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Community Ecology of Soil Fauna Under Periodically Flooded Forest and Anthropic Fields

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Abstract

The study evaluated the ecology of soil invertebrate faunal communities in periodically flooded forest (CF) fragments and anthropic fields (AF) in the Atlantic Forest. The sampling occurred in the rainy and dry seasons using pitfall traps. We estimated the total activity, richness, diversity, and evenness as well as the activity of the taxonomic and functional groups. Total activity and richness varied as a function of seasonality. Entomobryomorpha, Poduromorpha, and Symphypleona were the most representative taxonomic groups. Enchytraeidae and Blattaria were exclusive to CF. Auchenorrhyncha, Chilopoda, Heteroptera, and Thysanoptera were exclusive to AF. The functional group of microphagous/saprophagous (M/S) showed the highest activity, independent of the environment and season. Greater dissimilarity was observed among the invertebrate fauna in AF when compared to CF. Periodically flooded areas favored groups from the saprophagous trophic guild, while AF areas favored predator and herbivore groups. Soil fauna present in forest environments presented less seasonal variability.

Keywords: *Tabebuia cassinoides*, Conservation Unit, hydromorphism, pitfall trap.

1. INTRODUCTION

Soil fauna is composed of different invertebrates that have varying functions in the soil (Silva et al., 2016). They behave differently in their habitat and respond immediately to changes in the environment; thus, the changes imposed on their populations may not be uniform across communities (Coyle et al., 2017; Thakur et al., 2018). Plant stratification, coupled with direct and indirect interactions between ecosystem components at various levels of the food chain, are important factors for controlling the local dynamics of soil fauna (Nowrouzi et al., 2016). These changes in soil communities can help us understand and measure the consequences of landscape disturbances (Pompeo et al., 2016), especially in Conservation Units (CU's) aimed at preserving natural ecosystems.

Soil organisms and their biological processes or products may function as bioindicators, which could provide information on the quality, or degree of preservation, of all or part of the environment (Usman et al., 2016). The use of bioindicators is based on the fact that organisms, which are adapted to specific conditions for their survival, perform ecological interactions through which they respond to changes in the physical, chemical, and biological attributes of their ecosystem (Vasconcellos et al., 2013a). Thus, bioindicators are able to illustrate the degree of degradation and/or recovery of an ecosystem, the stage of ecological succession, habitat contamination, and climate change (Ertiban, 2019) through changes in the activity and richness of species in an ecosystem.

In this context, soil invertebrates have great potential as bioindicators (Ertiban, 2019) and can be considered an important parameter for soil quality assessment (Spiller et al., 2018), as they can act directly or indirectly on various edaphic processes, including soil aggregation, nutrient cycling, and biological cycles (Marsden et al., 2019). In addition, the soil

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invertebrate community is capable of responding to changes in abiotic factors such as solar radiation, soil temperature, and water content, which vary according to seasonality, through changes in their distribution and composition in their unique environments (Marx et al., 2012; Coyle et al., 2017).

Municipal natural parks (MNPs) fall under the category of CU. In addition to protecting the species within them, they promote the preservation of natural ecosystems of great ecological relevance and scenic beauty. These parks also provide education, recreation, and contact with nature, especially in regions of rapid urban expansion, such as Nilópolis, RJ (SOMADS, 2011). The Gericinó Municipal Natural Park (GMNP) is located in this municipality, and features anthropic fields as the main typology. This area is characterized by a high degree of anthropization, mainly affecting several species of grasses, some isolated trees and shrubs (SOMADS, 2011), in addition to fragments of a flooded forest comprised *Tabebuia cassinoides* (Lam.) DC trees. *Tabebuia cassinoides* forests account for more than 89 % of the total density of the tree community and is represented by individuals of the species (Pinto-sobrinho & Souza, 2012). This species, which is endemic to Brazil, occupies areas of Organosols and hydromorphic soils in southeastern states because its best development occurs in areas with groundwater oscillation (CNCFlora, 2019).

Tabebuia cassinoides is included in the IUCN's Red List of Threatened Species at the level "endangered (EN)"; thus its handling, cutting, marketing, processing, and transportation are prohibited (CNCFlora, 2019). This reflects the great economic interest that the species has aroused due to its anatomical characteristics and exceptional workability of its wood (Rachwal & Curcio, 2001). In fact, the wood of *T. cassinoides* ranks second in the world for the production of pencils, clogs, musical instruments, toys, and crafts (CNCFlora, 2019). As a result, *T. cassinoides* forests are currently restricted to only 2 % of their original area in the state of Rio de Janeiro, most of which is located at national or regional CU´s (Rachwal & Curcio, 2001).

This study was carried out based on the hypothesis that the functionality of the soil invertebrate faunal community changes according to the conditions of the environment. The objective of this study was to evaluate the ecology of invertebrate communities in the soil of a *T. cassinoides* forest and of anthropic fields, which are the most predominant environments of the Gericinó Municipal Natural Park, RJ.

2. MATERIAL AND METHODS

2.1. Description of the study area

The study was conducted in the Gericinó Municipal Natural Park (GMNP), located in the municipality of Nilópolis, a metropolitan region of the state of Rio de Janeiro, Brazil (22°49' S, 43°25' W). The park has a total area of approximately 100 ha, about 1 km from the Gericinó-Mendanha Environmental Protection Area (EPA), which is part of the Atlantic Forest Biosphere Reserve, within the United Nations Educational, Scientific, and Cultural Organization (UNESCO) (SOMADS, 2011). The surrounding environment is highly urbanized and exerts great expansion pressure on the park (Figure 1).
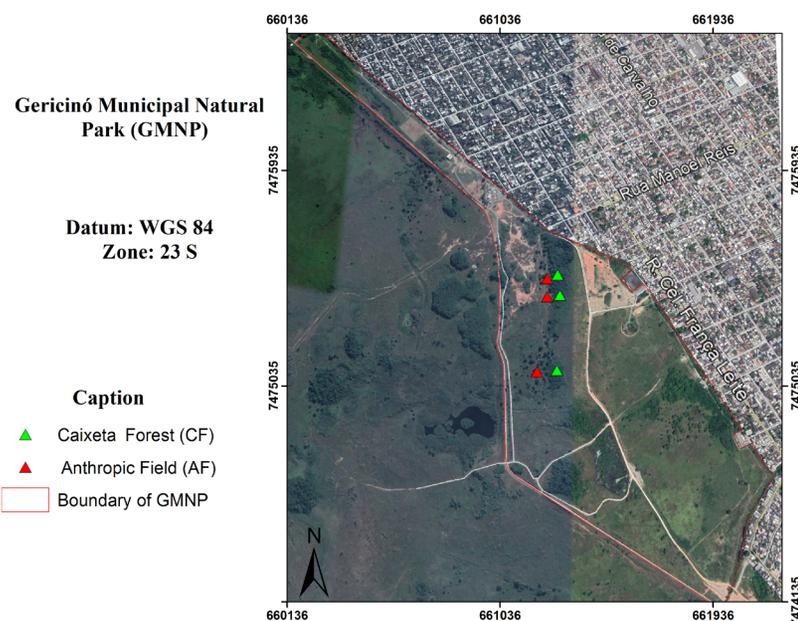

Figure 1. Area of the Gericinó Municipal Natural Park with highly urbanized environment in the Metropolitan Region of Rio de Janeiro.

The local climate, according to the Köppen classification, is type Aw (Alvares et al., 2013). In 2018 (the year of sampling), the average temperature was 26.6 ºC with a total precipitation of 930 mm in the rainy season (October to March). Meanwhile, in the dry season (April to September), the average temperature was 22.8 °C with a total precipitation of 303 mm (INMET, 2019). The park is mostly in lowland areas (13 – 47 m above sea level) (SOMADS, 2011), with predominantly Planossolo Háplico (Planosol) and Gleissolo Háplico (Gleysol) (Santos et al., 2018). The flow of water from the Guanabara watershed is artificially drained to the park, mainly during the rainy season (October to March). As a result, the drain has intermittent characteristics with significant water accumulation in the rainy season and no water depth in the dry period (April to September). Due to this characteristic, flooded forests with a predominance of *T. cassinoides* have developed at some points along the drainage bed, whose internal regions have notable water depth in the rainy season (Figure 2A and 2B).
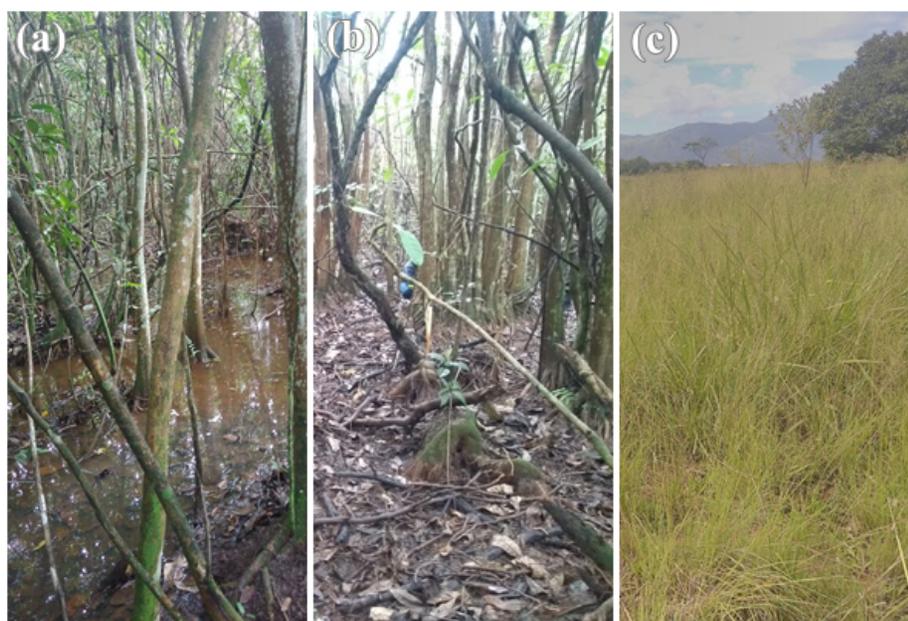

Figure 2. Study areas. (a) *Tabebuia cassinoides* forest with presence of water in the rainy season. (b) *Tabebuia cassinoides* forest in the dry season with no water. (c) Anthropic field with predominance of *Andropogon bicornis* L. located 20 m from the *T. cassinoides* forest.

In this context, three *T. cassinoides* forest fragments (CF) were selected, with areas of 406 m², 457 m², and 652 m², each setting as a repetition. In these fragments, a previous survey of tree individuals with diameter at breast height (DBH) ≥ 5 cm was carried out in two 10 × 10 m plots, and a percentage higher than 89 % of *T. cassinoides* was recorded for all fragments.

In addition, we selected three areas of anthropic field (AF), the typology that makes up the majority of the landscape in the park, each arranged in parallel and distanced 20 m from one of the *T. cassinoides* forests. This type of environment has herbaceous cover with a predominance of *Andropogon bicornis* L. (Figure 2C) and typically experiences natural fires, especially at the beginning of the dry season.

Table 1 presents the soil chemical characteristics and soil surface layer particle size (0-5 cm) in the study areas.

Table 1. Characterization of the soil chemical fertility, soil particle size, and humidity of *T. cassinoides* forest (CF) and anthropic field (AF) fragments at Gericinó Municipal Natural Park, RJ, Brazil.

Study area	pH H$_2$0	Ca^{+2}	Mg^{+2}	Al^{+3}	H+Al	K	P	TOC	Sand*	Silt*	Clay*	Humidity
		--------cmol$_c$ dm^{-3}----------				-mg dm^{-3}-		----------g kg^{-1}------------				%
CF	4.5	3.7	2.3	1.7	15.4	134.3	7.7	114.3	-	-	-	119.0
AF	4.8	1.4	1.6	1.0	3.9	64.4	5.4	16.6	530.7	140.7	322.	24.3

Ca^{+2}, Mg^{+2}, Al^{+3}: extractor KCl 1 mol L^{-1}; H+Al: extractor C$_4$H$_6$O$_4$Ca at pH 7; K and P: extractor Mehlich 1. TOC: total organic carbon. Values obtained from five simple samples of 0-5 cm depth, collected in January 2018. *Analysis not performed on organic soil samples (≥ 80 g kg^{-1} of organic carbon).

2.2. Sampling of invertebrate soil fauna

To capture the fauna, pitfall traps were used. These consisted of plastic and cylindrical containers approximately 10 cm in diameter and 10 cm in height, with a volumetric capacity of 750 mL, which were filled with preservative solution (4 % formaldehyde). A plastic sheet supported by wooden piles was placed over each trap to prevent dilution and/or overflow of the preservative solution after rain. The traps were installed in small holes dug in the ground, randomly distributed in each area. The traps were buried until their openings were at the same level as the ground surface, with a minimum distance of 10 m among the traps in each repetition.

Due to the presence of water in the CF area, the traps were installed in small mounds formed by the roots of *T. cassinoides*, always seeking the center of the plot in order to avoid the edge effect. The soil invertebrate fauna was sampled during the rainy season (between January 31st and February 7th) and the dry season (between the 4th and 11th of August) in 2018. In each period, five traps were set per plot, totaling 15 traps per treatment.

Traps remained in the areas for seven days prior to their collection. After this period, they were removed from the ground and sent to the laboratory for sorting and storage of the collected material. The classification of organisms into large taxonomic groups (class, order, and family) was performed under binocular magnifying glass. The organisms were then further classified into functional groups or trophic guilds, namely, predator, saprophagous, herbivorous, microphagous/saprophagous, and saprophagous/predator (Table 2).

Table 2. Classification of the soil invertebrate taxonomic groups into functional groups.

Functional group	Taxonomic group
Predator	Araneae, Chilopoda, Hymenoptera, Opilionidae
Saprophagous	Blattaria, Enchytraeidae, Isopoda, Psocoptera, Diplopoda, Thysanura
Herbivorous	Auchenorrhyncha, Diptera, Heteroptera, Orthoptera, Sternorrhyncha
Microphagous/ Saprophagous	Entomobryomorpha, Poduromorpha, Symphypleona
Saprophagous/ Predator	Acari, Coleoptera, Formicidae, Isoptera, Coleoptera larvae, Diptera larvae, Lepidoptera larvae, Thysanoptera

Source: Camara et al. (2018)

2.3. Data analysis

The values of activity (ind trap^{-1} day^{-1}) and richness (number of taxonomic groups), as well as Shannon diversity and Pielou evenness indexes were estimated for each environment in

each season. The Shannon diversity index (H') was estimated according to equation 1, while the Pielou evenness index (J) was estimated according to equation 2.

$$H' = -\Sigma pi \times \log pi \qquad \text{(Eq. 1)}$$
$$J = H' / \log S \qquad \text{(Eq. 2)}$$

Where $pi = ni / N$; ni is the importance value of each species or taxonomic group; N = total values of importance; and S = number of taxonomic species or groups.

After analyzing normality and homoscedasticity, the data were subjected to analysis of variance (ANOVA), assuming a completely randomized design. The averages were then evaluated with an F test (p <0.05) and, when necessary, were compared using the Bonferroni test (p <0.05), using the R software (Team, R. Core, 2020). Subsequently, principal component analysis (PCA) was performed to verify the relationships between the activity of the functional groups, the ecological index values, and the environments in the different periods. In addition, the degree of similarity between the environments was evaluated within each climatic season. This was done whilst considering the activity of all groups of invertebrate fauna in the soil (data without normal distribution) by non-metric multidimensional scaling (N-MDS) and the application of the Bray-Curtis distance. Both multivariate statistical analyses were performed using version 2.17c of the PAST software (Hammer et al., 2001).

3. 3. RESULTS

In both areas, there were no significant differences in Shannon diversity (H´) or Pielou evenness (J) indexes as a function of the season (Table 3). However, in the anthropic field (AF), both total activity and richness were more significant in the rainy season.

Table 3. Activity (ind trap^{-1} day^{-1}), richness, Shannon diversity (H') index, and Pielou evenness (J) index of the soil invertebrate community in the *T. cassinoides* forest and anthropic field, during the rainy and dry seasons, at Gericinó Municipal Natural Park, RJ, Brazil.

Season	Activity	Richness	H'	J
Tabebuia cassinoides forest				
Rainy	6.55± 1.16 a	7.27± 0.17 a	2.54± 0.09 a	0.67± 0.02 a
Dry	4.48± 0.89 a	7.10± 0.88 a	2.42± 0.06 a	0.65± 0.02 a
Anthropic field				
Rainy	26.94± 6.32 a	9.45± 0.68 a	2.46± 0.05 a	0.61± 0.01 a
Dry	8.68± 2.04 b	7.08± 0.33 b	2.07± 0.14 a	0.57± 0.04 a

Averages followed by different letters in the column differ significantly from each other (p <0.05) by ANOVA.

The soil invertebrate faunal organisms were distributed into 27 taxonomic groups (Table 4). Overall, the predominant groups in all areas and in both seasons were

Acari, Entomobryomorpha, Formicidae, Poduromorpha, and Symphypleona. The percentage participation of these taxonomic groups in the community varied widely, depending on the area and season. In the rainy season, Poduromorpha was most dominant in the CF area (approximately 35 % of the total community), and Symphypleona in the AF area (31 %). However, in the dry season, the Entomobryomorpha taxonomic group predominated in both areas (54 % of the total community in the CF area and 35 % in the AF area). In addition, there was a well-defined pattern for Acari, the percentage of which was higher in the AF area, in the rainy (12 % of the total community) and dry (22 % of the total community) seasons, in relation to the CF area (4 % and 8 %, respectively).

Table 4. Activity (ind trap^{-1} day^{-1}) of the taxonomic groups of the soil invertebrate community in the *T. cassinoides* forest (CF) and anthropic field (AF), in the rainy and dry seasons, at Gericinó Municipal Natural Park, RJ, Brazil.

Taxonomic group	CF	AF	CF	AF
	Rainy season		Dry season	
Acari	0.23± 0.08	4.24± 1.02	0.35± 0.14	2.78± 0.57
Araneae	0.19± 0.07	0.20± 0.06	0.24± 0.08	0.15± 0.04
Auchenorrhyncha	-	0.21± 0.08	-	0.03± 0.01
Blattaria	0.01± 0.01	-	-	-
Chilopoda	-	-	-	0.01± 0.01
Coleoptera	0.10± 0.05	0.19± 0.04	0.16± 0.06	0.08± 0.03
Diplopoda		0.22± 0.08	0.01± 0.01	0.02± 0.01
Diptera	0.36± 0.14	0.42± 0.12	0.06± 0.03	0.15± 0.06
Enchytraeidae	0.03± 0.02	-	0.01± 0.01	-
Entomobryomorpha	1.63± 0.40	8.73± 1.74	2.37± 0.47	4.37± 0.08
Formicidae	0.64± 0.20	1.92± 0.40	0.14± 0.06	1.31± 0.30
Heteroptera	-	0.03± 0.02	-	0.02± 0.01
Hymenoptera	0.04± 0.03	0.07± 0.02	0.07± 0.04	0.23± 0.03
Isopoda	0.05± 0.03	0.01± 0.01	-	0.10± 0.03
Isoptera	0.01± 0.01	0.01± 0.01	-	-
Coleoptera larvae	0.03± 0.02	0.01± 0.01	0.06± 0.03	-
Diptera larvae	-	-	0.13± 0.10	0.01± 0.01
Lepidoptera larvae	0.01± 0.01	0.01± 0.01	-	0.02± 0.01
Oligochaeta	0.01± 0.01	0.01± 0.01	-	-
Opilionidae	-	-	0.03± 0.02	0.01± 0.01
Orthoptera	0.03± 0.02	0.10± 0.03	0.04± 0.04	0.04± 0.02
Poduromorpha	2.32± 0.67	6.87± 2.23	0.42± 0.16	3.10± 1.19
Psocoptera	-	-	0.01± 0.01	0.01± 0.01
Sternorrhyncha	0.04± 0.03	0.19± 0.03	0.04± 0.03	0.01± 0.01
Symphypleona	0.82± 0.41	10.74± 1.99	0.26± 0.18	0.13± 0.06
Thysanoptera	0.01± 0.01	0.14± 0.03	0.01± 0.01	0.01± 0.01
Thysanura	-	0.10± 0.01	-	-

The individuals of the Enchytraeidae (rainy and dry seasons) and Blattaria (rainy season) groups were exclusive to the CF area, while Auchenorrhyncha, Chilopoda, Heteroptera, and Thysanoptera were recorded only in the AF area (Table 4). Furthermore, individuals from the Blattaria, Isoptera, Oligochaeta, and Thysanura groups were recorded only in the rainy season, while the Chilopoda, Diptera larvae, Opilionidae, and Psocoptera groups were observed only in the dry season.

The microphagous/saprophagous (M/S) functional group presented the highest level of activity, regardless of the plot and climatic season (Table 5). However, in AF during the dry season, its activity was similar to that of the saprophagous/predator (S/P) group. Both groups showed similar behavior in the CF, yet in the AF, the M/S group was the only one to differ between seasons (Table 5). Moreover, it is noteworthy to mention that the predator (P), saproghagous (S), and herbivorous (H) groups did not differ with season or environment.

Table 5. Activity (ind trap^{-1} day^{-1}) of the functional groups of the soil invertebrate community in the *T. cassinoides* forest (CF) and anthropic field (AF), during the rainy and dry seasons, at Gericinó Municipal Natural Park, RJ, Brazil. Where S/P: saprophagous/predator; M/S: microphagous/saprophagous; P: predator; S: saprophagous; and H: herbivorous.

Functional group	CF		AF	
	Rainy season	Dry season	Rainy season	Dry season
S/P	1.03 ± 0.36 Ba	0.72 ± 0.30 Ba	6.53 ± 2.02 Ba	4.21 ± 1.22 Aa
M/S	4.77 ± 1.48 Aa	3.05 ± 0.81 Aa	26.35 ± 7.95 Aa	7.59 ± 2.74 Ab
P	0.23 ± 0.09 Ba	0.34 ± 0.14 Ba	0.27 ± 0.11 Ba	0.40 ± 0.11 Ba
S	0.10 ± 0.07 Ba	0.12 ± 0.20 Ba	0.24 ± 0.12 Ba	0.13 ± 0.07 Ba
H	0.43 ± 0.19 Ba	0.14 ± 0.10 Ba	0.95 ± 0.38 Ba	0.24 ± 0.15 Ba

Averages followed by different capital letters in the column differ significantly from each other (p <0.05) by the Bonferroni test. Averages followed by different lowercase letters in the same line for the same area, differ significantly from each other (p <0.05) by ANOVA.

In the principal component analysis (Figure 3), the activity of functional groups and ecological indexes (variables) were separated into two coordinates (60.70 % for coordinate 1 and 36.90 % for coordinate 2), which explained 97.60 % of the total variability between CF and AF in relation to season.
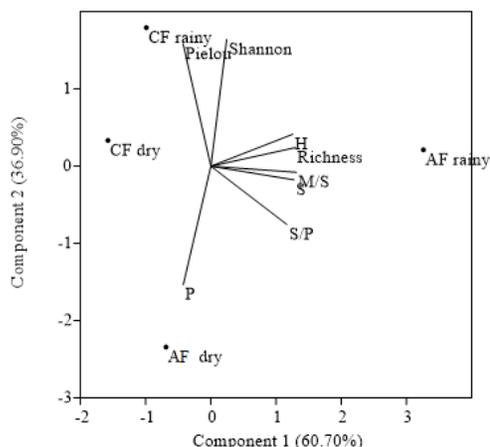

Figure 3. Principal component analysis of the activity of functional groups and ecological indexes. Where: CF – *T. cassinoides* forest; AF – anthropic field; rainy – rainy season; dry – dry season; S/P – saprophagous/predator; M/S – microphagous/saprophagous; P – predator; S – saproghagous; H – herbivorous; Shannon – Shannon diversity index; and Pielou – Pielou evenness index.

The anthropic field in the dry season (AF dry) presented an order opposite to the other areas according to coordinate 1 (main coordinate). However, the second coordinate segregated the anthropic field in the rainy season (AF rainy) (Figure 3). The AF area was associated with the richness and activity of the herbivorous functional group during the rainy season, while in this same period, the CF area was associated with evenness. Moreover, the functional group of predators had a higher association with AF in the dry season (Figure 3).

According to the non-metric multidimensional scaling (N-MDS), the two axes explained 81 % of the total data variability in the ordering diagram, due to the activity of soil invertebrate fauna being 63 % and 18 % for axis 1 and 2, respectively (Figure 4).
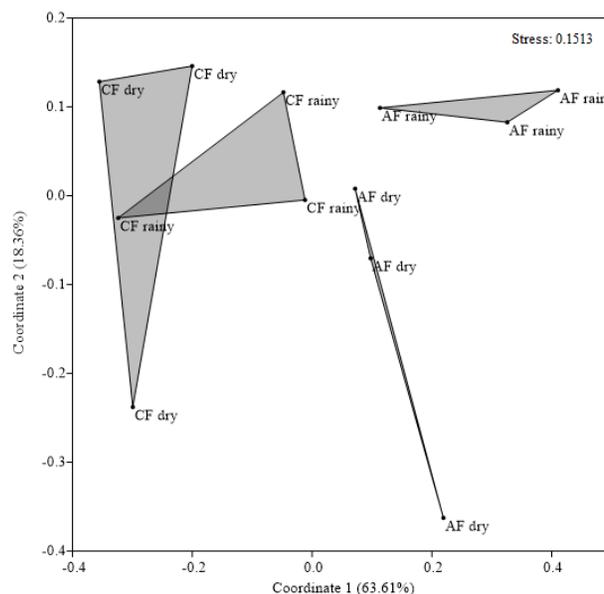

Figure 4. Ordering diagram of the activity of invertebrate fauna of the soil by non-metric multidimensional scaling (N-MDS). Where: CF.rainy – *T. cassinoides* forest rainy season; CF.dry – *T. cassinoides* forest dry season; AF.rainy – anthropic field rainy season; AF.dry – anthropic field dry season.

Greater data dissimilarity was observed in the AF (Figure 4). This greater dissimilarity was more expressive in coordinate 1, and the difference between the AF in the different study periods is evident. However, in coordinate 2 there was no difference between the environments (Table 6), which can be explained by the smaller axis variation.

Table 6. Coordinates 1 and 2 obtained by the N-MDS in relation to the activity of the soil invertebrate community in the *T. cassinoides* forest (CF) and anthropic field (AF), in the rainy and dry seasons.

Study area	Coordinate 1	Coordinate 2
CF rainy	-0.13± 0.09 c	0.03± 0.04 a
AF rainy	0.28± 0.08 a	0.10± 0.01 a
CF dry	-0.28± 0.04 c	0.01± 0.12 a
AF dry	0.13± 0.04 b	-0.14± 0.11 a

Averages followed by different letters in the column differ significantly from each other (p <0.05), by the Bonferroni test.

4. DISCUSSION

The effect of seasonality on the soil invertebrate community occurs most significantly in the activity and richness of individuals, especially in the AF. These results may be justified by the greater structural complexity of the environment provided by the vegetation cover in the CF area, which generates more appropriate microclimate conditions for the soil faunal community, which involves lower light and higher humidity (Marx et al., 2012). This same pattern in relation to lower availability of light and higher water content was found in other studies, where the Shannon diversity index (Vasconcellos et al., 2013b; Silva et al., 2016) and Pielou evenness index (Silva et al., 2016) values did not vary as a function of seasonality.

The soil invertebrate community showed higher levels of activity and higher richness values in the AF area during the rainy season. Natural fires occurring in the dry season are likely to have influenced these results. This justifies the absence of exclusive AF taxonomic groups in the dry season, as the vast majority of soil invertebrates are extremely sensitive to high temperature and low humidity (Vestergård et al., 2015). In addition, it is likely that the soil water content in this environment was higher in the rainy season, a condition that would be more favorable to the community as a whole.

Organisms such as Entomobryomorpha, Poduromorpha, and Shymphypleona (M/S), which showed greater activity levels in the study, are directly associated with higher soil water content, which favors the reproduction and survival of these organisms that are adapted to this type of environment (Marx et al., 2012). They perform vertical and horizontal soil migrations to avoid drought and arrive at areas where soil water content is higher (Oliveira Filho & Baretta, 2016). These organisms are more sensitive than others to microclimate modifications and may or may not be favored in certain environments (Bartz et al., 2014).

The Acari group, for example, is sensitive to soil moisture (Sylvain et al., 2014). Some studies indicate that this group declines in population during drought periods, and is not as responsive to low humidity (Tsiafouli et al., 2005; Vestergård et al., 2015). Moreover, the Formicidae group has ecological and biological characteristics, making them sensitive to the environment in which they play multiple roles in regulating ecological processes (Peters et al., 2016). Ants represent a third of the total biomass of insects, are highly active in the soil and move about in groups, facilitating their collection (Harada et al., 2013), thereby justifying their predominance.

The Enchytraeidae and Blattaria groups are represented by saprophagous (S) organisms, which are associated with higher soil organic matter (Table 1) content and favor the activity of decaying microbiota, with consequent nutrient cycling from the litter to the soil (Schmelz et al., 2013). The high water table level in the soil during the rainy season in CF probably influenced the migration of Enchytraeidae individuals closer to the soil surface, which allowed their capture by traps, which is not typical.

The Auchenorrhyncha and Heteroptera groups, belonging to the taxonomic group of herbivores, occurred only in AF. The exclusive presence of these groups may be related to the higher luminosity (Santos & Cabreira, 2019) and food availability (Ali & Agrawal, 2012) in AF due to the lower proportion of forest cover and higher grass density.

The main pattern of certain functional groups and ecological indexes of the soil faunal community reported above were corroborated by principal component analysis. In fact, the explanation for 97.6 % of the data variability concluded by this analysis (Figure 3) indicated a high correlation between the activity of functional groups and the ecological indexes considered. Although the anthropic field during the rainy season (AF rainy) presented a higher correlation with most variables, in this environment there was high dissimilarity due to seasonality.

It is noteworthy to mention that the predator group (P) presented a negative correlation in relation to the other variables. Naturally occurring fires, which cause direct and/or indirect effects on the soil, affecting the invertebrate soil community (Coyle et al., 2017) may justify the greater correlation of predators with AF in the dry season. Assessing changes in the trophic chain of the faunal community after controlled burning, Gongalsky et al. (2012) recorded a predominance of the predator group, while groups such as Acari presented higher mortality, indicating that predators have a higher tolerance to fire. The same authors also observed that the activity of invertebrate fauna groups is a variable that is more sensitive than richness, a result that corroborates this study.

Invertebrate soil communities play a key role in nutrient cycling as they accelerate organic matter decomposition processes, increasing nutrients to plants, and improving soil health (Sofo et al., 2020). However, humidity is a key factor in the activity of this community, especially during periods of hypoxia or anoxia (Coyle et al., 2017) caused by the rise of the water table. Therefore, moisture is an essential factor in the different dynamics that occur in the soil, acting directly on different chemical reactions and invertebrate metabolism, while regulating nutrient availability in the soil solution (Rosa et al., 2015).

The environmental variations between climatic periods influence the groups of invertebrate fauna of the soil (Silva et al., 2013), as observed in the N-MDS. These variations are directly related to the greater structural complexity of

the environment provided by the vegetation cover in the CF area, which provides less light and more humidity. This in turn generates microclimate waves more suitable for the edaphic faunal community (Marx et al., 2012), thereby reducing climatic variability.

5. CONCLUSIONS

Periodically flooded areas such as the *T. cassinoides* forest, favored taxonomic groups such as Enchytraeidae and Blattaria, which represent the saprophagous trophic guild.

Meanwhile, anthropic field areas favored taxonomic groups such as Auchenorrhyncha, Chilopoda, Heteroptera, and Thysanoptera; individuals of the trophic guild of predators and herbivores.

Furthermore, we concluded that soil fauna present in forest environments present less variability in climatic seasonality, in comparison to those in anthropic fields.

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REFERENCES

Ali JG, Agrawal AA. Specialist versus generalist insect herbivores and plant defense. Trends in Plant Science 2012; 17(5): 293-302.

Alvares CA, Stape JL, Sentelhas PC, Gonçalves JLM, Sparovek G. Köppen's climate classification map for Brazil. Meteorologische Zeitschrift 2013; 22: 711-728.

Bartz MLC, Brown GG, Orso R, Mafra AL, Baretta D. The influence of land use systems on soil and surface litter fauna in the western region of Santa Catarina. Revista Ciência Agronômica 2014; 45: 880-887.

Camara R, Santos GLD, Pereira MG, Silva CFD, Silva VFV, Silva RM. Effects of natural Atlantic Forest regeneration on soil fauna, Brazil. Floresta e Ambiente 2018; 25(1).

CNCFlora - Centro Nacional de Conservação da Flora. *Tabebuia cassinoides* in Lista Vermelha da flora brasileira. [cited 2019 jun 20]. Available from: http://cncflora.jbrj.gov.br/portal/pt-br/profile/Tabebuia cassinoides.

Coyle DR, Nagendra UJ, Taylor MK, Campbell JH, Cunard CE, Joslin AH et al. Soil fauna responses to natural disturbances, invasive species, and global climate change: current state of the science and a call to action. Soil Biology and Biochemistry 2017; 110: 116–133.

Ertiban SM. Soil Fauna as Webmasters, Engineers and Bioindicators in Ecosystems: Implications for Conservation Ecology and Sustainable Agriculture. American Journal of Life Sciences 2019; 7(1): 17-26.

Gongalsky KB, Malmström A, Zaitsev AS, Shakhab SV, Bengtsson J, Persson T. Do burned areas recover from inside? An experiment with soil fauna in a heterogeneous landscape. Applied Soil Ecology 2012; 59: 73–86.

Hammer, Harper DAT, Ryan PD. PAST: Paleontological statistics software package for education and data analyses. Palaeontologia Electronica 2001; 4: 1-9.

Harada AY, Farias PRS, Lopes LFC, Silva, AG, Brandão ADS. Assessment of ant communities in secondary forest in the eastern Amazon. Comunicata Scientiae 2013; 4:186-194.

INMET - Instituto Nacional de Meteorologia. [cited 2019 jun 20]. Available from: http://www.inmet.gov.br/portal/index.php?r=bdmep/bdmep

Marsden C, Martin-Chave A, Cortet J, Hedde M, Capowiez Y. How agroforestry systems influence soil fauna and their functions-a review. Plant and Soil 2019; 1-16.

Marx MT, Guhmann P, Decker P. Adaptations and predispositions of different middle European Arthropod Taxa (Collembola, Araneae, Chilopoda, Diplopoda) to flooding and drought conditions. Animals 2012; 2: 564-590.

Nowrouzi S, Andersen AN, Macfadyen S, Staunton KM, VanDerWal J, Robson SK. Ant diversity and distribution along elevation gradients in the Australian wet tropics: the importance of seasonal moisture stability. *PloS one* 2016; 11(4).

Oliveira Filho ILC, Baretta D. Por que devemos nos importar com os colêmbolos edáficos? Scientia Agraria 2016; 17: 21-40.

Pinto Sobrinho FA, Souza CRG. Composição florística e estrutura do componente arbóreo de uma Floresta Paludosa na planície costeira da bacia do rio Itaguaré, Bertioga, SP, Brasil. Revista do Instituto Florestal 2012; (1):51-66.

Peters VE, Campbell KU, Dienno G, García M, Leak E, Loyke C et al. Ants and plants as indicators of biodiversity, ecosystem services, and conservation value in constructed grasslands. Biodiversity Conservation Journal 2016; 25(8): 1481-1501.

Pompeo PN, Oliveira Filho LCI, Klauberg Filho O, Mafra AL, Baretta CRDM, Baretta D. Diversidade de Coleoptera (Arthropoda: Insecta) e atributos edáficos em sistemas de uso do solo no Planalto Catarinense. Scientia Agraria 2016; 17(1):16-28.

R Development Core Team. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, 2020.

Rachwal MFG, Curcio GR. Atributos pedológicos e ocorrência de caixeta no litoral paranaense, Brasil. Scientia Forestalis 2001; 59: 153-163.

Rosa MG, Filho OK., Bartz MLC, Mafra AL, Sousa JPF, Baretta D. Soil macrofauna and physical and chemical properties under soil management systems in the Santa Catarina Highlands, Brazil. Revista Brasileira de Ciência do Solo 2015; 39: 1544–1553.

Santos RN, Cabreira WV. Densidade da fauna invertebrada da serapilheira em função do efeito de borda de diferentes áreas de reflorestamento. Enciclopédia Biosfera. 2019; 16(30): 174-185.

Santos HG Dos, Jacomine PKT, Anjos LHC dos, Oliveira VA de, Lumbreras JF, Coelho MR, Almeida JA de, Cunha TJF, Oliveira JB de. 2018. Sistema Brasileiro de Classificação de Solos. Embrapa: 5ed, 353p.

Schmelz RM, Niva CC, Römbke J, Collado R. Diversity ofterrestrial Enchytraeidae (Oligochaeta) in Latin America: Current knowledge and future research potential. Applied Soil Ecology 2013; 69: 13–20.

Silva CF, Pereira GHA, Pereira MG, Silva AN. Fauna edáfica em área periodicamente inundável na restinga da Marambaia, RJ. Revista Brasileira de Ciência do Solo 2013; 37: 587-595.

Silva MSC, Correia MEF, Silva EMR, Maddock JEL, Pereira MG, Silva CF. Soil Fauna Communities and Soil Attributes in the Agroforests of Paraty. Floresta e Ambiente 2016; 23(2): 180–190.

Sofo A, Mininni A N, Ricciuti P. Soil Macrofauna: A key Factor for Increasing Soil Fertility and Promoting Sustainable Soil Use in Fruit Orchard Agrosystems. Agronomy 2020; 10(4): 456.

SOMADS - Secretaria de obras, urbanismo, meio ambiente e desenvolvimento sustentável. Plano de Manejo Participativo do Parque Natural Municipal de Gericinó. Nilópolis. 2011.

Spiller MS, Spiller C, Garlet J. Arthropod bioindicators of environmental quality. Agro Ambiente 2018; 12: 41-57.

Sylvain ZA, Wall DH, Cherwin KL, Peters DPC, Reichmann LG, Sala OE. Soil animal responses to moisture availability are largely scale, not ecosystem dependent: insight from a cross-site study. Global Change Biology 2014; 20: 2631-2643.

Thakur MP, Reich PB, Hobbie SE, Stefanski A, Rich R, Rice KE et al. Reduced feeding activity of soil detritivores under warmer and drier conditions. Nature Climate Change 2018; 8: 75–78.

Tsiafouli MA, Kallimanis AS, Katana E, Stamou GP, Sgardelis SP. Responses of soil microarthropods to experimental short-term manipulations of soil moisture. Applied Soil Ecology 2005; 29: 17–26.

Usman S, Muhammad Y, Maigana AC. Roles of soil biota and biodiversity in soil environment – A concise communication. Eurasian Journal of Soil Science 2016; 5(4): 255 – 265.

Vasconcellos RLF, Bonfim JA, Andreote FD, Mendes LW, Baretta D, Cardoso EJBN. Microbiological indicators of soil quality in a riparian forest recovery gradient. Ecological Engineering 2013a; 53: 313–320.

Vasconcellos RLF, Bonfim JA, Andreote FD, Mendes LW, Baretta D, Cardoso EJBN. Soil macrofauna as an indicator of soil quality in an undisturbed riparian forest and recovering sites of different ages. European Journal of Soil Biology 2013b; 1(58): 105-112.

Vestergård AM, Dyrnum K, Michelsen A, Damgaard C, Holmstrup M. Longterm multifactorial climate change impacts on mesofaunal biomass and nitrogen content. Applied Soil Ecology 2015; 92: 54–63.