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Changes in Land Use through *Eucalyptus* Plantations Impact Soil Fauna Communities in Brazilian Savannas

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Abstract: Soil fauna is responsible for one-quarter of all species on Earth, and these organisms play crucial roles in many ecosystem functions and services; however, these communities are facing several threats related to human activities, especially in the Cerrado ecoregion, the second largest biome. We aimed to evaluate the soil mesofauna communities in a native savanna (Cerrado) and two l eucalyptus stands to verify differences and infer possible impacts on soil mesofauna abundance and diversity through land-use changes, as well as find correlations between soil chemical parameters and soil mesofauna groups. Pitfall traps were installed in each one of the 12 plots per land-use type to evaluate soil mesofauna abundance and diversity in the dry and rainy seasons, and soil chemical analyses were performed at 0–20 and 20–40 cm depth per plot. We found that Collembola, Isoptera, and Diptera during the dry season collections, and Formicidae, Isoptera, and Diptera in the rainy season collection were more abundant in the Cerrado. The eucalyptus plantations have reduced the abundance of these groups, in addition to also representing a possible loss of biodiversity promoted by these monocultures. The organic matter, Potassium, Calcium, Phosphorous, and pH contents can be used as good soil mesofauna indicators in the Cerrado.

Keywords: soil mesofauna; Cerrado; soil chemistry

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1. Introduction

In the last centuries, land-use change activities have intensified to provide food, feed, energy, and fibers in order to meet the increasing demand caused by the expansion of the human population. These activities also resulted in major changes in the biogeophysical properties of the Earth's surface, with impacts on the climate, biogeochemical cycling, and habitat for biodiversity [1]. These processes are also manifested in the soil, with changes in the dynamics of soil fauna populations, generating negative effects on soil quality [2,3]. Soil's fauna is responsible for one-quarter of all species on Earth, and these organisms play crucial roles in many ecosystem functions and services; however, these communities are facing threats related to human activities [4].

In this context of anthropic land-use changes, the Brazilian savanna (Cerrado), which is the second-largest biome in South America, covering nearly 21% (~1.8 million km^2) of Brazil's territory, is one of the world's hotspots for biodiversity conservation due to high species endemism and rampant human threat [5,6]. Over 20,400 km^2 of native Cerrado were suppressed between 2017 and 2019 [7], and less than half of the original land covered by Cerrado ecosystems is still conserved [8], reinforcing it as one of the most threatened biomes on the planet.

When evaluating the change in land use, it has been noticed that in the last ten years, the forestation has increased more than 5% per year, and about 60% of the plantations are of *Eucalyptus* spp. [9]. These changes alter nutrient cycles due to modifications above and below ground. The changes in vegetation composition, nutrient inputs, and outputs lead to changes in the composition and diversity of soil fauna [10,11]. In this context, eucalyptus monoculture has long been questioned about its effects on soil biodiversity, as it can alter the diversity and distribution of soil fauna species due to the reduction of variation in litter composition, which exerts a strong influence in the soil fauna communities, especially on endemic organisms that are particularly vulnerable to ecosystem disturbances [12,13]. Also, soil management directly affects soil fauna by the use of heavy machinery to soil tillage [14,15]. Meantime, studies suggest that eucalyptus commercial stands, compared to other monoculture systems, cause less impact for soil fauna communities [3,10,16].

With this trend of land-use changes, it is necessary to have a better understanding of the soil fauna communities' composition, since these organisms are responsible for several ecosystem services, such as the formation of biogenic structures, improving aggregate stability, hydraulic conductivity, and total porosity. Also, the soil fauna promotes the incorporation of soil organic matter by litter decomposition, an essential process of nutrient cycling and, consequently, for the ecosystems self-sustainability [17,18].

Little is known about the conservation status of most soil organisms [18] and studies on edaphic fauna in the Cerrado ecoregion are still scarce, mainly in natural ecosystems, since few existing studies have been carried out in silvopastoral and pasture systems [19–21]; one recent work approached the regenerative macrofauna in the Cerrado [22]. This condition reinforces the need for studies of the edaphic fauna in the Cerrado ecoregion, mainly in areas covered by native Brazilian savanna (known as Cerrado) and altered areas, such as eucalyptus plantations, especially because soil biodiversity and its ecosystem functions should be explicitly considered in the establishment of nature protection priorities and policies and when designing new conservation areas, due to the numerous process that are conducted by these organisms [18].

Also, the edaphic fauna diversity is considered a key aspect for maintaining the structure and fertility of tropical soils, especially in nutrient-poor soil as a major part of Cerrado that is covered by latossolos (oxisoils), presenting potentially faster responses than other soil attributes, therefore serving as biological indicators sensitive to ecological changes in agrosystems [22–25]. In this context, the study of possible impacts on soil mesofauna is extremely important to better understand the impacts of eucalyptus plantations in the Cerrado ecoregion.

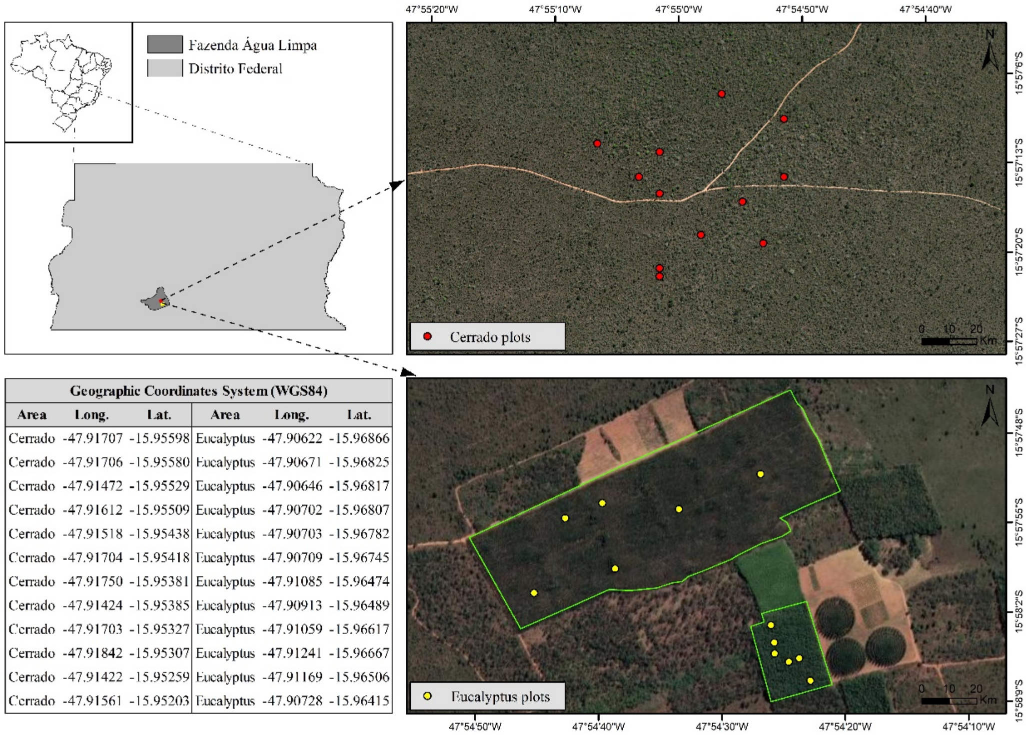
Thus, the present study aims to evaluate the edaphic community of mesofauna in Cerrado areas and eucalyptus plantations and their correlation to soil chemistry parameters, verifying possible changes in these communities due to the land-use changes. We aimed to respond to the following questions: (i) Do Cerrado and eucalyptus ecosystems differ in the diversity and abundance of mesofauna species? If so, does this difference change between rainy and dry seasons? (ii) Is there a relationship between soil chemistry and the soil mesofauna in the native Cerrado and eucalyptus stands? We hypothesized that (i) the diversity and abundance of soil mesofauna are lower in eucalyptus when compared to natural Cerrado and present changes trough dry and rainy seasons. (ii) Specific groups of soil mesofauna correlate to soil chemistry parameters.

2. Materials and Methods

2.1. Study Sites Description

The study was conducted at the University of Brasilia's experimental research station (Fazenda Água Limpa; 15°56′–15°59′ S and 47°55′–47°58′ W). The property covers >4.3 thousand hectares and it's inserted on Environmental Protection Area Gama and Cabeça-de-Veado, which is part of the Cerrado Biosphere Reserve. About 86% of the farm is preserved, and 45% of the land covered by native vegetation is classified as Cerrado sensu stricto. Of that 14% area left, 153.5 hectares are used for silviculture, mainly eucalyptus plantations. The region's climate is classified as AW according to Köppen's classification with well-defined dry (May to October—average values ranging from 3 to 13 mm) and rainy (November to April—average values ranging up to 219 mm) seasons. The mean annual precipitation is 1552 mm, where monthly means range from 9 mm in June to 249 mm in December [25]. Soils in the study site are mainly Oxisols [26] (U.S. soil classification system) or Red Latosols [27], characterized by high acidity and low nutrient (e.g., phosphorus-P) availability.

Two adjacent eucalyptus stands and a Cerrado area (less than 1 km apart from each other) were selected for this study. We randomly selected 12 20 m × 50 m plots following previously established protocols by [28], in a total of 1.2 hectares of native well conserved Cerrado sensu stricto were covered (Figure 1). The 12 sampling units present the following characteristics: basal area about ~13.11 m^2 ha^{-1}, ~156 woody individuals, and 36 woody species per plot [29]. To the best of our knowledge, an accidental fire occurred in 2011 within this area, which is a typical type of disturbance in Cerrado ecosystems in the Cerrado ecoregion in Central Brazil.



Geographic Coordinates System (WGS84)					
Area	Long.	Lat.	Area	Long.	Lat.
Cerrado	-47.91707	-15.95598	Eucalyptus	-47.90622	-15.96866
Cerrado	-47.91706	-15.95580	Eucalyptus	-47.90671	-15.96825
Cerrado	-47.91472	-15.95529	Eucalyptus	-47.90646	-15.96817
Cerrado	-47.91612	-15.95509	Eucalyptus	-47.90702	-15.96807
Cerrado	-47.91518	-15.95438	Eucalyptus	-47.90703	-15.96782
Cerrado	-47.91704	-15.95418	Eucalyptus	-47.90709	-15.96745
Cerrado	-47.91750	-15.95381	Eucalyptus	-47.91085	-15.96474
Cerrado	-47.91424	-15.95385	Eucalyptus	-47.90913	-15.96489
Cerrado	-47.91703	-15.95327	Eucalyptus	-47.91059	-15.96617
Cerrado	-47.91842	-15.95307	Eucalyptus	-47.91241	-15.96667
Cerrado	-47.91422	-15.95259	Eucalyptus	-47.91169	-15.96506
Cerrado	-47.91561	-15.95203	Eucalyptus	-47.90728	-15.96415

Figure 1. Study site's location in Brazil's Federal District, and the 12 plots randomly distributed within an area of preserved native Cerrado sensu stricto and two eucalyptus plantations at the University of Brasilia's research station.

The two eucalyptus stands differ in three years of age: The Mature stand (3.3 ha) was established in January 2010 and was eight years old when we started this experiment. *eucalyptus urophylla* ST Blake × *eucalyptus grandis* Hill ex-Maiden is the clone planted in the Mature stand, arranged in 3 m × 2 m spacing with soil tillage plowing down to 40 cm depth and fertilizer application along the planting line with 100 g of super simple phosphate in addition to 100 g of NPK (4-30-16). The Juvenile stand (23 ha) was planted in 2013 with a hybrid clonal planting: *eucalyptus grandis* × *eucalyptus urophylla* (GG 100), with 3 m × 3 m spacing. Before planting, subsoiling was performed up to 70 cm in depth and 600 kg ha^{-1} of super simple phosphate was applied. Fertilization was carried out in pits with 200 g per well of NPK (20-05-20) applied 15 cm away from the seedling with applications at fifteen days, two months, one year, and two years after planting. Six plots of 10 m × 10 m were randomly allocated in each one of the two eucalyptus stands for a more representative sampling of this type of land use, resulting in twelve plots (Figure 1).

2.2. Soil Mesofauna Abundance and Diversity

Soil mesofauna was evaluated during the dry (September) and rainy (January) seasons. Five fall plastic traps per plot randomly allocated (15 cm diameter) containing ~200 mL of water and 10 mL of colorless neutral detergent were used as described by [28] and left in the field for 48 h, after which they were collected and taken to the laboratory where all organisms were manually separated with the aid of a 0.125 mesh sieve and transferred to flasks containing absolute ethyl alcohol for fixation. Then, the organisms were identified at the highest possible taxonomic level (gender, order, or family whenever possible), using a magnifying lens and the assistance of taxonomic keys.

2.3. Soil Chemical Analyses

We collected four soil samples at two depths (0–20 cm; 20–40 cm) per plot and combined them into one sample per depth per plot. After the sampling, soils were air-dried in the shade and the dry soil samples were then analyzed according to [29], by the following methods: Active soil acidity pH (H_2O), Exchangeable aluminum (Al^{3+}), potential acidity (H^+ Al) by titration. Phosphorus (P) and potassium (K) by Mehlich-1 extractor, where the remaining P (Prem) was determined using molecular absorption spectrophotometer as well as calcium (Ca^{2+}) and magnesium (Mg^{2+}), and K by photometer of flame. Soil organic matter (OM) was determined by extraction and titration. For all samples, we calculated the total cation exchange capacity (CECt), effective cation exchange capacity (CECe), the sum of bases (SB), base saturation (V), and aluminum saturation (m).

2.4. Statistics

Soil mesofauna data were tabulated and the diversity was calculated by Shannon's diversity (h′) for each plot, and the treatments were compared using a *t*-test at 95% confidence. An analysis of similarities (Anosim) was performed comparing the soil mesofauna abundancy of groups in the two land uses and then complemented by a Simper analyses (a percentage similarity analyzes) to calculate the contribution of each species (%) to the dissimilarity between the two land-uses, where both analyses utilized the Bray–Curtis index. Also, soil mesofauna abundance data were tabulated and submitted to a multi variated analysis (Principal Component Analysis—PCA) comparing land use in the two collection seasons. Finally, in order to verify the correlation between edaphic fauna groups and soil chemical parameters, a redundancy analysis (RDA) was performed with the soil chemistry data considered as explanatory environmental variables and the collinear edaphic parameters have been removed from the statistical model.

3. Results

3.1. Diversity in Rainy and Dry Seasons

We found that soil mesofauna abundance and diversity changed between Cerrado and eucalyptus areas, with a reduction of some species in the planted ecosystems, corroborating with several studies [2,3,23] that also found this trend of the reduction of some soil fauna groups via land-use changes.

A total of 12,917 soil mesofauna individuals were collected during the dry and rainy seasons and separated into thirty-one broad taxonomic groups. In the Cerrado area, Isoptera was the most dominant group in both seasons, contributing with 42.4% and 37.1% in rainy and dry seasons, respectively. Formicidae was the second most abundant group, contributing with 17.2 and 46.2% in rainy and dry seasons, respectively. While in the eucalypt stands, Formicidae was the most dominant group, contemplating more than half of the collected individuals in booth seasons (63.6% and 56.6%, in rainy and dry seasons, respectively). The other two groups that had higher abundance in the plantations stands were Collembola in the rainy season (12.5%) and Diplopoda in the dry season (22%). The similarity analyses (Anosim) showed significant dissimilarities in booth seasons ($p = 0.0001$), presenting a higher R during the rainy season and a higher distinction between the two treatments ($R = 0.54$) when compared to the dry season ($R = 0.26$) collections (Figure 2).

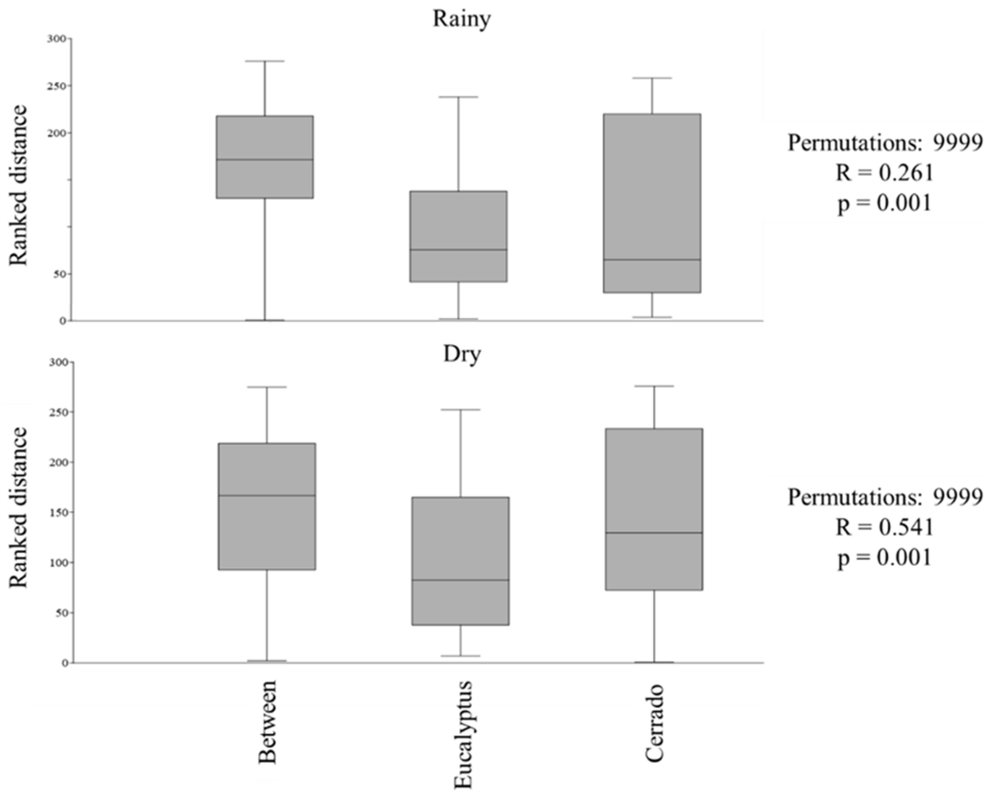


Figure 2. Similarity analyses (Anosim) by Bray–Curtis index in native Cerrado and eucalypt stands in Central Brazil, during rainy and dry seasons.

According to the SIMPER analyses, in the rainy season, four groups were responsible for 85% of the dissimilarity, where Collembola, Isoptera, Formicidae, and Diptera contributed with 31.05, 22.82, 20.05, and 11.7%, respectively. From those groups, only Formicidae was higher in eucalypt than in the Cerrado, while all of the other three groups were more abundant in the Cerrado area (Table A1). In the dry season collections, four groups were also responsible for almost 85% of the dissimilarity between the two areas, where Formicidae, Isoptera, Diplopoda, and Diptera contributed 45.8, 22.27, 10.8, and 5.93%, respectively. Following a similar trend to the rainy season analyses, only one of these four groups was higher in eucalyptus stands during the dry season (Diplopoda), when all other three were more abundant in the Cerrado area (Table A1).

The principal component analyses (PCA) also showed distinguished distribution between the two treatments and seasons. The PCA in the rainy collections explained 51.95% of the variance on the first two principal components in the rainy season, where the most robust gradient (PC1) explains 36.15% of the variation, whereas the second axis (PC2) explains 15.76% of the variation. The groups of Formicidae, Araneae, Hymenoptera, and Neuroptera groups clustered together with the eucalyptus plots while all other groups stayed clustered together with the Cerrado plots (Figure 3A).

In the dry season, the PCA explained 43.3% of the variance on the first two principal components in the rainy season, where the most robust gradient (PC1) explains 25.77% of the variation, whereas the second axis (PC2) explains 17.57% of the variation. The groups of Diplopoda and Neuroptera clustered together with the eucalyptus plots, while all other groups stayed clustered together with the Cerrado plots, even though the distinction of the two areas was less perceptive than in the rainy evaluation (Figure 3B).

Regardless of season collection, the Cerrado area presented a higher correlation with more mesofauna groups than the eucalypt; this trend can be perceptive, since the majority of groups clustered together in the Cerrado plots.

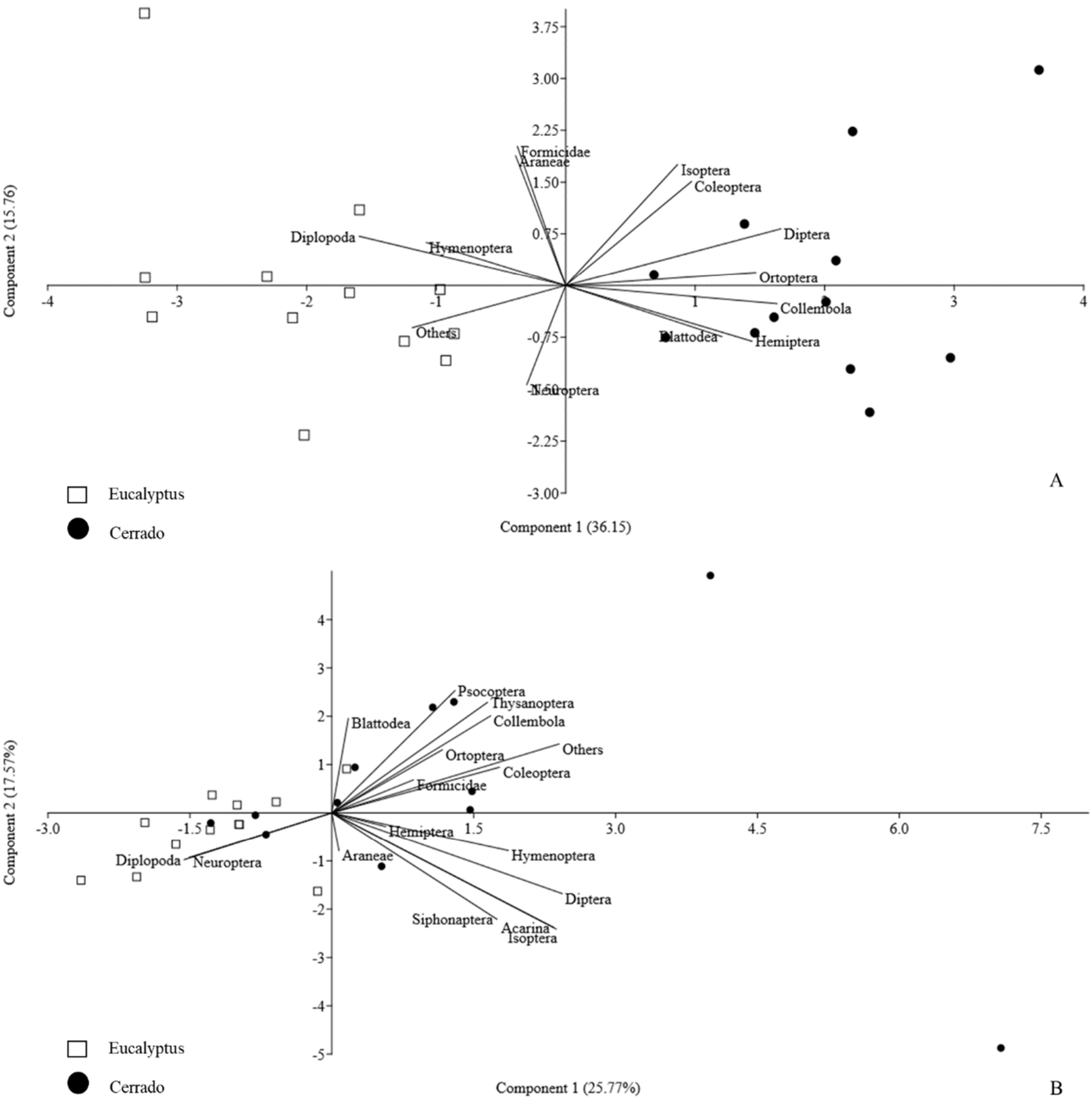


Figure 3. Principal component analysis (PCA) for mesofauna groups found in native Cerrado and eucalypt plantations in central Brazil-Brasília. In rainy (**A**) and dry (**B**) seasons.

Regarding Shannon's diversity index in the Cerrado area during the rainy season, the values ranged from 0.339 to 0.761, with 0.613 per plot, presenting higher results than the eucalyptus area that ranged from 0.259 to 0.708 with 0.526 (Figure 4). However, even with different mean values, there was no significant difference between treatments ($p > 0.05$).

Also, significant differences between the two land uses during the dry season collections ($p > 0.05$) were not observed, although the means per plot in the eucalyptus area were a little bit higher than the Cerrado, with means of 0.498 and 0.438, respectively. The diversity index varied from 0.16 to 0.92 in the Cerrado and 0.37 to 0.71 in the eucalyptus area (Figure 4).

3.2. Correlations between Soil Chemistry Parameters and Soil Mesofauna

The correlation between chemical parameters and soil mesofauna groups from the forward selection and Monte Carlo permutations suggests a high relationship between environmental variables (soil chemical attributes) and the response variable (edaphic mesofauna groups) (p-value = 0.0020) in both seasons. The RDA performed with the data collected during the dry season showed 88.1% of the explanation of the variability in the first axis and 11.9% in the second axis, covering 100% of the total variability (Figure 5A). Among the soil chemical parameters that are most related to soil fauna, organic matter and potassium stand out, where Acarina and Hymenoptera are related to the OM content, while Hemiptera Thysanoptera and Formicidae are more related to k content. Also, it was possible to observe that Diplopoda, Neuroptera, and Blattodea presented low correlation with these parameters.

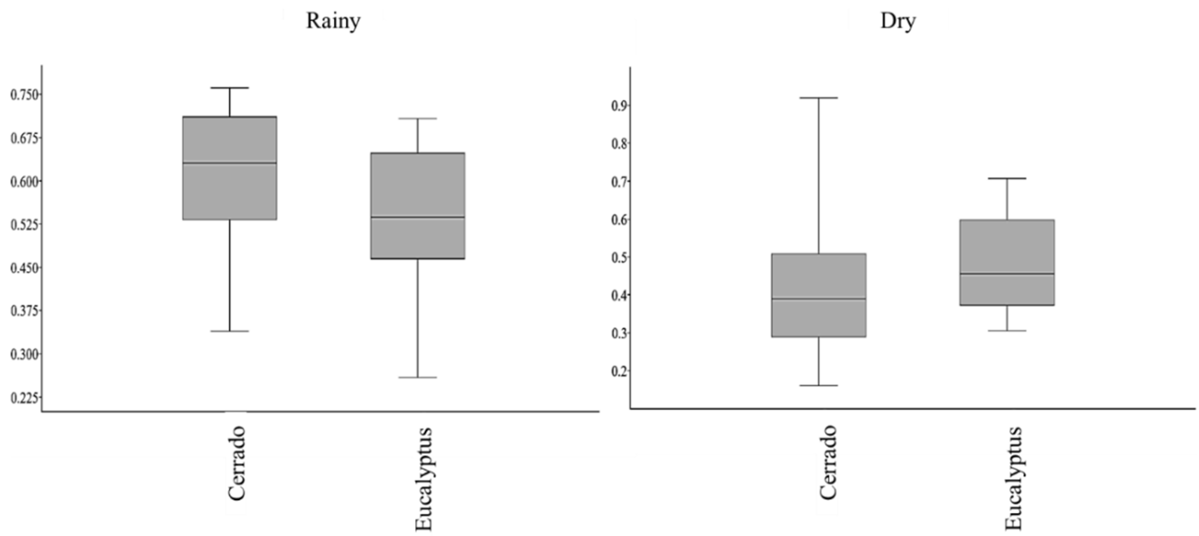


Figure 4. Shannon's diversity index in native Cerrado and eucalypt stands in Central Brazil, during rainy and dry seasons.

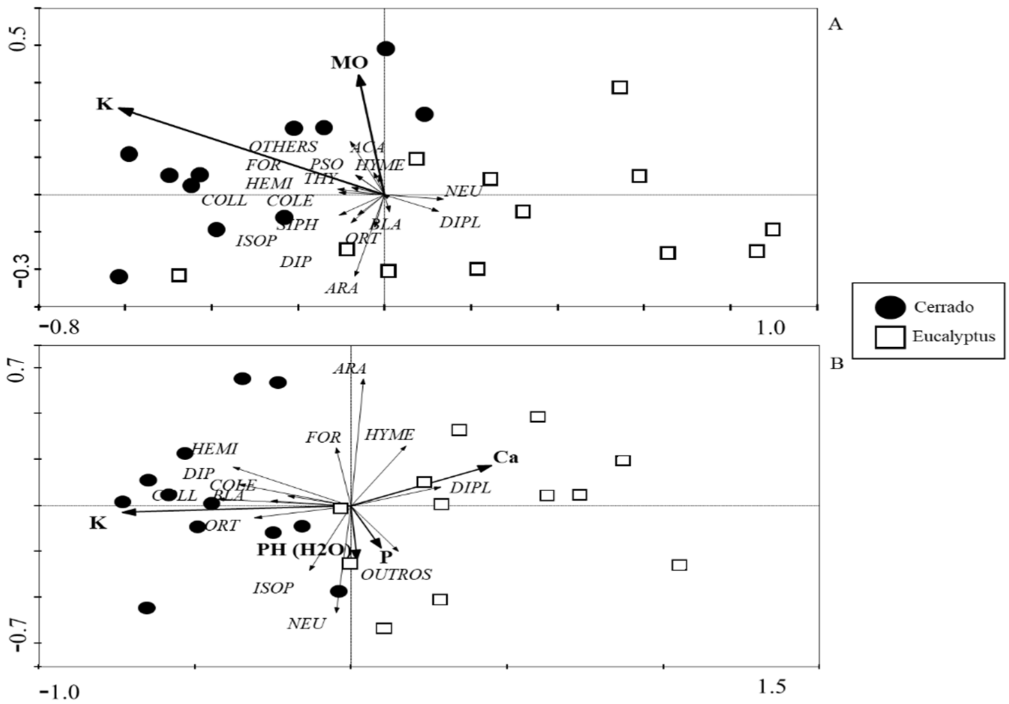


Figure 5. Redundancy Analysis (RDA) with chemical parameters as response variables to soil mesofauna distribution in native Cerrado and eucalyptus plantations in central Brazil-Brasília, in rainy (**A**) and dry (**B**) seasons. Where: Isopt = Isoptera; Coll = Collembola; For = Formicidae; Hemi = Hemipetra; Aca = Acarina; Hyme = Hymenoptera; Pso = Psocoptera; Thy = Thysanoptera; Cole = Coleoptera; Bla = Blattodea; Dip = Diptera; Siph = Siphonaptera; Ara = Araneae; Ort = Orthoptera; Dipl = Diplopoda; Neu = Neuroptera; Others = Larvae; K = Potassium; Ca = Calcium; pH (H_2O) = Ph in water base, and MO = Organic Matter.

In the rainy season collection, a different result was observed (Figure 5B), among the soil chemical parameters that are most related to soil fauna, Ca, Ph, P, and K stand out, where Diplopoda is related to the Ca content and presented low correlation with K contents. Isoptera, Neuroptera, and others (larvae) are more related to Ph and P contents and Araneae and Formicidae had a low correlation with these parameters. Diptera, Coleoptera, Blattodea, and especially Collembola presented a high correlation with K contents.

4. Discussion

4.1. Soil Mesofauna Presented Differences between eucalyptus and Cerrado Areas in Both Seasons

Our results showed that soil mesofauna communities presented differences in their composition between eucalyptus and Cerrado areas in both seasons. Even though Shannon's diversity index did not present differences between the two land uses, the higher means in Cerrado plots during the rainy season may be linked to the higher diversity of litter composition. According to [30] detritivores (mesofauna) presence, it is extremely related to litter quality, and that can partially explain this difference, where eucalyptus monoculture reduces the variety of litter composition compared to native Cerrado which is composed of a large diversity of vegetable species. Also, interactions between management practices, as the application of inputs, the transit of machines, and the alteration of vegetation cover can be critical stress factors for the communities established there [3].

Regarding the lower value of soil fauna diversity in the dry season in the Cerrado area, this could be a result of the vertical movement of edaphic fauna along the soil profile due to the increase in temperature and the decrease of soil moisture on the surface during the dry seasons in the Cerrado area, which could induce soil organisms to enter deep areas of the soil profile [31], and since the pitfall traps are allocated in the soil surface, this trend could be result from the denser canopy structure composition that consequently reduced temperature and soil moisture oscillations in the eucalypt stands when compared to the Savanna area that has a more widely spaced canopy structure and less shaded areas [32]

The dissimilarities between Cerrado and eucalyptus areas showed a higher presence of Diplopoda in eucalyptus stands during the dry season. This result can be explained due to the fact that Diplopoda is one of the most present edaphic groups in many eucalypt stands and is extremely dependent on litter for niche and food [33], and, since that litter layer in eucalyptus is usually higher when compared to Cerrado [34] because of the canopy structure and higher density of trees, Diplopoda organism's may be more dependent on that configuration. Also, this class presents a large diversity of habit behaviors; however, most of the species are considered soil detritivores, being most abundant in leaf litter and commonly found in dry forest and woodland, or more associated with rotting wood in higher rainfall areas, showing a cosmopolitan trend [35,36].

Isoptera and Diptera were more abundant in the Cerrado area being responsible for a huge part of the dissimilarities between the two treatments in both seasons. Isoptera is present in many tropical and subtropical ecosystems worldwide, playing a key role in the litter decomposition process, improving soil structure and fertility, contributing to the fully nutrient cycling process [37]. Also, due to the response from this group to habitat changes, these insects are considered bioindicators to land use management [38], and since the eucalypt plantations reduced their abundance, it can become a problem to the self-sustainability of these ecosystems functions and for the Cerrado ecoregion soil's biodiversity.

Diptera order is not usually considered a soil group, although some species have a temporary presence in soil and present a remarkable litter-decaying activity [3,33]. Some studies report that Diptera order is one of the most abundant soil fauna groups in eucalypt plantations [39,40], and since their presence was reduced in this ecosystem (less than half of the abundance of the Cerrado area in both seasons), this can represent a major problem due to their contributions to the nutrient cycling process.

Another group that presented differences between eucalyptus and Cerrado areas was Collembola, given that the abundance reduced in the plantations area during both seasons.

Filho et al. [41] affirmed that Collembola is very influenced by environmental factors such as vegetation, biological, chemical, and physical edaphic conditions, which vary according to the land-use system. In the same study, they state that the Collembola communities' composition is a relevant soil quality indicator, which leads us to believe that the reduction in this group of eucalyptus areas in central Brazil can represent a significant problem for the self-sustainability of these ecosystems since Collembola highly correlates to the nutrient cycling process [42]

Formicidae was the most present group in booth systems, being more present in the eucalyptus area during the rainy season and in Cerrado during the dry season. This group is generally reported as the most abundant group in soil fauna studies due to its crucial role in litter fragmentation and incorporation of organic material into the soil [43]. Accordingly, Formicidae was one of the three most abundant families during both dry and rainy seasons in both areas of our study. Also, Faria et al. [22] founded that Formicidae contributed 42.28% of the total soil fauna collected in a regenerating Cerrado, in Rio Verde–GO, the nearest state from Brasília, which corroborates with our findings.

According to the PCA analyses (Figure 3), regardless of season collection, Neuroptera order abundance correlated with eucalyptus areas. This group is present worldwide, especially in neotropical regions [44], and also commonly associated with roots of eucalyptus trees in the larvae phase in Australia [45] which could explain the higher presence of this group in the eucalyptus stands. Also, some species have a feeding habit of eating Araneae eggs [46]; this order was also more present in the eucalyptus stands when compared to the Cerrado area.

Since fauna communities are responsible for several ecosystem services, such as the improvement of the physical conditions of soils (i.e., aggregate stability, hydraulic conductivity, and total porosity), and are essential to the decomposition and incorporation of soil organic matter that promotes the nutrient cycle [18], the reduction of some groups found in the eucalyptus area can represent a major problem for the soil biodiversity, highlighting the problem of land-use changes from native Cerrado to eucalyptus plantations, that can promote serious implications on the whole nutrient cycling process and also the sustainability of these ecosystems.

4.2. Organic Matter, Potassium, Calcium, Phosphorous, and pH Are Correlated to Soil Mesofauna

According to Lavelle and Rossi [31], little is known about the factors that control or influence the spatial distribution patterns of soil fauna, where, presumably, environmental factors are responsible, at least in part, for the spatial pattern of these organisms. Our results indicate high canonical correlation values between soil chemical parameters and soil mesofauna, where organic matter, calcium, potassium, pH, and phosphorous are presented as good indicators, although these interactions between soil fauna communities and fertility parameters are complex [2]. Other studies highlighted that these parameters were valuable variables for the correlation between soil fauna and soil chemistry [11,23]. We founded that chemical parameters' correlations to soil mesofauna changed through seasons, which indicates that the analyzed environmental variables can influence the soil fauna groups in different ways between seasons, which corroborates with the findings of [3], which affirmed that correlations of the environmental variables with soil macrofauna in different land-uses in southern of Brazil also found a similar trend, with changes in these correlations across summer and winter.

Among the soil chemistry components, the potassium correlation to the soil fauna communities was the only environmental parameter that presented correlations in both seasons. This nutrient showed a higher correlation with soil fauna groups which corroborates with findings all over the world, covering from China [11] to Brazil [23]. Also, according to Rosa et al. [3], Orthoptera and Diptera presented a correlation to K soil contents in different land uses in south Brazil, which corroborates with our findings during the dry period collections. In the rainy season, we could observe a high correlation between Formicidae and K contents, which corroborates with the findings of [39], who affirmed that the addition of potassium in soil increased the dominance of the Formicidae family in livestock crop integration land in central Brazil, and also, [47], who found the same correlation trends between soil total K and Formicidae families in agricultural lands in southwestern China.

The other soil parameter that stood out in rainy season collection was organic matter and, since soil fauna is extremely necessary to the transformation of organic residues and incorporation of soil organic matter [48], their association was expected. From the groups associated with soil organic matter, the Acarina sub-class presented a high correlation with this environmental factor, and, since this group presented lower abundance in eucalypt stands compared to the Cerrado, this can represent a major problem for the nutrient cycling process and soil biodiversity. In this context, Carvalho et al. [49] affirmed that land-use changes in Central Brazil by the substitution of native forests to monocrop systems reduced the abundance, richness, and structuring of edaphic Acari communities, which corroborates with our findings.

Regarding Ca correlation to soil mesofauna, the Diplopoda class presented a high correlation to this soil element in dry season. This may be linked to the importance of calcium to Diplopoda as it is the main impregnating element in their cuticle [50]. The Isoptera group showed an opposite trend, with low correlation to Ca contents on soil, which corroborates with [19] study in an Oxisol in Cerrado, which affirmed that the Isoptera order had more abundance on sites that presented low Ca + Mg contents, which also could be observed in our results, where Isoptera showed a negative correlation with Ca contents on the soil. Furthermore, regarding Ca contents' correlation to soil mesofauna, Coleoptera showed positive correlations to this soil element which was also found by Lourente et al. [51], who affirmed that this group presented a positive correlation to Ca contents.

P content was positively correlated to Isoptera, Neuroptera, and unidentified larvae organisms (called Others). According to Weintraub et al. [52] soil fauna may affect soil P concentrations through direct and indirect effects on litter decomposition by detritivores activities that can promote organic matter shredding or consuming microbes and mineralizing the P contents in their biomass, which may explain the relationship between these groups and the P soluble contents on the soil. Also, Peng et al. [53] stated that soil P contents derived from litter are highly dependent on soil fauna activities by the fractionation of vegetable residues and organic matter.

Soil pH is usually a quality indicator of soils, representing some limitations to the life of vegetables or soil animals on the low levels of this parameter due to the influences on cation capacity exchange and organic matter decomposition [54]. Even though soil acidity generally limits the biodiversity of soil fauna, some groups can adapt to this type of environment and tolerate low levels of pH as it is commonly found in tropical soils [48]. We observed that most of the soil fauna groups presented a low correlation to the pH values, which could be explained by the low levels of pH founded in the Oxisols (Latossols) in the Cerrado [24], while only three soil fauna groups showed expressive correlation to the pH values, Neuroptera, Isoptera, and Larvae (others).

5. Conclusions

We evaluated the soil mesofauna communities in the Cerrado area and adjacent eucalyptus stands and their correlation to soil chemical parameters. Comparing the soil mesofauna communities' composition between the two land uses, we found dissimilarities between these two land uses, and, due to the fact that most groups of mesofauna are more present in the Cerrado area, the land-use changes by eucalyptus plantations may indicate a possible threat to soil ecological biodiversity; this trend represents a major concern about the possible spoiling of the whole nutrient cycling process and the full ecosystem functions. We also found that organic matter, potassium, calcium, phosphorous, and soil pH are good indicators for the evaluation of soil mesofauna communities, since they presented good correlations between environmental parameters and soil mesofauna groups. More comparative studies are encouraged, especially in other native savanna areas and eucalyptus stands so that we can better understand these trends and use this information for management and conservation actions.

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Appendix A

Table A1. SIMPER analyses of soil mesofauna in Cerrado and eucalyptus plantations in Central Brazil, Brasília-DF, during dry and rainy seasons collections.

Rainy Collections					
Overall Average Dissimilarity—58.3					
Taxon	**Average Dissimilarity**	**Contribution %**	**Cumulative %**	**Mean Eucalyptus**	**Mean Cerrado**
Collembola	18.1	31.05	31.05	15.5	82.9
Isoptera	13.3	22.82	53.87	1.17	168
Formicidae	11.69	20.05	73.91	78.8	68.3
Diptera	6.824	11.7	85.62	12.5	40.3
Hemiptera	3.78	6.484	92.1	3.58	16.3
Coleoptera	1.492	2.559	94.66	1.42	9.42
Araneae	1.122	1.925	96.59	6.5	5.5
Ortoptera	0.8821	1.513	98.1	0.5	3.92
Hymenoptera	0.2816	0.4831	98.58	1.08	0.25
Others	0.2481	0.4256	99.01	0.917	0
Diplopoda	0.241	0.4134	99.42	0.917	0
Blattodea	0.236	0.4048	99.83	0.0833	0.833
Neuroptera	0.1014	0.1739	100	0.333	0.0833
Dry season					
Overall average dissimilarity—62.79					
Taxon	**Average dissimilarity**	**Contribution %**	**Cumulative %**	**Mean Eucalyptus**	**Mean Cerrado**
Formicidae	28.75	45.8	45.8	91.8	198
Isoptera	13.98	22.27	68.06	2	159
Diplopoda	6.779	10.8	78.86	28	0.167
Diptera	3.723	5.93	84.79	9.67	30.3
Coleoptera	2.262	3.602	88.39	4.5	11.3

Table A1. *Cont.*

Araneae	2.033	3.239	91.63	12.8	3.75
Hymenoptera	1.025	1.633	93.26	2.25	6.17
Collembola	0.919	1.464	94.73	1.17	3.92
Others	0.7098	1.13	95.86	0.167	2.83
Hemiptera	0.5647	0.8994	96.76	2.17	3
Thysanoptera	0.5268	0.8391	97.59	0	1.92
Ortoptera	0.4608	0.734	98.33	1.25	1.92
Neuroptera	0.4186	0.6668	99	1.67	0
Acarina	0.2436	0.3879	99.38	0.25	3.67
Psocoptera	0.159	0.2532	99.64	0	0.75
Blattodea	0.1367	0.2177	99.85	0.417	0.333
Siphonaptera	0.09155	0.1458	100	0.25	0.417

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