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Scientific Article

Easy-to-obtain biological soil quality indicators for monitoring agroecological corn cultivation

Indicadores biológicos de qualidade do solo de fácil obtenção para o monitoramento do cultivo de milho com base agroecológica

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ABSTRACT - The soil is a natural resource of biotic and abiotic combinations affected by management and may significantly change their functionality. This study evaluates the impact of agricultural practices adopted under ecologically based management on corn cultivation compared with an adjacent native forest area. The study was developed in the experimental areas and laboratories of the Cascata Experimental Station - Embrapa Clima Temperado, Pelotas/RS. The diversity of edaphic fauna was obtained by the PROVID method, which resulted in similarity in both environments. It was observed that the Shannon diversity index and Pielou equitability index were significantly higher in corn cultivation. Compared to Renyi's diversity profile, the edaphic fauna in corn presented a higher index of species than in the native forest ($\alpha<2$), attributed to a greater source of food for some communities. The bait-lamina methodology was used for the feeding activity of the soil biota, evidencing an average activity in corn approximately 60% higher compared to the forest (48.14%). These indexes must be associated with the average content of OM present in the soil, being 6.04% in the forest and 2.39% in the corn, because when analyzed by the T-test, they present significant levels for the feeding activity. It is concluded that the assessment of the impact of agricultural practices adopted under ecologically based management in corn cultivation resulted in no significant difference when compared with the adjacent native forest area since levels of similarity between the environments were identified concerning biological parameters of the soil.

Keywords: PROVID. Bait-lamina. Agroecosystems. Agroecological management.

RESUMO - O solo é um recurso natural constituído por combinações bióticas e abióticas das quais são afetadas pelo manejo, podendo alterar sua funcionalidade. Nesse sentido, o objetivo deste estudo é avaliar o impacto de práticas agrícolas adotadas sob manejo de base ecológica no cultivo de milho em comparação com uma área de mata adjacente. O trabalho foi desenvolvido nas áreas experimentais e laboratórios da Estação Experimental Cascata - Embrapa Clima Temperado, Pelotas/RS. A diversidade da fauna edáfica foi obtida pelo método PROVID que resultou em similaridade em ambos os ambientes, sendo observado que a diversidade de Shannon e a equitabilidade de Pielou foram significativamente maiores no cultivo com milho. Quando comparado ao perfil da diversidade de Rényi, a fauna edáfica no milho apresentou maior índice de espécies que na mata ($\alpha<2$), atribuindo a uma maior fonte de alimentação para algumas comunidades. Para a atividade alimentar da biota do solo utilizou-se de bait-laminas, que constatou uma atividade média no milho cerca de 60% maior, quando comparada a mata (48,14%). Esses índices devem ser associados ao teor médio de MO presente no solo, sendo 6,04% na mata e 2,39% no milho, pois quando analisadas pelo teste *T* apresentam níveis significativos para a atividade alimentar. Conclui-se que a avaliação do impacto de práticas agrícolas adotadas sob manejo de base ecológica no cultivo de milho resultou sem diferença significativa, quando comparado com a área de mata adjacente, uma vez que se identificou níveis de semelhança entre os ambientes quanto aos parâmetros biológicos do solo.

Palavras-chave: PROVID. Bait-lamina. Agroecossistemas. Manejo agroecológico.

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INTRODUCTION

The adoption of sustainable production systems, such as ecologically-based systems, has increased considerably in recent years, driven mainly by society demand for food that is of higher quality and that, in its production process, results in lower environmental impacts (FERREIRA; STONE; DIDONET, 2017).

Primavesi (2008) adds that ecologically based management is intrinsically linked to the wisdom of each farmer who, based on their local experiences and observations, develops agricultural practices according to the specific characteristics of each environment, altering them as little as possible and thus extracting the natural potential of the soil.

According to EMBRAPA (2018), the soil is defined as a collection of natural bodies consisting of solid, liquid, and gaseous parts, three dimensional, dynamic, formed by mineral and organic materials that occupy most of the surface mantle of the continental extensions of the earth's crust. They contain living matter and can be vegetated in the nature in which they occur and, if necessary, modified by anthropogenic interference.

Soil results from the simultaneous and integrated action of the climate and organisms acting on a source material occupying a particular landscape or relief over a certain period. The soil is home to micro and macroorganisms, which make up its biodiversity and participate in essential processes such as nutrient cycling and the decomposition of waste and pollutants, as well as contributing to the absorption of water and nutrients by plants, as is the case with mycorrhizal fungi and biological nitrogen fixation (DIAS, 2017).

Moreira et al. (2018) state that biological processes are important for maintaining life in the soil, such as the decomposition of organic matter (OM) and the production of humus, nutrient cycling, biological control of pathogens, the formation of aggregates, the production of diverse metabolites, such as antibiotics, organic acids, hormones, allelopathy, as well as the production of food that maintains human society.

Given this, it is necessary to use soils sustainably and monitor them, analyze their current situation and resilience capacity, and make decisions for their restructuring. This monitoring can be carried out using physical, chemical, and biological indicators, making it possible to assess soil conditions and promote the maintenance of the productive sustainability of environments (SILVA et al., 2021).

The same occurs in methodologies aimed at gaining an understanding of the role of soil dwelling organisms in the construction and maintenance of soil quality, i.e. Sobucki et al. (2019) indicate the constant use of biological indicators for the assessment of soil quality, mainly since soil biota play a fundamental role in various ecosystem processes (nutrient cycling, energy flow) that occur in the soil.

In terms of identifying changes in an environment, often generated by the type of management, bioindicators are more efficient than chemical and physical indicators because, according to Lisboa et al. (2012) and Stöcker et al. (2017), biological indicators are highly sensitive, allowing assessments to be made soon after soil disturbances occur, detecting changes that occur in the soil as a result of its use and management. SILVA et al. (2021) discuss that biological indicators are living constituents present in the first layers of the soil and are represented by a great diversity of species, which perform numerous and complex functions, possessing a wide functionality and sensitivity, which makes it possible to detect changes resulting from soil management.

Góes et al. (2021) state that edaphic fauna has the potential to be used to assess soil quality, as some groups are sensitive to changes in environmental variables. Information on soil biota can be collected using a variety of methodologies. Ideally, these methods should be simple enough to be implemented easily and affordably (BARAZA et al., 2019).

This study aims to determine the impact of agricultural practices adopted under ecologically based management on corn cultivation compared to an adjacent forest area.

MATERIAL AND METHODS

The study was carried out between March and April 2021 in the experimental areas and laboratories of the Cascata Experimental Station (EEC, 31°37'15" S, 52°31'30" W, 170m altitude), Embrapa Clima Temperado, located in Pelotas/RS.

Soil chemical and biological parameters were monitored in two areas, A and B, 632m apart, cultivated with BRS 019 Tupi corn in an ecological conventional planting system 47 days after emergence, arranged in 5m long plots with four rows spaced 0.8m apart. The cultivation areas have been managed with ecologically based systems for at least 15 years.

The corn was grown in an ecologically based production system, and the soil was prepared as Schiedeck et al. (2021) described. The area was previously cultivated with oats and vetch, incorporated a week before sowing by plowing and light harrowing. Granulated poultry manure (2% Nitrogen - N) was applied to the sowing furrows at 1,500 kg ha^{-1}. The corn was sown on October 20, 2020, in experimental units with four five-meter rows, spaced 0.8m between rows and 0.25m between plants (50,000 plants ha^{-1}). In November, the sowing row was manually weeded, and a further 2,750 kg ha^{-1} of granulated chicken manure was applied as a top dressing. Considering the N content specified by the manure supplier and the average humidity and agronomic efficiency indexes cited in the Fertilization and Liming Manual for the States of RS and SC (SBCS, 2016), it is estimated that between 19 and 32kg ha^{-1} of N was supplied to the corn.

At the same time, the same monitoring standards were applied in adjacent areas of native forest (never managed), 25m away from the cultivation areas (Figure 1), which were composed of medium-sized shrubs and large native trees with a high aerial density that generated total shading of the surface, with sandy-textured soil and dark coloring, covered in leaf litter and apparent humidity.

The white dots, illustrated in Figure 1, represent the approximate position of the sample collection sites and the installation of the monitoring systems in each corn-growing area and the native forest area. In both situations, the points were chosen entirely at random.

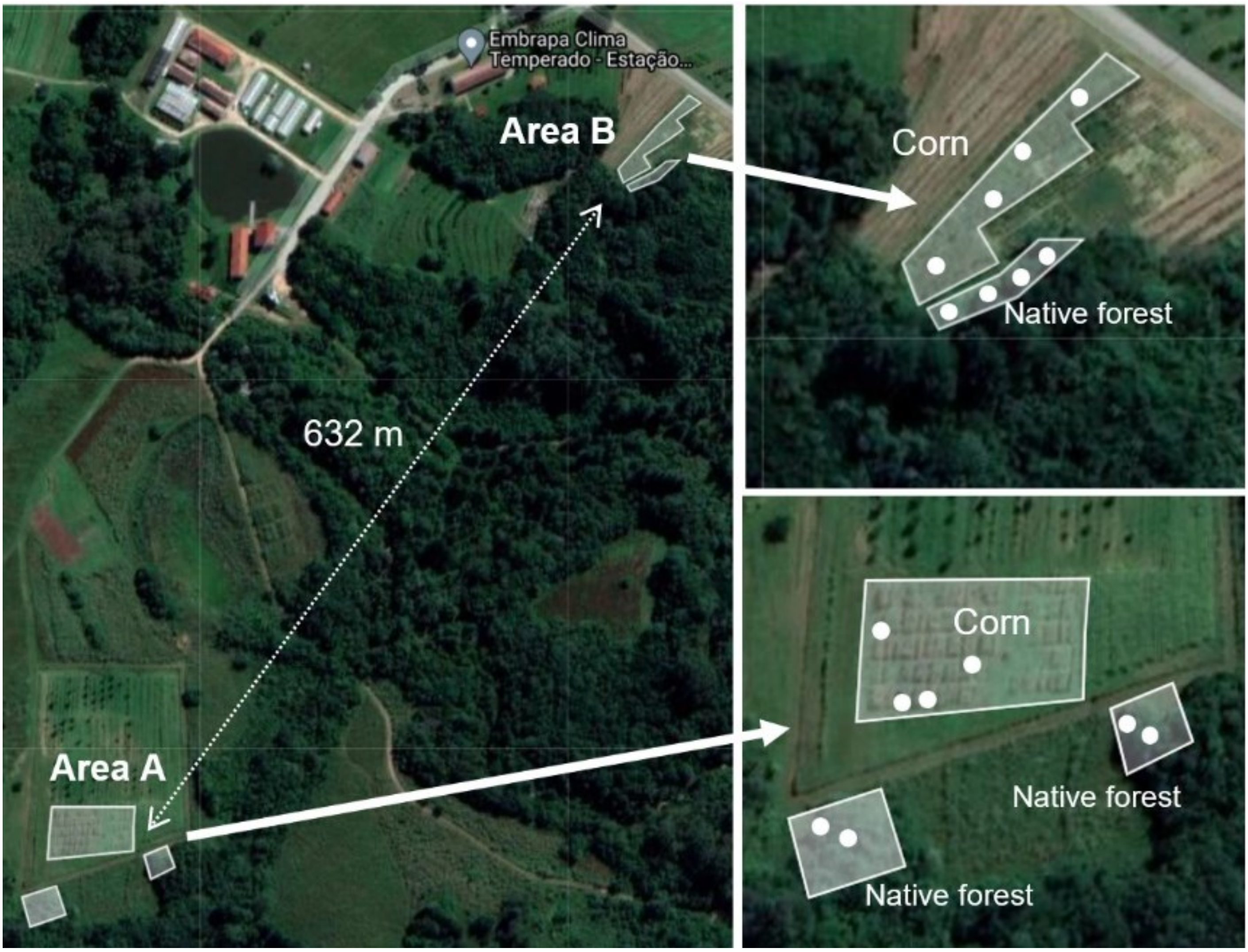

Figure 1. Sampling areas in corn fields and adjacent native forests. Cascata Experimental Station, Embrapa Clima Temperado. Pelotas, RS, Brazil. March-April 2021. The quadrilaterals represent the position of the sample areas, and the white circles represent the approximate location of the sample points.
Source: Google Maps, 2021.

Chemical analysis of the soil

A total of 16 soil samples were collected from four areas, four in each area of corn cultivation under an ecological management system and four in the respective areas of native forest. The principle behind this proposal was to establish a comparative factor for the results of the cultivated areas and those with an unchanged system.

All the samples were collected on April 14, 2021, i.e., four days after the rain, which had a previous average rainfall of 75.9mm, identifying that the soil had a slightly moist consistency in the friable condition, according to the methodology described by Santos et al. (2005). To open the furrows, a spade was used to cut to a depth of 10cm (from the removal of the surface layer, 5cm), where around 1.5kg of soil mass was extracted at each sampling point, identified and taken to the laboratory to be stored in a refrigerator until chemical analysis.

The soil samples were homogenized, and a 500g fraction was separated for analysis and passed through a sieve with a 2.0mm mesh to remove larger diameter particles, as well as plant material and crop remains, and were then sent for analysis at the Soil Analysis Laboratory (Laboratório de Análise de Solos - LAS) of the Universidade Federal de Santa Maria (UFSM) to obtain the following data present in the soil: Potassium, Calcium, Magnesium, pH(in water), base saturation index, and OM (Table 1).

Table 1. Average values of the chemical and physical variables of the soils in the different areas evaluated (n=16), considering a depth of 1cm. Cascata Experimental Station, Embrapa Clima Temperado.

Area	Environment	pH WATER [1:1]	$Ca^{2}\pm$ [$cmol_c\ dm^{-3}$]	$Mg^{2}\pm$ [$cmol_c\ dm^{-3}$]	Base Saturation [%]	$Ca.Mg^{-1}$
A	Forest	5.45	8.45	3.48	75.38	2.45
	Corn	5.63	5.48	1.88	74.93	2.90
B	Forest	5.08	6.85	2.13	58.00	3.23
	Corn	5.45	4.15	1.25	71.05	3.30
Average		5.40	6.23	2.19	69.84	2.97
Standard deviation		0.23	1.84	0.94	8.13	0.39
CV (%)		4.28	29.59	42.99	11.64	13.07
Area	**Environment**	**OM [%, $m.v^{-1}$]**	**P-Mehlich [$mg\ dm^{-3}$]**	**K [$cmol_c\ dm^{-3}$]**	**Clay [%]**	**Texture [%]**
A	Forest	6.65	23.15	0.57	17.75	3.75
	Corn	2.50	19.88	0.28	27.75	3.00
B	Forest	5.43	28.55	0.49	17.50	4.00
	Corn	2.28	45.47	0.30	20.00	3.75
Average		4.22	29.26	0.41	20.75	3.63
Standard deviation		2.17	11.38	0.14	4.80	0.43
CV (%)		51.42	38.89	34.78	23.13	11.95

CV: Coefficient of variation; Ca: Calcium; Mg: Magnesium; OM: Organic matter; K: Potassium.

Diversity of edaphic fauna using the PROVID method

The diversity of edaphic fauna was measured using the PROVID fall trap method, according to the methodology of Antoniolli et al. (2006). Two liter PET bottles were used to make the traps, in which four window-shaped openings (6 x 4 cm) were made, positioned 20 cm from the base.

The traps were buried in the ground, so the openings were at surface level. A solution of 200mL of 70% alcohol (v:v) and ten drops of neutral detergent were added to each trap.

The traps were installed on March 16, four in each area, and collected after seven days. One experimental unit was lost in the corn crop in area A, possibly due to the action of an animal passing by. The contents of the traps were placed in plastic jars and taken to the laboratory for identification.

The organisms collected were observed using an optical magnifying glass at 3.5x magnification and identified as appropriate by order, taxonomic group, or morphotype. The information was tabulated and used to calculate the diversity indexes.

Endofauna feeding activity using the bait-lamina method

The feeding activity of the soil biota was assessed using the bait-lamina methodology, according to the model proposed by Törne (1990) and described in Kratz (1998).

Polyethylene rods were constructed (Figure 2a) with dimensions of 1mm thick, 6mm wide, and 150mm long, with 16 biconical holes of 1.5mm diameter spaced 5mm apart.

The holes were filled with a homogeneous nutrient paste (Figure 2b) made up of powdered cellulose (70%), oatmeal (27%), and activated charcoal (3%) (RÖMBKE et al., 2006). The nutrient paste was applied to the blades and left to dry for 24 hours, and the process was repeated after drying for a further 24 hours. The filled slides were stored one by one in aluminum foil and taken to the field where the installation took place, always wearing gloves to minimize material contamination as much as possible.

In each area, four replicates were installed with 16 slides each, distributed in a 4x4 *grid* (Figure 2c), with a spacing of 10cm between centers, totaling 256 rods, which were tabulated (n=16) and the respective arithmetic averages established with the presentation of the result of the consumption of the baits in the areas studied.

The slides were inserted vertically into the soil so that the first hole was five centimeters from the surface. The bait blades were installed on March 19, and after 14 days, two blades were removed from each repetition to check the degree of consumption and estimate the date of complete removal. For the methodology to be valid and allow a comparison between areas, it is necessary to keep the blades in the soil for some time, during which there is a minimum average consumption of around 30%. On the other hand, the slides must be removed before maximum consumption, making the comparison unfeasible (ISO, 2016).

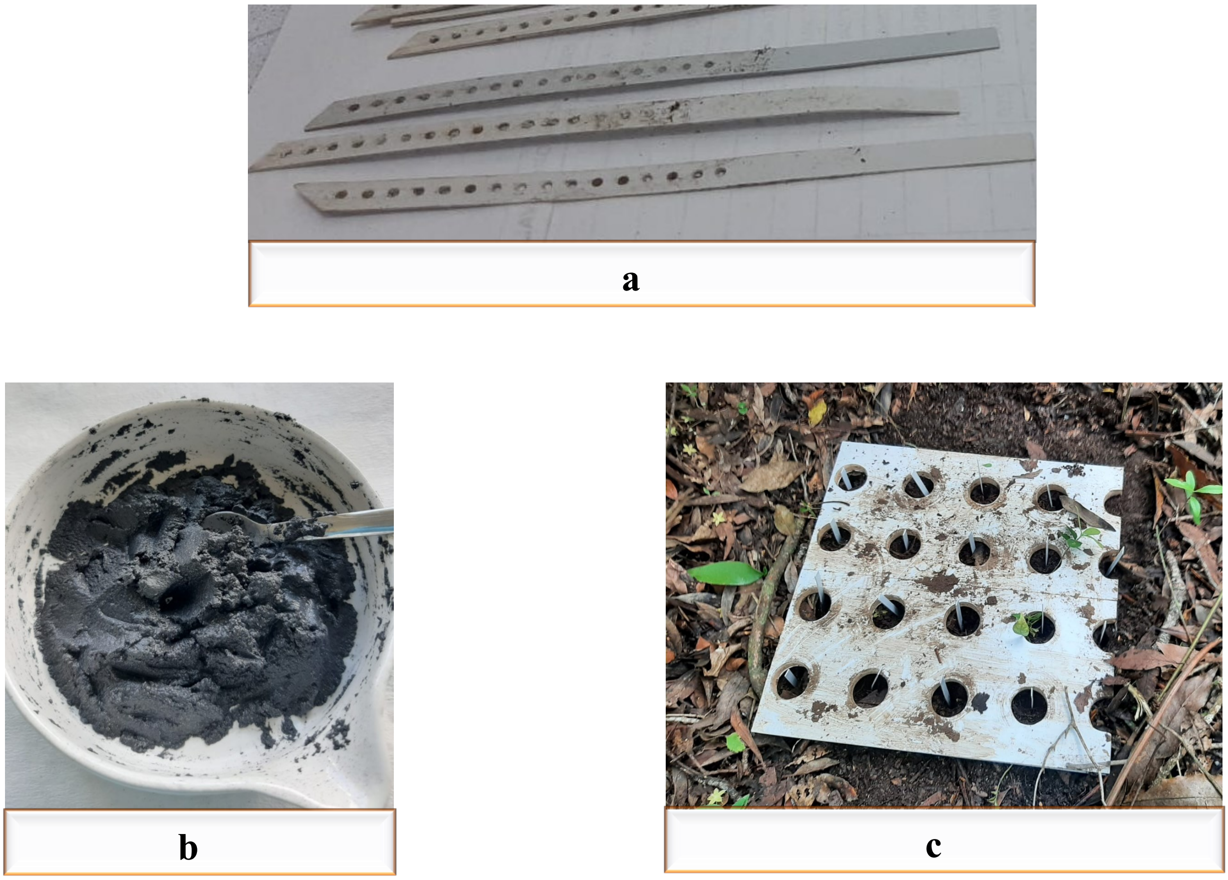

Figure 2. Elements of the bait-lamina methodology. Material developed at the Cascata Experimental Station, Embrapa Clima Temperado. Legend: (a) *Slides* - polyethylene rods (b) Bait (c) *Grid template*.

In this way, the slides in all areas were removed 21 days later. At the end of the period, they were carefully removed from the soil to avoid losing the remaining substrate, wrapped one by one in aluminum foil, and washed in the laboratory, where they remained refrigerated at 4ºC until the consumption was assessed.

The degree of consumption of the baits in each hole and all the slides was assessed according to ISO 18311 (2016) (Table 2).

To facilitate the process of identifying the percentage of consumption, a circular template was used with six sections representing 0%, 20%, 40%, 60%, 80%, and 100% consumption, which were assigned the values 0, 1, 2, 3, 4 and 5, respectively (Figure 3).

The sum of the values on both sides of the hole formed an estimate of the total percentage of consumption, i.e., for a hole to be considered open (grade 1), one side had to have a value of 4 and the other at least 3, which would add up to a value of 7 (= 70%). However, if one side had a value of 3 and the other had a value of 2 (= 50%), the hole was considered half open (score 0.5), allowing the values assigned to each side to be tabulated and converted into the scoring criteria.

The reading was taken systematically from the first hole (shallowest) to the sixteenth hole (deepest), regarding the orientation of the "A" side, the one with the greatest distance from the base, i.e., the 45º angle cut at the end of the rod. A magnifying glass (3.5x optical zoom) was used in both readings (sides A and B) of the bait consumption in the biconical holes to visualize better the area consumed and establish a spatial comparison of the circular area of the template proposed in this study.

Table 2. Criteria for assigning scores according to the degree of bait consumption in the holes, according to ISO 18311. Cascata Experimental Station, Embrapa Clima Temperado.

Criteria	Consumption (considering both sides)	Note
Open orifice	≥ 70% of bait consumed	1
Half open orifice	Between 69% and 31% of the bait consumed	0.5
Closed orifice	≤ 30 of bait consumed	0

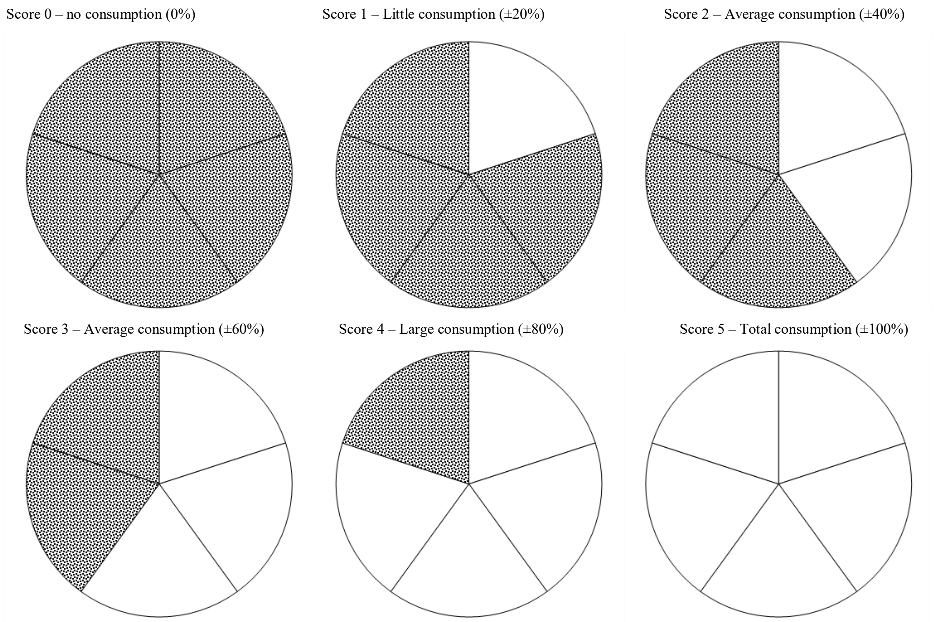

Figure 3. The scoring scale was used to infer food consumption in each hole of the bait-lamina. Material developed at the Cascata Experimental Station, Embrapa Clima Temperado.

Ecological indices of diversity

The experimental design and statistical procedure applied to the different diversity indexes were obtained using the free software Paleontological Statistics Software Package for Education and Data Analysis - PAST, version 4.03, as presented by Hammer, Harper, and Ryan (2001) and the definitions and interpretations substantiated by Daly, Baetens, and Baets (2018).

The comparison between the corn crop and the native forest between the two areas was made using the Morisita-Horn and Jaccard similarity indexes, while the comparison of the diversity indexes between the corn crop and native forest without considering the areas was made using permutation tests ($p<0.05$), with 9999 random matrices.

The richness of taxonomic groups (S) was calculated by adding up the number of groups and the abundance of individuals (n) by adding up all the individuals from all the groups in each sample. Simpson equitability (1-D) was used to estimate the probability of two randomly collected individuals in a community belonging to taxonomic groups. Thus, for interpretation in the Rényi diversity profile, the Simpson index was considered the inverse of dominance (*1/D*).

Sequentially, the uncertainty of predicting the identity of a taxonomic group from a randomly collected individual from a community was measured using Shannon diversity (H’). The Pielou evenness index (J’) was used to determine the uniformity of the distribution of the abundance of taxonomic groups in a community. Dominance, to identify the proportional abundance of the most abundant taxonomic group in the community, was obtained using the Berger-Parker index (*d*).

RESULTS AND DISCUSSION

Chemical analysis of the soil

The results of the chemical analysis show that the hydrogen potential indexes (pH) reached values above 5.0. Therefore, the pH results show that the corn-growing areas are on par with the native forest area, i.e., even though there have been structural, chemical, and biological changes, the environment with agroecological management has similar conditions when compared to a preserved forest environment, being in the same range, corresponding to +/- 5.0 pH.

According to Utobo and Tewari (2015), enzyme activity is influenced by temperature and pH and can be reduced when pH values are too high or too low. According to the SBCS (2016), the appropriate pH value for corn crops is between 5.5 to 6.0, and only below the lower limit value would condition the adoption of management practices to correct and raise the pH in the cultivated areas. However, the values are close to those of the adjacent native forest. As well as soil temperature, around 18ºC, pH values can also be associated with OM content, both in terms of increasing the feeding activity of endofauna and decreasing it.

Another indispensable factor in the context of this study is the dynamics of phosphorus (P) in the soil, which, according to Santos, Gatiboni, and Kaminski (2008), is associated with environmental factors that control the activity of microorganisms, which immobilize or release orthophosphate ions and act on the other physicochemical and mineralogical properties of the soil.

Thus, it is essential to analyze the availability of P in the soil, which can be extracted by various processes used to obtain "available P"; however, Bortolon et al. (2011) describe that the Mehlich method preferentially extracts the forms of P bound to calcium, overestimating the availability of P in soils recently fertilized with natural phosphates. It can be seen that both forest environments resulted in higher Ca levels than the managed environments.

Using the guiding parameters of the SBCS (2016) in interpreting the results of the clay content, the range of 16 to 35% corresponds to an average index, which represents around 15.1 to 20mg dm^{-3} of available P, representing an average range of availability in the soil.

Associated with the texture and clay content, it can be seen that the base saturations were above 70%, i.e., values close to 75%, as recommended by the SBCS (2016) for growing corn.

Diversity of edaphic organisms

A total of 7,337 organisms were collected in the corn-growing and native forest areas, and it was possible to classify them into 17 groups (Table 3). Collembola and Diptera were predominant in both areas, with more than 66% and 21% belonging to these orders.

Table 3. Absolute and relative abundance of organisms collected in the two areas analyzed. Cascata Experimental Station, Embrapa Clima Temperado.

Taxonomic order or group	Area A				Area B			
	Corn		Native forest		Corn		Native forest	
	n	%	n	%	n	%	n	%
Collembola	1113	61.19	1884	74.73	1197	70.87	665	50.84
Diptera	362	19.90	402	15.95	252	14.92	402	30.73
Coleoptera	167	9.18	144	5.71	109	6.45	113	8.64
Amphipoda	18	0.99	24	0.95	18	1.07	78	5.96
Hymenoptera	42	2.31	4	0.16	40	2.37	0	0.00
Trombiforme	26	1.43	15	0.60	14	0.83	10	0.76
Orthoptera	17	0.93	0	0.00	22	1.30	3	0.23
Dermaptera	2	0.11	13	0.52	0	0.00	19	1.45
Araneae	16	0.88	2	0.08	7	0.41	8	0.61
Larva[1]	20	1.10	11	0.44	1	0.06	0	0.00
Thysanoptera	13	0.71	8	0.32	5	0.30	4	0.31
Isopoda	7	0.38	11	0.44	4	0.24	0	0.00
Blattodea	9	0.49	1	0.04	8	0.47	3	0.23
Pulmonata	3	0.16	1	0.04	9	0.53	1	0.08
Hemiptera	4	0.22	0	0.00	2	0.12	0	0.00
Caterpillar[1]	0	0.00	0	0.00	1	0.06	2	0.15
Lepdoptera	0	0.00	1	0.04	0	0.00	0	0.00
Total	1819		2521		1689		1308	

Taxonomic order or group	Pooled samples				Total	
	Corn		Native forest			
	n	%	n	%	n	%
Collembola	2310	65.85	2549	66.57	4859	66.23
Diptera	614	17.50	804	21.00	1418	19.33
Coleoptera	276	7.87	257	6.71	533	7.26
Amphipoda	36	1.03	102	2.66	138	1.88
Hymenoptera	82	2.34	4	0.10	86	1.17
Trombiforme	40	1.14	25	0.65	65	0.89
Orthoptera	39	1.11	3	0.08	42	0.57
Dermaptera	2	0.06	32	0.84	34	0.46
Araneae	23	0.66	10	0.26	33	0.45
Larva[1]	21	0.60	11	0.29	32	0.44
Thysanoptera	18	0.51	12	0.31	30	0.41
Isopoda	11	0.31	11	0.29	22	0.30
Blattodea	17	0.48	4	0.10	21	0.29
Pulmonata	12	0.34	2	0.05	14	0.19
Hemiptera	6	0.17	0	0.00	6	0.08
Caterpillar[1]	1	0.03	2	0.05	3	0.04
Lepdoptera	0	0.00	1	0.03	1	0.01
Total	3508		3829		7337	

[1]Not identified.

According to Sales, Baldi, and Queiroz (2018), springtails are noticeable in soils with high humidity. According to Baretta et al. (2011), the predominance of springtails is justified by their food base being a wide variety of other organisms and OM, and they are generally found in forest litter.

The same occurs with dipterans, and Halabura and Haiduk (2021) and Marinho et al. (2021) report that this group is extremely important for maintaining ecosystems, as they allow these insects to be considered bioindicators of environmental quality. Casaril et al. (2019) point out that dipterans are an important part of the abundance of soil fauna in many ecosystems, even in the larval stage, as they help characterize the edaphic fauna.

The similarity between the corn areas was 99% for the quantitative Morisita-Horn index and 88% for the qualitative Jaccard index, while the adjacent native forest areas resulted in a similarity of 91% for the Morisita-Horn index and 63% for Jaccard (Table 4).

Table 4. Evaluation of the Morista-Horn and Jaccard similarity indices of the areas evaluated (n=15). Cascata Experimental Station, Embrapa Clima Temperado.

Area	Similarity of Morisita-Horn (I_{M-H})			
	Corn A	Native forest A	Corn B	Native forest B
Corn A	1.00	-	-	-
Native forest A	0.98	1.00	-	-
Corn B	0.99	1.00	1.00	-
Native forest B	0.97	0.91	0.92	1.00
Area	**Similarity of Jaccard (I_J)**			
	Corn A	Native forest A	Corn B	Native forest B
Corn A	1.00	-	-	-
Native forest A	0.81	1.00	-	-
Corn B	0.88	0.71	1.00	-
Native forest B	0.69	0.63	0.69	1.00

The Morisita-Horn index shows that the corn crop and the adjacent native forest in the two areas are very similar in abundance, with values above 0.97 in all comparisons. This index tells us how similar or different two sets of data are to each other, ranging from 0 (no similarity) to 1 (complete similarity) (CHAO et al., 2006).

Forest A and Corn B were very similar in terms of the edaphic organisms found; in line with agroecological thinking, the presence of an organism in the environment cannot be disregarded without considering its interactions with it. Vieira (2021) confirms that these interferences are beneficial and leave the system rich in fertility and biodiversity, thus ensuring efficiency in maintaining ecological functions, which provides living conditions for all these organisms.

According to the Jaccard index, the two corn-growing areas were also very similar, while the similarity between the two adjacent native forest areas was only 0.63. The Jaccard index indicates the proportion of species shared between two samples concerning the total number of species, disregarding abundance but considering presence or absence (REAL; VARGAS, 1996).

However, when looking at the similarity between the corn crop and the adjacent native forest, it can be seen that there was greater equivalence in area A (0.81) than in area B (0.69).

Based on these results, it was assumed that the areas have equivalent diversity, and the samples were evaluated together. There was a significant difference between the corn crop and the adjacent native forest for the Shannon and Pielou indexes, while for the Simpson and Berger-Parker indexes, there was no statistical difference (Figure 4).

Shannon diversity and Pielou evenness were significantly higher in the corn-growing area. Góes et al. (2021) found greater diversity in the forest than in the corn fields, but in their research areas, they showed that Collembolos appeared as the predominant individuals in the cultivated areas compared to the forest areas. Similar results were found by Stöcker et al. (2017), who found that the native forest showed lower dominance values compared to the area managed with agroforestry systems, which can be attributed to the low number of individuals collected in the forest, thus reducing the dominance value, as the native forest may be in a state of equilibrium of food source additions to these organisms.

Rényi diversity profile (Figure 5) shows that the corn crop had a higher species diversity index than the native forest for the first alphas (α), attributing this to a greater food source for some communities.

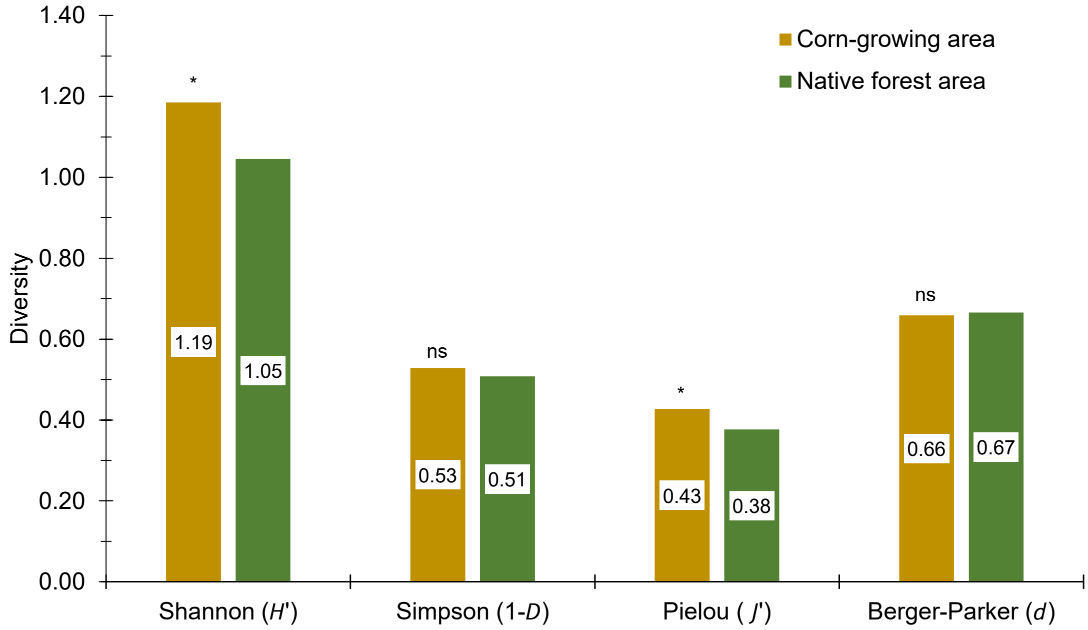

Figure 4. Diversity indexes of the edaphic fauna collected in corn-growing and adjacent native forest areas. Cascata Experimental Station, Embrapa Clima Temperado.
Legend: *significant difference by diversity permutation test; *ns*, not significant.

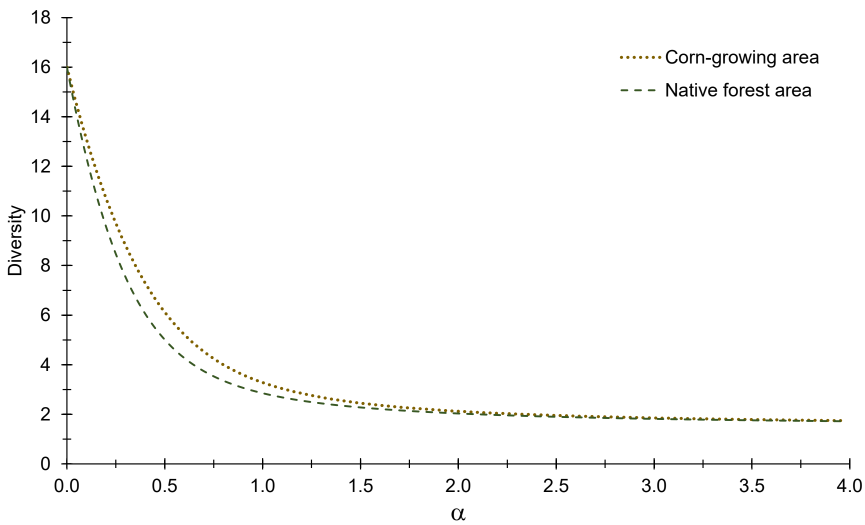

Figure 5. Rényi diversity profile of the edaphic fauna collected in the corn-growing and adjacent native forest areas. Cascata Experimental Station, Embrapa Clima Temperado.
Legend: a = 0, richness of taxonomic groups (S); a = 1, Shannon species-equivalent ($e^{H'}$); a = 2, Simpson inverse dominance (*1/D*); a = ¥, Berger -Parker inverse dominance (*1/d*).

From an agroecological point of view, this result indicates that the management adopted on the corn did not harm the edaphic fauna compared to what occurred simultaneously in the native forest. This observation can be confirmed by the shape of the curves, which show congruence and angular parametrization from α=2. However, this does not mean that there is no impact on the environment.

Feeding activity of epi-edaphic fauna

The average feeding activity of the endofauna and the average organic matter content in the agroecological corn-growing area and the adjacent native forest are shown in Figures 6 and 7.

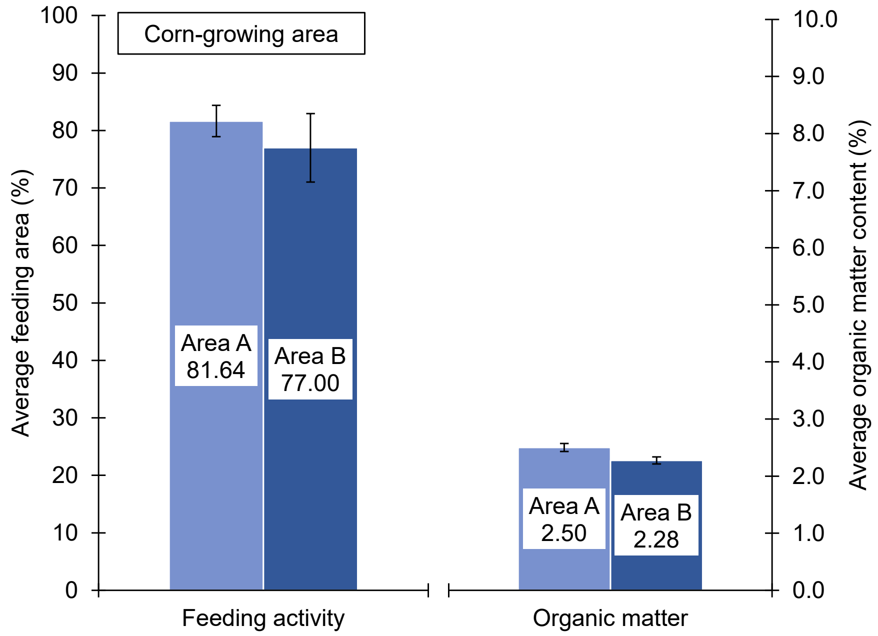

Figure 6. Average feeding activity (%) of endofauna and average organic matter content (%) of the soil in corn-growing areas (n = 16). Cascata Experimental Station, Embrapa Clima Temperado.

The average consumption of the nutrient mass of the slides in the corn crop (Figure 6) was higher in Area A (81.64%) than in Area B (77.00%).

An associative analysis of the OM present in the soil shows that, in both areas, it presents a proportional ratio, with a nominal value close to the quotient obtained in the feeding activity, indicating that low OM levels induce greater feeding activity, due to the availability of food for the biota.

This fact is confirmed by Cardoso and Andreote (2016), who described that, in agricultural areas, this microbiota is of great importance, acting as a basis of selection for plants and acting significantly against the invasion of soils by exogenous organisms.

In the adjacent forest, it can be seen that the microorganisms' food consumption was in opposition to the presence of organic matter in terms of the percentage of OM in the soil compared to lower levels of bait consumption, as shown in Figure 7.

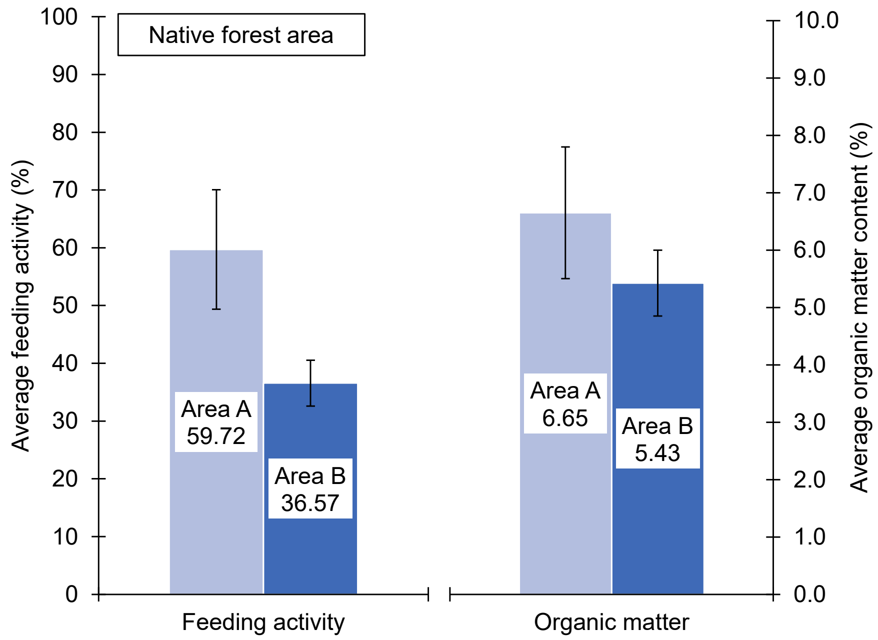

Figure 7. Average feeding activity (%) of the epi-edaphic fauna and average organic matter content (%) of the soil in the adjacent forest (n = 16). Cascata Experimental Station, Embrapa Clima Temperado.

One aspect that could explain these values is presented by Mattos (2015) in terms of the occurrence and abundance of microorganisms in an environment, which are determined by the availability of nutrients and physical-chemical factors such as pH, temperature, texture, and soil moisture.

It is important to note that when the soil was collected, the environmental variables were relative humidity of 87.3% and soil temperature of around 18ºC. These factors are essential for a more accurate interpretation of the environment because, according to Costa and Sangakkara (2006), soil humidity and temperature are the two main climatic factors influencing the decomposition rate, increasing as soil humidity and temperature increase.

It can also be seen that there was greater consumption of the bait mass in native forest area A than in area B since the topography in this area is flatter, and the surface is partially waterlogged. Rodrigues et al. (2011) state that rainfall plays a fundamental role in bacterial development in the soil, probably because it creates a favorable microenvironment for these microorganisms.

Moreira and Siqueira (2006) report that an increase in soil OM stimulates microorganisms, favoring, among other factors, physical aggregation, promoting a better microbial habitat, and favoring the decomposition of vegetative crop remains. In this sense, Cardoso and Andreote (2016) describe that in natural areas, soil microbiota is extremely important in nutrient cycling and in sustaining the ecosystem, acting at the base of the food chain that permeates these environments.

As these areas have the same management, corn, and forest, arithmetic averages were used to obtain the average percentage of food activity and organic matter content, making it possible to check the level of statistical significance using the *T*-test. According to Altman (1991), this test is widely used to assess the equality of two means and is the most appropriate because it is a parametric test, which provides us with greater statistical power and, consequently, more reliable results.

Correlatively, the test applied to the mean values of the OM content in the study areas shows that there was a confidence level greater than 95%, validating the statistical hypothesis that the adjacent forest and the agro-ecological corn crop are profiled, as they are in the same environmental condition, which allows for the development of sustainable agriculture, even when using a conventional soil preparation management system. This is supported by Rényi diversity analysis, which shows no negative effects on the edaphic fauna of the environments studied.

The comparative data on the feeding activity of edaphic fauna and the presence of OM can be confirmed by Silva et al. (2019), who described that edaphic fauna is responsible for fragmenting organic waste by producing enzymes responsible for breaking down complex biomolecules into simpler compounds, helping to form humus.

Peguero et al. (2019) corroborate the results, stating that soil fauna is essential in controlling the decomposition of organic material, with low levels of enzymatic activity being recorded when there are lower levels of substrates present in the habitat, and this activity increases as the availability of nutrients in the soil decreases.

In general, it was identified that simplified visual interpretation might not be fully representative of the intensity of microorganism activity since Reinecke et al. (2008) point out that such measures of food consumption by soil biota are indicative of microbial decomposition rates and may be a premise for adjustments to the analysis methodology.

CONCLUSION

Through the analyses to determine the diversity of organisms, it was concluded that the ecologically based management adopted for corn presented parameters for preserving biodiversity since the edaphic fauna was not affected, allowing us to infer that there are suitable conditions for production without compromising the environment.

The experiments proved effective in determining the evaluation of the soil biological parameters, as they made it possible to assess the levels of similarity between the environments.

There was no significant difference between the area of native forest and corn-growing under agroecological management.

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