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MACROFAUNA DIVERSITY IN A SYNTROPIC AGROFORESTRY SYSTEM

DIVERSIDADE DA MACROFAUNA EM UM SISTEMA AGROFLORESTAL SINTRÓPICO

DIVERSIDAD DE MACROFAUNA EN UN SISTEMA AGROFORESTAL SINTRÓPICO

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ABSTRACT:

The objective of this research was to evaluate the reflection of a Syntropic Agroforestry System (SAS) on the structure of soil macrofauna, since the edaphic fauna becomes an excellent bioindicator and has a peculiar susceptibility to interference in the environment. Macrofauna samples were collected (TSBF method) in three areas: SAS, Forest Fragment (FF) and Secondary Forest (SF). Soil invertebrates > 2 mm in diameter were identified at the level of taxonomic order and stage of development. The ecological parameters were carried out based on density (number of individuals per square meter), richness (Margalef index), diversity (Shannon index) and evenness (Pielou index). The predominant macrofauna groups were Hymenoptera (29%), Coleoptera (19%), Haplotaxida (20%) and Isopoda (8%). Although the SAS had the highest density (164 individuals) and richness (I = 2.5) of individuals, the diversity and uniformity indices were higher in the FF area (H = 2.04) and (e = 0.89). Although Agroforestry Systems are a viable alternative for the development of macrofauna, the resources of the SAS were not yet sufficient to sustain a wide variety of organisms, since they were still in the initial stage of development.

KEYWORDS: Macrofauna, Agroforestry system, Diversity.

RESUMO:

O objetivo desta pesquisa foi avaliar o reflexo de um Sistema Agroflorestal Sintrópico (SAS) sobre a estrutura da macrofauna do solo, visto que a fauna edáfica torna- se um excelente bioindicador e possui uma peculiar suscetibilidade à interferência no ambiente. Foram coletadas amostras da macrofauna (método TSBF) em três áreas: SAS, Fragmento de mata (FM) e Mata secundária (MS). Os invertebrados do solo de tamanho >2 mm de diâmetro foram identificados em nível de ordem taxonômica e estádio de desenvolvimento. Os parâmetros ecológicos foram realizados com base na densidade (número de indivíduos por metro quadrado), na riqueza (índice de Margalef), na diversidade (índice de Shannon) e na equitabilidade (indice de Pielou). Os grupos predominantes da macrofauna foram Hymenoptera (29%), Coleoptera (19%), Haplotaxida (20%) e Isopoda (8%). Embora o SAS tenha apresentado a maior densidade (164 indivíduos) e riqueza (I=2,5) de indivíduos, os índices de diversidade e uniformidade foram maiores na área de FM (H= 2,04) e (e= 0,89). Apesar dos Sistemas Agroflorestais serem uma alternativa viável para o desenvolvimento da macrofauna, os recursos do SAS ainda não eram suficientes para sustentar uma grande variedade de organismos, uma vez que ainda se encontrava em estágio inicial de desenvolvimento.

PALAVRAS CHAVE: *Macrofauna, Sistema agroflorestal, Diversidade.*

RESUMEN:

El objetivo de esta investigación fue evaluar la reflexión de un Sistema Agroforestal Sintrópico (SAS) sobre la estructura de la macrofauna del suelo, ya que la fauna *edáfica se convierte en un excelente bioindicador y tiene una peculiar susceptibilidad a la interferencia en el ambiente. Se colectaron muestras de macrofauna (método TSBF) en tres áreas: SAS, Fragmento de Bosque (FB) y Bosque Secundario (BS). Se identificaron invertebrados del suelo > 2 mm de diámetro a nivel de orden taxonómico y etapa de desarrollo. Los parámetros ecológicos se llevaron a cabo en base a la densidad (número de individuos por metro cuadrado), riqueza (índice de Margalef), diversidad (índice de Shannon) y uniformidad (índice de Pielou). Los grupos de macrofauna predominantes fueron Hymenoptera (29%), Coleoptera (19%), Haplotaxida (20%) e Isopoda (8%). A pesar de que el SAS presentó la mayor densidad (164 individuos) y riqueza (I = 2,5) de individuos, los índices de diversidad y uniformidad fueron mayores en el área FB (H = 2,04) y (e = 0,89). Si bien los Sistemas Agroforestales son una alternativa viable para el desarrollo de la macrofauna, los recursos de las SAS aún no eran suficientes para sustentar una amplia variedad de organismos, ya que aún se encontraban en la etapa inicial de desarrollo.*

Palabras clave: *Macrofauna, Sistema agroforestal, Diversidad.*

INTRODUCTION

Agriculture, the main activity responsible for the production of food for humanity, has been gaining more and more new techniques and procedures. As this activity evolves, the consequences caused by it increase even more, such as environmental and social degradation, deforestation and loss of biodiversity (GREGIO, 2020). Thus, many initiatives have sought to reconcile environmental conservation and agriculture in order to reduce environmental impacts. One of these alternatives is the Agroforestry Systems (AS), which are presented from the ecological and sustainable perspective of the activities (GIOVANNINI, 2023).

There are different classifications for agroforestry systems, among which the syntropic AFS (SAS) stand out, proposed by the Swiss farmer/researcher Ernst Götsch from 1980 onwards. Syntropic agriculture, also known as successional agroforestry, unlike conventional agriculture or traditional agroforestry, focuses on life and biogeochemical processes, in order to dispense with external inputs and imitate the functioning of an environment subjected to the dynamics of ecological succession (PASINI, 2017).

The creation of this method of agriculture arose from the need to harmonize agricultural activities with natural processes, in order to produce with high diversity and quantity, using techniques such as dense consortia with the incorporation of native forest, weeding and selective pruning, without the use of pesticides, heavy machinery and control of pests and diseases, the latter being seen as indicators of the balance or imbalance of the system (GÖTSCH, 1996).

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Different studies have shown important results in the implementation of syntropic agroforestry systems, among which those related to the restoration of microfauna and large food production (GREGIO, 2018), recovery of degraded areas (MICHELON, 2019), and improvement of soil quality (FIGUEIREDO, 2020) stand out. However, despite the importance it exerts, little focus has been given to this type of agriculture (GREGIO, 2020).

The extreme simplification of landscapes and ecosystems, due to the intensive use of soil, with inadequate production practices, explains the reduction of biodiversity, leading to numerous changes in the composition and diversity of soil organisms, in different degrees of intensity due to changes in habitat, food supply, creation of microclimates and intra- and interspecific competition (HOFFMANN *et al.*, 2018). From this perspective, one of the strategies used to assess possible impacts that occur on the soil as a result of the type of use and management techniques is the edaphic fauna, because, as they are organisms sensitive to changes in the environment, they are considered excellent bioindicators (VELÁSQUEZ *et al.*, 2012; FRANCO *et al.*, 2016).

Among the various criteria for classifying edaphic fauna, the most used involves the separation of the animal's bodies according to their diameter. The smallest group comprises the microfauna, which includes organisms < 0.2 mm, with its main representatives being nematodes and protozoa. The mesofauna measures 0.2-2.0 mm, and includes organisms such as Acari, Collembola, Palpigradi, Protura, Pauropoda, Diplura, Enchytraeidae and Symphyla; while the macrofauna is represented by invertebrates visible to the naked eye (> 2 mm), including termites, ants, earthworms, beetles, armadillos, spiders, centipedes, snake lice, snails, scorpions, bedbugs, cicadas, fly larvae and moths (MELO *et al.*, 2009).

The environmental functions and interactions performed by macrofauna are crucial for soil maintenance and fertility, representing a very important part, both in natural environments and in areas cultivated by man (KORASAKI *et al.*, 2013). Factors such as diversity and density of the most frequent groups of macrofauna can undergo modifications according to the system of tillage and cultivation, and systems with less soil disturbance and that maintain vegetation cover on their surface tend to present a greater diversity of edaphic fauna.

Therefore, this study aimed to evaluate the reflection of a Syntropic Agroforestry System through the diversity of groups of edaphic macrofauna.

METHODOLOGY

The study was carried out in the agreste region of Alagoas, in the Cangandu Village, located 12.9 km from the center of the municipality of Arapiraca, in transition areas of the Atlantic Forest and Caatinga biomes, at the coordinates: latitude -9.800147 and longitude - 36.570232, on the private property called Canguru Park, which has cultivation areas in conventional and syntropic management, with table cassava being one of the main cultivated products.

The area where the municipality of Arapiraca is located is characterized by high temperatures, with an annual average of 25º C and annual rainfall totals between 750 and 1000 mm. In addition, the months of May, June and July are the wettest with more than 50% of the annual total and the driest seasons are recorded in spring and summer, lasting 4 to 5 months (NIMER, 1977). However, in 2022 an average above normal was recorded for the municipality, totaling a rainfall index of 1478.3 mm (SEMARH, 2022).

The Syntropic Agroforestry System occupies a total of 8 ha and was implemented in 2021, with approximately 1 year of management in the period in which the study was carried out. In its surroundings, there is 1 ha of protected area (remnant of forest fragment), in addition to areas with natural regeneration, allowing the maintenance and preservation of endemic fauna and flora (BARTPAPO [...], 2020). The main species used for planting crops (tree row) were: Banana (*Musa* sp) x Mastic (*Schinus terebinthifolia* Raddi, 1820*)*; Banana (*Musa* sp) x Moringa (*Moringa oleífera* Lam., 1891); Coconut from Bahia (*Cocos nucifera* L., 1753) x Pineapple (*Ananas comosus* (L.) Merril, 1917) and Coconut from Bahia (*Cocos nucifera* L., 1753) x Tommy Mango (*Mangifera indica* L., 1753). In the strips between rows, table cassava was cultivated (*Manihot esculenta* Crabtz, 1766*)* and corn (*Zea mays* L., 1753).

All plants were fertilized with inputs external to the property, applied directly to the soil, every 30 days with manure, which was available (pig, cattle, sheep), phosphate rock dust and mulch from tree pruning at the time of the system transition. During the experiment period, the cultivation strips were fallow, where spontaneous plants predominated.

To carry out the study, macrofauna samples were collected in the SAS area and in two preserved areas, one of Forest Fragment (FF) resulting from the process of fragmentation of native vegetation; and another from Secondary Forest (MS) which is in the process of natural regeneration, for comparison. Soil blocks and litter were collected using a wooden template of dimensions 25 cm x 25 cm x 10 cm (Tropical

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Soil Biology and Fertility - TSBF method) proposed by Anderson and Ingram (1993), modified to a depth of 0-10 cm. 12 samples were collected in each area, one per month, 27 m apart from each other, from August 2022 to July 2023. In the SAS area, the collections occurred in two X shaped transects (A and B), with 324.4 and 400.48 m respectively, while in the MS, due to the narrow size of the area (about 500 m long and 70 m wide) and its location (near a dam that separates two rural properties) the collections occurred at random points, as well as in FM, due to the difficult access to this area.

The soil and litter samples were stored in plastic bags, duly identified and later taken to the research laboratory of the State University of Alagoas (*Universidade Estadual de Alagoas* - UNEAL), where soil invertebrates with a body diameter greater than 2 mm were manually sorted and preserved in 70% alcohol. With the aid of a stereoscope, the organisms found were counted and identified according to Rafael et al. (2012) at the taxonomic level of order and stage of development (adult and larva).

The ecological parameters were carried out based on density (number of individuals per square meter), richness (Margalef index), diversity (Shannon index) and evenness (Pielou index). The data obtained for the density of organisms found in the rainy and dry seasons were submitted to analysis of variance (ANOVA) and then to the Tukey test at 5% probability.

Soil samples from the arable layer (0-20 cm) were collected from the three study areas and sent to the private laboratory Central Analítica, located in the municipality of Maceió-AL, where the physical and chemical parameters of the soil were determined. The three study areas have the same physical characteristics, classified as Sandy Clay Loam, type 2 soil, which presents a balance between sand, silt and clay contents (Table 1). The FF soil showed higher levels of potassium, sodium, magnesium and calcium, as well as higher Cation Exchange Capacity (CEC) and percentage of organic matter. The SAS area had the highest phosphorus content, possibly due to the initial management of the implementation of the system, in which phosphate rock dust was applied during the first months. The three areas showed a high base saturation (v), around 71 to 90%, which demonstrates a low acidity in the soils analyzed, with pH in the range of 6, ideal for the availability of nutrients for the plants.

Table 1 - Soil chemical characteristics of the Syntropic Agroforestry System (SAS), Forest Fragment (FF) and Successional Forest (SF) at the depth of 0-20 cm, in Arapiraca-AL.

Area	pH	P	K	Na	Mg	Ca	H + Al	CEC	V	M.O.
	H_2O	ppm			meq/100 ml				%	
SAS	6.5	87	36	16	1	2.1	0.9	3.26	78.4	2.46
FF	6.6	2	124	54	2.8	5.2	1.9	8.55	81.6	5.39
SF	6.2	3	96	35	2.2	3.7	2	4.18	75.9	5.13

Source: Survey data, 2023.

RESULTS AND DISCUSSION

A total of 398 macrofauna individuals were found, of which 164 were in the SAS, 106 in the SF and 128 in the FF. In decreasing order of density of organisms, the groups with the highest representativeness were: Hymenoptera, Haplotaxida, Coleoptera and Isopoda (Table 2).

The density of macrofauna differed between the collection times, being higher observed in the dry season (P< 0,001). This dynamic can be attributed to the sensitivity that most macrofauna individuals have about climatic conditions. In a research conducted by Almeida *et al.* (2015), on the influence of seasonality in relation to macrofauna in a preserved area of the Caatinga, in Paraíba, where the annual rainfall index is approximately 400 mm, they found that the higher density of individuals was conditioned to dry seasons. These findings suggest that the abnormal scenario of high rainfall in the state of Alagoas, in 2022, may have contributed to the reduction in the number of individuals found. On the other hand, Lima *et al.* (2010), when evaluating the relationship between macrofauna and climatic conditions in different management systems in Piauí, a region with an average annual rainfall of 1,400 mm, found that the higher density of organisms was more associated with the rainy season. This discrepancy highlights the importance of considering the specific climate context, as well as other factors that may influence macrofauna responses.

Table 2 - Density (individuals m^2) of taxonomic groups of soil macrofauna at 10 cm depth in an area of Syntropic Agroforestry System (SAS) of Secondary Forest (SF) and Forest Fragment (FF) in dry and rainy periods.

Group	**SAS**		**SF**		**FF**	
	Drought	Rainy	Drought	Rainy	Drought	Rainy
Araneae	2	2	4	0	3	2
Scorpione	1	0	0	0	0	0

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Coleoptera	38 adul e 5lar	8 adul e 1 lar	6 adul e 2 lar	2 adul e 2 lar	2 adul e 3 lar	6 adul e 2 lar
Orthoptera	0	1	0	0	0	0
Isóptera	8	0	0	0	0	0
Dermaptera	4	4	0	0	0	1
Hymenoptera	51	6	27	26	5	2
Thysanoptera	0	0	0	0	9	3
Diptera	1 lar	0	1 lar	0	0	0
Blattaria	4	0	0	0	2	1
lepidoptera (pupa)	0	0	0	0	1	0
Isopoda	1	0	3	2	17	12
Diplopoda	1	6	4	1	7	4
Geophilomorpha	0	0	0	1	0	0
Haplotaxida	1	19	15	10	22	14
Pulmonata	0	0	0	0	0	10
Density*	117a	47b	62a	44b	71a	57b

*adul: Adults individuals; *lar: Individuals in larvae form.* Measures followed by equal letters do not differ from each other by Tukey's test, at 5% probability.

Source: Survey data, 2023.

Representatives of the orders Hymenoptera (ant), Coleoptera (beetle) and Haplotaxida (earthworm) are considered “ecosystem engineers”, a concept introduced by Jones *et al.* (1994) and which concerns organisms that cause soil modifications. These modifications consist of biogenic structures (tunnels, channels, aggregated pores, coprolites, mounds and nests) through the movement of soil particles by these organisms, causing changes in both physical and chemical attributes (SWIFT *et al.*, 2010).

The order Hymenoptera comprises species that, although some cause agricultural and economic losses, play a fundamental role in soil maintenance and quality (KORASAKI *et al.*, 2013). The high incidence of this group both in the SAS area (34.8%) and in the SF area (50%) can be considered common, since most of these organisms live in colonies and on the ground, with different shapes, nests and habitats, and can be found even in terrestrial environments with few resources for survival (SANTOS *et al.*, 2006; MELO *et al.*, 2009). In addition, some genera of Hymenoptera seem to prefer simpler and more open environments, where solar radiation falls directly on the soil (ALMEIDA *et al.*, 2007). This characteristic contributes to the predominance of these organisms in younger areas, with less dense vegetation, as occurs in the SAS. Similar results were also observed by Brown *et al.* (2009), who found a higher percentage of these organisms in an agroforestry system with shorter implementation time.

The order Haplotaxida plays a crucial role in soil fertility, impacting both its physical and chemical and microbiological characteristics. Earthworms feed on dead organic matter, especially of plant origin, which favors the decomposition of this material and the distribution of nutrients in the soil (KORASAKI *et al.*, 2013). Thus, the greater presence of these individuals in the areas of SF (23.6%) and FF (28.1%), compared to the area of SAS (12.2%), may be related to the high contribution of organic matter, resulting from the diversity of plant species in these environments.

This result contrasts with that recorded by Lima *et al.* (2010), who found a higher density of earthworms in Agroforestry Systems (AS) compared to areas of native forest. However, it is important to consider that the two AS investigated in the aforementioned study had between 6 and 10 years of implantation, which suggests that these systems provided abundant vegetation cover, due to regular management through pruning and mowing. This, in turn, created favorable conditions for the survival and proliferation of earthworms.

Individuals of the order Coleoptera, both in their adult and larval stages, were found in the three areas studied, however, a higher occurrence was observed in the SAS area (31.7%) compared to those of SF (11.3%) and FF (10.2%). According to Martins *et al.* (2021), areas with crops, such as beans, corn, and cassava, may favor the presence of coleoptera, since some representatives of this group have a food preference for cultivated plants. Thus, the presence of this type of crop in the SAS may have favored the increase in the population of these insects, being a favorable environment for their occurrence.

The order Isopoda encompasses organisms that inhabit both aquatic and terrestrial environments. Terrestrial isopods play an important role in litter decomposition, mediating microbial activity, and nutrient cycling. The main effects on this group are the rapid growth of plants with increased litter production and favorable temperature and humidity conditions, in addition to responding well to environments with a high concentration of organic matter (LOUREIRO *et al.*, 2006; CORREIA *et al.*, 2008). The fact that these individuals had a higher occurrence in FF may be associated with the fact that collections were carried out near a small stream present in this area, which comes from a spring found in the neighboring vicinity. Thus, the high soil moisture in this FF portion may have contributed to the development of these

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organisms, as well as the higher organic matter content (5.39%) compared to SAS area (2,46%).

Although some groups observed were less representative, they perform important functions for soil quality and proper functioning (SILVA *et al.*, 2015).

When observing the ecological parameters, it was verified that the area with the highest richness index was the SAS (I = 2.15), followed by the FF area (I = 2.06) and the SF (I = 1.5) (Table 3). Regarding the Shannon diversity and Pielou equitability indexes, FF stood out, presenting H = 2.04 and e = 0.85, respectively, which indicates a better distribution of macroinvertebrates in the taxonomic groups collected, suggesting that, although species richness is high in the SAS, FF has a more balanced community structure, that is, with greater ecological diversity in terms of invertebrates. This result differs from that found by Lima *et al.* (2010) who observed a higher Shannon index and Pielou equitability in cultivated systems than in native forest.

Table 3 - Margalef Richness Index (I), Shannon Diversity (H) and Pielou Equitability Index (e) in an area of Syntropic Agroforestry System (SAS), Secondary Forest (SF) and Forest Fragment (FF).

Area	**Margalef Wealth Index (I)**	**Shannon Diversity Index (H')**	**Pielou Equitability Index (*e*)**
SAS	2.15	1.75	0.7
SF	1.5	1.46	0.7
FF	2.06	2.04	0.85

Source: Survey data, 2023.

The highest richness index observed in the SAS results from the exclusive presence of three groups in this area, Scorpione (0.6%), Orthoptera (0.6%) and Isoptera (4.9%), which may suggest the presence of specific and contributing factors to the appearance of these individuals in this area. The orders Orthoptera and Isoptera mainly encompass phytophagous individuals, that is, those that feed on living parts of vegetables, and some species have a food preference for cultivated plants, which can cause damage to the roots, stem and leaves. In addition, inadequate soil conditions can favor the appearance of termites (SPERBER *et al.*, 2012; CONSTANTINO, 2012). On the other hand, these individuals perform fundamental functions in the soil, especially in the recycling of mineral nutrients and soil formation. The order Scorpione, on the other hand, has specific requirements in relation to its habitat and micro-habitat, however, some species have high distribution flexibility, and can even be found in anthropic environments (LOURENÇO and EICKSTEDT, 2009).

The greater diversity observed in FF is a reflection of a greater stability of the environment. According to Ronquim (2010), factors such as a higher percentage of CEC associated with a higher content of organic matter, as presented in FM (Table 1), can characterize the soil as good, which favors plant fertility and contributes to the area presenting a greater diversity of food and micro-habitat for soil organisms.

The lower diversity indices in the SAS (H = 1.75) and SF (H = 1.46) areas are associated, among other factors, with the high population of the Hymenoptera group, since the predominance of a certain group to the detriment of others leads to low levels of diversity and uniformity (BIANCHI *et al.*, 2017).

It is important to emphasize that although agroforestry systems offer an environment conducive to the development of macrofauna, the SAS under study was still in an early stage of development (implemented in 2021), with young plants predominating the environment. Thus, the lack of structural complexity and plant diversity, characteristics of more mature systems, which are essential to provide different niches and resources necessary to sustain a more diverse community of macrofauna, contributed to the low diversity index in this area.

FINAL CONSIDERATIONS

The three study areas showed little variation among the taxonomic groups found, with the Hymenoptera, Haplotaxida, Coleoptera and Isopoda groups predominating.

A higher density and richness of organisms was recorded in the syntropic agroforestry system, compared to forest areas. Characteristics such as the age of SAS and the presence of cultivated plants contributed to the predominance of the orders Hymenoptera and Coleoptera and to the exclusivity of Scorpione, Orthoptera and Isoptera.

The Forest Fragment stood out in diversity and uniformity of individuals, demonstrating better stability of the environment for the development and distribution of macrofauna individuals.

Although Agroforestry Systems are a viable alternative for macrofauna, the resources of the SAS were not yet sufficient to sustain a wide variety of organisms, since it was still in the initial stage of development, and it is therefore important that new studies are carried out in order to have more current results about the system, which can serve as a comparison.

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