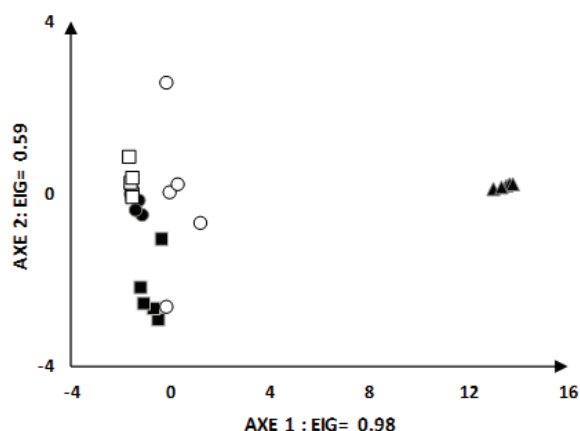


Figure 5. Detrended correspondence analysis (DCA) for sample units of five vegetation types sampled at the Serra do Rola Moça State Park, Belo Horizonte, Minas Gerais state, Brazil. Note: RS = Rock Savanna (▲); CG = Ferruginous Savanna or Canga (■); EFSSF = Ecotone between ferruginous Savanna and semi-deciduous seasonal forest (●); ERSSF = Ecotone between rock Savanna and semi-deciduous seasonal forest (□); SSF = Semi-deciduous seasonal forest (○).

The different patterns of structural and floristic similarity between Canga and the other vegetation types indicate that this one presents particular ecological features, but in a different way for each perspective. Thus, our initial hypothesis was validated with different unfolding for composition and community structure. While CG showed similar structural behavior to SR, the greatest floristic similarity occurred between CG and the forest ecosystems EFSSF, ERSSF, and SSF in spite of the SR with singular composition.

CG and SR showed similar structural behavior probably due to the compatibility of environmental conditions, such as soil depth, water availability, high radiation incidence and concentration of heavy metals, which show a high restriction situation in both (Porto & Silva, 1989; Larson, Matthes, & Kelly, 2000; Ribeiro & Walter, 2008). The pattern of dominance, characterized by few species of high representativeness, low richness, density, and basal area in relation to other vegetation types are related to such conditions that prevent the success of most tree species in rocky outcrops (Rizzini, 1997; Vincent & Meguro, 2008; Jacobi, Carmo, & Vincent, 2008). This result is expected for plant physiognomies in which the presence of shrub and herb species is considered more representative than those of tree species (Castro, Martins, & Fernandes, 1998; Ribeiro & Walter, 2008; Carmo & Jacobi, 2013). The iron saturation presents in Canga (Schaefer et al., 2015) was possibly equivalent to typical factors of Savanna vegetation types, such as aluminum toxicity, heavy metals, and other characteristics that constitute similar environmental restrictiveness in SR physiognomy (Ribeiro & Walter, 2008). Therefore, its presence acts as a driver of population structural characteristics and community richness.

The greater floristic similarity between CG and other vegetation types to the detriment of SR, demonstrated by species sharing by ordering, is probably due to phytogeographic factors in association with soil attributes. While SR is a vegetation type with a typical composition from Cerrado domain (Appendix 1), which corresponds to Savanna vegetation, with tree occurring sparse in the soil cracks (Ribeiro & Walter, 2008), the CG trees occur in rock discontinuity spots where its establishment is possible (Carmo & Jacobi, 2013). In these places, the vegetation is composed of typical species of forest formations (Appendix 1), forming sparse forest points in the middle of the field formation (Viana & Lombardi, 2007; Carmo & Jacobi, 2013).

The tree composition of ferruginous environments in the *Quadrilátero Ferrífero* shows a greater correspondence with seasonal forests of the Atlantic Domain than with formations from other Brazilian phytogeographic domains, including Savannas (Viana & Lombardi, 2007; Carmo & Jacobi, 2013). In this way, the SR is composed of species related to the domain's biogeographic origin which show adaptations to their unique conditions (Ribeiro & Walter, 2008), while the CG physiognomy is occupied by the forest species able to withstand the iron saturation restriction (Porto & Silva, 1989; Kruckeberg, 2004; Carmo & Jacobi, 2013). In these sites, forest species have developed

strategies for survival, such as tillering, adoption of reserve organs, bioaccumulation of heavy metals, sclerophylly, and the development of ecotypes (Porto & Silva, 1989; Teixeira & Lemos-Filho, 1998; Viana & Lombardi, 2007). Considering the CG group and the other plant physiognomies, the presence of iron saturation and the others harsh conditions probably acts as a filter that selects species with phenotypic plasticity that allows survival in each condition of environmental restrictiveness, determining their abundance patterns and form of occurrence.

Another important result is the high specificity of the vegetation types regarding the floristic composition, with the units presenting low number of shared species. This result is probably related to the diversity of environments present in the system, due to the interaction between relief variations, soil heterogeneity and phytogeographic influences (Jacobi & Carmo, 2008; Carmo & Jacobi, 2013). In this context, the presence of ferruginous soils in the place probably exerts a direct influence in this pattern by adding a series of available habitats in their interaction with the environmental conditions. Thus, landscapes with the presence of this factor tend to have additional specific components in relation to landscapes in similar situations of topography and phytogeographic influence, in which the ferruginous soils are absent. It is also possible to mention the presence of the ecotone between Canga and Forest, which presents characteristics that go beyond the mixture of two core areas and that probably would not be present in the absence of the environmental conditions that favored the Canga existence. This result suggests the ferruginous soils presence as potentiators of floristic heterogeneity in vegetation types matrices, which is already considered for herbaceous-shrub vegetation (Jacobi et al., 2007; Gibson et al., 2010; 2012; Skirycz et al., 2014).

Our results indicate that the Canga tree community presents specific structural behavior and floristic composition within the system, resulting from the association with the other vegetation types and conditions present there. Its structural patterns are similar to those of other vegetation types in similar environmental conditions, such as Savannas, but with floristic composition associated with the forests present in the system. Such complexity demonstrates the exclusivity of this vegetative type and reinforce the biological peculiarity of such formations and the necessity of their conservation.

Conclusion

The Canga tree communities are particular floristic-structural units within the vegetation types

set associated with ferruginous soils. Its relationships with other adjacent vegetation types occur in different ways, being related to similarities and differences in relation to environmental conditions.

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Appendix 1. Floristic composition of families and species for the vegetation types of Serra do Rola Moça State Park, Belo Horizonte, Minas Gerais state, Brazil.

	RS	CG	EFSSF	ERSSF	SSF
ANACARDIACEAE			x		x
<i>Tapirira obtusa</i> (Benth.) J.D.Mitch.			x		x
ANNONACEAE		x	x	x	x
<i>Annona cacans</i> Warm.			x		x
<i>Guatteria villosissima</i> A.St.-Hil.		x	x	x	x
<i>Unonopsis lindmanii</i> R.E.Fr.					x
<i>Xylopia brasiliensis</i> Spreng.					x
<i>Xylopia sericea</i> A.St.-Hil.				x	
APOCYNACEAE	x		x		x
<i>Aspidosperma australe</i> Müll.Arg.					x
<i>Aspidosperma olivaceum</i> Müll.Arg.					x
<i>Aspidosperma parvifolium</i> A.DC.			x		
<i>Aspidosperma ramiflorum</i> Müll.Arg.					x
<i>Aspidosperma spruceanum</i> Benth. ex Müll.Arg.					x
<i>Aspidosperma subincanum</i> Mart.					x
<i>Aspidosperma tomentosum</i> Mart.	x				
<i>Rauwolfia sellowii</i> Müll.Arg.					x
AQUIFOLIACEAE		x		x	
<i>Ilex conocarpa</i> Reissek		x		x	
ARECACEAE	x			x	x
<i>Geonoma brevispatha</i> Barb.Rodr.				x	
<i>Geonoma schottiana</i> Mart.				x	x
<i>Syagrus flexuosa</i> (Mart.) Becc.	x				
ASTERACEAE	x		x	x	
<i>Eremanthus erythropappus</i> (DC.) MacLeish			x	x	
<i>Eremanthus glomerulatus</i> Less.	x				
<i>Vernonanthura divaricata</i> (Spreng.) H.Rob.				x	
BIGNONIACEAE			x	x	x
<i>Handroanthus albus</i> (Cham.) Mattos			x		
<i>Handroanthus serratifolius</i> (Vahl) S.O.Grose				x	
<i>Jacaranda puberula</i> Cham.					x
BORAGINACEAE					x
<i>Cordia sellowiana</i> Cham.					x
BURSERACEAE				x	x
<i>Protium brasiliense</i> (Spreng.) Engl.					x
<i>Protium spruceanum</i> (Benth.) Engl.				x	
CALOPHYLLACEAE	x				
<i>Kielmeyera coriacea</i> Mart. & Zucc.	x				
CELASTRACEAE	x	x	x	x	x
<i>Cheiloclinium serratum</i> (Cambess.) A.C.Sm.					x
<i>Maytenus evonymoides</i> Reissek				x	
<i>Maytenus robustoides</i> Loes.		x			
<i>Maytenus salicifolia</i> Reissek		x	x	x	
<i>Plenckia populnea</i> Reissek	x				
<i>Salacia elliptica</i> (Mart. ex Schult.) G.Don					x
CHLORANTHACEAE					x
<i>Hedyosmum brasiliense</i> Miq.					x
CHRYSOBALANACEAE	x				x
<i>Couepia grandiflora</i> (Mart. & Zucc.) Benth.	x				
<i>Licania apetala</i> (E.Mey.) Fritsch					x
<i>Licania hoehnei</i> Pilg.					x
<i>Clethra scabra</i> Pers.			x	x	
COMBRETACEAE					x
<i>Terminalia glabrescens</i> Mart.					x
<i>Terminalia januariensis</i> DC.					x
CONNARACEAE					x
<i>Connarus regnellii</i> G.Schellenb.					x
CUNONIACEAE			x	x	
<i>Lamanonia ternata</i> Vell.			x	x	
EBENACEAE					x
<i>Diospyros hispida</i> A.DC.					x
ERYTHROXYLACEAE	x				
<i>Erythroxylum suberosum</i> A.St.-Hil.	x				
EUPHORBIACEAE		x	x	x	x
<i>Alchornea triplinervia</i> (Spreng.) Müll.Arg.		x	x	x	
<i>Croton urucurana</i> Baill.					x
FABACEAE	x	x	x	x	x
<i>Albizia polycephala</i> (Benth.) Killip					x
<i>Bauhinia longifolia</i> (Bong.) D.Dietr.					x
<i>Bauhinia rufa</i> (Bong.) Steud.					x
<i>Copaifera langsdorffii</i> Desf.		x	x	x	x
<i>Dalbergia foliolosa</i> Benth.					x
<i>Dalbergia miscolobium</i> Benth.	x				

	RS	CG	EFSSF	ERSSF	SSF
<i>Dalbergia villosa</i> (Benth.) Benth.				x	x
<i>Machaerium dimorphandrum</i> Hochne					x
<i>Machaerium villosum</i> Vogel			x	x	
<i>Mimosa scabrella</i> Benth.			x		
<i>Piptadenia gonoacantha</i> (Mart.) J.F.Macbr.					x
<i>Stryphnodendron adstringens</i> (Mart.) Cov.	x				
<i>Swartzia myrtifolia</i> J.E.Sm.			x		
<i>Zollernia ilicifolia</i> (Brongn.) Vogel					x
HYPERICACEAE			x		
<i>Vismia guianensis</i> (Aubl.) Pers.			x		
LAMIACEAE	x	x	x	x	
<i>Aegiphila lhotzkiana</i> Cham.			x		
<i>Aegiphila sellowiana</i> Cham.		x	x	x	
<i>Aegiphila verticillata</i> Vell.	x				
<i>Hyptidendron asperinum</i> (Epling) Harley			x		
<i>Vitex megapotamica</i> (Spreng.) Moldenke			x	x	
LAURACEAE		x	x	x	x
<i>Aniba canelilla</i> (Kunth) Mez		x	x		
<i>Cinnamomum glaziovii</i> (Mez) Kosterm.					x
<i>Cinnamomum triplinerve</i> (Ruiz & Pav.) Kosterm.			x		
<i>Endlicheria paniculata</i> (Spreng.) J.F.Macbr.			x	x	
<i>Nectandra cissiflora</i> Nees				x	
<i>Nectandra grandiflora</i> Nees				x	
<i>Nectandra megapotamica</i> (Spreng.) Mez				x	x
<i>Ocotea aciphylla</i> (Nees & Mart.) Mez				x	
<i>Ocotea corymbosa</i> (Meisn.) Mez				x	x
<i>Ocotea elegans</i> Mez.				x	
<i>Ocotea odorifera</i> (Vell.) Rohwer				x	x
<i>Ocotea pulchella</i> (Nees & Mart.) Mez			x		x
<i>Persea major</i> L.E.Kopp			x	x	x
<i>Persea rufotomentosa</i> Nees & Mart.				x	
LECYTHIDACEAE					x
<i>Cariniana estrellensis</i> (Raddi) Kuntze					x
<i>Cariniana legalis</i> (Mart.) Kuntze					x
LYTHRACEAE			x	x	
<i>Lafoensia pacari</i> A.St.-Hil.			x	x	
MAGNOLIACEAE					x
<i>Magnolia ovata</i> (A.St.-Hil.) Spreng.					x
MALPIGHIACEAE	x			x	x
<i>Byrsonima coccolobifolia</i> Kunth	x				
<i>Byrsonima laxiflora</i> Griseb.				x	
<i>Byrsonima myricifolia</i> Griseb.					x
<i>Byrsonima verbascifolia</i> (L.) DC.	x				
MALVACEAE					x
<i>Eriotheca macrophylla</i> (K.Schum.) A.Robyns					x
<i>Helicteres brevispira</i> A.St.-Hil.					x
<i>Luehea divaricata</i> Mart.					x
<i>Luehea grandiflora</i> Mart. & Zucc.					x
MELASTOMATACEAE			x		x
<i>Miconia dorianae</i> Cogn.					x
<i>Miconia pusilliflora</i> (DC.) Triana					x
<i>Tibouchina granulosa</i> Cogn.			x		
MELIACEAE		x	x	x	x
<i>Cabralea canjerana</i> (Vell.) Mart.		x	x	x	x
<i>Guarea kunthiana</i> A.Juss.					x
<i>Trichilia clausenii</i> C.DC.					x
MONIMIACEAE				x	x
<i>Macropeltis dentatus</i> (Perkins) I.Santos & Peixoto				x	x
<i>Mollinedia widgrenii</i> A.DC.					x
MORACEAE					x
<i>Maclura tinctoria</i> (L.) Steud.					x
<i>Naucleopsis oblongifolia</i> (Kuhl.) Carauta					x
<i>Sorocea guillemintiana</i> Gaudich.					x
MYRSINACEAE					x
<i>Cybianthus peruvianus</i> (A.DC.) Miq.					x
MYRTACEAE	x	x	x	x	x
<i>Calypttranthes brasiliensis</i> Spreng.				x	
<i>Calypttranthes clusifolia</i> O.Berg					x
<i>Calypttranthes concinna</i> DC.		x	x	x	
<i>Calypttranthes widgreniana</i> O.Berg				x	
<i>Eugenia acutata</i> Miq.					x
<i>Eugenia aurata</i> O.Berg		x			
<i>Eugenia dodonaeifolia</i> Cambess.					x
<i>Eugenia sonderiana</i> O.Berg			x	x	
<i>Marlierea excoriata</i> Mart.					x
<i>Myrcia amazonica</i> DC.		x	x	x	x
<i>Myrcia eriopus</i> DC.					x

	RS	CG	EFSSF	ERSSF	SSF
<i>Myrcia guianensis</i> (Aubl.) DC.	x	x	x		
<i>Myrcia hebeptala</i> DC.					x
<i>Myrcia mutabilis</i> (O.Berg) N.Silveira		x			
<i>Myrcia obovata</i> (O.Berg) Nied.			x	x	
<i>Myrcia pulchra</i> (O.Berg) Kiaersk.				x	
<i>Myrcia retorta</i> Cambess.		x	x	x	
<i>Myrcia splendens</i> (Sw.) DC.		x	x	x	x
<i>Myrcia tomentosa</i> (Aubl.) DC.				x	
<i>Myrcia venulosa</i> DC.			x	x	
<i>Myroxylon peruiferum</i> L.f.					x
<i>Myrsine coriacea</i> (Sw.) Roem. & Schult.	x				x
<i>Myrsine gardneriana</i> A.DC.				x	
<i>Myrsine guianensis</i> (Aubl.) Kuntze	x				
<i>Myrsine lineata</i> (Mez) Imkhan.			x		
<i>Myrsine umbellata</i> Mart.		x	x	x	
<i>Pimenta pseudocaryophyllus</i> (Gomes) Landrum				x	
<i>Psidium cupreum</i> O.Berg			x		
<i>Psidium myrtilloides</i> O.Berg			x		
<i>Psidium salutare</i> (Kunth) O.Berg					x
<i>Psidium sartorianum</i> (O.Berg) Nied.					x
<i>Siphoneugena densiflora</i> O.Berg			x	x	
<i>Siphoneugena reitzii</i> D.Lcgrand		x			
NYCTAGINACEAE		x	x		x
<i>Guapira opposita</i> (Vell.) Reitz		x	x		x
OLACACEAE					x
<i>Heisteria silvianii</i> Schwacke					x
OPILACEAE				x	x
<i>Agonandra excelsa</i> Griseb.				x	x
PENTAPHYLACACEAE				x	
<i>Temstroemia brasiliensis</i> Cambess.				x	
PERACEAE		x	x	x	
<i>Pera glabrata</i> (Schott) Poepp. ex Baill.		x	x	x	
PHYLLANTHACEAE					x
<i>Hieronyma alchorneoides</i> Allemão					x
PROTEACEAE			x	x	x
<i>Euplassa legalis</i> (Vell.) I.M.Johnst.				x	
<i>Euplassa rufa</i> (Loes.) Sleumer			x		
<i>Roupala meisneri</i> Sleumer			x	x	
<i>Roupala montana</i> Aubl.					x
<i>Roupala rhombifolia</i> Mart.				x	
RHAMNACEAE					x
<i>Colubrina glandulosa</i> Perkins					x
ROSACEAE		x	x	x	
<i>Prunus myrtifolia</i> (L.) Urb.		x	x	x	
RUBIACEAE			x	x	x
<i>Alseis floribunda</i> Schott					x
<i>Amaloua intermedia</i> Mart. ex Schult. & Schult.f.					x
<i>Faramea latifolia</i> (Cham. & Schltdl.) DC.				x	
<i>Ixora brevifolia</i> Benth.					x
<i>Psychotria vellosiana</i> Benth.			x		
<i>Rudgea jasminoides</i> (Cham.) Müll.Arg.					x
RUTACEAE					x
<i>Galipea jasminiflora</i> (A.St.-Hil.) Engl.					x
<i>Metrodorea stipularis</i> Mart.					x
SALICACEAE			x	x	x
<i>Casearia arborea</i> (Rich.) Urb.					x
<i>Casearia decandra</i> Jacq.			x	x	
SAPINDACEAE			x		x
<i>Allophylus floribundus</i> Radlk.					x
<i>Cupania vernalis</i> Cambess.			x		x
<i>Cupania zanthoxyloides</i> Cambess.					x
<i>Matayba mollis</i> Radlk.					x
SAPOTACEAE	x				x
<i>Chrysophyllum gonocarpum</i> (Mart. & Eichler) Engl.					x
<i>Chrysophyllum marginatum</i> (Hook. & Arn.) Radlk.					x
<i>Pouteria caimito</i> (Ruiz & Pav.) Radlk.					x
<i>Pouteria gardneri</i> (Mart. & Miq.) Baehni					x
<i>Pouteria gardneriana</i> (A.DC.) Radlk.					x
<i>Pouteria torta</i> (Mart.) Radlk.	x				
SCHOEPFIACEAE					x
<i>Schoepfia brasiliensis</i> A.DC.					x
SOLANACEAE			x		
<i>Solanum pseudoquina</i> A.St.-Hil.			x		
STYRACACEAE	x			x	x
<i>Styrax ferrugineus</i> Nees & Mart.	x				
<i>Styrax latifolius</i> Pohl					x
<i>Styrax leprosus</i> Hook. & Arn.				x	

	RS	CG	EFSSF	ERSSF	SSF
SYMPLOCACEAE	x		x	x	
<i>Averrhoidium paraguayense</i> Radlk.			x		
<i>Symplocos celastrinea</i> Mart. ex Miq.			x	x	
<i>Symplocos mosenii</i> Brand	x				
<i>Symplocos pubescens</i> Klotzsch ex Benth.			x		
THYMELAEACEAE			x	x	
<i>Daphnopsis brasiliensis</i> Mart. & Zucc.			x	x	
<i>Daphnopsis utilis</i> Warm.				x	
VOCHYSIACEAE	x		x	x	x
<i>Qualea multiflora</i> Mart.					x
<i>Vochysia thyrsoidea</i> Pohl	x				
<i>Vochysia tucanorum</i> Mart.			x	x	

Note: RS = Rock Savanna; CG = Ferruginous Savanna; EFSSF = Ecotone between ferruginous Savanna and semi-deciduous seasonal forest; ERSSF = Ecotone between rock Savanna and semi-deciduous seasonal forest; SSF = Semi-deciduous seasonal forest.