José Max Barbosa Oliveira-Junior
Lenize Batista Calvão
(Organizadores)

Ecologia

e conservação da biodiversidade

2

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APRESENTAÇÃO

O e-book **"Ecologia e conservação da biodiversidade 2"** é composto por dez capítulos com diferentes abordagens, relacionadas à ecologia e conservação das espécies em sistemas terrestres e aquáticos. Este e-book traz uma diversidade de artigos que abordam temas variados de questões ecológicas e os desafios para conservação de espécies nos mais variados tipos de ecossistemas. Esses desafios incluem alterações climáticas, derramamento de óleos em praias, uso de agrotóxicos, sobrepesca e perda de habitat devido as atividades antrópicas que levam a perda de diversidade de espécies, de serviços ecossistêmicos (e.g., polinização) e da diversidade de interações bióticas. Destacamos aqui que todos nós, como seres humanos racionais, temos a responsabilidade de cumprir conjuntamente com os objetivos do desenvolvimento sustentável (ODS) propostos no plano de ação Agenda 2030. Os ODS abrange as três dimensões do desenvolvimento sustentável: a econômica, a social e a ambiental e portanto são integrados e indivisíveis (PNUD, 2016).

Nesse contexto, o **capítulo I** discute a importância de entender a relação entre o clima, tempo e aparecimento de doenças, para o enfrentamento adequado e oportuno dos surtos e para a manutenção da promoção da saúde na coletividade. Interessante, que esse estudo não deixa de mencionar que fatores sociais também contribuem para a promoção da saúde na coletividade, sendo necessário a implementação de programas estruturados de controle de vetores, juntamente com ações que promovam a melhoria socioeconômica da população susceptível, bem como, da infraestrutura dos serviços médicos oferecidos. No **capítulo II,** os autores identificaram e a avaliaram aspectos e impactos ambientais locais de derramamento de petróleo em praias nordestinas no Brasil, apontando como os mais significativos o derramamento/vazamento de óleo/produto químico no mar, caracterizados quanto à severidade das consequências diretas e indiretas que podem acarretar ao meio ambiente. **No capítulo III,** a presença de espécies da fauna ameaçadas e a dependência das comunidades humanas locais são fatores que reforçam a necessidade da continuação da aplicação e a criação de medidas de conservação para os manguezais do Paraná, uma vez que esses ambientes estão ameaçados pelas atividades antrópicas. Os manguezais, segundo os autores, prestam diversos serviços ecossistêmicos sendo eles a pesca (serviços de provisão); estabilização do clima e proteção contra eventos extremos (serviços regulatórios); e festas tradicionais (serviços culturais). O **capítulo IV** demonstra que o revolvimento do solo por extratores de minhocoçu gera alterações químicas no solo que alteram a composição de espécies do Cerrado *stricto sensu*. O **capítulo V** aponta que as abelhas desempenham um papel muito importante no ambiente como polinizadores. Os autores destacam que a nutrição com recursos tróficos saudáveis e sem resíduos de agroquímicos oriundo de atividades antropogênicas se constitui na essência da

saúde das abelhas. O **capítulo VI,** avaliou a qualidade do mel produzido em apiários da zona rural sendo muito importante na cadeia de consumo local. O **capítulo VII** ressalta que a herbivoria pode causar danos relevantes a vegetação, e os autores destacam a importância de remanescentes de vegetação nativa para manutenção da diversidade, interações ecológicas e serviços ecossistêmicos. O estudo sugere também a necessidade da manutenção de fragmentos de cerrado próximo e ou/ circunvizinhos às áreas agrícolas a fim de serem zonas de amortecimento dos ataques de herbívoros. **O capítulo VIII** avaliou anualmente o crescimento e condições de populações de peixes, um trabalho bastante exaustivo e que ajuda elucidar questões importantes como sobrepesca, e, como ela pode impactar nas populações humanas locais que dependem desse recurso. **O capítulo IX** demonstra que o uso indiscriminado de agrotóxicos são muito prejudicais e ameaçam a vida dos organismos aquáticos, desta forma identificar essas substâncias e os limiares que levam a perda da vida aquática é fundamental para o uso adequado dessas substâncias. **O capítulo X** propôs detectar e caracterizar a biodiversidade de vertebrados em um conjunto de fazendas com 7.868 hectares sob cultivo orgânico e manejo ecológico, localizadas na região de Ribeirão Preto, SP.

A você leitor e leitora, desejamos uma excelente leitura! Com carinho,

José Max Barbosa Oliveira-Junior
Lenize Batista Calvão

SUMÁRIO

CAPÍTULO 4

THE EXTRACTION OF THE GIANT EARTHWORM ALTERS THE SOIL CHEMICAL CHARACTERISTICS AND TREE COMPOSITION IN THE CERRADO

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ABSTRACT: Anthropic disturbances are one of the main causes of loss of biodiversity and alteration in natural ecosystems. By resources exploitation humans alter the environmental conditions of a given location and make it inhospitable for some species. The giant earthworm (*Rhinodrilus alatus,* Righi) extraction in the Cerrado biome for sale to fishermen generates the revolving of the soil in addition to burning caused by extractors to facilitate the location of these animals. Thus, to evaluate the impacts of this activity on soil characteristics and composition of the Cerrado woody plant species is important to the conservation of this biome. For this we used 12 areas of Cerrado *stricto sensu* with different intensities of giant earthworm extraction and sampled the soil, tree plants, and the intensity of fire in a plot of 20 x 50 m. Our results showed that in the areas with higher intensity of giant earthworm extraction there is a change in soil chemical composition, mainly due to the increase in aluminum (Al^{3+}) and phosphorus concentrations as well as the increasing in cation exchange capacities (CEC). In addition, the intensity of giant earthworm extraction also influenced the woody species composition, probably due to the influence of Al^{3+} and CEC on the species composition showed by this work. The intensity of fire was not changed by the extraction of giant earthworm. Thus, we suggest that soil revolving by earthworm extractors generates soil chemical changes that alters the composition of species of the Cerrado *stricto sensu*.

KEYWORDS: Giant earthworm extraction, anthropogenic disturbances, Cerrado *stricto*

sensu, soil disturbances, Cerrado plants.

1 | INTRODUCTION

The increasing human population and therefore the demand for raw materials and food, many natural biomes are facing an increase in the exploitation of their resources (Williams et al. 2015). These activities may alter the natural conditions of the ecosystem and cause the loss of some specialist species (Gámez-Virués et al. 2015; Ribeiro et al. 2015). However, most of these activities are not supervised by environmental agencies and little has been studied about their consequences for biodiversity conservation, especially in non-forest biomes (Overbeck et al. 2015). In the Cerrado, one hotspot for conservation in the word (Myers et al. 2000), some of the main anthropic activities are the extraction of earthworms, widely used for sport fishing (Drumond et al. 2012). This activity, in addition to increasing human circulation in fragments of the Cerrado, generates intense soil revolving and application of fire to vegetation to facilitate collection (Drumond et al. 2013). Thus, the extractivism of giant earthworms can have an impact on the natural characteristics of the soil and vegetation of the Cerrado.

The extractivism of one species decreases the size of its population and can have an effect on the size of populations of other species and the entire ecosystem (Schmidt and Ticktin 2012; Poisot et al. 2013). For instance, selective cut of large canopy trees can cause more light to enter the vegetation and thus alter environmental conditions such as irradiation, average temperature, and soil characteristics (Rocha-Santos et al. 2016). Thus, anthropogenic disturbances can act as environmental filters leaving only species capable of surviving the new conditions, generally generalist species that have a broader ecological niche (Lôbo et al. 2011; Gámez-Virués et al. 2015; Carrié et al. 2017). Among these, some species have strong invasive potential and may dominate some areas after disturbances and change the structure and composition of the vegetation (Heringer and Thiele 2019).

The giant earthworm species, *Rhinodrillus alatus* Righi (Oligochaeta), is endemic to the Cerrado, restrict to the central region of the state of Minas Gerais and with an extension of its occurrence limited to approximately 20,000 km² (Drumond 2008). The extraction of these giant earthworms in the Cerrado is done by traditional extractors who sell them on Brazilian highways to fishermen, most of whom are destined for the Pantanal biome (Drumond et al. 2013). The extractors, remove this earthworms from their own areas of Cerrado vegetation, or invade private reserves and conservation units (Drumond et al. 2015a). In addition to causing the soil revolving inside the cerrado phytophysiognomies, they set fire to the soil to facilitate visualization of *R. alatus* feces and locate individuals (Drumond et al. 2015b). Thus, the activity of extractors, in addition to endangering the population density of these giant earthworms, may be altering soil characteristics and increasing the occurrence of fire in the biome.

One of the determining characteristics for the Cerrado vegetation is the composition of the soil and the fire regime (Gottsberger and Silberbauer-Gottsberger 2006). The soils of the Cerrado are naturally dystrophic, acidic and alic, which is related to the constitution of its source material and to its high weathering process (Fageria and Gheyi 1999; Silveira et al. 2000). Under these conditions, calcium, magnesium, and phosphorus deficiency and high aluminum concentration are often reported as a limiting factor in the structure, composition and productivity of this ecosystem (Goodland and Pollard 1973; Lloyd et al. 2008; Neri et al. 2012a, 2013; Vourlitis et al. 2013, 2014). Likewise, the natural fire regime is essential for the nutrient cycling in the Cerrado, and many species have become dependent on the natural frequency of fire for the maintenance of their life cycles due to reproductive strategies obtained throughout evolution (Durigan and Ratter 2016). As a result, possible changes caused by earthworm extraction in soil characteristics and fire frequency can be prejudicial to the conservation of the Cerrado's natural vegetation.

Considering these risks caused by giant earthworm extraction in the Cerrado in the conservation of natural characteristics and its biodiversity, our objective in this study was: (1) to evaluate if there are changes in soil characteristics in areas with intense giant earthworms extraction; (2) if the earthworm extraction activities increase the intensity of the fire; and (3) whether this disturbance alters plant composition and species richness in remnants of Cerrrado *stricto sensu*. For this we quantified the intensity of the earthworm extractivism during the last 10 years and the local fire intensity, and we sampled soil characteristics and floristic composition of 12 fragments of Cerrado. Our hypothesis is that the disturbance generated by giant earthworm extraction causes: (1) changes in soil chemical and physical characteristics; (2) increase the intensity of fire in the Cerrado; and (3) thus also changes the woody floristic composition and the number of endemic species of the fragments.

2 | MATERIALS E METHODS

2.1 Study area

The study was conducted in three municipalities of the state of Minas Gerais, Paraopeba, Caetanópolis and Curvelo, within the Cerrado *lato sensu* domain. Twelve Cerrado *stricto sensu* fragments were selected under different disturbance intensities and a 20x50m plot was installed inside each fragment. Cerrado *stricto sensu*, most characteristic phytophysiognomy of the Cerrado, occupies approximately 70% of the Cerrado biome, and it is characterized by prominent herbaceous dominated by grasses, and cover of trees and shrubs varying between 10 to 60 % (Eiten 1972; Ribeiro and Walter 1998). Of these, only one remnant is included in a conservation unit, Paraopeba National Forest, coordinated by the Chico Mendes Institute for Biodiversity Conservation (ICMBio). The remaining 11 fragments are legal reserves, inserted in pasture, agricultures and eucalyptus plantations. The Cerrado fragments of the region suffer daily disturbances generated by the extraction of

Rhinodrilus alatus. The climate of the region is characterized as humid subtropical, Aw type in the Köppen system, with an extensive dry season from April to September and usually less than 1400 mm of annual precipitation with concentrated rainfall during summers (Neri et al. 2012b). Data collections were carried out between September 2015 and January 2016.

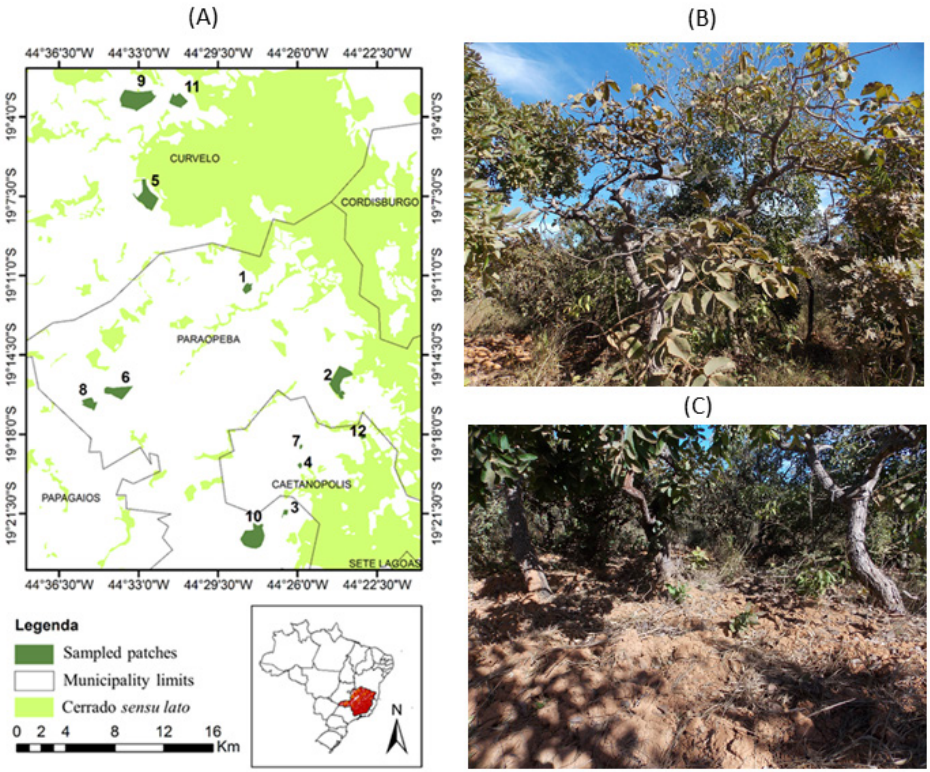

Figure 1. Map of study area (A), cerrado stricto sensu physiognomy (C) and soil of cerrado strito sensu after revolving by giant earthworm extractors.

2.2 Giant eathworm extraction instensity

To estimate the intensity of giant earthworm extraction in the Cerrado areas studied, we interviewed the area owners or administrators regarding the performance of extractors in the last ten years. Giant earthworm extraction foci within the sampled plots were also quantified. Thus, we ranked the intensity of giant earthworm extraction from 0 to 3: “0”, there was no focus of earthworms extraction in the plot nor record of performance of extractors in the fragment during the last 10 years; “1”, there was no focus of earthworm extraction in the plot, but there was sporadic performance of extractors in the fragment during the determined period; “2”, there was a focus of earthworm extraction in the plot and frequent records of

the extractors performance in the fragment during the determined period; “3”, there were two or more focus of earthworm extraction in the plot and records intense performance of earthworm extractors in the fragment during the last 10 years..

2.3 Soil Variables

Three random soil samples of 0-15 cm depth were collected from each plot, then homogenized, air dried and sieved (Giroldo and Scariot 2015), for subsequent chemical analysis at the UFV Soil Department. Important soil chemical constituents were considered as pH, exchangeable base sum, cation exchange capacity, aluminum saturation index and concentrations of aluminum (Al^{3+}), potassium (K), calcium (Ca^{2+}), phosphorus (P), and magnesium (Mg^{3+}) according to protocol described by EMBRAPA (Vegetação et al. 2011). For the physical characteristics, we calculated the proportion of fine sand, coarse sand, silt, and clay in the samples, also following the protocol of EMBRAPA.

2.4 Plant community sampling

For sampling we installed a permanent plot (20 x 50 m) inside each fragment of Cerrado *stricto sensu*, considering only living woody individuals in which at least one stem had a circumference at ground height greater than 10 cm (CGH ≥ 10cm). Thus, we recorded CGH, the individual’s height, and height reached by fire in individuals with carbonization marks. The species were collected and later identified according to APG IV (2014). Every species was classified as endemic or not according to the list of flora in Brazil (Reflora).

2.5 Burning Intensity

Burning intensity was measured by the number of sampled individuals that were affected by fire, based on the observation of carbonization marks, and by the calculation of the biomass volume affected by fire. For volume affected by fire we used the equation obtained by Cetec (1995) to calculate the total volume of the stem with the bark in woody individuals of Cerrado *stricto sensu*:

Individual volume of tree = (0.000038857 x Diameter ^ 1.70764 x Height ^ 1.32032);

however, for height we only considered the height at which carbonization marks were observed.

2.6 Statistical analysis

To analyze the effect of giant earthworm extraction on soil chemical characteristics we summarize the soil variables using the first two axes of a principal component analyses (PCA). We used linear regression to evaluate the relationship between earthworm extraction and soil PCA axes 1 and 2. Subsequently, we repeated the linear regression separately for all chemical and physical soil variables considered. Linear regression analysis was also used to evaluate the relationship between giant earthworm extraction intensity and fire intensity (individuals and volume affected by fire) in the studied areas. To obtain vegetation

composition data we used an ordination analysis, the non-metric multidimensional scaling (NMDS) method, using “Bray-Curtis” as a measure of similarity and species abundance data in the sampled plots. Subsequently, we used linear regression to assess the influence of extraction of giant earthworms and soil characteristics with the two axes of NMDS, species richness and number of endemic species. We tested data normality with Shapiro Wilk test. All statistical analyses were performed in R software version 3.2.1 (R Developement Core Team 2015).

3 | RESULTS

The first axis of soil chemical PCA explained 45% of the variation of the soil variables, while the second axis explained 38%. Only the first axis of soil chemical PCA was related to the extraction of giant earthworms by increasing their values ($t = 2,404$; $p = 0.037$; Fig. 2). In addition, cation exchange capacity ($t = 3.441$; $p = 0.006$), phosphorus concentration ($t = 3,016$; $p = 0.013$), and aluminum concentration ($t = 6,369$; $p = 0.000$) were also positively influenced by the intensity of earthworm extraction. The soil variables pH, exchangeable base sum, aluminum saturation index, potassium, and magnesium were not directly related to the intensity of extraction of giant earthworms. No soil physics variable was significantly influenced by the activity of extracting giant earthworms. Regarding the fire intensity variables, none showed a significant relationship with the extraction of giant earthworms.

Were sampled 2,837 individuals of woody plants belonging to 102 species, 71 genera and 37 families. The species composition had a significant relationship with the giant earthworm extraction demonstrated by the alteration of second axis of the NMDS ($t = -2,519$; $p = 0.030$; Fig.3) but did not change the number of endemic species. The second axis of NMDS also had a negative relationship with the cation exchange capacity ($t = -2.345$; $p = 0.041$) and with the aluminum concentration ($t = -3,067$; $p = 0.011$).

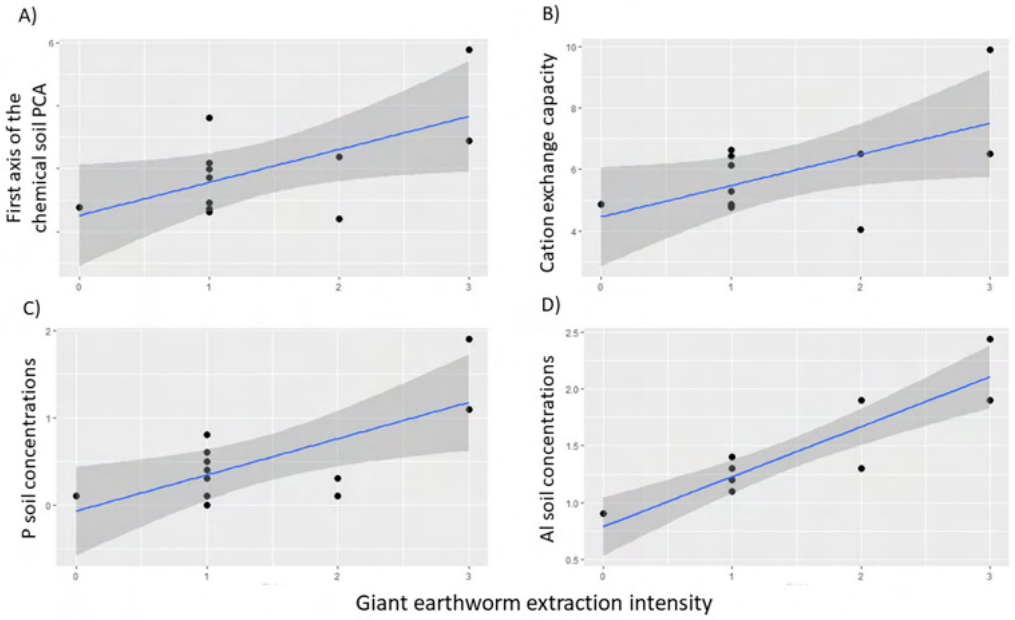

Figure 2. Relationship between the intensity of giant earthworm extraction and the chemical characteristics of the soil in the Cerrado stricto sensu: (A) axis 1 of the PCA of chemical characteristics of the soil; (B) effective cation exchange capacity; (C) phosphorus concentration; and (D) aluminum concentrations.

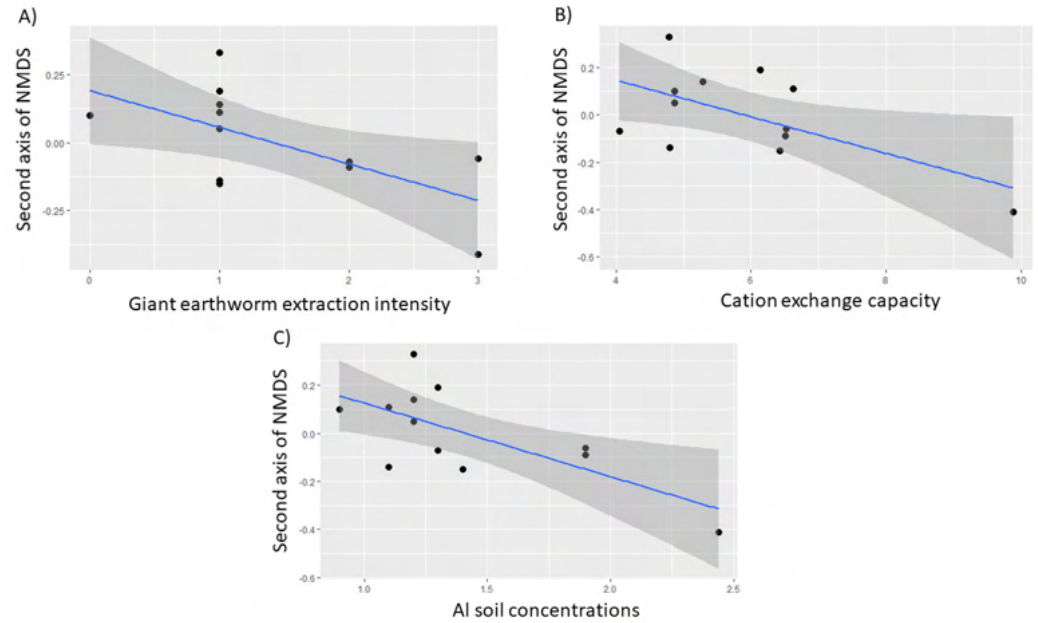

Figure 3. Relationship between the intensity of giant earthworm extraction (A), soil cation exchange capacity (B) and soil aluminum concentrations (C) with the second axis of NMDS of vegetation composition of Cerrado stricto sensu.

4 | DISCUSSION

Our results suggest that the giant earthworm extraction results in changes of the chemical characteristics of the soil and the woody floristic composition of the Cerrado *stricto sensu*. This activity increases the soil cation exchange capacity, phosphorus concentrations and aluminum concentrations. Likewise, the increased capacity for cationic exchanges and increased aluminum concentrations alongside with the disturbance of earthworm extraction alters the floristic composition of the remnants possibly allowing establishment of species intolerant to low nutrients generally found in Cerrado *stricto sensu*. However, the activity of extractivists does not affect the physical characteristics of the soil. In addition, fire intensity did not increase which earthworm extraction. Thus, our results show that the giant earthworm extraction activity threatens the conservation of specific characteristics of the soil and vegetation of the Cerrado *stricto sensu*.

The influence of giant earthworm extraction on soil chemical composition can be explained by the consequent soil revolving, a practice used in agriculture that increases the rate of mineralization of organic matter, and thus the cationic exchange capacity and phosphorus concentration in the soil (Ciotta et al. 2003; Santana et al. 2018). Similarly, soil revolving increases clay decomposition, especially in latosols, which generates an increase in Al3+ concentration (Ronquim 2010). Another effect can be that the aluminum concentration is greater at 15 cm depth than on the surface (Pavinato et al. 2009) which may explain the increase in aluminum in the uppermost layers soil of Cerrado with higher earthworm extraction intensity. Thus, the increase in Al^{3+} might be an effect of homogenization of the chemical characteristics between the soil surface and deeper layers but without the most of the root biomass that usually chelate Al^{3+} (Delhaize et al. 1993; Hocking 2001; Kochian et al. 2004). However, by accelerating mineralization processes, the intensity of this long-term disturbance can result in a rapid depletion of soil carbon and nutrient reserves in giant earthworm extraction areas.

As predicted, the giant earthworm extraction has significantly influenced the composition of tree species, and different factors may be behind it. First, the greater availability of nutrients and their ease of uptake (higher CTC) in areas with high intensity of extraction of giant earthworms may have favored a greater diversification of species. In the Cerrado *stricto sensu*, stress factors such as the low availability of soil nutrients act filtering in lower-sized tree species, with slow growth and reduced specific leaf area (Westoby et al. 2002; Hoffmann et al. 2012; Bueno et al. 2013b). In this way, improvements in soil nutritional quality in these areas, even if transient, may have allowed the establishment of other species typical of less dystrophic formations of the Cerrado, such as Cerrado woodland (Cerradão) and seasonal forests (Bueno et al. 2013a; Neri et al. 2013; Meira-Neto et al. 2017). Secondly, the increase in aluminum concentrations may also have acted as an environmental filter, filtering out intolerant species. According to Neri et al. (2013), tree

species of forest physiognomies have higher tolerance to high concentrations of aluminum, which corroborates the feasible occurrence of these species in the altered areas of Cerrado *stricto sensu*. Finally, it is important to mention that, to facilitate the search and capture of minhococu, part of the vegetation that makes up the lower stratum of the vegetation is disturbed or totally removed during the extraction (Paro 2013). In addition to threatening the survival of herbaceous plants, this impact can delay the natural regeneration process of the plant community, mainly because this activity has occurred in the region for more than fifty years, which reinforces the influence of extraction on the composition of tree species.

The fire set by earthworm extractors is not increasing the frequency of fire, demonstrated by the lack of significative influence of earthworm extraction intensity in these variables. The occurrence of natural burning is essential for maintaining diversity and structure of cerrado, especially the Cerrado *stricto sensu* (Lehmann et al. 2014; Pellegrini et al. 2016). However, fire-handling practices in the conservation of APPs and cerrado conservation units are not yet adopted (Durigan and Ratter 2016). In addition, biome fragmentation may be hindering the natural spread of fire in this biome (Abreu et al. 2017).

Thus, in addition to the impacts of the conservation of giant earthworms, the extractivism of this species can cause loss of important ecosystem functions performed by this biome due to change in species composition sensitive to soil chemical alterations. Thus, the regulation and management of giant earthworm extraction might be necessary in order to mitigate the effects on the soil chemical and plant composition of the Cerrado *stricto sensu*. However, further studies are needed to evaluate the effects of the giant earthworm extraction on functional aspects of this ecosystem. For now, it would be necessary rotation between areas to mitigate the extraction intensity in Cerrado and increase environmental supervision mainly in legal preservation areas.

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