

Fire Influence on the Ants Community in Savanic and Forest Environments of the Cerrado Biome

Aline das Graças Costa¹ 
Fillipe Tamiozzo Pereira Torres¹ 
Gumercindo Souza Lima¹
Fabiano Rodrigues de Melo¹ 
Vinícius Barros Rodrigues¹ 
Vicente Paulo Santana Neto¹ 
Tiago Vinicius Fernandes² 

¹Universidade Federal de Viçosa (UFV), Departamento de Engenharia Florestal, Viçosa, MG, Brasil.

²Universidade Federal de Minas Gerais (UFMG), Departamento de Genética, Ecologia e Evolução, Belo Horizonte, MG, Brasil.

Abstract

The objective of this work is to evaluate the effect of fire on ant assemblages in savanna and forest typologies in the Reserva Natural da Serra do Tombador in Cavalcante – Goiás, Brazil. Ant pitfalls traps were installed and subdivided into Burnt Cerrado (BC), Unburnt Cerrado (UC), Burnt Forest (BF) and Unburnt Forest (UF), and the samples were sorted, assembled and identified. The constancy and abundance of individuals, and the frequency of distribution of the genera in the total area and by treatment were evaluated. The UF, BF, UC and BC had 19, 14, 8 and 15 genera, with Jackknife 1 index indicating 18.5, 24.4, 8.9 and 20.4 respectively. The Shannon diversity index for the genera was 0.8462, 0.7604, 0.6448 and 0.5992 for UF, BF, BC and UC respectively. The Cerrado showed greater abundance of individuals and greater ant diversity index in relation to Forest when in presence of fire.

Keywords: Wildfires, Insect, Formicidae, Bioindicator, Forestry.

1. INTRODUCTION AND OBJECTIVES

Wildfire is considered a phenomenon that causes major economic, environmental and social impacts (JAFARI GOLDARAG et al., 2016; KAYET et al., 2020), which could get worse in the next decades due to climate change that could trigger an increase of these fires (FLANNIGAN et al., 2013; JOLLY et al., 2015). Fire can shape the landscape and change the habitat, flora and fauna structures in a drastic way, reducing the area of forests and other natural environments (AXIMOFF & RODRIGUES, 2011; CAMARGO et al., 2018).

In the tropics, the Cerrado is the biome with the highest amount of forest fires and burnt areas (SCHMIDT & ELOY, 2020). Savannas can be characterized by continuous grass layers with scattered trees and shrubs, growing under dry seasonality and warm climatic conditions (ALVARADO et al., 2017). In Brazil, the Cerrado (Savanna) is a large fire-prone ecosystem, and it has evolved under the influence of

fire (PIVELLO, 2011), covering about 2 million km², which represents about 25% of the country's area (DURIGAN & RATTER, 2016). Vegetation in the Cerrado consists of different landscapes along environmental gradients and fire disturbances, such as savanna physiognomies, in greater proportions, and campestrial and forest formations (BUENO et al. 2018). The thick rhytidome, tubercles, bulbs, shoots, underground rhizomes, thick bark and the typical tortuous shape of tree species are characteristics of the savanna fire adaptation (GOTTSBERGER & SILBERBAUER, 2006; COSTA-MILANEZ et al., 2015). Moreover, fire is considered an important event for the maintenance of the biodiversity in the biome (MARAVALHAS & VASCONCELOS, 2014; KELLY & BROTONS, 2017), and it is considered an important evolutionary force once it resumes the savanna ecological succession stage, benefiting certain species and the dynamic environments (KEELEY et al., 2012). However, the increase in deforestation caused by pastures and agricultural crops

using fire (PEREIRA JÚNIOR et al., 2014; DALLE LASTE et al., 2019) and the rise in global temperature (BEDIA et al., 2014; EUGENIO et al., 2016; JOLLY et al., 2015; STEPHENS et al., 2020) threaten the savanna integrity. It is estimated that more than half of the Cerrado vegetation coverage has already disappeared (BEUCHLE et al., 2015).

In the savanna, due to its heterogeneous vegetation (SANO et al., 2019) with different formations and types of forests, the woody composition is different along the gradient, mainly where it is related to fire-adapted and fire-independent species (HAIDAR et al., 2013). In typical forest physiognomies, wildfires stunt the natural regeneration (SANTOS et al., 2018). Tropical forests are more fire-sensitive environments, where a single fire event can drastically change the vegetation structure (BARLOW et al., 2003). The flammability of savannas and tropical forests tends to increase due to factors such as fragmentation and land usage changes (VELDMAN, 2016), and alterations after a fire event and its effects in these environments can be monitored by bioindicators (SILVEIRA et al., 2013).

Ants are widely used as bioindicators (RIBAS et al., 2012) once they indicate degradation or conservation in different areas (SILVA et al., 2013; OBERPRIELER & ANDERSEN, 2020) and in fire disturbance (ARCUSA, 2019). Fire causes direct or indirect effects on ants, altering the structure of their habitats, harming species richness and the composition of their functional groups (ANDERSEN et al., 2012; SILVEIRA et al., 2012; PAOLUCCI et al., 2016).

The foraging and nesting of Formicinae colonies are extensive, however they may be restricted to some specific micro-habitat, once they can be affected by temperature variations, humidity and resources availability (HOLDOBLER & WILSON, 1990; AGOSTI et al., 2000; FÉRNANDEZ & SHARKEY, 2006). The type and intensity of degradation or alteration in the environment can produce different responses,

by benefiting or harming species (ROCHA et al., 2015). Wildfires damage the soil ecosystems and compromise their functionality, reducing the diversity of some of the organisms in it, although it can also favor fire-adapted flora and fauna (ZAITSEV et al., 2016).

The objective of this work is to evaluate the effect of fire on ant assemblages in savanna and forest typologies in Brazilian Central-West region. The occurrence, distribution and abundance of genera in unburned and post-fire areas were evaluated in these two typologies. Understanding the effects of disturbance on communities is important to direct conservation efforts and manage ecological resources (DORNELAS, 2010), and it is also necessary to know the effect of the heterogeneity provided by fire on the diversity of ant species in vulnerable environments (TAYLOR et al., 2012). Many works present the responses of ants after a fire event in Cerrado and Atlantic Forest biomes (HOFFMAN et al., 2009; PACHECO & VASCONCELOS, 2012; MARAVALHAS & VASCONCELOS, 2014; VASCONCELOS et al., 2017), however they do not compare these responses in different phytophysionomies in the same area of study.

2. MATERIALS AND METHODS

2.1. Study area

The study was carried out in a protected area (Reserva Particular de Patrimônio Natural - RPPN) called Reserva Natural da Serra do Tombador (RNST) located in the municipality of Cavalcante, in the north of Goiás state, in Brazil. The area has 8730 ha and was converted into a Protected Area in 2007, by Fundação Grupo Boticário de Proteção à Natureza, as contribution to the conservation of the Cerrado biome (FUNDAÇÃO GRUPO BOTICÁRIO, 2011) (Figure 1).

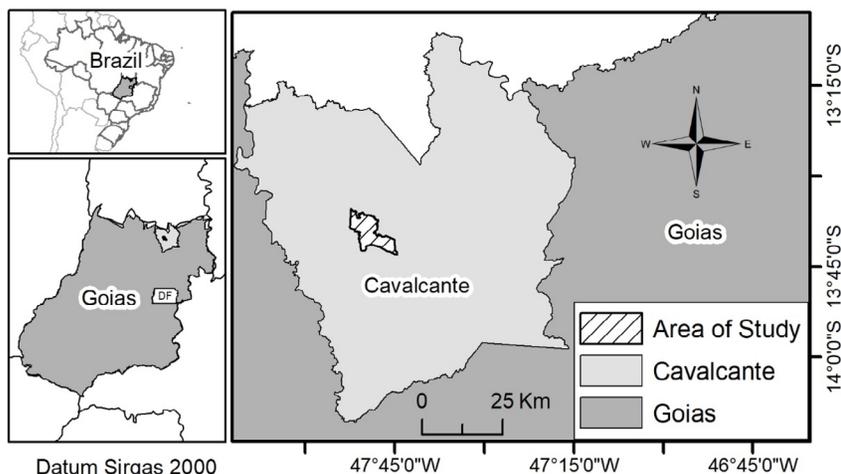


Figure 1. Localization of the Reserva Natural Serra do Tombador, Goiás, Brazil.

The RNST is located in a classic Cerrado vegetation area with distinct formations and it is covered by a mosaic of savanna vegetation that goes from open to closed ones, with grassland vegetation and forest formations. There are five predominant landscapes in the RNST: Savanna is dominant (78.0%), mostly represented by the Cerrado and Campo Rupestre; the forest landscape (20.0%) is represented by the Dense Ombrophilous Forest and Semideciduous Seasonal Forest and the other typologies are Anthropogenic formations (2.0%), Veredas (0.8%) and Rocky Outcrop (0.3%) (FUNDAÇÃO GRUPO BOTICÁRIO, 2011).

The region is located in the hydrographic basin of the Tocantins River with a warm and semi-humid Aw type climate (Koppen) with a dry season in winter (RIBEIRO et al., 2008). The temperature in 2017 ranged from 12°C to 35°C and precipitation from 7 to 319mm. June, July and August months are generally dry (00mm) and the rainy season occurs between November and March, with an average monthly rainfall of 132mm (INMET, 2018). In October 2017, anthropogenic originated fire affected more than 80% of the protected area.

2.2. Data collect

Ant traps were installed in the RNST savanna and forest formations. These typologies were subdivided into burnt areas (affected by the fire) and unburned areas (not affected) with the same ecological conditions as the areas were burned before the fire, totaling four treatments in forest formations: Burnt Forest (BF) and Unburnt Forest (UF) and in savanna formations: Burnt Cerrado (BC) and Unburnt Cerrado (UC).

Pitfalls traps were used to sample the ant fauna (adapted from BOSCARDIN et al., 2014). The traps were made from a 400mL plastic container with 100mL of alcohol and 100mL of water, and they were protected by plastic lids 10cm above the container. A linear 100m transect was made in each treatment

and ten traps were placed 10m apart from each other in the transect, totaling 40 traps in the four above paragraph mentioned areas. The 100m transect arranged in 10 traps is a suggested methodology to standardize surveys with the Formicidae family, as there would be no variations in ant composition at distances of up to 100 meters within a forest area (SARMINENTO-M, 2003). The traps were left in the field for 48 hours. The traps were installed on February 22, 2018 and left in the field for 48 hours, being collected on February 24, 2018.

Then, the samples were sent to the Community Ecology Laboratory of the Universidade Federal de Viçosa (LabEcol/UFV) for sorting, assembly and identification of the species (BACCARO et al., 2015).

2.3. Statistical analysis

After identifying and quantifying the species (Annex), the constancy and abundance of individuals and the frequency of genera distribution in the total area were evaluated by treatment in R environment. The richness estimator indices of Jackknife 1st order, Sorensen similarity and Shannon diversity to identify the similarity and diversity between the genera of the areas were obtained.

The dataset was tabulated and analyzed using generalized linear modeling (GLM) in R statistical software and graphs were created by using the ggplot2 package (WICKHAM, 2016).

3. RESULTS

In the total grouping of data, 1,397 individuals of 72 species (Annex), distributed in 28 genera of seven subfamilies were collected. The richest subfamily in diversity was Myrmicinae, with 38 species and 11 genera (approximately 57% of individuals). The genus *Pheidole* (Myrmicinae) was the most representative in number (49.03%) followed by *Ectatomma* (Ectatomminae) (10.74%) (Table 1).

Table 1. Formicidae genera distribution by treatment in Cerrado vegetation types, Reserva Nacional Serra do Tombador, Goiás, Brazil.

Subfamily/Genus	UF	BF	UC	BC	Total
Dolichoderinae					20
<i>Dolichoderus</i>	2	-	-	-	2
<i>Dorymyrmex</i>	-	-	-	12	12
<i>Forelius</i>	-	-	-	1	1
<i>Linepithema</i>	3	-	-	2	5
Ectatomminae					287
<i>Ectatomma</i>	37	30	83	-	150
<i>Gnamptogenys</i>	16	16	-	105	137

Table 1. Continued...

Subfamily/Genus	UF	BF	UC	BC	Total
Formicinae					115
<i>Brachymyrmex</i>	3	-	3	2	8
<i>Camponotus</i>	3	13	9	75	100
<i>Nylanderia</i>	6	1	-	-	7
Myrmicinae					798
<i>Acromyrmex</i>	1	-	-	-	1
<i>Atta</i>	10	9	-	-	19
<i>Cephalotes</i>	-	1	-	-	1
<i>Crematogaster</i>	3	-	-	8	11
<i>Mycocepurus</i>	-	-	-	4	4
<i>Ochetomyrmex</i>	-	37	-	7	44
<i>Pheidole</i>	99	155	103	328	685
<i>Sericomyrmex</i>	4	16	-	-	20
<i>Solenopsis</i>	-	1	6	-	7
<i>Trachymyrmex</i>	1	-	-	3	4
<i>Wasmannia</i>	2	-	-	-	2
Non-Identified					1
Non-Identified	-	-	-	1	1
Ponerinae					86
<i>Centromyrmex</i>	-	-	1	-	1
<i>Dinoponera</i>	1	-	24	5	30
<i>Hypoponera</i>	-	1	-	-	1
<i>Neoponera</i>	3	26	9	-	38
<i>Odontomachus</i>	3	8	-	1	12
<i>Pachycondyla</i>	3	1	-	-	4
Pseudomyrmecinae					90
<i>Pseudomyrmex</i>	20	-	-	70	90
TOTAL	220	315	238	624	1397

Where: forest formations = Burnt Forest (BF) and Unburnt Forest (UF) savanna formations = Burnt Cerrado (BC) e Unburnt Cerrado (UC)

The BC treatment was the most representative in number (44.67%), while the UF was the least one (15.75%). BF and UC represented 22.55% and 17.04% of the individual's abundance, respectively. According to Figure 2, the fire episode revealed no difference in abundance in the forest formation (BF x UF), unlike the treatments in the savanna formation (BC x UC), which showed greater abundance of ants in BC. The similarity of *Sorensen* by genus showed that the BC and UC treatments showed no similarity (0.35), while the BF and the UF showed it (0.61).

The distribution of genera types was different among treatments. Out of the 28 genera found, UF presented 19 and BF presented 14, with Jackknife 1 index indicating 18.5

and 24.4 respectively to these treatments. UC had a smaller number of genera (8) and BC presented 15, with 8.9 and 20.4 of Jackknife 1 index, respectively. In the savanna formation, *Gnamptogenys* and *Pseudomyrmex* stood out for appearing with a high representation of individuals in the burned area. On the other hand, the genus *Ectatomma*, which showed high distribution in the UC, was not represented in the savanna formation affected by fire. The genus *Ochetomyrmex*, not found in the UF, was highly representative in the BF. *Pseudomyrmex*, which was distributed in UF, was not found at BF. The genera *Pheidole* and *Camponotus* were the only ones present in all treatments. The *Atta* genus only occurred in forest treatment, before and after burning (Figure 3).

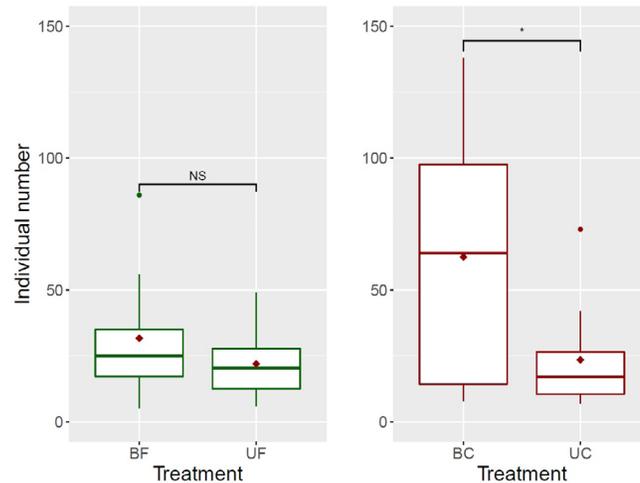


Figure 2. Distribution of Formicidae individuals by treatments in the Reserva Nacional Serra do Tombador, Goiás, Brazil.

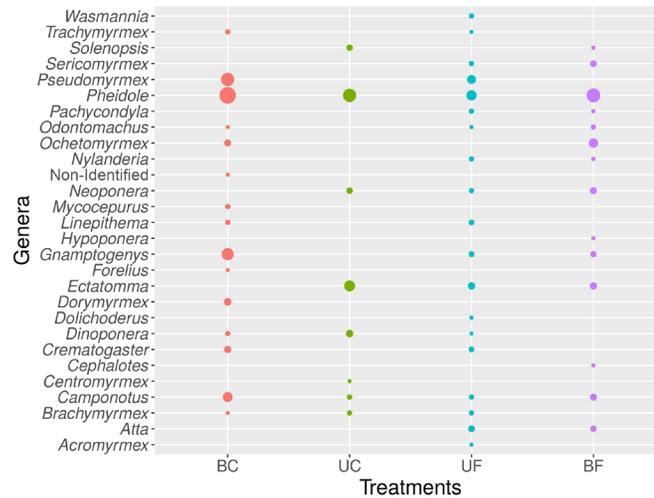


Figure 3. Distribution of Formicidae genera by treatment in the Reserva Nacional Serra do Tombador, Goiás.

The *Shannon* diversity index for the forest area genera was 0.8462 for the area not affected by fire and 0.7604 for the affected area. The index values for the savanna area were 0.6448 for the burned environment and 0.5992 for the unburned environment.

4. DISCUSSION

In several studies in Brazil central region, Myrmicinae was also the subfamily with the highest species richness (SOARES et al., 2010; MARAVALHAS & VASCONCELOS, 2014). In the entire Neotropical region, Myrmicinae is the largest and most diverse subfamily, with ease in adaptation to different ecological niches, high degree of social complexity (DORVAL et al., 2017) and presence in a wide variety of habitats, from tropical forests to savannas and deserts (WILSON, 2003). In the region of Uberlândia, Prata and Caldas Novas cities, located in the center of Brazil, in footpaths, thin savannah, dense

savanna and savannah vegetation, 135 species of ants were recorded in pitfalls traps, being *Pheidole* the most diversified genus (20%), followed by *Camponotus* (16%) (PACHECO & VASCONCELOS, 2012). Collections in native cerrado and eucalyptus areas in Ivinhema city, Mato Grosso do Sul state, in midwest region of Brazil, registered the genus *Pheidole* with the highest number of species, followed by *Ectatomma* and *Camponotus*, with *Pheidole* being the most abundant genus both in the Cerrado and in the eucalyptus areas (SOARES et al., 2010). *Pheidole* is one of the largest genera, being generalists, occurring in different environments and having high numerical dominance and hyperdiversity, present in areas of tropical forests, savannas and deserts (WILSON, 2003; ECONOMO et al., 2014). *Ectatomma* is found in various environments, from forests to savannas, as they have nomadic life habits, are generalist predators and need a greater variety of habitats to forage in search of food resources (HOLLDOBLER & WILSON, 1990; BACCARO et al., 2015).

In general terms, both in forests and in the cerrado, fire may not significantly affect the abundance of ants, but it interferes in the diversity of genera (VASCONCELOS et al., 2017). However, ecosystems that depend on the maintenance of more dynamic ecological states may benefit from fire, unlike ecosystems characterized by a stable climatic condition, which can be harmed by fires (HOFFMAN et al., 2009; VASCONCELOS et al., 2017). Savannas are ecosystems considered dependent on fire, with a burning process that helps in their maintenance (HOFFMAN et al., 2009; VASCONCELOS et al., 2017).

Variable fire regimes can produce habitat heterogeneity, benefiting myrmecory (MARAVALHAS & VASCONCELOS, 2014). Besides the local variations in the incidence of fire in nutrient content and soil moisture that lead to large variations in plant cover, the mosaic of plant formations found in the Cerrado is an important factor for the maintenance of ant species (PACHECO & VASCONCELOS, 2012). Maravalhas & Vasconcelos (2014) support the pyrodiversity/biodiversity hypothesis for neotropical savanna ants, in which a fire regimes mosaic may be crucial for the maintenance of ant species (ARAÚJO et al., 2013).

In tropical forests, wildfires are rarer when comparing to Cerrado, as they do not have characteristics of adaptation to burning, such as resistant plants (HOFFMAN et al., 2009). Changes in the structure of vegetation caused by fire can cause changes in ant communities, reducing the abundance of forest specialist ants (PAOLUCCI et al., 2017), as well as the severity and frequency of fire influence on the constitution of invertebrates in general (GONGALSKY & PERSSON, 2013; BUCKINGHAM et al., al., 2019). Also, the time since disturbance can affect species biotic factors, such as dispersal, physiology and competition (HUEBNER et al., 2012; MALMSTRÖM, 2012; AUCLERC et al., 2019).

Fire significantly decreases the diversity of ants in tropical forests (VASCONCELOS et al., 2017). This decrease in diversity may be related to the complexity of the forest environment and changes in vegetation structure after fire (BARLOW et al., 2003; PILON et al., 2021). Forest areas present greater leaves litter production, less tree spacing and greater biomass per unit area than the cerrado, increasing the biome's production and heterogeneity (SILVA et al., 2013). In forests and other habitats with strong vertical stratification, species diversity is high, but the relative dominance may be lower (PANIZZI & PARRA, 1991). More heterogeneous environments present greater availability of resources for generalist ant species and greater variety for specialist ones (RIBAS et al., 2003). Pacheco & Vasconcelos (2012) found, on average, less species variety in the structurally least complex habitat, despite the low variation in species abundance among the remaining

habitats, and the strong differences in vegetation structure among them. In deserts, pastures and savannas, this behavior does not occur, as fire may not significantly affect both the abundance and diversity of ants, due to the adaptation of the cerrado to fire (VASCONCELOS et al., 2017), in addition to the hypothesis that fire promotes the biodiversity of this phytophysiognomy (ARAÚJO et al., 2013; MARAVALHAS & VASCONCELOS, 2014).

Some soil arthropods abundance may increase with the fire frequency, while others may be harmed or not change (CAUT et al., 2014; CANEDO-JÚNIOR et al., 2016; ANJOS et al., 2017; FAGUNDES et al., 2018). The diet of the Formicidae family is classified by genera (FERNÁNDEZ et al., 2006), being influenced by variations in temperature, humidity and resource availability (HOLDOBLERET & WILSON, 1990; CURBANI et al., 2021). However, their eating habits are diversified, what facilitates the exploring of most terrestrial ecosystems (JAFFE, 2004). Fire can alter species richness, composition and dominance, harming or benefiting them (RIBAS et al., 2012; ROCHA et al., 2015). Its intensity, frequency and extension change the competitive balance among species and, consequently, the structure of communities, benefiting species with generalist habits (FRIZZO et al., 2011).

Gnamptogenys are generally found in humid forests, but they appear in savanna areas, once they have generalist habits and benefit from different environments (RICO-GRAY et al., 2007; BACCARO et al., 2015), even with fire disturbance. *Pseudomyrmex* have nesting habits, building nests in dead and hollow plant branches (WARD, 1990), which may have favored their presence in BC. The *Ectatommas* are known as army ants, with nomadic and predatory life habits, and with a huge variety of habitats requirements to forage and move to find new food resources (HOLDOBLER & WILSON, 1990). They are also generalists, but oftenly appear in savanna areas in South America and in humid forests (RICO-GRAY et al., 2007).

The *Ochetomyrmex* genus stands out for its richness in species and in great morphological variety, which turns it into a large representative genus of species for obtaining food, reproduction and nesting (BACCARO et al., 2015). It is restricted to South America, ranging from lowland tropical forests to the east of the Andes and nesting in plant litter (FERNÁNDEZ, 2003). The occurrence of *Pseudomyrmex* in unburned forest is due to the genus' preference for native vegetation (WARD, 1990) and because they are food dependent on plant products (FERNÁNDEZ & SHARKEY, 2006).

Pheidole and *Camponotus* are the most numerous genera of species in the family, with most of these species being omnivorous (BACCARO et al., 2015). Ants of the genus *Atta*

belong to the tribe Attini (Myrmicinae), and use plant material as a substrate of symbiotic fungus – the genus' main food source (FOWLER & CLAVE, 1991). They are known as leaf-cutting ants or saúvas, also important herbivores of neotropical forests, due to their cutting leaves habit (COSTA et al., 2009). They are considered fire resistant because they proliferate in altered habitats or in early succession stages (SANTOS et al., 2008).

In tropical forest environments, ants are considered organisms with high richness and abundance in variety, representing more than 60% of the arthropod fauna, with differentiated composition and foraging (ELLWOOD et al., 2004), being found in all forest strata, from canopy to the ground (VASCONCELOS et al., 2008). Diversity in UF is greater than in BF because of its heterogeneity as a result of the strong vertical stratification and increase in food and housing resources, as already mentioned (PANIZZI & PARRA, 1991; RIBAS et al., 2003). Both the richness and the composition of genera can be explained by environmental heterogeneity mediated through the complexity and variability of resources (TEWS et al., 2004; SANDERS & NICKEL, 2008), in addition to being an environment that does not have characteristics of adaptation to fire (HOFFMAN et al., 2009). The diversity index of the burnt savanna formation, on the other hand, is greater than the unburnt one, and it reinforces its adaptation (BOND et al., 2005; ARAÚJO et al., 2013), resistance (HOFFMAN, 2009; ANDERSEN et al., 2014; VASCONCELOS et al., 2017) and promotion of biodiversity through fire events (MARAVALHAS & VASCONCELOS et al., 2014; KELLY & BRONTONS, 2017).

The adaptation of savanna formations to fire is noticeable due to the greater abundance and diversity of the burnt phytophysiology when compared to the unburnt one. The Cerrado is an ecosystem considered adapted to fire due to its dynamic ecological states (HOFFMAN et al., 2009; VASCONCELOS et al., 2017), with thick and tortuous bark trees that characterize the arboreal adaptation to these events (GOTTSBERGER & SILBERBAUER, 2006), in which these characteristics of environmental heterogeneity can benefit ant communities (MARAVALHAS & VASCONCELOS, 2014). However, in the forest phytophysiology, this adaptation is not perceived when comparing burnt and unburnt forest environments. Forest biomes have high heterogeneity (PANIZZI & PARRA, 1991; RIBAS et al., 2003) with a more stable climate condition, nevertheless it can be disrupted by fire episodes (HOFFMAN et al., 2009; VASCONCELOS et al., 2017), affecting the fauna and flora diversity.

5. CONCLUSIONS

This study states, by using ants as fire impact bioindicators, that the savanna formation of the Cerrado is favored by fire as it demonstrates greater abundance of individuals and a greater diversity index when compared to not burnt savanna, in addition to emergence of new ant genera in the burned area.

The forest physiognomy of the Cerrado, on the other hand, by presenting a statistical difference in the abundance of individuals and similarity between burnt and unburnt forest formation, in addition to the smaller number of genera and lower diversity index in the forest affected by fire, leads to the conclusion that fire can negatively impact on the diversity of ant genera in this phytophysiology.

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CORRESPONDENCE TO

Vicente Paulo Santana Neto

Departamento de Engenharia Florestal, Rua Purdue - Campus UFV, CEP 36570-900, Viçosa, MG, Brasil.

e-mail: vipsneto@gmail.com

AUTHORS' CONTRIBUTIONS

Aline das Graças Costa: conceptualization (lead); formal analysis (lead); methodology (lead); writing (original draft-lead).

Fillipe Tamiozzo Pereira Torres: methodology (equal); project administration (lead); supervision (supporting).

Gumercindo Souza Lima: data curation (equal); project administration (equal); supervision (equal).

Fabiano Rodrigues de Melo: methodology (equal); project administration (equal); supervision (equal).

Vinícius Barros Rodrigues: data curation (equal); formal analysis (equal); investigation (equal).

Vicente Paulo Santana Neto: writing (original draft-supporting); writing (review & editing-equal).

Tiago Vinicius Fernandes: data curation (supporting); formal analysis (supporting); investigation (supporting).

SUPPLEMENTARY MATERIAL

The following online material is available for this article: Annex. Distribution of ant subfamilies and species by phytophysiology affected and not affected by the Cerrado fire at Reserva Nacional Serra do Tombador, Goiás, Brazil.

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