Scientific Paper

Biodiversity and abundance of the edaphic macrofauna in two animal husbandry systems in Sancti Spíritus, Cuba

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Abstract

Objective: To determine the biodiversity and abundance indexes of the edaphic macrofauna in two animal husbandry systems in the Yaguajay municipality, Sancti Spíritus province, Cuba.

Materials and Methods: A study was conducted in areas of a Basic Unit of Cooperative Production, belonging to the Animal Husbandry Enterprise Obdulio Morales, from the Yaguajay municipality, in the Sancti Spíritus province, Cuba. A silvopastoral system and a natural pastureland, which had been exploited for more than 10 years, were evaluated, distributed in a complete randomized design, with three repetitions per treatment. The macrofauna was sampled during two years in the rainy and dry season in the litter and at the depths 0-10; 10-20 and 20-30 cm, according to the methodology of the Tropical Soil Biology and Fertility International Research Program. The macrofauna was identified to the order level, and Kruskal-Wallis non-parametric analysis with the software InfoStat ®.

Results: A total of 1 207 individuals were collected, from which 840 corresponded to the silvopastoral system and 367 to the system of natural pastures. In both systems coleopterans prevailed (133 and 313 individuals for the pastureland and the silvopastoral system, respectively), followed by oligochaetes (78 and 144 individuals, respectively). When analyzing the ecological indexes, no marked difference was found between the evaluated systems.

Conclusions: The silvopastoral system provides the community of macroinvertebrates with favorable conditions for the optimum development of the edaphic macrofauna. In this system higher quantity and diversity of individuals were found.

Keywords: biota, Choleoptera, soil fertility, Oligochaeta

Introduction

One of the challenges faced by Cuban agriculture is stopping the processes that degrade soils and establishing a sustainable agricultural system, capable of meeting the increasing food demand of the population (Aguilar *et al*., 2016).

The soils dedicated to animal husbandry in Cuba show limiting factors and have lost their fertility, due to their deficient management, which influences negatively the productivity of animal husbandry systems.

An analysis conducted by Lok (2016) indicated that 90,6 % of the utilizable agricultural areas of the animal husbandry enterprises evaluated in Cuba is affected by one or more limiting factors: 45 % with low natural fertility; 20,5 % with low water holding capacity, mainly in sandy soils; 22,0 % with irregular topography and 7,4 % has salinity.

In addition, 29,7 % of animal husbandry soils in Cuba has bad drainage, which affects the air-water balance in the soil and favors compaction; 26 % shows acidity and 11,8 % is stony.

These limitations influence negatively the establishment and later development of pastures and forages.

Soil conservation in areas dedicated to animal husbandry must be aimed at performing management practices, which allow to stop the degradation of this resource or recover its characteristics in a range which does not affect the production and quality of agricultural productions. It should be based on the knowledge of the status of its properties, soil type, slope, pasture, purpose of its exploitation and livestock characteristics (Lok, 2016).

Due to the above-stated facts, it is necessary to evaluate soil quality through indicators that constitute a powerful tool for decision-making in soil management and use at local, regional and global scale, and its study must be done in a particular way, according to the conditions of each agroecosystem (García *et al*.,

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2012). One of these indicators could be the analysis of abundance, diversity and functionality of the edaphic biota, specifically macrofauna, due to the feasibility for its determination.

Velazquez and Lavelle (2019) emphasize the advantages of using the communities of macroinvertebrates as soil quality indicators, due to their simplicity and low cost. In addition, the macrofauna is very sensitive to soil conditions. Because of the diversity of adaptive strategies of these organisms, they are generally represented in an interval from 10 to 15 orders. The study of these communities allows to obtain a general estimation of the soil, based on ecosystemic services.

The objective of this research was to determine the biodiversity and abundance indexes of the edaphic macrofauna in two animal husbandry systems in the Sancti Spíritus province, Cuba.

Materials and Methods

Characterization of the study area. The study was conducted in areas of the Basic Unit of Cooperative Production La Elvira, belonging to the Agricultural Enterprise Obdulio Morales, in the Yaguajay municipality, Sancti Spíritus province, Cuba. This productive entity has a total area of 1 878 ha. From them, 720 ha are aimed at animal husbandry.

Edaphoclimatic conditions. The soil belongs to the grouping of Gleysols, and to the genetic type vertic Gleysol (Hernández-Jiménez *et al.,* 2015). These soils have flat topography, show clayey texture, effective depth of 0,90 m and a deficient surface and internal drainage. Rainfall in the experimental area during the research varied between 1 200 and 1 400 mm as annual average, with two well-differentiated seasons: a rainy season (May-October), in which 76 % of the rainfall occurred and a dry season (November-April). The mean annual temperature was 25,6 ºC.

Experimental design and treatments. The experimental design was complete randomized, with three repetitions per treatment. Two systems were evaluated, with more than 10 years of exploitation, which constituted the treatments:

Silvopastoral system. The tree composition was formed by the tree species *Leucaena leucocephala* (Lam.) de Wit; *Albizia niopoides (*Spruce ex Benth*.)* Burkart and *Taliparitii elatum (*Swartz) Fryxell. The herbaceous composition was integrated by natural pastures.

Pastureland. A silvopastoral system was evaluated, mainly composed by the species *Bothriochloa pertusa* (L.) A. Camus and *Urochloa ruzziziensis* (R. Germ & C.M. Evrard). The pasture cover in all the paddocks was over 90 %.

Experimental procedure. The macrofauna sampling was carried out between 7:00 and 9:00 a.m., in representative sites of each plot, in both seasons during two years, according to the Methodology of the Tropical Soil Biology and Fertility International Research Program (Anderson and Ingram, 1993). This methodology consists in the extraction of 25 x 25 x 30-cm monoliths in a transept, whose point of origin is randomly determined and in linear direction. Twelve monoliths were evaluated per system and per season. The litter strata 0-10, 10-20 and 20-30 cm were taken into consideration. The macrofauna was manually collected *in situ*. The earthworms were preserved in 4 % formaldehyde and the remaining invertebrates, in 70 % alcohol, for their later identification in the laboratory.

The macrofauna was identified to the taxonomic level of order, using the keys proposed by Ruiz *et al.* (2008). The average density values (ind m^{-2}) were determined for the edaphic community, for each taxon and per stratum, in each studied system. Density was determined depending on the number of individuals. The indexes described below were calculated:

Shannon-Wiener diversity index ($H'=\Sigma pi \log_2 pi$). With the data of the number of individuals per order of the macrofauna, which expresses the uniformity of the important values through all the sample species. This index assumes that the individuals are randomly selected and that all the species are represented in the sample (Magurran, 1988).

Evenness index. Shannon Evenness (E) has a range between 0 and 1. The value is 0 when there is total dominance of a species, and 1 when all the species are represented by the same number of individuals (Magurran, 1988). It was calculated from the formula:

$$E = H' / H \max. = H' / \ln S$$

Where:

S = number of species of the sample

Simpson's index. It is known as a measure of concentration and refers to the probability of extracting individuals from the same species. It is used as measure of dominance, given its marked dependence on the most abundant species. The following formula corresponds to it:

$$D = \frac{\sum(n_i(n_i-1))}{(N(N-1))}$$

Where:

n_i-number of individuals of the species i

N-Total number of individuals

Margalef index (MI). Also known as Margalef biodiversity Index, it is a measure used in ecology to estimate the biodiversity of a community based on the numerical distribution of the individuals of the different species, related to the number of existing individuals in the analyzed sample. The formula is the following:

$$MI = (S - 1)/LnN$$

Where:

S: total number of species
N: total number of individuals from all the species

Through the *Species Diversity & Richness* software version 4.1.2 (Pisces Conservation Ltd., 2020), the above-described diversity indexes and the range abundance curve for the edaphic macrofauna communities in each studied system were determined.

Statistical analysis. For the analysis of the studied variables, the fulfillment of the variance homogeneity (Levene, 1960) and normal distribution (Shapiro and Wilk, 1965) assumptions was tested. When the homogeneity requisite was not fulfilled, *Kruskal-Wallis* non-parametric analysis was carried out. For the statistical processing the InfoStat software, free version for Windows, was used.

Results and Discussion

A total of 1 207 individuals (table 1) were collected. From them, 840 corresponded to the silvopastoral system and 367 to the natural pastures.

The silvopastoral system showed higher taxonomic richness (table 1), because the trees present make higher litter contribution and improve the physical properties of soils, by increasing the quantity of micropores in charge of soil drainage and aeration (Benavides *et al*., 2015). In addition the tree crown allows the regulation of the factors temperature and humidity, which favor the medium microclimate and the development of the edaphic macrofauna.

Schindler *et al*. (2016) and Martínez-Pastur *et al*. (2017) stated that the systems with trees are capable of preserving biodiversity and contributing environmental services to the ecosystems.

When analyzing the ecological indexes (table 2), no marked difference was found between the evaluated systems. Shannon-Wiener Index is an estimator of diversity and its value is usually between 1,5 and 3,5.

The number of species is the most used measure for biodiversity analyses. The Shannon and

Table 1. Number of individuals per order in both systems.

Order	Natural pastures	Silvopastoral system	Total
Coleoptera	133	313	446
Haplotaxida	78	144	222
Spirobolida	5	11	16
Mollusks	7	43	50
Lepidoptera	9	40	49
Arachnida	16	18	34
Isopoda	50	117	167
Chilopoda	16	50	66
Ortoptera	39	46	85
Diptera	10	20	30
Hemiptera	9	43	52
Total	367	840	1 207

Table 2. Biodiversity indexes per system.

Index	Natural pastures	Silvopastoral system
Shannon Wiener	1,83	1,94
Evenness	0,76	0,81
Simpsons D	4,75	5,00
Margalef	1,52	1,48

Evenness indexes indicated moderate diversity values and showed that the macrofauna community of the silvopastoral system is more diverse and uniform than in the pastureland system.

The Shannon Index values were higher than the ones reported by Escobar-Montenegro *et al*. (2017), who referred 1,69 in pasturelands and 1,68 in a silvopastoral system, although without significant differences between them.

The species richness, determined by Margalef Index showed homogeneity of taxa in the two systems. However, Margalef (2002) stated that values lower tan 2,0 are related to low biodiversity zones (in general, as result of anthropogenic effects). Values higher than 5,0 are considered indicative of high biodiversity. In this study low diversity of the macrofauna was found in the two treatments (natural pastures and silvopastoral system), which can be due to the deficient drainage of this soil and to the disturbances caused by man's activity when managing these systems. A rehabilitation plan of these areas is necessary, with higher quantity of species, especially of cultivated grasses and herbaceous legumes, which contribute to soil amelioration and conservation.

Regarding Simpson's Index, the highest value appeared in the silvopastoral system, which indicates the higher probability that two randomly chosen individuals in a community come from different species.

Figure 1 shows the range/abundance curve of the edaphic macrofauna community for the richness per order of the system of natural pastures. It was found that the order Coleoptera was the most abundant followed by Oligochaeta and Isopoda. The least represented were the individuals from the orders Lepidoptera, Hemiptera, Gastropoda and Spirobolida, with less than 10 individuals.

The silvopastoral system showed higher abundance of the macrofauna (figure 2), which coincides with the report by Cabrera-Dávila (2017) and is ascribed to the higher soil cover, which offers optimum temperature and humidity conditions for the development of the edaphic fauna. This curve also showed that the order Coleoptera, followed by Oligochaeta, was the most abundant in the silvopastoral system. The least represented were Araneae and Spirobolida.

The presence of coleopterans as the most abundant orders in both systems is important, because they perform valuable ecological functions for the balance of agroecosystems. They are fundamental in cleaning grasslands, by burying manure and preventing the grazing area that contains dung from being rejected by livestock (Cárdenas-Castro and Páez-Martínez, 2017).

According to Cabrera-Dávila (2017), this order, according to its functionality, can be detritivorous, predator and herbivorous. The functional group of detritivores comprises a large part of the invertebrates that inhabit within the soil (endogeal) and in its surface (epigeal). The latter are the main ones in charge of crushing plant and animal remains that make up the litter, which reduces the size of detritus particles and increases the surface exposed to the decomposing activity of bacteria and fungi. Without the action of detritivorous organisms the organic matter decomposition processes and recycling of nutrients in the soil become slower.

On the other hand, predators consume living invertebrates and small vertebrates, so that they modify the balance of their populations, the balance between them and the available resources in the ecosystem.

Herbivores feed on the living parts of plants, which influences the quantity of plant material that enters the soil and, thus, contribute to the increase of its fertility.

Regarding Oligochaeta, many authors report that this group is prevailing in the edaphic macrofauna in most animal husbandry systems (Chávez-Suárez *et al.,* 2016). They are classified for their activity as ecosystem engineers, influence the transformations of organic matter and soil physical properties, by establishing channels and pores which favor aeration, drainage, aggregate stability and water holding capacity. In addition, they generate biogenic structures, which are nutrient reservoirs, control the availability of resources for other organisms and activate the edaphic microflora through mutualistic interactions (Lavelle *et al*., 2016).

These results endorse the importance of silvopastoral systems for the conservation of animal husbandry soil fertility compared with grass monoculture, which coincides with the report by Sánchez and Crespo (2004) in Cuba, regarding the higher abundance of macrofauna in silvopastoral systems with regards to monoculture pastures.

The grass monoculture model has proven that it is not the best technological alternative in tropical ecosystems (Mauricio, 2012), due to the low nutritional quality of these species, especially when continuous grazing prevails. These conditions generate critical periods in the dry season, during which forage availability and quality decrease drastically and, thus, milk and beef production and the reproductive parameters are affected in cattle production systems

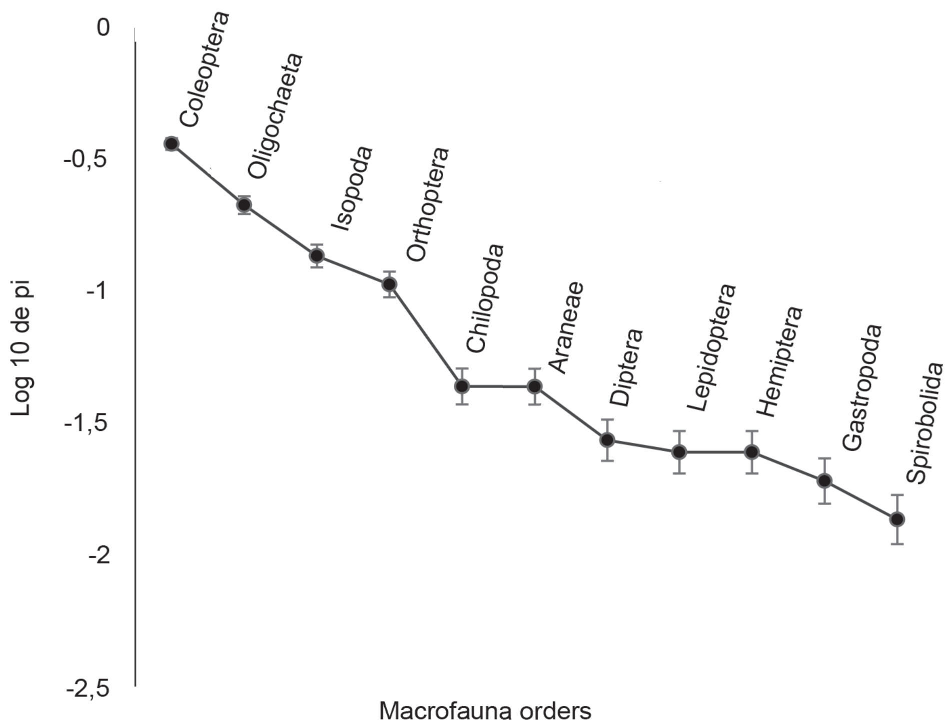

Figure 1. Range/abundance curve of the edaphic macrofauna in natural pastures.

Figure 2. Range/abundance curve of the edaphic macrofauna in the silvopastoral systems.

(Cuartas-Cardona *et al*., 2014; Navas-Panadero, 2017).

The density of edaphic macrofauna is affected by the richness of plant species present in the systems and the cover. This could be explained because diverse plant species provide the soil biota with propitious habitats for its development, because of the availability of nutrients and temperature and humidity conditions that favor its development. This coincides with recent studies conducted by Wu and Wan (2019), who proved the hypothesis that the macrofauna depends on the specific conditions of soil microhabitats created by the vegetation. These authors emphasize that the spatial distribution of soil macrofauna is clearer in its community composition, abundance and diversity than mesofauna. The above-explained facts also have repercussion on the heterogeneity of resources for the feeding, development and refuge of the macrofauna, because a favorable microclimate is not created.

Due to the above-exposed argument, it is necessary to minimize the unbalance of food production that characterizes the systems without trees (Murgueitio-Restrepo *et al*., 2016) and make a more efficient use of the associations of grasses with legume trees, which contribute to improve soil fertility.

Conclusions

The silvopastoral system provides the macroinvertebrate community with favorable conditions for the optimum development of the edaphic macrofauna. In this system higher quantity and diversity of individuals was found.

The taxonomic composition of the edaphic macrofauna is similar in the evaluated systems, and there are differences regarding the diversity and evenness of the orders. The orders Coleoptera and Oligochaeta were the most dominant ones. Nevertheless, there was no marked difference between the ecological indexes in both animal husbandry systems.

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Authors' contribution

- Marta Beatriz Hernández-Chávez. Conceived the idea of the research, participated in the data analysis and interpretation and wrote the paper.
- Wendy Mercedes Ramírez-Suárez. Conceived the idea of the research, participated in the data analysis and interpretation and wrote the paper,
- Alexis Abilio-Zurita. Participated in the conception of the research, conducted the experiments, the data collection and participated in the analysis and discussion of the results.
- Marlen Navarro-Boulandier. Participated in the conception of the research, in the data analysis and interpretation.

Conflict of interests

The authors declare that there is no conflict among them.

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