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RESEARCH ARTICLE

REVISED Diversity of functional edaphic macrofauna in *Musa acuminata* x *Musa balbisiana* (AAB) agroecosystems

[version 4; peer review: 2 approved, 1 approved with reservations]

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Abstract

Background

This study focused on evaluating the diversity and richness of the edaphic macrofauna in eight banana farms in the western zone of Nicaragua.

Methods

The sampling design was random and descriptive, it was divided into two phases, the first was the collection of the sample, and the second was the classification, coding, and storage of the extracted macrofauna populations. The sampling method employed included the extraction of soil and litter samples. Soil samples were collected using a wooden frame (monolith), with each sample weighing approximately 1 kilogram and taken from a depth of 0.20 cm. Litter samples were collected from the soil surface. A total of 80 samples were collected, with 40 soil samples and 50 litter samples obtained across the 8 plantain farms.

Results

The results showed that the relative abundance of biodiversity was higher in the 0–20 cm soil depth stratum than in the branch and leaf

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biomass strata. The values of the diversity indices of Simpson's Dominance, Shanon, Margalef, and Equity were in the normal range, with a tendency towards low diversity. Likewise, in the richness of species, the Dominance or most abundant genus were earthworms (*Oligochaeta*) and Hymenoptera (*Solenopsis*, *Leptothorax*, *Camponotus*, *Pheidole*), indicating the directly proportional relationship, that is to say, that the greater the number of earthworms the production increases and the greater the number of Hymenoptera it decreases, confirmed with the Pearson correlation coefficient with a reliability of 95%.

Conclusions

It was concluded that based on the estimates of the diversity indicators, two detritivore genus (earthworms and Hymenoptera) were the ones with the more dominance, being important in the production of the banana agrosystem due to the decomposition of organic matter and its nutritional contribution to the plant. We observed a direct correlation with earthworms and an indirect relationship with Hymenoptera.

Keywords

Eco-Intensification, Eco-system, Plantain, Diversity, Microfauna



This article is included in the **Agriculture, Food and Nutrition** gateway.



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REVISED Amendments from Version 3

We've carefully addressed all the feedback provided, ensuring comprehensive improvements throughout the manuscript:

Enhanced Abstract: The methodology section in the abstract has been clarified to provide a more detailed explanation of the monolith sampling technique. This adjustment ensures better understanding for readers.

Refutation of Unsupported Claim: We've revised the section to accurately represent the data, acknowledging the lack of support for the initial claim. This ensures alignment with observed findings.

Implementation of Bootstrap Technique: Following the reviewer's suggestion, we've incorporated the bootstrap technique to enhance result robustness, strengthening the validity of our conclusions.

Methodology Enhancement: The methodology section now includes a detailed explanation of how the bootstrap technique was applied, enhancing transparency and credibility.

Graphical Improvements: Figures 6, 1, and 2 have been revised to improve clarity and presentation. Additionally, Figure 7 has been added to provide further context and visualization.

Terminology Clarifications: Various terminology adjustments have been made for consistency and accuracy throughout the manuscript.

Textual Refinements: We've clarified and enhanced sections for better readability and comprehension, ensuring a smoother flow of information.

These revisions aim to address the reviewer's concerns comprehensively while improving the overall quality and reliability of the manuscript. The attached document reflects all the updates made in response to the feedback.

Any further responses from the reviewers can be found at the end of the article

Introduction

Soil management in banana agroecosystems is essentially successful for resilient agro-ecological production, adapted to climate change, and biodiversity, fundamentally in Latin America. [Berning *et al.* \(2022\)](#), [Gliessman \(2013\)](#), [Rousseau *et al.* \(2012\)](#), and [Delgado *et al.* \(2010b\)](#) indicate that agro-ecological conditions of the soil represent one of the ways to adapt precisely to the development of production in the banana sector ([McLaughlin *et al.*, 1995](#); [Challinor *et al.*, 2009](#); [Rousseau *et al.*, 2013](#)). The combination of *Musa acuminata* × *Musa balbisiana* (AAB) constitutes a food source in the Latin American diet ([Belalcázar, 2003](#)). For this reason, it is important to develop agricultural practices linked to the benefit of edaphic biodiversity and thus have productive and intensive agriculture characterized by various degrees of intensification of traditional, customary, transitional and organic agriculture ([Delgado *et al.*, 2010a](#)). Improving ecosystems and taking advantage of the usefulness of biodiversity in this process requires understanding the structure and function of biological and physical-chemical combinations. They include stability of the edaphic structure, reuse, storage, and supply of organic matter (OM) and nutrients, available soil moisture, and management of damage to micro, and macrofauna.

Similarly, authors such as [McKelvie-Sebileau *et al.* \(2022\)](#), [Samudio \(2010\)](#), [Shiyam *et al.* \(2010\)](#), and [Gizzi *et al.* \(2009\)](#) suggest that in nutritional irrigation systems where crops such as corn, beans, pumpkin, papaya, pineapple, coffee, cocoa are included, they demand the conservation of fungi, bacteria, viruses, harmful insects, nematodes and weed organisms, to do more effective environmental perceptions and producer profitability ([López, 1995](#); [MIFIC, 2007](#)).

Likewise, [Gutiérrez-Luna *et al.* \(2022\)](#), [Rodríguez *et al.* \(2013\)](#) and [Brown *et al.* \(2001\)](#) investigated that the impact of cultural practices of soil health should be evaluated through chains that maintain soil fertility. From this perspective, soil fertility studies of plantain should include previously unexplained constituents of the macrofauna as indicators of the richness in biodiversity, abundance, and degree of alteration of the ecological functions of the population.

On the other hand, invertebrate pests attract a lot of attention, and they cost farmers and producers millions of dollars ([Tresson *et al.*, 2022](#); [Velásquez *et al.*, 2012](#); [Alcaraván, 2003](#); [Decaëns *et al.*, 2004](#); [Cardona *et al.*, 1998](#)).

[Brown *et al.* \(2001\)](#) and [Pocasangre, Brown and Quesada \(2009\)](#) show that limited physical-chemical elements and fertility can lead to population decline. In the same way, they added that beneficial invertebrates for their basic and fundamental functions have received little attention. In general, [Velasquez *et al.* \(2007\)](#) shows that their behavior is taken for granted and the management of agroecosystems is rarely altered for their benefit. The importance of the invertebrate

edaphic macrofauna is closely linked to analyzing both the quantitative and qualitative biomass period over time and the generation of genetic biological components.

Medina *et al.* (2021), Djigal *et al.* (2012), Laossia *et al.* (2008) and Ruiz (2008) indicate that these organisms can experience a shortage of oxygen and light, fewer open spaces, poor availability and quality of food and a very strong variability of microclimates to be able to live in the soil, examples of these microorganisms are the centipedes, termites, earthworms, insects, mites (Medina *et al.*, 2021). Populations of all macrofauna reach millions per hectare and their biomass varies in tons per hectare (Priego-Castillo *et al.*, 2009; Wardle *et al.*, 1995). Their diversity can exceed 1,000 species in complex ecosystems (such as tropical forests), but precise data on the specific diversity of tropical edaphic megafauna in particular habitat is still lacking (Anderson, 1993; Zerbino, 2010; Zerbino *et al.*, 2008).

This work focused on evaluating the diversity and abundance of soil macrofauna in eight banana-producing farms in the North Pacific area of Nicaragua. The size of the samples is approximately 1 kilogram each. The depth of the soil samples is 0-20 centimeters. The sampling was based on litter and monolith extraction and is inspired by the TSBF method (Soil Monolith; Mulch scrutiny; CD: Direct capture). The period of sampling was in 2020 year. The taxa covered were Richness (number of species), DAFGA (RRID:SCR_003319), Relative abundance (Density number of individuals 1 m² for each species), Functional Groups (Density number of individuals 1 m² for each species), Shannon-Wiener Index (SW), Margalef Diversity Index, Proportional abundance indices, Dominance indices, Simpson index, Equity indices, and Pielou index. The taxonomical resolution depends on the degree of differentiation of morphological characteristics within the individual tribes, so in this studies the diversity by functional groups. Table 6 it is organized the Taxonomic classification of the edaphic macrofauna in kingdom, phylum, subphylum, class, order, family and genus (Zuniga-Gonzalez *et al.*, 2022b).

Methods

Table 1 shows the statistical description of the data used in this study. The full protocol can be found on protocols.io. The data describes the total population of species collected in litter strata by 0-20 cm soil depth. The first column refer the number of farm studied, four in Leon municipally and other four in Posoltega municipally. The second column describe the number of species find in each find identified by 30 genus. The third and fourth column refer the maximum and minimum of ind. x species find in each farm. The column fifth, sixth and seventh refer the mean, Std. Desviation and variance of the ind. x species find by each farm.

Geographic location of the study

The study was carried out in eight banana farms in the city of León and Posoltega (Table 2). The climatic conditions in the León area are characterized by having a rainfall of 1,529.7 mm, an average temperature per year of 38°C, and an altitude of 60 meters. The Posoltega area is characterized by an average annual temperature of 39°C, 2,000 mm of rain and an altitude of 70.42 meters above sea level, both areas are located in the western region of Nicaragua, see Figure 1 (MIFIC, 2007).

Agro system farms

The 8 selected farms or plots are in a process of changing production systems. Previously, these farms had a monoculture production system. These were annuals like cotton, peanuts, sugar cane. These systems heavily used insecticides and mechanized labor. However, these farms are currently moving to a production system from conventional to organic or

Table 1. Descriptive statistics.

Farm	N	Minimum	Maximum	Mean	Std. Deviation	Variance
Farm1	30	0.00	150.00	17.3333	35.30003	1246.092
Farm2	30	0.00	325.00	18.6667	61.99184	3842.989
Farm3	30	0.00	50.00	4.8333	12.14022	147.385
Farm4	30	0.00	65.00	7.5000	17.75067	315.086
Farm5	30	0.00	150.00	12.6667	33.18530	1101.264
Farm6	30	0.00	225.00	17.1667	52.50096	2756.351
Farm7	30	0.00	155.00	11.8333	33.20478	1102.557
Farm8	30	0.00	125.00	15.0000	34.56628	1194.828

Source: Self calculation' authors.

Table 2. Location of banana farms in the study area.

ID farmer	*Farm name	Area	Community	Municipality	Latitude	Longitude
1	Santa Isabel	266	Rio Grande N° 3	León	12°31'15.4"N	86°54'40.2"W
2	Quinta Cony	15.2	San Pedro	León	12°39'52.7"N	86°51'06.4"W
3	San Martín	72.2	San Pedro	León	12°39'52.7"N	86°51'06.4"W
4	El Verdón	7.6	San Pedro	León	12°39'52.7"N	86°51'06.4"W
5	San Joaquín	4.6	El Trianon	Posoltega	12°30'34.3"N	86°59'14.9"W
6	Montes Verdes	2.3	Chiquimulapa	Posoltega	12°32'03.0"N	86°59'09.7"W
7	María de los Ángeles	3.8	El Trianon	Posoltega	12°30'34.3"N	86°59'14.9"W
8	Los Ángeles	5.3	El Trianon	Posoltega	12°30'34.3"N	86°59'14.9"W

Source: Self calculation' authors.

*A farm typically includes one plots of land, where five point were sampled.

**Figure 1. Study area.** Map data ©2022 Google.

agroecological production. The cultivation of *Musa acuminata* × *Musa balbisiana* (AAB) is managed in association with horticultural items, changing chemical inputs for organic ones, such as the use of organic fertilizers and good agricultural practices. Administratively, the farms in Chinandega are managed by cooperatives, while those in León are managed by individual producers.

Investigative process phase

Tables 2 and 5 show eight farms that describe the name, area, community and municipality. In these farms, the investigation begins with the field phase where 40 edaphic samples of 0–20 cm depth and 40 biomass samples (leaf litter) were collected on the surface. A total of 80 samples of macrofauna populations were identified, coded, stored in the second phase. The study area in each farm (in each farm, samples were taken at five different points within the 1000 square meter parcel) was 0.7 ha delimited 1 plot in 1,000 m² (50 cm long × 20 cm wide), as described in Rousseau *et al.* (2012, 2013), and Medina *et al.* (2021). The area where the sample was collected are: Farm1 246.5 ha, Farm2 14.1, ha, Farm3 67 ha, Farm4 7 ha, Farm5 4.2 ha, Farm6 2.1 ha, Farm7 3.5 ha, Farm8 4.9 ha. In total 80 sample were collected in 1000 m² for 40 biomass sample and 40 edaphic sample in 0–20 cm depth.

After selecting the sampling area, sampling points are placed to collect soil samples. A wooden box 20 cm wide by 20 cm long was used to mark the sampling points, and to remove approximately 1 kg of soil. Divided into two consecutive layers (fallen leaves, 0–20 cm), each of them is surrounded to prevent microorganisms from escaping from the bottom, after which the material is sieved and separated manually and the insects found are placed in an airtight plastic bottle. After measuring 500 cubic centimeters in volume, they are labeled and preserved in 70% alcohol.

Identification of macrofauna species

The collected individuals were analyzed by order and family, the microorganisms were placed in Petri dishes and then observed under a 4–400× stereo microscope, to detail the specific structures of each of the species. Large animals include all organisms greater than 1.5 mm in length.

Diversity components

The diversity and richness of species present in this study were analyzed using the indicators reported by the authors Zerbino (2010) and Rousseau *et al.* (2012, 2013). Richness (number of species): the number is the number of species for

each farm, which was determined and totaled for each sampled system. The total number of individuals per species was counted and estimated.

Functional groups

Population abundance and species richness were determined by three main functional groups: herbivores, detritivores, and predators. To estimate the density, PAST (RRID:SCR_019129) 4.03 software was used, the indices selected for the study were: Dominance (D), Shannon-Wiener (H'), Margalef (Mg), Simpson (1-D), and Pielou (J').

Dominance Index (D): It is the comparative importance of a species related to the degree of influence it has on the individuals of the plantain agro system. It is based on competition for resources, which is why the characterization of the collected sample is used and then organized by functional group. Its inverse is the Simpson index.

Shannon-Wiener Index (H') (Equation 1): Considers the number of species found in the study area (species richness) and the relative frequency (abundance) of each of these species. It is used to determine the number of species and how those species are distributed. It is usually expressed as H' , expressed as a positive number that varies between 0.5 and 5. Values between 0.5–2 indicate a situation with low diversity, 2–3 is a normal situation, and 3–5 or more indicates a situation of high diversity.

$$H' = - \sum p_i \ln p_i \quad (1)$$

S : Richness or number of species; p_i : ratio of individuals of the species (i) with respect to the total number of individuals (that is, the relative abundance of the species i).

Margalef Diversity Index (DMg) (Equation 2): measures the specific richness of an area and the relationship between individuals and the total sample. The value 0 is when there is only one species in the sample ($s=1$, therefore $s-1=0$), values less than 2 are considered areas of low biodiversity and values greater than 5 are indicative of high biodiversity. Where:

$$D_{mg} = S^{-1} / \ln N \quad (2)$$

S = number of species; N = total number of individuals.

Simpson's Index (1-D) (Equation 3): this index is based on dominance. This is the inverse parameter of the concept of community unity or equality. Consider the representativeness of the most important species without evaluating the contribution of the remaining species. Values from 0 to 0.5 bring the value closer to a situation of high diversity, and values from 0.5 to 1 bring the value closer to low biodiversity.

Where:

$$\lambda = \sum p_i^2 \quad (3)$$

P_i = the number of individuals among the total species (i). Strongly influenced by the importance of the dominant species. Its value is the reciprocal of fairness, so the diversity is known as $1 - \lambda$.

Pielou Index (J) (Equation 4): stock market index. It measures the relationship between the observed diversity and the maximum expected diversity. Its value is between 0 and 0.1, so 0.1 corresponds to situations in which all species occur equally.

Where:

$$J' = H' / H'_{max} \quad (4)$$

Data analysis

Using IBM SPSS Statistics (RRID:SCR_016479) v.22 program, the data of individuals collected and ordered by categories were processed. Tables were created showing the groups of species present in each farm studied. For the analysis of the diversity indices, the PAST (RRID:SCR_019129) 4.03 software was used. Finally, Pearson's correlation was applied to identify the most dominant and most common group useful to understand the dominant interrelationship and its productivity within the plantain agro system.

Results and Discussion

The results showed that diversity and richness of the edaphic macrofauna was evaluated in eight farms in the western area. A total of 78.72% of the individuals were identified in the soil from 0–20 cm², while the remaining 21.26% in the foliage. In the first four farms in the León area, 23 genera were found, and in the Posoltega farms, 21 genera. The relative abundance of León was 1,450 individuals per m², while in the Posoltega area it was 1,700 individuals per m².

The farms selected for this study have agro-climatic differences and in farm management, the 4 farms in the Chinandega area have a higher rainfall regime and management is by associated cooperatives. The 4 farms in León have less rainfall and management is individual, that is, each producer manages his own farm.

Relative and dominant abundance

The genera *Geophilus* and *Leptothorax* had dominance with 70 individuals (Ind. m²), *Philoscia* with 160 Ind. m² and *Oxidus* with 110 Ind. m² and *Hypoconera* are 165 Ind. m², and earthworms are 590 Ind. m². Tables 1, 3 and 4, and Figure 2 (Zuniga-Gonzalez *et al.*, 2022a) show the general relative abundance of macrofauna found in the four banana plantations in the city of León between the litter layer and soil depths of 0–20 cm. In these plots was less mulch and leaf litter in the streets of the plantation. In the municipality of Posoltega, *Pheidole* sp. 280 Ind. m², *Solenopsis* sp. 290 Ind. m², *Asiomorpha* 170 Ind. m², *Earthworm* 600 Ind. m². A characteristic of the Chinandega area is that there was more leaf litter on the ground, covered ground, higher soil moisture, more vegetation between the streets (Tables 5 and 6). The genus *Pheidole* sp., was found in the soil of a banana plantation in the city of León, and the genus *Solenopsis*. However, the frequencies of *Earthworm* individuals are similar in both communities. Zerbino *et al.* (2008) presented the two most abundant groups of the subclass Oligochaeta of the order Opisthopora and insects of the order Hymenoptera, representing 46 and 20% of the total number of individuals collected, respectively. This confirms our findings with earthworms (*Opisthopora*) and Hymenoptera (*Pheidole* and *Solenopsis*) accounting for 37.77 and 18.25%, respectively, of all individuals collected.

In a study by Priego-Castillo *et al.* (2009) and Castillo and Vera (2000), reported that the Hymenoptera group was the most abundant, with 62.49% of the total individuals collected during the 2,000 agricultural cycle in organic and conventional banana plantations in Guacimo, Costa Rica. This means that the soil is moist throughout the year. However, the presence of *Earthworms* (*Opisthopora*) was 11.92% and abundant in all stages, this is due to rainfall patterns, that is, humidity, although rainfall is higher in Chinandega.

In the municipality of León, Farm 1 shows that *Earthworms* dominated at 150 Ind. m² and *Oxidus* dominate with 70 Ind. m². In farm 2, *Earthworms* dominated at 325 Ind. m², and *Hypoconera* spp. with 115 Ind. m², likewise in farm 4 El Verdón, stand out, genus *Leptothorax* (*Opisthopora*) of 45 Ind. m², 65 Ind. m² of *Scarabaeidae* and 65 Ind. m² of *Earthworms*, however, in farm 3, only the genus, *Philoscia*, in Farm 3, measures 45 Ind. m² and *Earthworms* dominated at 50 Ind. m² (Tables 5 and 6). The municipal of León has a greater wealth of sexes with 23 representative genus, but a lower overall dominance (Ind. m²). In four farms (San Martín, Santa Isabel, Quinta Cony, and El Verdon) *Earthworm* frequencies were found to be similar, but less common genera such as *Leptothorax* and *Asiomorpha* were found. climatic conditions and agroecological management are factors that have influenced these results that are similar to Priego-Castillo *et al.* (2009) in Costa Rica.

These data on *Earthworm* populations in litter and layers from 0 to 20 cm² have been confirmed by Castillo and Vera (2000), Pashanasi (2001), Zerbino (2010), and these populations have a beneficial role in the soil. Training is very important and sensitive to management practices in the banana farms of León and Posoltega. In this area, the rains have created favorable conditions for the macrofauna and the management of the soil make these results more notable than in León.

Table 4 shows the relative abundance by farm and by functional group, noting that the detritivores group is more abundant, followed by predators. The leaf litter and humidity conditions make organic matter a propitious environment for the detritivores group. These dominance groups exerted a beneficial function on the soil, allowing increased production yields because they are the responsible for breaking down OM and providing nutrition for plants (Brown *et al.*, 2000).

For the municipality Posoltega, in farm 6, earthworms dominate with 225 Ind. m² and *Solenopsis* spp. with 190 Ind. m², farm 8 had *Asiomorpha* spp. with 125 Ind. m² (Tables 5 and 6). Plantain farms in Posoltega are repopulated with *Solenopsis* worms and ants (Pashanasi, 2001; Zerbino, 2010; Rousseau *et al.*, 2012). This is likely because they occupy the same ecological niches in which they coexist, interact with similar food sources, land, husbandry and management skills, and benefit from abundant and prosperous communities. These data are supported by Zayas *et al.* (2022), Quiroz-Medina *et al.* (2021), Castillo y Vera (2000), and Rousseau *et al.* (2013).

Table 3. Total relative abundance (p_i) according to functional group by farms.

Species number	Genus	Leon municipality				Posoltega municipality				Total %									
		Farm 1	p_i	Farm 2	p_i	Farm 3	p_i	Farm 4	p_i	Farm 5	p_i	Farm 6	p_i	Farm 7	p_i	Farm 8	p_i	Biomass	p_i
		Ind. m ²		Ind. m ²		Ind. m ²		Ind. m ²		Ind. m ²		Ind. m ²		Ind. m ²		Ind. m ²		Ind. m ²	
HERBIVORES																			
	1	Diptera	0.00	0.00	5.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
	2	Elateridae	15.00	0.60	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
	3	Leptothorax	10.00	0.40	5.00	0.50	10.00	0.67	45.00	1.00	10.00	0.00	0.00	0.00	0.00	10.00	1.00		
	Total	25.00	1.00	10.00	1.00	15.00	1.00	45.00	1.00	10.00	0.00	0.00	0.00	0.00	0.00	10.00	1.00	115.00	0.04
	p_i		0.05		0.02		0.10		0.20				0.03			0.00	0.02		
DETRITIVORES																			
	4	Philoscia	95.00	0.26	20.00	0.05	45.00	0.38	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00		
	5	Lathrobium	35.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	25.00	0.08	0.00	0.00	5.00	0.01		
	6	Oxidus	70.00	0.19	40.00	0.10	0.00	0.00	0.00	0.00	0.03	30.00	0.10	0.00	0.00	0.00	0.00		
	7	Asiomaorpha	15.00	0.04	0.00	0.00	5.00	0.04	10.00	0.07	0.00	5.00	0.02	40.00	0.24	125.00	0.35		
	8	Earthworms	150.00	0.41	325.00	0.81	50.00	0.42	65.00	0.43	150.00	0.88	225.00	0.73	100.00	125.00	0.35		
	9	Laboptera	0.00	0.00	5.00	0.01	15.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
	10	Lobopoda	0.00	0.00	5.00	0.01	0.00	0.00	5.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
	11	Bolbelamus	0.00	0.00	5.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
	12	Reticulitermes	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.03	0.00	0.00	0.00	0.00	5.00	85.00	0.24		
	13	Scarabeidae	0.00	0.00	0.00	0.00	0.00	0.00	65.00	0.43	0.00	0.00	20.00	0.06	0.00	15.00	0.04		
	14	Darkling beetle	0.00	0.00	0.00	0.00	5.00	0.04	0.00	0.00	0.00	0.00	5.00	0.02	10.00	0.00	0.00		
	15	Cylindroiulus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00	0.06	0.00	0.00	5.00	0.00	0.00		
	16	Coproporus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.00	0.00		
		Total	365.00	1.00	400.00	1.00	120.00	1.00	150.00	1.00	170.00	1.00	310.00	1.00	165.00	355.00	1.00	2035.00	0.65
	p_i		0.70		0.71		0.83		0.67		0.45		0.60	0.46		0.79			
PREDATORS																			
	17	Geophilus	65.00	0.50	0.00	0.00	0.00	0.00	0.17	0.00	0.00	5.00	0.02	0.00	0.00	20.00	0.24		
	18	Pheidole	0.00	0.00	0.00	0.00	0.00	0.00	0.17	80.00	0.40	0.00	0.00	155.00	0.82	45.00	0.53		
	19	Carabidae	15.00	0.12	0.00	0.00	0.00	0.00	0.17	15.00	0.08	5.00	0.02	0.00	0.00	0.00	0.00		
	29	Hypoponera (ponerini)	50.00	0.38	115.00	0.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
21	Camponotus	0.00	0.00	30.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			

Table 3. Continued

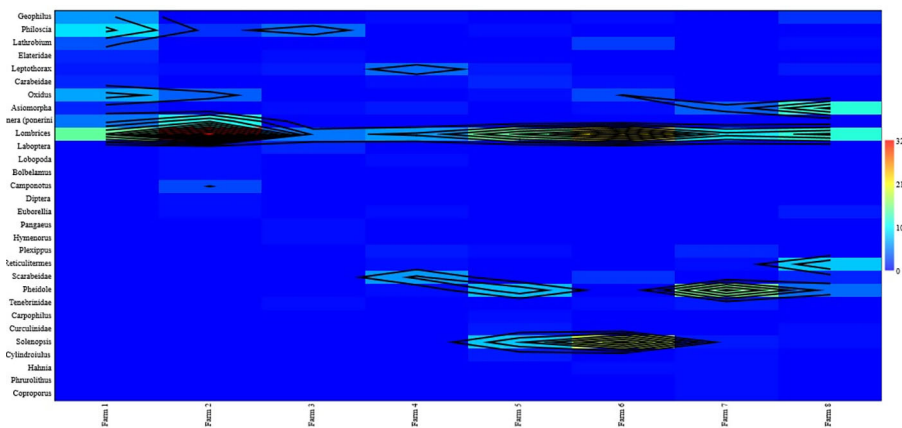
Species number	Genus	Leon municipality				Posoltega municipality								Total %					
		Farm 1	p_i	Farm 2	p_i	Farm 3	p_i	Farm 4	p_i	Farm 5	p_i	Farm 6	p_i	Farm 7	p_i	Farm 8	p_i	Biomass	p_i
		Ind. m ²		Ind. m ²		Ind. m ²		Ind. m ²		Ind. m ²		Ind. m ²		Ind. m ²		Ind. m ²		Ind. m ²	
22	<i>Euborellia</i>	0.00	0.00	5.00	0.03	0.00	0.00	5.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	10.00	0.12		
23	<i>Pangaeus</i>	0.00	0.00	0.00	0.00	5.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
24	<i>Hymenarus</i>	0.00	0.00	0.00	0.00	5.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
25	<i>Plexippus</i>	0.00	0.00	0.00	0.00	0.00	0.00	10.00	0.33	5.00	0.03	0.00	0.00	15.00	0.08	0.00	0.00		
26	<i>Carpophilus</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00		
27	<i>Curculinidae</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00	0.05	0.00	0.00	0.00	0.00	5.00	0.06		
28	<i>Solenopsis</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	85.00	0.43	190.00	0.93	10.00	0.05	5.00	0.06		
29	<i>Hahnia</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.02	5.00	0.03	0.00	0.00		
30	<i>Phrurolithus</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.03	0.00	0.00		
	Total	130.00	1.00	150.00	1.00	10.00	1.00	30.00	1.00	200.00	1.00	205.00	1.00	190.00	1.00	85.00	1.00	1000.00	0.32
	p_i		0.25		0.27		0.07		0.13		0.53		0.40		0.54		0.19		
	Total S and p_i	520.00	3.00	560.00	3.00	145.00	3.00	225.00	3.00	380.00	3.00	515.00	2.00	355.00	2.00	450.00	3.00	3150.	1.00
															Grand total				
Standard deviation		35.3		61.95		12.14		17.75		33.19		52.50		33.20		34.57			

Source: Self calculation' authors.

Table 4. Total relative abundance (p_i) according to functional group in the farms of the León and Chinandega municipality.

Functional group	Farm 1 p_i	Farm 2 p_i	Farm 3 p_i	Farm 4 p_i	Farm 5 p_i	Farm 6 p_i	Farm 7 p_i	Farm 8 p_i	Total p_i
Herbivores	5	2	10	20	3	0	0	2	4
Detritivores	70	71	83	67	44	60	46	79	64
Predators	25	27	7	13	53	40	54	19	32
Standard deviation	34.3	61.95	12.14	17.7	33.19	52.5	33.2	34.5	

Source: Self calculation^a authors.

**Figure 2.** Overall relative abundance of macrofauna found. This heatmap was constructed using PAST software.

Diversity indices

Table 7 shows the diversity indices per farm. In general, the farms studied present a taxonomic variety of biomass (3,150 individuals). In general, a low dominance (less than 40%) is observed in each of the farms. The Shannon-Wiener index shows low diversity with values less than 2, except for farms 1, 4 and 8 with values close to 2, meaning normal diversity. The Shannon indexes are not superior to those of Melo (2010), who had a high diversity value of the Shannon index of $H' = 2.61$, which indicates that the Kikuyu prairie has the highest richness in both families and organisms. Rousseau *et al.* (2012, 2013), present low-quality data on diversity, dominance, wealth, and stock market indices.

The Simpson index confirms this low diversity with values close to 1. The specific richness of the area and the relationship between individuals and the total sample reflected by the Margalef index (DMg) with values less than 2. This is considered as areas of low biodiversity. The Pielou evenness index indicates that not all farms presented situations where all species were equally abundant (Krebs, 1999).

Functional groups

Table 3 shows a summary of the relative abundance of biodiversity in the study area by functional group (Castañeda *et al.*, 2022; Quiroz-Medina, 2021). As mentioned above, the species equity indices are not equal. The lowest percentage of taxonomic presence is in the functional group of herbivores. The biomass has a greater presence (above 50% in the group by function of detritivores and in the group of predators below 50%).

In studies reported by Zerbino *et al.* (2008) and Zerbino (2010), shown that the discrepancies in the constitution of the macrofauna's community and proportions of functional groups are aspects influenced by the species, the richness of plant species and management, and states that it affects living organisms. This is because they determine the available resources and influence the interactions between herbivores, their controllers, and the predators identified by Moore *et al.* (2004).

This supports the findings that monoculture influences has a significant impact on resource availability, thus affecting the interactions between functional groups per square meter in the city of Posoltega. The results indicated that the texture

Table 5. Total population of taxa collected in litter strata and 0-20 cm² soil depth.

Taxa number	Taxa	Posoltega municipality								Standard deviation
		Farm 1 Ind. m²	Farm 2 Ind. m²	Farm 3 Ind. m²	Farm 4 Ind. m²	Farm 5 Ind. m²	Farm 6 Ind. m²	Farm 7 Ind. m²	Farm 8 Ind. m²	
1	<i>Geophilus</i>	65	0	0	5	0	5	0	20	22.51
2	<i>Philoscia</i>	95	20	45	0	5	0	0	0	33.96
3	<i>Lathrobium</i>	35	0	0	0	0	25	0	5	13.87
4	<i>Elateridae</i>	15	0	5	0					7.07
5	<i>Leptothorax</i>	10	5	10	45	10	0	0	10	14.33
6	<i>Carabeidae</i>	15	0	0	5	15	5	0	0	6.55
7	<i>Oxidus</i>	70	40	0	0	5	30	0	0	26.18
8	<i>Asiomorpha</i>	15	0	5	10	0	5	40	125	44.43
9	<i>Hypoponera (ponerini)</i>	50	115	0	0	0	0	0	0	41.96
10	<i>Earthworms</i>	150	325	50	65	150	225	100	125	89.91
11	<i>Laboptera</i>	0	5	15	0	0	0	0	0	5.35
12	<i>Lobopoda</i>	0	5	0	5	0	0	0	0	2.31
13	<i>Bolbelamus</i>	0	5	0	0	0	0	0	0	1.77
14	<i>Camponotus</i>	0	30	0	0	0	0	0	0	3.78
15	<i>Diptera</i>	0	5	0	0	0	0	0	0	1.77
16	<i>Euborellia</i>	0	5	0	5	0	0	0	10	1.77
17	<i>Pangaeus</i>	0	0	5	0	0	0	0	0	5.82
18	<i>Hymenorus</i>	0	0	5	0	0	0	0	0	29.63
19	<i>Plexippus</i>	0	0	0	10	5	0	15	0	5.82
20	<i>Reticulitermes</i>	0	0	0	5	0	0	5	85	29.63
21	<i>Scarabeidae</i>	0	0	0	65	0	20	0	15	22.68
22	<i>Pheidole</i>	0	0	0	5	80	0	155	45	56.46
23	<i>Tenebrinidae</i>	0	0	5	0	0	5	10	0	3.78
24	<i>Carpophilus</i>	0	0	0	0	5	0	0	0	1.77
25	<i>Curculinidae</i>	0	0	0	0	10	0	0	5	3.72
26	<i>Solenopsis</i>	0	0	0	0	85	190	10	5	68.6
27	<i>Cylindroiulus</i>	0	0	0	0	10	0	5	0	3.72
28	<i>Hahnia</i>	0	0	0	0	0	5	5	0	2.31
29	<i>Phrurolithus</i>	0	0	0	0	0	0	5	0	1.77
30	<i>Coproporus</i>	0	0	0	0	0	0	5	0	1.77

Source: Self calculation¹ authors.

Table 6. Taxonomic classification of the edaphic macrofauna in kingdom, phylum, subphylum, class, order, family and genus.

Species number	Kingdom	Phylum	Class	Order	Family	Genus	Functional group
1	Animalia	Arthropoda	Insecta	Diptera	Housefly (Muscidae)	<i>Diptera Linnaeus, 1758</i>	Herbivores
2	Animalia	Arthropoda	Insecta	Coleoptera	Elateridae Leach, 1815	<i>Click beetle adults and larvae (wireworms)</i>	Herbivores
3	Animalia	Arthropoda	Insecta	Hymenoptera	Myrmicinae	<i>Leptothorax Mayr, 1855</i>	Herbivores
4	Animalia	Arthropoda	Malacostraca	Isopoda	Philosciidae	<i>Philoscia Latreille, 1804</i>	Detritivores
5	Animalia	Arthropoda	Insecta	Coleoptera	Staphylinidae	<i>Lathrobium Gravenhorst, 1802</i>	Detritivores
6	Animalia	Arthropoda	Diplopoda	Polydesmida	Paradoxosomatidae	<i>Oxidus Cook, 1911</i>	Detritivores
7	Animalia	Arthropoda	Diplopoda	Polydesmida	Paraxosomatidae	<i>Orthomorpha coarctata (De Saussure, 1860)</i>	Detritivores
8	Animalia	Annelida	Clitellata	Oligochaeta	Lumbricidae	<i>Earthworms</i>	Detritivores
9	Animalia	Annelida	Insecta	Blattidae	Ectobiidae	<i>Loboptera Brunner von Wattenwyl, 1865</i>	Detritivores
10	Animalia	Annelida	Insecta	Coleoptera	Tenebrionidae	<i>Lobopoda Soller, 1835</i>	Detritivores
11	Animalia	Arthropoda	Insecta	Coleoptera	Bolboceratidae	<i>Bolbelasmusunicornis (Schrank, 1789)</i>	Detritivores
12	Animalia	Arthropoda	Insecta	Isotera	Rhinotermitidae	<i>Reticulitermes Holmgren, 1913</i>	Detritivores
13	Animalia	Arthropoda	Insecta	Coleoptera	Scarabaeidae	<i>Scarab Beetle Latreille, 1802</i>	Detritivores
14	Animalia	Annelida	Insecta	Coleoptera	Tenebrionidae Latreille, 1802	<i>Darkling beetle</i>	Detritivores
15	Animalia	Arthropoda	Diplopoda	Julida	Julidae	<i>Cylindrus terutonicus Pocock, 1900</i>	Detritivores
16	Animalia	Arthropoda	Insecta	Coleoptera	Staphylinidae	<i>Coproporus Kraatz, 1857</i>	Detritivores
17	Animalia	Arthropoda	Chilopoda	Geophilomorpha	Geophilidae	<i>Geophilus Leach, 1814</i>	Predators
18	Animalia	Arthropoda	Insecta	Hymenoptera	Formocidae	<i>Pheidole Westwood, 1839</i>	Predators
19	Animalia	Arthropoda	Insecta	Coleoptera	Carabidae Latreille, 1802	<i>Ground beetles</i>	Predators
20	Animalia	Arthropoda	Insecta	Hymenoptera	Ponerinae	<i>Hypoconera Santschi, 1938</i>	Predators
21	Animalia	Arthropoda	Insecta	Hymenoptera	Formicidae	<i>Camponotus Mayr, 1861</i>	Predators
22	Animalia	Arthropoda	Insecta	Dermoptera	Anisolabididae	<i>Euborellia Burr, 1910</i>	Predators
23	Animalia	Arthropoda	Insecta	Hemiptera	Cydnidae	<i>Pangaeus Stal, 1862</i>	Predators
24	Animalia	Arthropoda	Insecta	Coleoptera	Alleulidae	<i>Hymenorus (Mulsant, 1851)</i>	Predators
25	Animalia	Arthropoda	Arachnida	Araneae	Salticidae	<i>Plexippus (Audouin, 1826)</i>	Predators
26	Animalia	Arthropoda	Insecta	Coleoptera	Nitidulidae	<i>Carpophilus Stephens, 1830</i>	Predators
27	Animalia	Arthropoda	Insecta	Coleoptera	Curculionidae Latreille, 1802	<i>True weevils and bark beetles</i>	Predators
28	Animalia	Arthropoda	Insecta	Hymenoptera	Myrmicinae	<i>Solenopsis Westwood, 1840</i>	Predators
29	Animalia	Arthropoda	Arachnida	Araneae	Hahnidae	<i>Hahnia C. L. Koch, 1841</i>	Predators
30	Animalia	Arthropoda	Arachnida	Araneae	Phrurolithidae	<i>Phrurolithus C.J Koch, 1839</i>	Predators

Source: Self calculation' authors.

Table 7. Diversity index by farm.

Index	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6	Farm 7	Farm 8
Genus Typos	10	11	9	11	11	10	11	11
Ind. m ²	520	560	145	225	380	515	355	450
Dominance (D)	0.167	0.3887	0.2366	0.2138	0.2545	0.3347	0.287	0.2044
Simpson (1-D)	0.833	0.6113	0.7634	0.7862	0.7455	0.6653	0.713	0.7956
Shannon (H)	1.989	1.358	1.73	1.824	1.673	1.393	1.6	1.828
Margalef (Mg)	1.439	1.58	1.607	1.846	1.683	1.441	1.703	1.637
Equitability (J)	0.8637	0.5663	0.7873	0.7605	0.6975	0.6051	0.6671	0.7622

Source: Self calculation' authors.

of the biocenosis is consistent with the edaphic properties and the quantity and quality of the residues (Almonte, 2022; Leyva, 2012; Curry, 1992). In zero tillage, management practices that promote the presence of residues with spatial and temporal diversification of plant species have richer, more diverse and equitable communities, with a predominance of deterioration functional groups (Priego *et al.*, 2009; Zerbino, 2010; Zerbino *et al.*, 2008). This is consistent with the findings in the present study (see Tables 3-8).

Table 8. Diversity Indexes by functional group.

Indexes	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6	Farm 7	Farm 8
Herbivores								
Genus Typos	2	2	2	1	1	0	0	1
Ind. m ²	25	10	15	45	10	0	0	10
Dominance (D)	0.52	0.5	0.5556	1	1	0	0	1
Index (1-D)	0.48	0.5	0.4444	0	0	0	0	0
Index (H)	0.673	0.6931	0.6365	0	0	0	0	0
Index (Mg)	0.3107	0.4343	0.3693	0	0	0	0	0
Index (J)	0.971	1	0.9183	0	0	0	0	0
Detritivores								
Genus Typos	5	6	5	5	4	6	6	5
Ind. m ²	365	400	120	150	170	310	165	355
Dominance (D)	0.2843	0.6731	0.3333	0.3822	0.7837	0.5473	0.4325	0.3073
Index (1-D)	0.7157	0.3269	0.6667	0.6178	0.2163	0.4527	0.5675	0.6927
Index (H)	1.388	0.7131	1.257	1.132	0.4845	0.9716	1.135	1.271
Index (Mg)	0.678	0.8345	0.8355	0.7983	0.5841	0.8716	0.9793	0.6812
Index (J)	0.8627	0.398	0.7812	0.7034	0.3495	0.5423	0.6333	0.7898
Predators								
Genus Typos	3	3	2	5	6	4	5	5
Ind. m ²	130	150	10	30	200	205	190	85
Dominance (D)	0.4112	0.6289	0.5	0.2222	0.35	0.8608	0.6759	0.3564
Index (1-D)	0.5888	0.3711	0.5	0.7778	0.65	0.1392	0.3241	0.6436
Index (H)	0.9632	0.639	0.6931	1.561	1.259	0.3422	0.713	1.262
Index (Mg)	0.4109	0.3992	0.4343	1.176	0.9437	0.5636	0.7623	0.9004
Index (J)	0.8768	0.5816	1	0.9697	0.7025	0.2468	0.443	0.7843

Source: Self calculation' authors.

The analysis confirmed that Posoltega had lower populations of herbivores per m² and 460 carnivores per m² (Table 3). This confirms the conditions for the detritivores with the decomposition of the organic matter that produces the rainy regime and the greatest amount of litter.

Table 8 shows the diversity indicators by functional groups. These are predominantly detritivores of 400 Ind. m², and predators 205 Ind. m², in contrast to El Verdón on farm 4, which has a low population of herbivores of 45 Ind. m², detritivores 150 Ind. m² due to the large population of predators found. Similarly, at Farm 8 Los Angeles there were only 10 Ind. m² herbivores. This is due to the large population of 85 Ind. m² predators, also to the agro climatic conditions (Tables 3-5 and 6).

The data collected in the León area show that the herbivorous functional group has a low proportion of Diversity by the values of the Shannon-Wiener index (H) with a value close to 1 denoting low diversity, this is considered within normality, Dominance Simpson (1-D) with a value close to 1 and Pielou Equity (J') very close to 1 as in the case of farm 2, meaning equally abundant species. However, the Margalef Diversity Index (DMg) showed a value below 2 considering for areas of low diversity, similar to the work of Frederick *et al.* (2018).

Three indicators dominance in the functional group of detritivorous organisms in the city of León. Margalef Diversity (DMg) with a value below 2 means that no farm with this group can be considered as having high diversity. For Simpson Dominance (1-D) it can be said that they are at a midpoint between 1 and 0 with a normal diversity and a Pielou Equity Index (J') with a value close to 1 situation where all species are equally abundant, of the indices for the Predators group were dominated by three indices: DMg in farm 4, which almost reaches value 2, it can be said that they are within the normal range, and Shannon-Wiener Diversity (H) with values lower than 1 indicating low diversity. This contrasts with the Posoltega area, where Simpson (1-D) dominates with a value close to 0, which implies a high diversity, these organisms are favored because on these farms, litter was found in the alleys creating decomposing matter favored by humidity (Depaquit *et al.*, 2016).

Table 8 shows the estimates of the indices of population abundance and species richness, determined by functional groups. According to the DMg, the value found was less than 2 considered as a zone of low biodiversity, which assumes that the number of individuals is equal to the number of species. In the Simpson index, the probability that eight individuals taken at random are of the same species is 0.2 in the case of León and 0.19, this constitutes a low probability, since most of the farms are made up of the genus *Earthworms*, and that had a lot of abundance of the same species. The Pielou Equity Index (J) confirms these with values close to 1 where all species are equally abundant (Bottinelli *et al.*, 2010).

Diversity and productivity

Samples were taken for the comparative study between plantain production and the two most abundant genera, earthworms and Hymenoptera, both of which are beneficial in the decomposition of OM and the supply of nutrients to the plant. In the dominance of worms, the Quinta Cony (Farm 2) was found where 325 Ind. m² collected, followed by the Montes Verde farm (Farm 6) with 225 Ind. m². Hymenoptera were dominant on the San Joaquín farm (Farm 5) with 175 Ind. m² and on farm 7 with 165 Ind. m² (Pimentel *et al.*, 1997) (Table 9 and Figure 3).

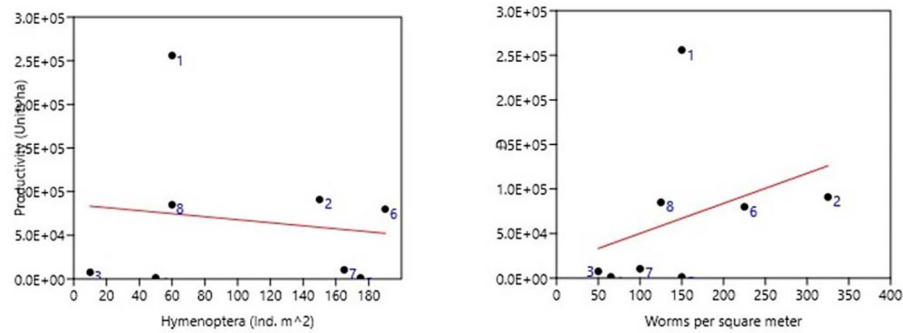
To compare the psyllium production of each farm, the proportion of worms and insects of the two most abundant genera, the order Hymenoptera, was taken, indicating that a greater number of worms indicates a greater production. It was observed that for Hymenoptera, the production is lower. The farms with the highest production in the León area were Quinta Cony with 91,000 ha and Santa Isabel with 25,600 ha. The farm of 80,000 ha in farm 8 and farm 6 with 85,000 ha in Montes Verdes for the Posoltega area (Figures 3, 4 and 5).

Pearson's correlation analysis commonly correlates agricultural production (plantain units ha) and the abundance of earthworms and hymenopteran insects, projecting a correlation close to 1 with 95% confidence. The relationship between plantain production per ha and the abundance of earthworms of Ind. m² establishes a direct relationship, with a Pearson correlation coefficient of 0.743, close to 1, and a perfect or strong relationship in the Pearson correlation analysis (Table 10). That is, by increasing the number of earthworms in the soil, the production of plantain per ha increases in the farms studied in both regions (León and Posoltega). On the other hand, a Pearson correlation coefficient of 0.261 (Table 9) was obtained, which indicated that the relationship between production and abundance of Hymenoptera is very close to 0, thus showing a weak correlation between production and abundance of Hymenoptera insects (Ma *et al.*, 2022).

The city of León has three strong ties. The first relationship (Pearson correlation coefficient 0.988) between productivity (psyllium units per ha on the farm) and earthworm abundance (Table 10) shows a strong correlation. The second

Table 9. Agricultural production (banana units per ha) and the abundance of earthworms and hymenopteran insects (Ind. m²).

Farm ID	Community	Production Units ha	Hymenoptera Ind. m ²	Earthworm Ind. m ²	Abundance estimated overall Earthworm production Ind. m ²	Abundance estimated overall Hymenoptera production Ind. m ²
1	Santa Isabel	256,000	60	150	38183.9	33585.36
2	Quinta Cony	91,000	150	325	96299.82	88084.08
3	San Martín	7,500	10	50	4974.8	2206.36
4	El Verdón	1,300	50	65	9956.16	1524.32
5	San Joaquín	1,250	175	150	38183.9	25825
6	Montes Verdes	80,000	190	225	63090.72	70250
7	María de los Ángeles	10,500	165	100	21579.35	4125
8	Los Ángeles	85,000	60	125	29881.62	85000

Source: Self calculation^a authors.

Variable	Slope a	Intercept	Std error a	Std error b	r	P (uncorr.)
Hymenoptera (Ind. m ²)	-173.01	85168	502.21	63089	-0.13927	0.7422
Earthworms (Ind. m ²)	337.18	16413	366.91	62711	0.3512	0.39365

Figure 3. Productivity vs. Hymenoptera and Earthworms.

relationship between productivity and abundance of Hymenoptera insects has a Pearson correlation coefficient of 0.942 (Table 10), indicating a strong correlation. A third relationship between the abundances of earthworms and hymenopteran insects is a Pearson correlation coefficient of 0.968 (Table 10), which is very strong because the coefficient is close to 1, indicating that the number of earthworms becomes a direct relationship as it increases. In the municipality of Posoltega, the relationship between earthworm production and abundance is weak, with a Pearson correlation coefficient of 0.465. A Pearson correlation coefficient of -0.484 (Table 10) indicates a negative relationship, with a decrease in the second abundance ratio of earthworms and hymenopterans. However, the abundance of hymenopteran insects is preserved. The increase in the number of worms increased the production and abundance of Hymenoptera, with a Pearson correlation coefficient of 0.469, favoring a direct relationship. On the other hand, the relationship between the number of hymenopteran insects and production is inversely correlated, with a Pearson correlation coefficient of -0.484 (Table 10). That is, as the number of Hymenoptera decreases, production decreases (Table 10). Table 11 and Figure 6 show the Pearson correlation coefficients by farm.

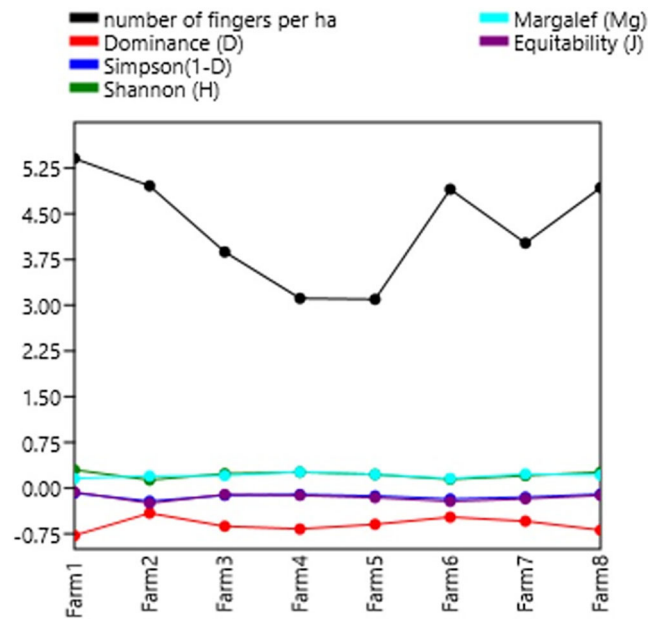


Figure 4. Relationship between diversity indices and productivity in plantain agroecosystems, Nicaragua.

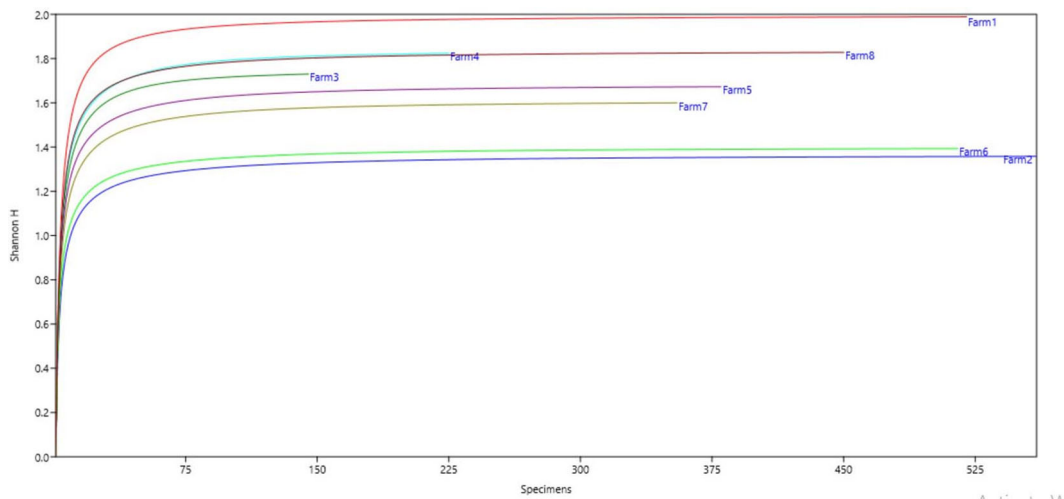


Figure 5. Shannon Index.

Table 10. Pearson correlation coefficients of the banana production with the density Ind. m² of earthworms and Hymenoptera insects.

Study zone	Banana Production	Earthworms	Hymenopteras
Both areas			
Banana Production		0.743*	0.261*
Earthworms	0.743*		0.608*
Hymenopteras	0.261*	0.608*	
León			
Banana Production		0.988*	0.942*
Earthworms	0.988*		0.968*
Hymenopteras	0.942*	0.968*	

Table 10. *Continued*

Study zone	Banana Production	Earthworms	Hymenopteras
Posoltega			
Banana Production		0.465*	-0.484*
Earthworms	0.465*		0.469*
Hymenopteras	-0.484*	0.469*	

Source: Self calculation' authors.

*Significance $p < 0.05$.**Table 11.** Pearson correlation by farm.

Farm1	Farm2	Farm3	Farm4	Farm5	Farm6	Farm7	Farm8
1	.781**	.765**	.377*	.502**	.526**	.278	.407*
.781**	1	.667**	.539**	.704**	.686**	.433*	.520**
.765**	.667**	1	.426*	.513**	.477**	.302	.394*
.377*	.539**	.426*	1	.461*	.450*	.303	.462*
.502**	.704**	.513**	.461*	1	.863**	.747**	.518**
.526**	.686**	.477**	.450*	.863**	1	.368*	.428*
.278	.433*	.302	.303	.747**	.368*	1	.590**
.407*	.520**	.394*	.462*	.518**	.428*	.590**	1

Source: Self calculation' authors.

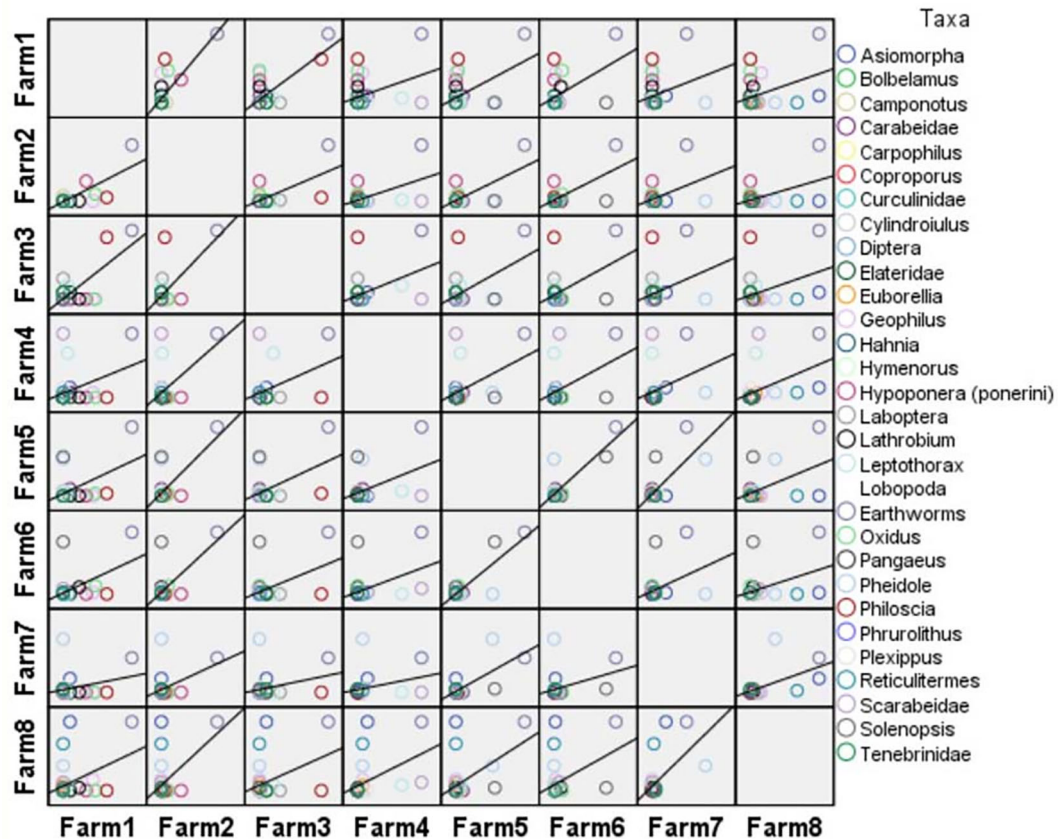
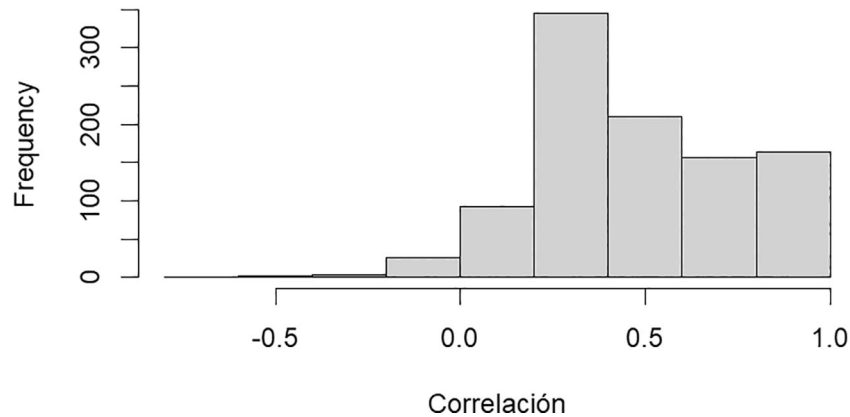
*Significance $p < 0.05$.**Significance $p < 0.01$.**Figure 6.** Pairwise Pearson correlation plot.

Table 12. Bootstrap statistics for Hymenoptera and Worms.

	Original*	Bias	Std. error
Hymenoptera	-0.139	0.04	0.36
Worms	0.351	0.12	0.27

*t1.

Distribución de Correlaciones Bootstrap para 'Worms'

**Figure 7. Bootstrap correlation distribution for Worms.**

The results of the bootstrap analysis reveal insights into the relationship between banana production and the abundance of Hymenoptera insects and earthworms (Table 12, Figure 7). The correlation analysis indicates a slight negative correlation between banana production and Hymenoptera abundance, with a coefficient of approximately -0.139. Despite a positive bias observed in the bootstrap samples, the correlation remains relatively stable, suggesting that higher banana production may be associated with lower abundance of Hymenoptera insects. Conversely, there exists a positive correlation between banana production and earthworm abundance, with a coefficient of approximately 0.351. Despite a slight positive bias, the correlation remains robust, implying that higher banana production tends to coincide with increased earthworm abundance. These findings underscore the complex interplay between agricultural productivity and the ecological dynamics of insect and soil communities, emphasizing the importance of considering multiple factors in sustainable agricultural management.

Conclusions

The Shannon-Wiener (H') Diversity values were in the range of 1.6–1.9, which indicates a situation of low diversity, Margalef Diversity (D) obtained values between 1.4–1.8, lower than 2, considered as areas of low biodiversity, the Simpson's dominance ($1-D$) presented values between 1.4–1.8, considering that the closer it is to 1, a situation of low diversity is considered, and that of equality of Pielou (J') presents 5–8, so that the values close to 1 correspond to situations where all species are equally abundant. These results were due to the relative abundance of two detritivore genera (earthworms and Hymenoptera), which are organisms that decompose OM and provide nutrients to the plant.

Finally, it is concluded that these two genera are important in the production of the plantain agro system due to the decomposition of OM and its nutritional contribution to the plant, observing a direct correlation with earthworms and an indirect one with Hymenoptera.

Data availability

Underlying data

Zenodo: Data for: Diversity of Functional Edaphic Macrofauna in *Musa acuminata* × *Musa balbisiana* (AAB) Agroecosystems. <https://doi.org/10.5281/zenodo.7242968> (Zuniga-Gonzalez *et al.*, 2022a).

This project contains the following underlying data:

- DataLeon.csv (data for farms in Leon)
- DataPosoltega.csv (data for farms in Posoltega)
- Figue_2.jpg
- Figure_1.jpg
- Figure_3.jpg
- Figure_4.jpg
- Figure_5.jpg
- NIH.csv (data on genera)
- Tabla 3.png
- Table 4_.jpg
- Table 5.png
- Table 6.png
- Table_1.jpg
- Table_10.jpg
- Table_11.jpg
- Table_2.jpg
- Table_7.jpg
- Table_8.jpg
- Table_9.jpg

Data are available under the terms of the [Creative Commons Attribution 4.0 International license](#) (CC-BY 4.0).

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Version 4

Reviewer Report 14 August 2024

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The study focuses on evaluating the diversity and richness of edaphic macrofauna in banana farms in Nicaragua. This is a relevant area of research as soil biodiversity plays a crucial role in agroecosystem productivity and sustainability. The specific focus on banana farms adds practical significance, considering the economic importance of bananas in tropical agriculture. This research presents a solid foundation and offers meaningful insights into soil biodiversity in banana farms. With a short additional detail and expanded discussion, it could serve as an important reference for both scientists and practitioners in the field of agroecology

SMALL POINTS

- In one of the headings of the material and methods it is say 'Identification of macrofauna species', but the description includes "...the microorganisms were placed in Petri dishes and then observed under a 4-400× stereo microscope". Are macroorganism of microorganism? Please clarify.
- A deeper discussion on the implications of the findings for banana farm management and broader ecological impacts would add depth to the study. Just adding some sentences in the discussion and conclusion would be enough strength the manuscript.

Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Yes

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Plant Sciences

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Version 3

Reviewer Report 21 March 2024

<https://doi.org/10.5256/f1000research.161242.r238299>

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My general comment is that a good effort has been done to improve the text and data availability, but there are still a few issues in the text, and most importantly, the claim that there is a strong relationship between taxa abundance and crop productivity is not supported by the data that are presented. This section needs to be changed. Please find detailed comments in the PDF linked [here](#).

Competing Interests: No competing interests were disclosed.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 08 Apr 2024

C. A. Zuniga-Gonzalez

Thank you for your valuable feedback. We have thoroughly addressed all your comments and suggestions. Specifically, we have ensured the robustness of our data by applying bootstrap analysis to the correlation between production and the abundance of

Hymenoptera and worms. This has strengthened the reliability of our findings and provided more insight into the relationship between agricultural productivity and soil fauna abundance. We appreciate your attention to detail and are confident that these enhancements significantly improve the quality of our study.

Competing Interests: I want to confirm that I have no competing interests that could sway my assessment of the manuscript or peer review report.

Version 1

Reviewer Report 19 July 2023

<https://doi.org/10.5256/f1000research.139795.r177964>

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Main comments

- Please improve the English language and grammar.
- Please give more information about the differences between the plots and use them to explain the differences in soil macrofauna communities.
- Please compare your results to past studies on similar cultures.

Minor comments

First page

- Dominion = Dominance?
- Conclusions: are you sure that these ants are detritivore?

Introduction

- Second sentence: please reduce the number of citations.
- Paragraph #2 (Similarly...) : please reduce the number of citations.

Last paragraph:

- Change to "this work focused..."

- Please describe the management of the plots (conventional/organic, tillage, pesticides, fertilization, irrigation and so on).
- Please replace the second sentence and the rest by a description of the method, period of sampling, taxa covered, taxonomical resolution. No need to give the structure of the paper.

Methods

- Please say in the text that sampling is based on litter and monolith extraction and is inspired by the TSBF method.
- *Table 1*: Please mention what these columns refer to.
- *Table 2*: Latitude and longitude are incorrectly formatted, with two commas in some cases, no commas in other cases. Please reformat with dots (".") as decimal separators and do not use other separators.
- Please describe the management of the plots (see comment above regarding the first page).
- The size of the sampling area is not clear. Please clarify.
- Was it really 4mm the smallest body size covered? Usually it is 1.5 mm for soil macrofauna.
- Please change "measured variables" by 'diversity components' or something similar.
- Please delete " (various population densities 1 m²)".
- Isn't it 'Dominance' instead of 'Domain'?
- No need to give the formula of the Shannon index.

Results & Discussion

- *Table 3 & 4*:
 - The title should be 'total and relative...by function groups in the different plots' Please use the unit Ind. m⁻² for the absolute abundances.
 - Please add the standard deviation or the standard error.
- *Figure 2*: The name of the taxa is difficult to read because of the low quality of the plot.
- *Table 5*: These are taxa, not species. Please translate into ind.m⁻², add errors, and remove totals by location.
- *Table 6*: "lumbrices" is not a correct genus or taxa, please correct.
- There are many typos in the name of family and genus. Please correct (e.g., Formocidae).
- Please compare your results with previous studies on banana plantations.

- *Table 7*: please explain what is "taxa_" and "individuals".
- *Table 8*: Please use "ind.m-2" not "x m2".
- Contrary to what you say, there are herbivores in the farm 8. Please correct.
- You can't link the absence of herbivore to the presence of spiders, based on correlation only. You need an experiment for that. Please remove this sentence.

Diversity and productivity

- Very interesting, but it is not clear if you did extra sampling for this topic. Please clarify. If so, please describe the sampling, if not, please explore the relationship with other taxa or functional groups.
- In any case, please explain how productivity estimates were related to soil fauna sampling: was it measured in each subplot (in this case you have one measure of productivity for one soil fauna monolith), or is it at a larger scale?
- *Table 9*:
 - Please clarify what you mean by earthworm production and add units.
 - The title of the last column is not clear, please clarify and provide the units.
- *Figure 3*:
 - Please use worm and Hymenoptera for the x axis and the productivity for the Y axis.
 - What do you mean by "real"?
- In all the results sections, you should explain and use the difference among plots to explain the variations in soil macrofauna. For instance, don't you have soil data or management data?
- *Table 10*: please say "banana production".
- *Figure 3 & table 11*:
 - If you have several replicates per farm, please use them in fig. 3 and add the regression line for all data and by plot, and include plot as a random factor in the analysis.
 - Consider changing table 11 by a pairwise correlation plot the tests on one side of the diagonal (see ggpairs() in R for instance).
- *Figure 4*: please add taxa richness and if possible functional groups' abundance.

Data availability:

- Please put the data from the two sites into one file.

- Please use the standard reporting template for soil macrofauna communities:
<https://zenodo.org/record/7691884>
- Important: Please provide the raw data; by monolith or by layer, not aggregated by plot.
- Please also add metadata: coordinates, date of sampling (year, month, day), management, and so on (see the template).

Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?

Partly

If applicable, is the statistical analysis and its interpretation appropriate?

Partly

Are all the source data underlying the results available to ensure full reproducibility?

Partly

Are the conclusions drawn adequately supported by the results?

Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Soil ecology

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 11 Aug 2023

C. A. Zuniga-Gonzalez

Main comments

[1] Please improve the English language and grammar.

Response: Dear reviewer we appreciate your valuable observation, we are proceeding with the total revision of the article.

[2] Please give more information about the differences between the plots and use them to explain the differences in soil macrofauna communities.

Response: Thanks for this observation. In Methods section was added this information with the subtitle farms data where explicated your characteristics and differences.

[3] Please compare your results to past studies on similar cultures.

Response: Yes, the past studies were compared with Costa Rica and Nicaragua studies. However, were added more cites as you indicated. Table 2 (Paragraph one) is similar to Zerbino *et al.* (2008), we also, refers the works of Priego-Castillo *et al.* (2009) and Castillo and Vera (2000) for the table 4, 5 and 6, also we refer to Pashanasi (2001), Zerbino (2010), the results of table 5 are referred and similar to Melo (2010), Rousseau *et al.* (2012, 2013). For the results of the Table 8 and 9 were added the cites.

Response: Dear thanks for this observation, it was added. In each result was added cite as you indicated.

Minor comments

[4] First page Dominion = Dominance?

Response: Thanks for it. We checked all the article and it was changed.

[5] Conclusions: are you sure that these ants are detritivores?

Response: Dear reviewer you know that Detritivorous ants are those that primarily feed on dead organic matter and help break down and recycle organic materials in ecosystems. We find two genera (earthworms and Hymenoptera), so the ants are referred to the detritivore genus because ants feeds on dead and decaying organic matter, such as plant material (*Musa acuminata* x *Musa balbisiana* (AAB), they are moist soils with a lot of plant organic matter. Thanks for the observation.

Introduction

[6] Second sentence: please reduce the number of citations. Paragraph #2 (Similarly...) : please reduce the number of citations.

Response: Thanks for this observation, we have been checked all article and changed it.

[7] Last paragraph: Change to "this work focused..."

Response: It was changed.

[8] Please describe the management of the plots (conventional/organic, tillage, pesticides, fertilization, irrigation and so on).

Response: Thanks for this observation we have added a subsection (Agro system farms) in the methods section, there we explain the characteristics of the 8 farms and how they have been moving from conventional practices to agroecological farms.

[9] Please replace the second sentence and the rest by a description of the method, period of sampling, taxa covered, taxonomical resolution. No need to give the structure of the paper.

Response: Dear thanks for your observations, it was added in the last paragraph of the Introduction, second sentences as you indicated. We have added a cite of the protocol.oi where we explicate the methodology. Thanks for the observation.

Methods

[10] Please say in the text that sampling is based on litter and monolith extraction and is

inspired by the TSBF method.

Response: It was added. Also we added the cite [47].

[11] Table 1: Please mention what these columns refer to.

Response: Thanks for this observation, a comment on this was added before Table 1.

[12] Table 2: Latitude and longitude are incorrectly formatted, with two commas in some cases, and no commas in other cases. Please reformat with dots (".") as decimal separators and do not use other separators.

Response: Thanks for this observation. We made the changes. (e.g., 12°31'15.4"N Latitude 86°54'40.2"W Longitude)

[13] Please describe the management of the plots (see the comment above regarding the first page).

Response: Yes it was added as indicated in [8] item. Was elaborated a chart with your differences.

[14] The size of the sampling area is not clear. Please clarify.

Response: Ok thanks for this observation. The description of Tables 2 and 5 is explicating that the area is of 0.7 ha, and a total of 80 samples of macrofauna populations were identified, coded, and stored in the second phase. The study area in each farm or plot was 0.7 ha delimited 1 in 1,000 m² (50 cm long × 20 cm wide), as described in Rousseau et al. (2012), Rousseau et al. (2013), and Medina et al. (2021) . However, we added this area for each plot: The area where the sample was collected are: Farm1 246.5 ha, Farm2 14.1, ha, Farm3 67 ha, Farm4 7 ha, Farm5 4.2 ha, Farm6 2.1 ha, Farm7 3.5 ha, Farm8 4.9 ha. In total 80 samples were collected in 1000 m2 for 40 biomass samples and 40 edaphic samples in 0-20 cm depth.

[15] Was it really 4mm the smallest body size covered? Usually, it is 1.5 mm for soil macrofauna.

Response: Dear thanks for this observation, it was corrected.

[16] Please change "measured variables" by 'diversity components' or something similar.

Response: It was changed.

[17] Please delete " (various population densities 1 m2)".

Response: It was eliminated.

[18] Isn't it 'Dominance' instead of 'Domain'?

Response: It was changed.

[19] No need to give the formula of the Shannon index.

Response: Dear reviewer, thanks for this observation. Dear reviewer, we have decided to give the formula.

Results & Discussion

[20] Table 3 & 4:

- The title should be 'total and relative...by function groups in the different plots' Please use the unit Ind. m⁻² for the absolute abundances.

- Please add the standard deviation or the standard error.

Response: Ok it was made in both tables.

[21] Figure 2: The name of the taxa is difficult to read because of the low quality of the plot.

Response: Ok we sent another figure with the best resolution.

[22] Table 5: These are taxa, not species. Please translate into ind.m⁻², add errors, and remove totals by location.

Response: Ok thanks for this observation. All was changed.

[23]Table 6: "lumbrices" is not a correct genus or taxa, please correct it.

Response: Yes, it is correct, thanks for this observation. All was changed.

[24] There are many typos in the name of family and genus. Please correct (e.g., Formocidae).

Response: Ok thanks for this observation. It was checked and corrected.

[25] Please compare your results with previous studies on banana plantations.

Response: Of course, it was checked and added as you indicated.

[26] Table 7: please explain what is "taxa_" and "individuals".

Response: Thanks for this observation, the taxa was change by Genus Types and individuals, by Ind. m²

[27] Table 8: Please use "ind.m⁻²" not "x m²".

Contrary to what you say, there are herbivores in the farm 8. Please correct.

You can't link the absence of herbivore to the presence of spiders, based on correlation only. You need an experiment for that. Please remove this sentence.

Response: Ok thanks for this observations. It was corrected.

[28] Diversity and productivity

Very interesting, but it is not clear if you did extra sampling for this topic. Please clarify. If so, please describe the sampling, if not, please explore the relationship with other taxa or functional groups.

In any case, please explain how productivity estimates were related to soil fauna sampling: was it measured in each subplot (in this case you have one measure of productivity for one soil fauna monolith), or is it at a larger scale?

Response: Dear reviewers thanks for this observation. The sampling is the same that was recollected, but in this moments of the analysis we compare the populations of the Hymenoptera (Insects) and Oligochaeta (Worm or Earthworm) that were the more representative in this study. So, we the Pearson correlation coefficient that is a measure of linear correlation between two sets of data in this case the Agricultural production (banana

units per ha) and the abundance of *Earthworms* and hymenopteran insects (Ind. m²). It is the ratio between the covariance of two variables and the product of their standard deviations.

[29] Table 9:

- Please clarify what you mean by earthworm production and add units.

Response: Thanks, we refer the abundance of Earthworms and the unit Ind. m² was added.

- The title of the last column is not clear, please clarify and provide the units.

Response: Thanks, It was change by Abundance Estimated overall Earthworm production Ind. m².

[30] Figure 3:

- Please use worm and Hymenoptera for the x axis and the productivity for the Y axis.

- What do you mean by "real"?

Response: Dear is ok the change was made. The Real is the production of Banana or plantains, during the periods studied. Measured in Units by ha. Dear reviewer by best interpretation all was change by **Production (Units ha)**.

[31] In all the results sections, you should explain and use the difference among plots to explain the variations in soil macrofauna. For instance, don't you have soil data or management data?

Response: Dear all results section was checked and added the comments that you indicated. Regarding to the management data the farmer don't had information because the cost to get it (Laboratory of soil).

[32] Table 10: please say "banana production".

Response: OK

[33] Figure 3 & table 11:

- If you have several replicates per farm, please use them in fig. 3 and add the regression line for all data and by plot, and include plot as a random factor in the analysis.

- Consider changing table 11 by a pairwise correlation plot the tests on one side of the diagonal (see ggpairs() in R for instance).

Response: Dear reviewer thanks for your observation but our aim was to relate the plots versus the genus identified, however, yes we go to make o add the table that you suggest us as Fig 5. Dear, we appreciate your observation, but due to a problem that we had already defined in the methodology that we work with SPSS, which suggests that we do it with SPSS and we have added fig. 6.

[34] Figure 4: please add taxa richness and if possible functional groups' abundance.

Response: Dear thanks for this observation, only we added taxa richness, the functional group' abundances, we consider that was discussed on the table 3 and 4. Was added the Fig 5. Shannon Index.

[35] Data availability:

Please put the data from the two sites into one file.

Response: Ok

Please use the standard reporting template for soil macrofauna communities:

<https://zenodo.org/record/7691884>

Important: Please provide the raw data; by monolith or by layer, not aggregated by plot.

Please also add metadata: coordinates, date of sampling (year, month, day), management, and so on (see the template).

Response: Ok thanks for your consideration.

Competing Interests: The authors disclose that we don't have any competing interests that might be construed to influence your judgment of the article's or peer review report's validity or importance.

Author Response 10 Jan 2024

C. A. Zuniga-Gonzalez

Dear Reviewer 2, the data availability, has been duly addressed:

1. **Data Compilation:** The data from both sites has been consolidated into a singular file as requested.
2. **Template Utilization:** The standard reporting template for soil macrofauna communities, accessible at <https://zenodo.org/record/7691884>, has been utilized to format the dataset.
3. **Data Format:** The provided data remains in its raw form, organized either by monolith or by layer, ensuring it is not aggregated by plot, as specified.
4. **Metadata Inclusion:** Essential metadata such as coordinates, sampling date (year, month, day), management details, and other relevant information, following the template, have been added to the dataset.

By adhering to these instructions, we've ensured the data is compiled appropriately, formatted using the standard template, remains in its raw form, and includes essential metadata, thereby meeting the specified requirements for data availability.

Competing Interests: No competing interests were disclosed.

Reviewer Report 07 March 2023

<https://doi.org/10.5256/f1000research.139795.r155921>

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The article is interesting and important in the banana production activity.

1. "The first was.." - must say 'the first one'.

2. In the results, the correct way is 'ind/m²'. Example: 160 ind/m².

3. "In four farms (San Martín, Santa Isabel and El Verdon)..." and which one is the last?

4. Incorrect to cite too many authors: "These data are supported by Zayas et al. (2022), Quiroz-Medina et al. (2021), Castillo y Vera (2000), Pashanasi (2001), Zerbino (2010), Rousseau et al. (2012) and Rousseau et al. (2013)." - Maybe you could cite just three authors together in the text; because information is the same.

5. It is not a conclusion, but a result: "The diversity and richness of the edaphic macrofauna was evaluated in eight farms in the western area. A total of 78.72% of the individuals were identified in the soil from 0–20 cm², while the remaining 21.26% in the foliage. In the first four farms in the León area, 23 genera were found, and in the Posoltega farms, 21 genera. The relative abundance of León was 1,450 individuals per m², while in the Posoltega area it was 1,700 individuals per m²."

6. Bibliography incomplete as: Ruiz N, Lavelle P, Jiménez J: SOIL MACROFAUNA FIELD MANUAL.2008; p. 113.

Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Yes

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Climate change, Ecology, Mangroves and tropical forestry

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Author Response 07 Mar 2023

C. A. Zuniga-Gonzalez

I appreciate the comments of the reviewer¹ and I confirm and accept the improvements to be incorporated.

Competing Interests: I have no competing interests. The reviewer's observations are valid and pertinent to improve the article's contribution.

Author Response 08 Aug 2023

C. A. Zuniga-Gonzalez

The article is interesting and important in banana production activity.

Dear Reviewer, thanks for this.

1. "The first was.." - must say 'the first one'.

Response: It was improvements.

2. In the results, the correct way is 'ind/m²'. Example: 160 ind/m².

Response: Dear reviewer all the results were checked and improvements.

3. "In four farms (San Martín, Santa Isabel and El Verdon)..." and which one is the last?

Response: The Quinta Cony was added, thanks for this observation.

4. Incorrect to cite too many authors: "These data are supported by Zayas et al. (2022), Quiroz-Medina et al. (2021), Castillo y Vera (2000), Pashanasi (2001), Zerbino (2010), Rousseau et al. (2012) and Rousseau et al. (2013)." - Maybe you could cite just three authors together in the text; because information is the same.

Response: It was correcting that only 3 authors were added, but in this case was putting 4.

5. It is not a conclusion, but a result: "The diversity and richness of the edaphic macrofauna was evaluated in eight farms in the western area. A total of 78.72% of the individuals were identified in the soil from 0–20 cm², while the remaining 21.26% in the foliage. In the first four farms in the León area, 23 genera were found, and in the Posoltega farms, 21 genera. The relative abundance of León was 1,450 individuals per m², while in the Posoltega area it was 1,700 individuals per m²."

Response: Dear reviewer it was translated to the results section, thanks for this

observation.

6. Bibliography incomplete as: Ruiz N, Lavelle P, Jiménez J: SOIL MACROFAUNA FIELD MANUAL.2008; p. 113.

Response: It was corrected and added the link <https://hal-bioemco.ccsd.cnrs.fr/bioemco-00560386> and the Bioemco as a source.

Dear reviewer, thanks for all your observations.

Competing Interests: The authors disclose that we don't have any competing interest.

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