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MANAGEMENT OF AGROECOSYSTEMS AND FUNCTIONAL DIVERSITY OF SOIL-ASSOCIATED ARTHROPODS IN THE EASTERN AMAZON

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Abstract: In the Eastern Amazon, the change in vegetation cover by converting forest areas to pastures affects the diversity of arthropods, and non-conservationist management in these areas can reduce functional diversity, compromising the sustainability of the agroecosystem. Accordingly, the objective of this work was to analyze the composition of the functional groups of the arthropod community associated with the soil under different management regimes in agroecosystems in the Eastern Amazon. For this, the study was carried out in three agroecosystems, namely bean cultivation, cassava cultivation and pasture, and in an area of secondary forest used as a reference. Arthropods were captured by means of fall traps installed in the center of agroecosystems. The captured arthropods were identified at the order and family level and later grouped according to their function. A total of 19,850 individuals were collected and classified into six different functional groups: herbivores, social insects, omnivores, predators, saprophages and xylophages. The arthropods in bean and cassava cultivation agroecosystems were more abundant and diversified in most functional groups. The results revealed that agroecosystems with crop rotation and intercropping, with the incorporation of plant residues and associated with spontaneous plants favored the diversity of functional groups.

Keywords: Slash-and-burn agriculture, edaphic fauna, ecological effect of fire, agroecology and biodiversity conservation.

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MANEJO DE AGROECOSSISTEMAS E DIVERSIDADE FUNCIONAL DE ARTRÓPODES ASSOCIADOS AO SOLO NA AMAZÔNIA ORIENTAL

Resumo: Na Amazônia oriental, a mudança na cobertura vegetal pela conversão de áreas florestais em pastagens afeta a diversidade de artrópodes, e o manejo não conservacionista dessas áreas pode reduzir a diversidade funcional, comprometendo a sustentabilidade do agroecossistema. Nesse contexto, o objetivo deste trabalho foi analisar a composição dos grupos funcionais da comunidade de artrópodes associados ao solo sob diferentes manejos em agroecossistemas na Amazônia Oriental. Para isso, o experimento foi realizado em três agroecossistemas: Feijão, mandioca e pasto - e em uma área de floresta secundária utilizada como referência. A captura dos artrópodes foi realizada por meio de uma armadilha de queda, instalada no centro dos agroecossistemas. Os artrópodes capturados foram identificados em nível de ordem e família, posteriormente agrupados de acordo com sua função. Foram coletados 19850 indivíduos, classificados em seis diferentes grupos funcionais: Herbívoros; Insetos Sociais; Onívoro; Predadores; Saprófago e Xilófago. Os agroecossistemas de cultivo do feijão e mandioca foram mais abundantes e diversificados na maioria dos grupos funcionais. Os resultados revelaram que agroecossistemas com rotação de culturas, consorciados, com incorporação de resíduos vegetais e associados a plantas espontâneas favorecem a diversidade de grupos funcionais.

Palavras-chave: Agricultura de corte e queima, fauna edáfica, efeito ecológico do fogo, agroecologia e conservação da biodiversidade.

MANEJO DE AGROECOSISTEMAS Y DIVERSIDAD FUNCIONAL DE ARTRÓPODOS ASOCIADOS AL SUELO EN LA AMAZONIA ORIENTAL

Resumen: En la amazonia oriental, los cambios en la cobertura vegetal por la conversión de los fragmentos forestales en pastizales afectan la diversidad de los artrópodos, y el manejo no conservacionista de esos sitios puede reducir la diversidad funcional, comprometiendo la sostenibilidad del agroecosistema. En este contexto, el objetivo de este trabajo fue analizar la composición de los grupos funcionales de la comunidad de artrópodos asociados al suelo por diferentes manejos en agroecosistemas de la Amazonía Oriental. Para eso, se realizaron los experimentos en tres agroecosistemas: frijol, yuca y pastizal, y además en un bosque secundario que fue utilizado como referencia. La captura de los artrópodos se realizó mediante una trampa de caída, instalada en el centro de los agroecosistemas. Los artrópodos capturados fueron identificados por orden y nivel familiar, luego agrupados según su función. Fueron capturados 19850 individuos, clasificados en seis diferentes grupos funcionales: Herbívoros; Insectos sociales; Omnívoro; Depredadores; Saprofito y Xilófago. Los agroecosistemas de cultivo de frijol y yuca fueron más abundantes y diversificados en la mayoría de los grupos funcionales. Los resultados revelaron que los agroecosistemas con rotación de cultivos, intercalados, con incorporación de residuos vegetales y asociados a plantas espontáneas favorecen la diversidad de grupos funcionales.

Palabras clave: agricultura de roza y quema, fauna edáfica, efecto ecológico del fuego, agroecología y conservación de la biodiversidad.

1. Introduction

The conversion of forest into agricultural areas is becoming increasingly common in the Amazon. In this biome, burning is usually practiced in the clearing of areas for agricultural cultivation and management of pastures (Santos et al., 2017), as in the southeast part of Pará, where this pattern of exploitation has been widely adopted by rural producers. In general, after deforestation, annual crops are established, and later they are replaced by pastures (OLIVEIRA, 2014; ALVES; HOMMA, 2004).

Exploitation begins with burning and clearing the forest to clean the area and obtain ash, used for temporary fertilization in annual crops (WATRIN et al., 2003). However, fire causes various physical, chemical and biological changes in the soil (SÁ et al., 2007; VASCONCELOS et al., 2013; SANTANA et al., 2017). It can negatively affect the microclimate, vegetation, habitats and food resources of many species, resulting in loss of biodiversity (Gardner et al., 2009).

Non-conservationist management is primarily responsible for the loss of biodiversity (FAO, 1985; FAO, 2011), which can also be related to the reduction of the diversity of functional features of the ecosystem, as it has interactions with the food chain (GRAVEL et al., 2016). Functional traits are reflected in the interactions of biotic communities, in the dynamics of resources, in ecosystem services, and in the functioning and stability of the ecosystem (BRASIL; HUSZAR, 2011; DÍAZ; CABIDO, 2001). Therefore, reducing the diversity of functional traits leads to the loss of sustainability of agroecosystems through their effects on the growth, reproduction and survival of species (VIOLLE et al., 2007).

The expansion of agriculture has been evident in the last decades in the Amazon, so it is important to analyze the effect of management on the diversity of functional traits of communities aiming at more sustainable practices. The edaphic fauna community can be used in the analysis of changes in the composition of functional management traits. A large number of species, mainly arthropods, live in the upper layers of the soil, on the surface and in the litter, and are very sensitive to environmental changes (MENTA, 2012; LAVELLE; SPAIN, 2001; PODGAISKI, 2013). Accordingly, the objective of this work was to analyze the composition of functional groups of the arthropod community associated with the soil under different management regimes in agroecosystems in the southeast part of Pará State in the Eastern Amazon, Brazil.

2. Material and methods

The research was carried out on a family farm near the municipality of Marabá in southeastern Pará, Brazil (5°17'31.10"S - 49°10'54.63"W). The agroecosystems were located in a Quartzarenic Neosol (EMBRAPA, 2006). The region's climate is classified as Isothermic Tropical Rainy of Jungle (Afi), with an average temperature of 28°C, relative humidity between 76.9 and 88.4% and an average annual rainfall of 1,925.7 mm, with the rainy period occurring between the months of November and April and the dry period between May and October (Almeida, 2007).

The study area consisted of four agroecosystems: bean cultivation, secondary forest, cassava cultivation, and pasture (Figure 1) (RODRIGUES et al., 2016). The selected agroecosystems had the following composition:

1. Secondary forest: With more than 20 years of conservation, and with high diversity of plants, and abundant litter on the ground.
2. Bean cultivation: Cultivated with cowpea (*Vigna unguiculata* (L.) Walp - 1842), exploited for eight years using crop residue management, crop rotation, and biannual plowing for incorporation of plant material and breaking up the soil.
3. Cassava cultivation: This is a crop that comes from slash-and-burn agriculture (conversion of the forest into cultivation area). A heterogeneous cultivation of cassava (*Manihot esculenta* Crantz - 1766), corn, rice, and pumpkin. After harvesting the annual crops, the cassava residue received practically no crop treatment, so spontaneous plants grew abundantly.

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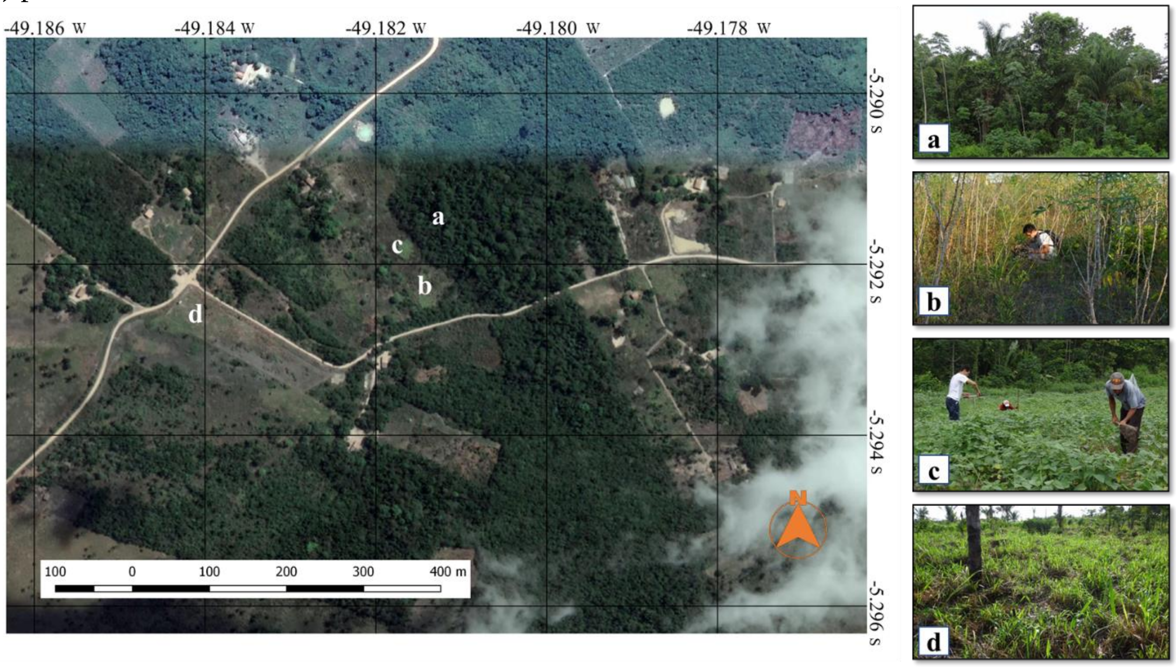
4. Pasture: Cultivated with forage Brachiaria (*Urochloa brizantha* (A. Rich.) R. D. Webster - 1987) about 10 years ago, after a slash-and-burn cultivation, and controlling invaders with slash-and-burn management done annually.

The arthropods were captured with trap-door type ground traps, made from plastic bottles according to Rodrigues et al. (2016). In these bottles, an ethylene glycol solution was added to attract arthropods (FREITAS; FRANCINI; BROWN, 2003). In the center of each of the four agroecosystems, four traps were installed, allocated in the area at a distance of 20 m from each other creating in the shape of a square on the ground, and they were left in the field for seven days.

Figure 1 – Coordinates and images of the four selected agroecosystems. Representation of agroecosystems: **(a)** Secondary forest; **(b)** Cassava cultivation; **(c)** Bean cultivation and **(d)** Pasture.
Figura 1 - Coordenadas e imagens dos quatro agroecossistemas selecionados. Representação de agroecossistemas: (a) Floresta secundária; (b) Cultivo de mandioca; (c) cultivo de feijão e (d) pasto.



The experimental design included 4 agroecosystems x 4 traps x 6 samples. Sampling was carried out according to regional climatic seasonality (dry and rainy season). In the laboratory, the collected specimens were placed in plastic pots containing 70% alcohol and subsequently sorted and counted in the respective groups, in accordance with their taxonomy and morphospecies, using a stereoscopic microscope with 40x magnification and dichotomous keys for identification.

After identification, the arthropods were grouped by diet, according to Merlim (2005), Audino et al. (2007), Vergara (2008), Silveira (2010) and Manhães (2011). The taxa whose eating habits could not be described were not used in the analysis. The analyses used were descriptive, abundance (number of individuals), ANOVA and Tukey test ($p < 0.05$) to differentiate functional groups by agroecosystem, and Pearson correlation ($p < 0.05$) as an association index, to see whether there was a correlation between meteorological factors and the community of arthropod functional groups associated with the soil. The statistical programs used were Past 4.0 and BioEstat 5.0.

3. Results

A total of 19,850 arthropods were collected and sorted into herbivores, social insects, omnivores, predators, saprophages and xylophages. The functional groups with the largest number of families were herbivores (14) and predators (11), followed by saprophages (6), omnivores (4), social insects (2) and xylophages (1) (Table 1). Cassava cultivation had the largest number of families, both in the general count and in the dry period, followed by bean cultivation, forest and pasture. The rainy season promoted population growth in all agroecosystems.

Table 1 – Abundance of arthropod families by functional group in relation to seasonality (S = dry season and C = rainy season) in different agroecosystems.
Tabela 1- Abundância de famílias de artrópodes por grupos funcionais em relação à sazonalidade (S = período seco e C = período chuvoso) em diferentes agroecossistemas.

Functional group (Family)	Bean		Forest		Cassava		Pasture	
	S	C	S	C	S	C	S	C
HERBIVORES	12	202	15	71	34	140	4	34
Acrididae	1	15	-	1	3	5	-	3
Alydidae	-	6	-	1	-	1	-	-
Aphididae	-	0	5	1	6	-	-	-
Berytidae	-	1	-	-	-	-	-	-
Cerambycidae	-	-	1	-	-	-	-	1
Cercopidae	-	-	-	1	-	-	-	-
Chrysomelidae	-	27	-	6	9	58	-	2
Cicadelidae	-	15	-	5	5	7	-	1
Curculionidae	10	94	3	44	2	58	4	12

Cydnidae	-	3	5	6	-	-	-	-
Miridae	-	-	-	-	-	7	-	-
Pyrrhocoridae	-	24	-	1	-	1	-	-
Rhyparochromidae	1	12	-	-	9	-	-	-
Scutelleridae	-	5	1	5	-	3	-	15
SOCIAL INSECTS	1650	1117	419	229	3431	6194	433	413
Formicidae	1650	1116	419	227	3431	6194	433	413
Termitidae	-	1	-	2	-	-	-	-
OMNIVORES	44	252	23	75	65	50	29	87
Elateridae	-	121	-	-	-	9	-	5
Gryllidae	44	72	22	65	50	24	29	69
Opilliones	-	16	1	9	15	10	-	-
Rhaphidophoridae	-	43	-	1	-	7	-	13
PREDATORS	139	323	51	53	105	320	6	90
Anthicidae	-	1	-	-	2	-	-	-
Araneae	82	116	19	22	42	33	3	31
Carabidae	4	62	-	7	10	8	2	10
Carcinophoridae	19	13	1	1	33	139	-	2
Histeridae	-	6	-	6	-	-	-	-
Lampyridae	-	-	-	-	-	-	-	1
Mesoveliidae	-	3	-	-	-	-	-	-
Reduvidae	7	1	14	-	11	2	1	-
Rhysodidae	-	-	-	1	-	3	-	-
Scydmaenidae	24	-	-	-	-	-	-	-
Staphylinidae	3	121	17	16	7	135	-	46
SAPROPHAGES	20	125	77	63	70	313	2	35
Blaberidae	-	-	-	-	-	1	-	-
Blattellidae	-	-	7	-	1	-	-	3
Blattidae	-	-	1	3	3	3	-	4
Nitidulidae	15	59	69	35	15	22	-	9
Scarabaeidae	1	15	-	18	44	103	1	19
Tenebrionidae	4	51	-	7	7	184	1	-
XYLOPHAGES	170	431	317	600	93	264	119	1041
Bostrichidae	170	431	317	600	93	264	119	1041

The functional groups had significant correlations with precipitation, except for the saprophages and social insects (Table 2). The herbivore, omnivore and predator groups showed a positive and strong correlation with relative humidity and precipitation. The temperature did not have a strong and significant correlation with the functional groups.

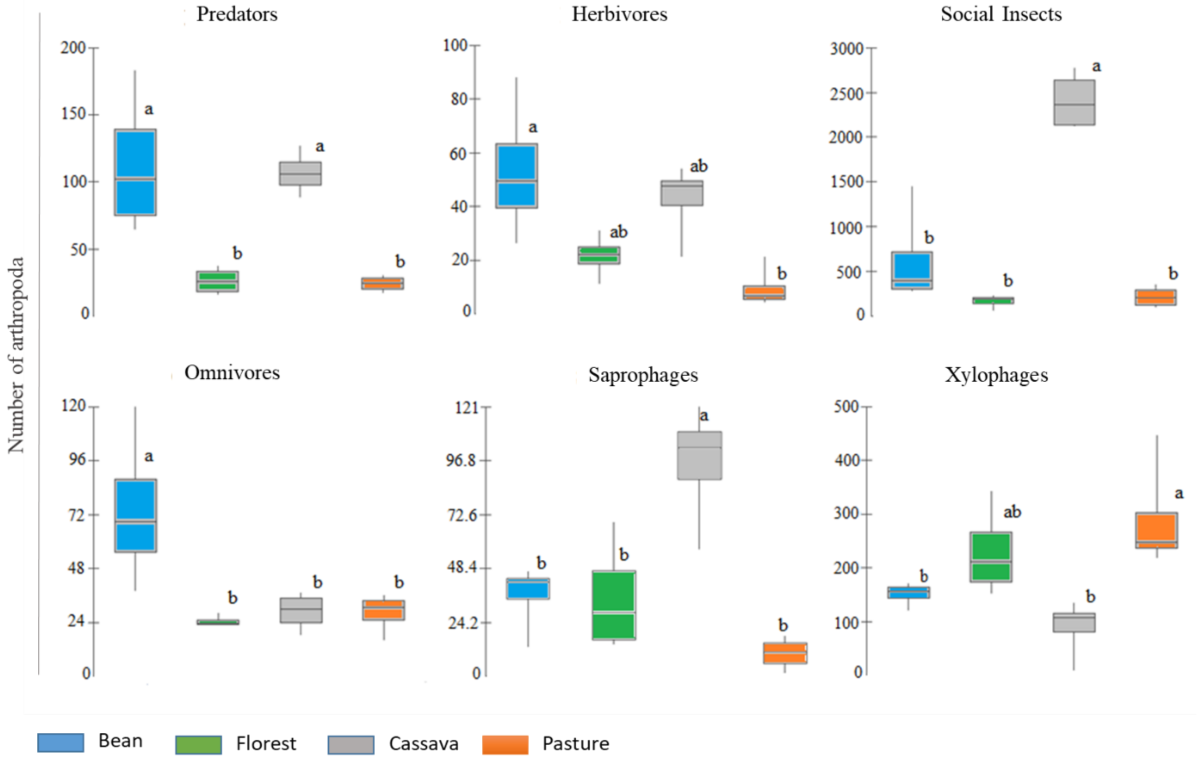
The bean and cassava cultivation agroecosystems showed the highest number of individuals per functional group, except for the xylophage group. Pasture differed significantly only in the xylophage functional group. The tests demonstrated the effect of the management of agroecosystems in the functional groups, with less representation in the pasture managed with slash-and-burn methods (Figure 2). The agroecosystems showed the following significance levels: herbivores (F = 6.1435; p = 0.0091), predators (F = 11,724; p = 0.001), social insects (F = 41.2212; p = <0.0001), omnivores (F = 6.5278; p = 0.0075), saprophages (F = 12.4568; p = 0.0008) and xylophages (F = 5.7682; p = 0.0112).

Table 2 – Pearson linear correlation between functional groups and meteorological factors.
Tabela 2 – Correlação linear de Pearson entre grupos funcionais e fatores meteorológicos.

Functional groups	Temperature	Precipitation	Relative humidity
Herbivores	0.21^{ns}	0.98*	0.60^{ns}
Social insects	-0.15^{ns}	0.39^{ns}	0.16^{ns}
Omnivores	-0.06^{ns}	0.94*	0.68^{ns}
Predators	0.04^{ns}	0.90*	0.53^{ns}
Saprophages	0.12^{ns}	0.69^{ns}	0.07^{ns}
Xylophages	-0.29^{ns}	0.81*	0.67^{ns}

* Significant correlation at 5% probability, ^{ns} not significant.

Figure 2 – Box-plot with median and interquartile of the number of arthropods in the functional groups by agroecosystem; different letters indicate significant difference (p<0.05), and the colors of the box-plot represent the agroecosystems.
Figura 2 - Box-plot com mediana e quartis do número de artrópodes nos grupos funcionais por agroecossistemas; as letras diferenciam os agroecossistemas em um nível de significância de 5% e as cores do box-plot representam os agroecossistemas.



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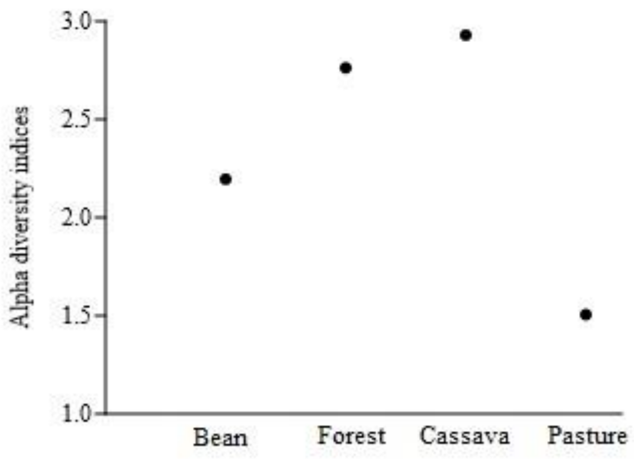
Fisher's alpha diversity index was higher in the cassava, forest and bean cultivation agroecosystems. The pasture showed the lowest alpha diversity index, resulting in better relationships between the number of individuals and species in the cassava and forest agroecosystems. The permanence of spontaneous plants resulted in a greater family diversity of functional groups. The burning of resources due to slash-and-burn management reduced the diversity index of families in the functional groups (Figure 3).

Figure 3 - Fisher's alpha diversity index of functional groups for different agroecosystems.
Figura 3 - Índice de diversidade alfa de Fisher de grupos funcionais para os diferentes agroecossistemas.

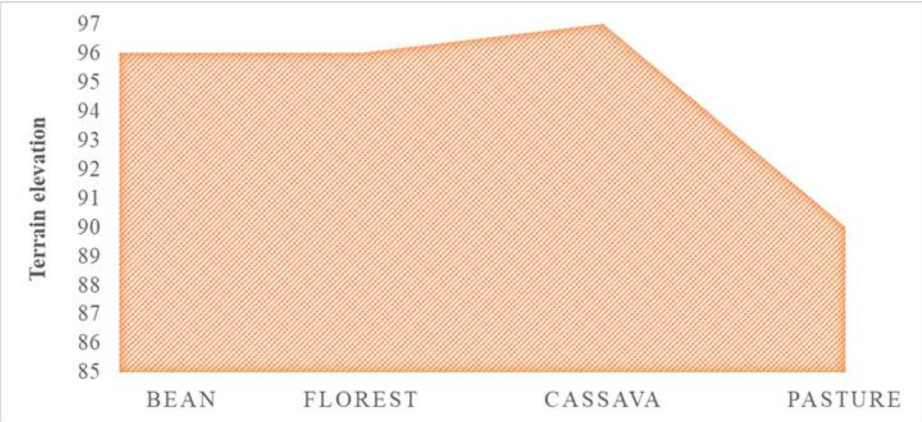


4. Discussion

The southeast of Pará is a region located in the Eastern Amazon, where most of the soils are not flooded, but affected by seasonal rains (MORAES et al., 2005). This influences the arthropod population of the soil in dry and rainy periods. During the dry season, the reduction in the availability of water and food resources decreases the population of functional groups in agroecosystems. In contrast, during the rainy season, water availability increases primary productivity, causing a positive effect on the food chain (MOHAMED et al., 2004; ARAÚJO, 2013). This reduction in the dry period and increase in the rainy season of functional groups individuals' number in agroecosystems is a bioregulation in the predator-prey cycle relation (arthropods functional groups - food resources) in a logistical growth (VERHULST, 1838).

The results showed that all functional groups had positive correlations with precipitation. Social insects and saprophages showed weaker correlations with precipitation, the fact that they do not have strong correlations with precipitation seems to be a characteristic of these functional groups (BAPTISTA, 2010; BRAGA, 2014). Social insects had an abundant population in all agroecosystems in the dry period, with a reduction in the population in the rainy period. This seasonal effect has been observed in the Amazon and other biomes, such as the Caatinga and the Atlantic Forest (NUNES, 2010; SANTOS et al., 2012; FERNANDES, 2016). However, this was not seen in the cassava cultivation agroecosystem, which had twice as many social insects in the rainy season. indicating the migration of ants in search of higher and drier soils (Figure 4), as the temperature and humidity at ground level affect the occurrence of ants of various species (SILVA, 2014).

Figure 4 – Soil elevation in agroecosystems. Google Earth Pro data.
Figura 4 – Elevação do solo nos agroecossistemas. Dados do Google Earth Pro.



The management of bean and cassava agroecosystems offers more floral resources from beans and adventitious plants, diversity of plant structures and incorporation of waste, positively affecting the communities of functional groups. Thus, the availability of food resources and the diversity of plant structure combined with microclimates may have promoted an environment that is potentially favorable to functional groups (AUAD; CARVALHO, 2011; VILLANUEVA-LÓPEZ et al 2019). The forest showed an abundance of intermediate functional groups, which was expected, since it is an area of natural vegetation, due to its greater diversity of niches, which can give greater stability to arthropods (NUNES; ARAÚJO FILHO; MENEZES, 2008; SILVA et al., 2012).

The most populous groups were social insects and xylophages. They are naturally numerous groups, such as the social insects which showed greater abundance (13,883 individuals); being dominant in all samples, representing 57% of the individuals captured. Studies have shown that social insects are dominant, representing 53% of collected arthropods (MANHÃES, 2011). It is a very widespread group with a larger number of individuals than most other terrestrial animals (TRILEHON; JHONSON, 2011). Xylophages, represented by Bostrichidae, are numerous in pastures and forests (Galdino-da-Silva et al., 2016), and the cultivation of beans and cassava between the two can explain the high population of these insects in agroecosystems due to their transience between pasture and forest.

In the forest, the xylophage group was more populous, which makes sense, since they are associated with tree vegetation, due to eating habits and preference for forest species (FERREIRA FILHO et al., 2002). The xylophage group drew attention for its significant association with pasture. There was already evidence of the preference of this functional group for pasture and forest (PAES et al., 2012; GALDINO-DA-SILVA et al., 2016). The preference of this functional group for starchy foods (Lelis, 2000; Schafer et al., 2000) may explain its association with pastures. With increasing age, pasture may offer stems and roots with a higher starch content (Vantini et al., 2005), and therefore, residue stem and root fragments after slash-and-burn management may have favored the largest number of xylophages.

The functional groups with the largest number of families were herbivores, predators, saprophages and omnivores. The cassava, bean and forest agroecosystems had the highest number of families. Monoculture and slash-and-burn management represented by pasture reduced the supply of habitat and food resources, decreasing the population and families of functional groups (NUNES et al., 2008; REDIN et al., 2011). Therefore, simplifying agroecosystem and burning vegetation reduce the population and families of functional groups, reflecting the effect of vegetation and agroecosystem management practices on functional attributes (LAVELLE; SPAIN, 2001; PODGAISKI, 2013).

The seasonal effect of precipitation has shown that in dry periods, there are decreases in the population of arthropod functional groups, showing the sensitivity to reduced food supply (FERNANDES et al., 2011; SOUTO et al., 2008). However, there is a negative effect of burning methods on the diversity of functional groups with a 43.75% reduction of families when compared to the forest. While the cassava agroecosystem was 31.25% above the forest. The decreased supply of resources resulted in the loss of alpha diversity in the pasture agroecosystem with slash-and-burn management (VASCONCELOS et al., 2020).

5. Conclusions

- The main functional groups found in the agroecosystems were herbivores, social insects, predators, saprophages, omnivores and xylophages.
- The composition of vegetation cover and meteorological variables influenced the occurrence of functional groups. The rainy season minimized the effects of management and vegetation cover on functional groups, making them more populous and widespread in the agroecosystems.
- Sampling in the dry period was essential to differentiate the influence of management over the functional groups.
- The agroecosystems of bean and cassava cultivation were able to provide support (shelter, food, refuge) to functional groups during the dry period, making up a greater number of individuals and families and greater diversity of functional groups.
- Agroecosystems with crop rotation and intercropping, with incorporation of plant residues and associated with spontaneous plants favored the diversity of functional groups.

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