

Changes in the edaphic macrofauna in a Cambisol under different management conditions

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Abstract

Soil is part of the biosphere and the edaphic macrofauna is made up of the organisms that inhabit the surface of the soil. The research aimed to determine the change of the edaphic macrofauna under different management conditions in Cambisol. The experimental work was carried out on the 'Aeropuerto' farm in the municipality of Cienfuegos. To sample the macrofauna, the methodology of the International Research Program 'Biology and Fertility of Tropical Soils' was used. The management systems evaluated were: a reference soil, under undisturbed forests (> 50 years), a soil conserved under pastures (more than 10 years), and an agrogenic soil with continuous cultivation (planted with sugarcane for more than 60 years). The identified edaphic macrofauna was grouped into three phyla, seven classes and 20 orders. The highest total values of insects (60.08 m²) were obtained in forest management and the lowest values were obtained in pasture and continuous cultivation, which were similar (38.62 and 37.8 m²). Forest management (91.3 individuals) revealed the highest values of the predatory, detritivorous and herbivorous functional groups compared to pasture management (50.6 individuals) and cultivation management (20.75 individuals), with statistical differences. It was concluded that, under the management of continuous cultivation, the total values of insects and the functional groups of the macrofauna are low. This could be a negative indicator of the degradation process that commonly occurs in continuous cultivation. The study provided the possibility of relating the changes in the macrofauna to the management conditions for experimental and productive purposes.

Palabras clave:

agrogénico, cultivo continuado, depredadores, pastos.

Introduction

Soil is part of the biosphere and is directly related to the landscape, vegetation, climate and society as a whole (Brevik and Hartemink, 2010). Some authors, such as Yu *et al.* (2018); Zúñiga *et al.* (2018), explain that soil is considered a non-renewable natural resource, fundamental for human beings and the biosphere in general. It is also the surface layer of the earth's crust in which numerous organisms live and vegetation grows, where there is a balance between organic plant residues and soil organisms (Huarauya, 2014). On the other hand, edaphic macrofauna has important ecological functions and ecosystem services, which include the decomposition of organic matter, the sequestration of organic carbon, the recycling of nutrients, the maintenance of soil structure, and the infiltration of water (Lavelle *et al.*, 2006; Ruiz *et al.*, 2008; Gholami *et al.*, 2016).

Disturbances in the soil, derived from agricultural activity, can have a negative effect on soil fauna, mainly on macrofauna, because they are found on the soil surface and are more susceptible to eventual environmental alterations (Kamau *et al.*, 2017). Edaphic macrofauna is abundant in primary and secondary forests. Nevertheless, in areas disturbed by anthropogenic action, it is reduced because its biological activity is constantly affected in interaction with the properties and components of the soil (Negrete *et al.*, 2007). Basically with chemical properties, such as the content of exchangeable cations, pH, texture, and water retention capacity (Barros *et al.*, 2002). Given these conditionals and interest in delving deeper into these concepts of soil biology, the objective of this research was to determine the change in the composition, function and abundance of the edaphic macrofauna, under different management conditions, in a Cambisol.

Materials and methods

Description of the sites evaluated

The research was conducted on the 'Aeropuerto' farm in the municipality of Cienfuegos, Cuba, during the rainy period of the year (May-October 2019); a sampling was carried out for each management. For the study, an agroecosystem with different management systems (soil managed under forest, continuous cultivation, and pasture) was selected. Experimental design and treatments. The experimental design was completely randomized, with five replications per treatment. Three management systems were evaluated, which constituted the treatments (Figure 1): reference, under undisturbed secondary forests (more than 50 years), the vegetation of which was represented by ceiba [*Ceiba pentandra* (L.) Gaertn], carob (*Ceratonia siliqua* L.), bay cedar (*Guazuma ulmifolia*), and mango (*Mangifera indica* L.); conserved under pastures, pangola grass *Digitaria decumbens* (more than 10 years); and agrogenic: continuous cultivation.



Figure 1. Representation of the agroecosystem studied, Aeropuerto farm, with the different soil management systems, municipality of Cienfuegos. Coordinates: 22° 10' 06" north latitude, 80° 24' 36" west longitude. Scale 1:10 000.



Manejo referencia

Manejo conservado

Manejo agrogénico



It was planted with sugarcane for more than 60 years and is currently kept under vianda crops, *Manihot esculenta* Crantz (cassava); it is characterized by an intensive use of the soil, such as preparation and cultivation work with animal traction and sometimes with tractors. In addition, chemical fertilization and pesticides are applied. The average temperature in the area is 24.6 °C, with January being the coldest month with 22.1 °C and July being the warmest month with 27.2 °C. The average accumulated rainfall in the area is 1 412 mm and they are representative of the experimental area (Viera *et al.* , 2024).

Sampling characteristics and techniques used

To study the edaphic macrofauna, a sampling was carried out between 7:00 and 9:00 am, as recommended by Cabrera *et al.* (2017), where there is a favorable state of temperature and moisture for the permanence of this edaphic fauna in the rainy period of the year. In each management, a 100 m transect was selected, whose point of origin and direction was determined at random. For the study, ten monoliths of 25 x 25 x 20 cm were excavated in each area, which were divided into three depths: leaf litter, 0-10 cm, and 10-20 cm. Each monolith was separated by a distance of 5 m (Ceballos and Mischis, 2007).

The methodology used was that of the International Research Program 'Biology and Fertility of Tropical Soils' (Anderson and Ingram, 1993). The soil moisture in the different management systems was as follows: forest 47.2%, pasture 32.2%, and continuous cultivation 26.4%. The visible macrofauna was collected by breaking the aggregates manually and with tweezers. The earthworms were preserved in 4% formaldehyde and the remaining invertebrates in 70% alcohol for subsequent identification at the Plant Health Laboratory of the province of Cienfuegos.

Macrofauna (predators, detritivores, and herbivores) was identified and characterized by the practical manual on edaphic macrofauna as a biological indicator of soil quality, according to results in Cuba (Cabrera, 2014), up to the following taxonomic levels: phylum, class and order. The functional classification was carried out according to Cabrera *et al.* (2011), which included: 1) leaf litter detritivores, which are the main consumers of organic matter of plant and animal origin, present on the surface and in the first five cm of the soil; 2) herbivores, which comprise the groups that feed on the living parts of plants and 3) predators, which feed on small live animals. The composition, function and abundance of the macrofauna were used as the response variable.

To determine the significant differences between the different soil managements, a non-parametric Kruskal-Wallis test was performed since the assumptions of normality and homogeneity of variance were not met. The statistical package used was SPSS® version 17. A significance level of 0.05 was used for all analyses.

Results and discussion

The soil under forest management is characterized by an undulating relief, altitude of 29 masl, secondary forest vegetation over 50 years old, and material of calcareous clay origin. On the other hand, the soil under continuous cultivation is represented by a flat and slightly undulating relief, altitude of 29 m, vegetation with *Manihot esculenta* Crantz (cassava), and material derived from sandstone without carbonates. The soil with grass has a slightly undulating relief, altitude of 29 m, vegetation of *Saccharum officinarum* L. (sugarcane) in the last 10 years, although it is currently under grass of *Digitaria decumbens* L., the type of cattle is bovine, with a rotational grazing system.

The taxonomic composition of the macrofauna of the soil under the forest, natural pasture, and continuous cultivation systems is shown in Table 1.

Table 1. Taxonomic composition of the edaphic macrofauna collected in Cambisols.

Phylum	Class	Order	Forest	Management of cultivation	Pasture
Arthropoda	Insecta	Hymenoptera	x	x	x
		Dictyoptera	x	x	-
		Coleoptera	x	x	x
		Isoptera	x	x	x
		Psocoptera	x	-	-
		Lepidoptera	x	x	-
		Orthoptera	-	-	x
		Thysanoptera	-	-	x
		Collembola	x	-	x
	Arachnida	Araneae	x	x	x
	Malacostraca	Isopoda	x	-	x
	Chilopoda	Geophilomorpha	x	-	-
	Diplopoda	Polydesmida	x	-	x
		Polyxenida	x	-	-
		Trigoniulidae	x	x	x
Mollusca	Gastropoda	Subulinidae	x	-	x

Phylum	Class	Order	Forest	Management of cultivation	Pasture
Annelida	Clitellata	Bradybaenidae	x	-	x
		Lymnaeidae	x	-	-
		Haplotaxida	x	x	x

In this way, the edaphic macrofauna was grouped into three phyla, seven classes, and 20 orders. The greatest diversity was found in the forest system (17 orders), which is associated with the presence of trees of ceiba (*Ceiba pentandra*), carob (*Ceratonia siliqua*), bay cedar (*Guazuma ulmifolia*), mango (*Mangifera indica*), which improve soil conditions because of the amount of leaf litter they incorporate. Similar results were obtained by Hernández *et al.* (2008) since they observed the presence of leaf litter and branches on the soil surface, which benefits the moisture, temperature, and development of the edaphic macrofauna in shrublands.

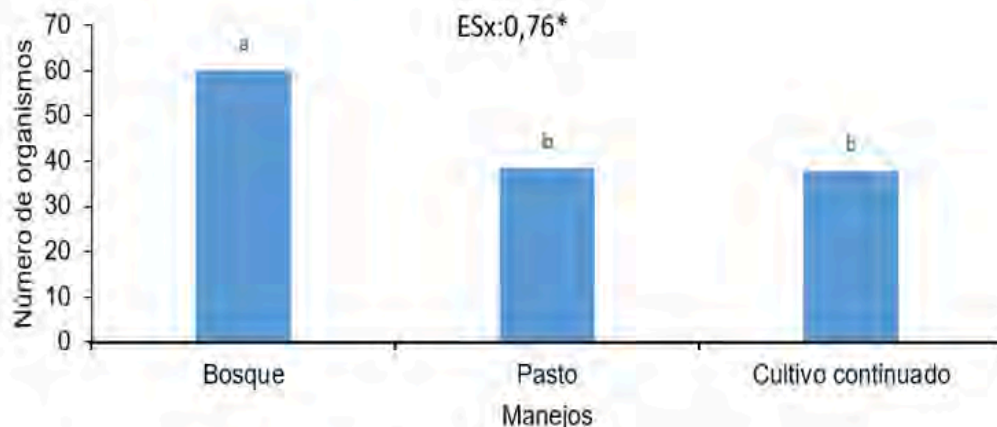
Regarding natural pasture management, the presence of 13 orders of macrofauna was determined. Likewise, in this management, there is a vegetation cover that guarantees moisture, a fundamental condition for soil organisms, especially those that breathe through their integuments. In addition, the soil under continuous cultivation leads to compaction, acquiring a plastic appearance. When the results in forest management and natural pasture management are compared, they coincide with those obtained by Chávez *et al.* (2018), who also found a low taxonomic proportion in the management of continuous cultivation, a result that they attribute to the fact that, in deforested areas, there is a shortage of leaf litter, which creates unfavorable conditions for certain soil organisms. In addition, the continuous grazing method causes changes in soil structure.

On the other hand, the continuous grazing method causes changes in the biological properties of the soil, which result from the trampling of animals (Medina, 2016), which limits the number of pore spaces and therefore the density of individuals. The taxonomic analyses carried out in pasture management, on macrofauna, differ from those found by Vega *et al.* (2014), who only determined seven orders in a silvopastoral system on a brown soil with carbonates, located in the municipality of Jiguaní, province of Granma, Cuba. Nonetheless, they coincide with the work by Cabrera *et al.* (2017) and Ramírez *et al.* (2018), where in a natural pasture and silvopastoral system, they found three phyla, seven classes and 11 orders; this favors the development of macrofauna given the stability of temperature and moisture.

Figure 2 shows the total number of organisms according to the type of management. In the case of forests, the total results of organisms show significant differences compared to the other two management systems. This is related to the fact that, under this management, there is an appropriate vegetation that keeps temperature and moisture stable, whose moisture and temperature values are referred to above, which create favorable conditions for the reproduction of organisms.



Figure 2. Total number of organisms in the different management systems in Cambisols. Means with equal letters do not differ for $p < 0.05$.



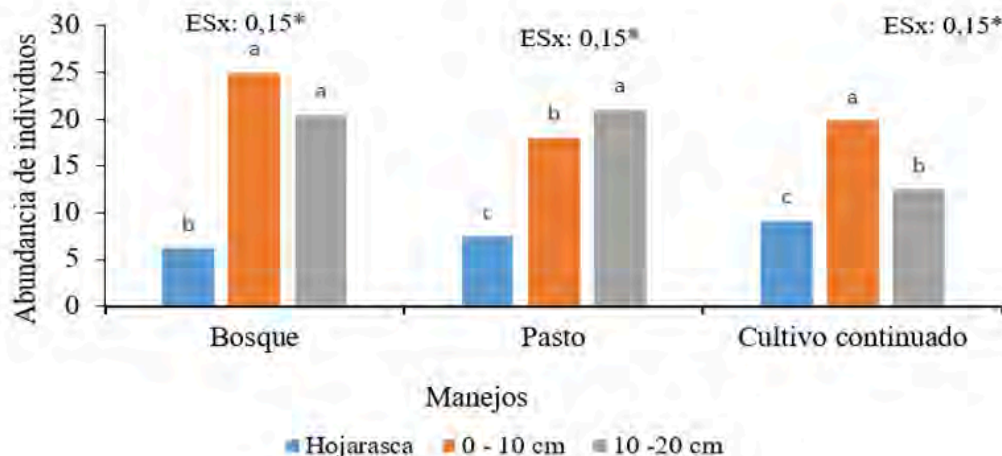
Similar results were described by Delgado *et al.* (2011) when they studied the presence of insects in several systems (forest, monoculture *Coffea arabica* L., and production system associated with *C. arabica*). The greatest variety and biomass of insects was found in the forest system (6 112 individuals m⁻²), the monoculture with 2 303 individuals m⁻², and the agroforestry system of *C. arabica* with 3 552 individuals m⁻².

When comparing the population of organisms in the pasture and continuous cultivation systems, it was observed that there are no notable significant differences, which is related to the fact that, in these systems, there is no diverse flora or family of plants that attract species of insects of different orders, unlike the forest system where there is a greater composition of plant species that serves as a shelter for the habitat and reproduction of insects. In view of these determinations, the similarity found between the pasture and continuous cultivation systems, regarding the population of organisms, could be conditioned by the fact that, in both systems, the plant population has similar morphological characteristics, and because of the influence of temperature and humidity ranges, which produce variability and permanence of the insect population in these management systems, compared to the forest system, where these conditions are more stable (Balota and Chaves, 2011).

In this regard, Cabrera *et al.* (2011) explain that the insect population decreases consecutively in pastures, various crops, and sugarcane fields due to livestock management in pastures and constant agricultural tillage in continuous cultivation systems. This is related to the fact that, in pastures, the insect population is locally restricted in an area with little access to nutrients and shelter.

In Figure 3, it was observed that the soil under forest shows the highest abundance of individuals at depths of 0-10 cm and 10-20 cm, both with equal statistical significance, and they differ from the leaf litter level, whose numbers are lower, which results in significant notable differences compared to both depths. This is explained by the fact that organisms in their life cycle alternate their permanence on the surface of the soil when temperature, moisture, solar radiation, and the action of occasional predators increase.

Figure 3. Abundance of total individuals according to agricultural management and depth in the different management systems. Means with the same letters for each soil management system do not differ according to Tukey $p < 0.005$



Therefore, Delgado *et al.* (2011) show similar results in terms of the analysis of the number of insects in different depths of soil subjected to cultivation and natural forest, and they find that, at depths greater than 20 cm, moisture, nutrients, and oxygen are scarce, so under these conditions, the survival of insects is not possible.

In the soil under pasture management, significant differences are observed when the soil depths are compared. In this case, at the leaf litter level, the average number of individuals (7.5), at 0-10 cm (18), and at 10-20 cm (21). Based on these results, it is inferred that the numerical differences in organisms between levels are due to the fact that insects have periodic life habits during the day and night; they store nutrients during the day and shelter during the day and reproduce at night at depths higher than leaf litter level. Similarly, the numerical difference in insects found at depths of 0-10 cm and 10-20 cm is related to the fact that insects remain for most of their life cycle at the levels of greater depth studied (10 -20 cm), even when there are possibilities of survival at a lower level (0-10 cm). This is due to a biological condition of organisms to seek shelter and face natural predators and the drastic changes of atmospheric phenomena, such as excess moisture, temperature, solar radiation, and oxygen diffusion.

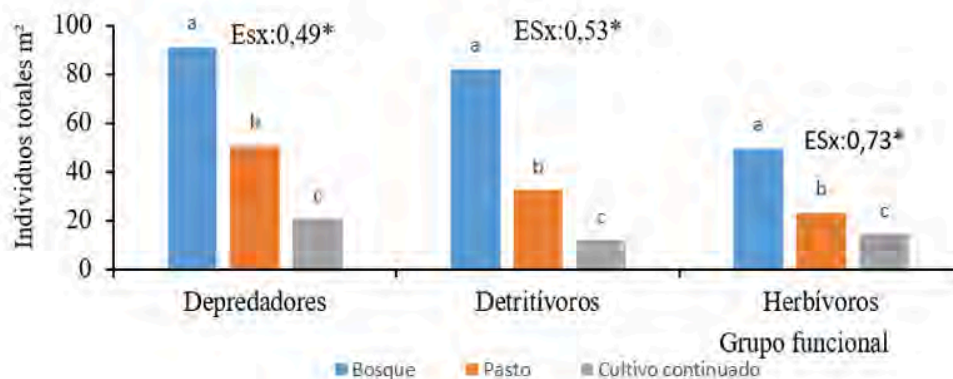
Under continuous cultivation, significantly bigger differences are observed when the number of organisms is related to the different strata. Based on this analysis, the depth between 0 and 10 cm is where the largest number of insects are found (24.95), followed by 10-20 cm (12.45) and finally, the level of leaf litter (9.1). From the general analysis comes the information that explains why organisms do not have to remain at a higher depth level (10-20 cm); however, they find safe shelter in the medium depth levels (0-10 cm), where the physical and chemical parameters are appropriate for reproduction and survival.

Likewise, the preference of macrofauna for the first centimeters of the soil is fundamentally due to factors such as the area of plant roots and the degree of compaction resulting from the transit of animals on the soil surface (Medina, 2016). This limits the amount of pore spaces, which modifies the density and diversity of the macro- and microfauna. Additionally, with respect to the depth, the work by Fernández *et al.* (2015) is similar to the results found. Thus, in leaf litter, there was no difference in the strata of 0-10 cm and 10-20 cm. Likewise, they observed ten species of insects in the horizons near the surface of the soil. These species were herbivorous and are mostly associated with crop plants.

In a study by Chávez *et al.* (2018), they found similar results at the depths studied. They quantified 57 individuals at 0-10 cm and 55 individuals at 10-20 cm, in an area with natural grass belonging to the UBPC 'Francisco Suárez Soa', located in the municipality of Bayamo, province of Granma.

Figure 4 shows that the edaphic macrofauna in the different management systems is represented by the taxonomic class, predators (spiders, beetles, scorpions, slugs), detritivores (cockroaches, millipedes, flies), and herbivores (cockroaches, beetles, crickets, grasshoppers).

Figure 4. Functional groups of the macrofauna in different management systems in brown soils. Means with equal letters for each soil management system do not differ for $p < 0.05$.



Forest management showed a bigger number of predatory insects, with 91.3 individuals, with significant differences compared to pasture management (50.6 individuals) and cultivation management (20.75 individuals). On the other hand, forest management revealed the highest values of the detritivorous and herbivorous functional groups with significant differences compared to pasture and cultivation systems. The latter management system revealed low values in the three functional groups studied.

Therefore, the functional contribution made by soil organisms (detritivores, predators, and herbivores) in the different management systems studied is directly related to the transformation of plant remains. The edaphic macrofauna contributes to the decomposition of organic matter, making nutrients assimilable for the rest of the microorganisms that participate in the food chain, mainly represented by fungi and bacteria. Similar results are reported by De Almeida *et al.* (2020); Barros *et al.* (2020) when they explain that predators (Hymenoptera) modify the structure, which allows the pore space to increase and in turn favors water infiltration, aeration, and the stability of aggregates.

On the above, Cabrera *et al.* (2019) mentioned that detritivores are the zoological group that actively participates in the food chain. This is because they are mainly responsible for crushing plant and animal remains, reduce the size of the particles and increase the surface exposed to the decomposition activity of bacteria and fungi. Likewise, Gutiérrez *et al.* (2020) studied the influence of the functional zoological groups of the soil by using guinea grass (*M. maximus*) and star grass (*C. nlemfuensis*) grasslands as agroecosystems in the municipality of San José de las Lajas, province of Mayabeque; this study reports the predominance of detritivores in livestock and silvopastoral ecosystems.

Conclusions

Forest management showed greater taxonomic presence, unlike continuous cultivation and pasture management, which indicates that the soil under forest offers better conditions for the habitat

of organisms. On the other hand, the forest had a greater presence of organisms compared to pasture and continuous cultivation. Regarding the analysis of depths and management systems, it was observed that at the depth of 0-10 cm, there was a greater representation of individuals than in the forest and continuous cultivation management systems; likewise, the pasture and forest management systems showed more individuals at the depth of 10-20 cm, and the leaf litter level did not show a considerable number of individuals. Regarding the functional group, forest management showed the largest numbers of individuals, represented by detritivores, predators, and herbivores, which differs from continuous cultivation, so these results precisely set a pattern in the knowledge of the dynamics of the macrofauna of the soil subjected to different management systems and pave the way for future research related to the conservation of biodiversity and soil fertility.

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Journal Information
Journal ID (publisher-id): remexca
Title: Revista mexicana de ciencias agrícolas
Abbreviated Title: Rev. Mex. Cienc. Agríc
ISSN (print): 2007-0934
Publisher: Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias

Article/Issue Information
Date received: 00 June 2025
Date accepted: 00 August 2025
Publication date: 25 October 2025
Publication date: Oct-Nov 2025
Volume: 16
Issue: 7
Electronic Location Identifier: e3769
DOI: 10.29312/remexca.v16i7.3769

Categories

Subject: Article

Keywords:

Keywords:

agrogenic
continuous cultivation
pastures
predators

Counts

Figures: 4
Tables: 1
Equations: 0
References: 29
Pages: 0