Agro-Industrial Waste Management: A Case Study of Soil Fauna Responses to the Use of Biowaste as Meadow Fertiliser in Galiza, Northwestern Spain

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1. Introduction

In the recent past, world wide traditional agricultural practice was based on the addition of biowaste, especially manure and slurry, to the soil. This reuse of biowaste allowed the recycling of nutrients and improved the level of organic matter. In the past, the amount of animal waste available was smaller than the amount currently produced, and the environmental impact of such waste application would be consider lower [1]. Over the past 50 years, the intensification of agricultural and livestock breeding activities has produced an increase in the number of livestock and, consequently, in the production and accumulation of large amounts of waste. This increase, associated with the use of mineral fertilisers and pesticides for fodder production, has weakened the complementary relationship between livestock and agricultural production. For this reason, the addition of organic waste to the soil has become a significant problem with potential environmental consequences. This practice can affect watercourses and trophic chains and can contribute to atmospheric pollution.

Agro-food industries are a relevant sector of the economy, and their activity is frequently associated with the production of wastewater. In regions such as Galiza (northwestern Spain), where the primary agricultural activity is the breeding of cattle for milk production, the industries that are dedicated to the processing and packaging of milk constitute a fundamental part of the agri-food sector, generating a significant volume of waste. In recent years, the increase in industrial activity has caused an increase in sewer sludge, and concerns about the economic and environmental impacts of sludge disposal have started to emerge. The recycling of biowaste by incorporating it into agricultural and/or forestry soil is one of the recommended methods for the elimination of this waste because, in addition to being economical, this method benefits the soil as a result of the incorporation of organic matter and nutrients. However, the addition of such waste is not without risk of environmental degradation or negative effects on the health of humans and other animals. Hence, it is fundamental to monitor the use of these materials in the soil. The current legislation requires only the assessment of the nutrient content and the needs of the recipient crop, the heavy metal concentrations in the waste and in the recipient soils, the bacterial content, and the risk of nitrate water pollution [2]. However, given the importance of the biological compartment of the soil in maintaining and sustaining system function, the monitoring of anthropogenic practices, such as the addition of organic waste to soil, should also consider soil biology as a fundamental indicator.

1.1. Organic biowaste

Three primary sources of organic waste exist: i) agricultural and forestry activities, ii) urban activity, and iii) industrial activity [1]. Wastes originating from agricultural and forestry activities include livestock slurry, manure, crop remains, and waste from pruning and from the maintenance of woodlands. Industries generate organic wastes, which include the subproducts of the agri-food industry (e.g., bagasse, coffee dregs, remains from slaughterhouses, subproducts of the fruit and legume industries, and milk serum), wool and skin remains, and cellulose sludge. Such organic waste is increasingly considered not only an environmental problem but also a potential resource whose recovery could lead to important economic benefits. This paradigm shift is powered partly by legislation and partly by market forces.

The addition of such wastes to the soil has several advantages, especially the improvement of the chemical and physical properties of the soil. These wastes (adequately composted) will increase the humus content and, as a consequence, the water retention capacity of the soil. The wastes also improve the soil structure, which is fundamental for root penetration and appropriate drainage and aeration [3]. In addition, organic waste is an important source of nutrients, and its addition to the soils closes the mineral cycle [4,5]. In agricultural areas, where soils are not limited by the organic matter content, as can be the case in Galiza [6], organic waste can help to ameliorate other adverse effects, such as acidity. Several studies indicate that these organic materials, if added to acidic soils, can be effective as acid neutralisers [7,8]; this effect is associated with an increase in fodder crop yield [9,10]. From a biological viewpoint, fertilisation with organic waste also induces an increase in microbial activity, which in turn improves nutrient availability for plants [11]. Similarly, the addition of organic waste reduces the amount of chemical fertiliser needed, thus leading to savings in energy and raw materials, with a concomitant reduction in the greenhouse effect. [12] includes the addition of organic waste among the management practices related to carbon sequestration. [13,14] have observed that organic agriculture systems (no synthetic fertilisers) produce less greenhouse gas than traditional systems.

1.1.1. Associated risks and applicable European legislation

In addition to its role as a source of nutrients, organic waste can also be a source of heavy metals and pathogens (viruses and bacteria) [16, 15]. Organic waste can also add excess nutrients, primarily N and P, that induce the eutrophication of superficial and phreatic watercourses [17]. To minimise such negative effects and regulate the use of organic waste as fertiliser in agriculture, Norm [18] refers to waste and contains the main definitions and principles that govern waste management, emphasising that waste assessment and elimination must be performed without creating risks for water, air, soil, or the flora and fauna.

Considering the great variety of waste types and the specific capacity and sensitivity shown by each soil type to the possible risks represented by the wastes cited above, scientists and researchers criticise the provisions of the current legislation in the field, which are limited to certain chemical analyses [19, 20]. It has been proposed that, in programs for the management of a specific waste type, the effect of that waste on soil should be quantified with parameters that are specific to the recipient soils and whose alteration can lead to the deterioration or the improvement of the soil quality. Moreover, it must be noted that the buffering capacity of soils prevents the detection of the negative consequences of exposure to a contaminant before saturation is reached. For this reason, certain authors propose that chemical analyses should be complemented by the assessment of other types of parameters that permit the collection of information on the bio-available fraction of contaminants and that reflect the effect of other pollutants that have not been identified [21,22]. Using several types of analyses, it will be possible to assess the effect of the waste on soil quality in a concrete and exact manner.

1.2. Soil fauna as a quality indicator

The sensitivity of the soil fauna to environmental disturbances and the roles played by the fauna in physical, chemical, and biological processes are attributes that allow the fauna to be used as an indicator of soil quality [23-29]

The response of the soil fauna to the addition of fertiliser is variable. Generally, the effects of fertiliser application in moderate doses are positive, originating from the modification of microclimatic conditions or from resource availability [4, 30-38].

1.2.1. Quantification of soil fauna

Bio-monitoring allows the identification and quantification of changes over time through the analysis of the following characteristics of the soil fauna: traditional ecological measurements (species abundance and diversity), morphological or behavioural changes, and accumulation in tissues. According to [39], the three levels of interaction between the fauna and soil quality are organisms and populations, communities, and biological processes. The most commonly used parameter in the quantification of the impact of agricultural practices is the assessment of communities because this scale integrates all of the soil factors, including management and pollution effects. At this level, the parameters most commonly used are the abundance of individuals or species, biomass, specific composition, trophic strategies, and the presence or abundance of key species.

Among the organisms that compose the soil fauna, the macrofauna reflects an integration of the processes that occur in the system because the macrofaunal organisms feed on primary decomposers (such as bacteria, fungi, and actinomycetes) and secondary consumers (such as protozoans). Moreover, because macrofaunal organisms are easily collected and because their ecological role is better documented than the roles of the micro- and mesofauna, certain authors view the macrofauna as the most appropriate category for the assessment of the impact of agricultural practices [24].

The data obtained from assessments of the soil macrofauna can be analysed with both univariate and multivariate techniques. Among the univariate techniques, the most general measurements are diversity indices, which synthesise the information on diversity in only one value. These indices are normally distributed and, hence, can be analysed with robust parametric tests such as an analysis of variance. This type of analysis allows rapid comparisons, subject to the statistical test, among the obtained values for different habitats or for the same habitat over time [40].

All multivariate techniques are based on similarity coefficients calculated for each pair of samples. These techniques facilitate the classification or grouping of samples in similar groups, with the distance between a pair of samples reflecting their relative dissimilarity with respect to species composition. Multivariate statistics allow higher resolution (i.e., subtle alterations can be detected) because all of the available information for the community is used. Moreover, by combining community data with soil variables, specific information can be obtained on the factors that are responsible for the alterations [41].

2. Case study: The response of the soil macrofauna to organic waste used as a meadow fertiliser in Galiza

2.1. Agro-industrial organic waste production in Galiza

In Galiza cattle farming produces the most manure, followed by pig and poultry farming (Table 1). This manure contains high levels of organic matter and mineral nutrients.

	Spain (Ton x $10^{3)}$	Galiza (Ton x $10^{3)}$	Galiza (%)
Cattle	42.085,3	6.909,6	16,4
Sheep	12.128,2	98,8	0,8
Goat	1.458,4	18,7	1,3
Pig	25.242,0	907,2	3,6
Horse	2.637,8	242,5	9,2
Broiler	7.695,4	712,7	9,3
Rabbit	407,2	85,7	21,0
Total	91.654,3	8.975,1	9,8

Table 1. Amount of animal manure production for different farm cattle in Galiza and Spain (year 2003)

Nitrogen is present in organic forms and as ammonia, the latter being more abundant in poultry and pig wastes; K is present as highly soluble salts in urine. Potassium is present primarily in organic form (Table 2).

	N (%)	P_2O_5 (%)	K_2O (%)
Cattle	0,35	0,28	0,22
Broiler	1,40	1,00	0,60
Sheep	0,75	0,60	0,30
Pig	0,60	0,45	0,50

Table 2. Content of N, P_2O_5 y K_2O for different animal manure in Galiza (NW Spain)

Manure from broiler chickens

Manure from broiler chickens is the product resulting from the fermentation of poultry manure on a bed that is usually composed of a cellulosic-lignic material, such as straw, sawdust, or rice skin, with a high nutrient content and low humidity. This type of manure contains a high percentage of dry matter and is richer in organic matter and nutrients than other types of manure [42]. Usually, poultry manure is used as a fertiliser for crops of high economic importance, such as corn, soy, hay, and horticultural crops [43].

Cattle manure slurry

Most of the cattle manure slurry produced in Galiza contains a very low percentage of dry matter (less than 6%), which can make the management of the slurry difficult [44]. Table 3 presents estimates of the annual production of nitrogen, phosphorus, potassium, and organic matter. The phosphorus content is considered to be high, and, for this reason, it is not necessary to add this nutrient in its chemical form [45].

	N	P_2O_5	K_2O	CaO	Organic matter
Cattle slurry	65.232	38.251	95.272	44.334	920.919
Pig slurry	8.095	5.980	7.725	5.864	222.685
Total	73.327	44.231	102.998	50.198	1.143.603

Table 3. Fertilizer power from cattle slurry produced in Galiza (NW Spain) (Equivalent Tons/year)

Slurry from dairy-industry purifiers

In Galiza, the sludge generated by the dairy industry is becoming more important given that this autonomous community produces nearly 40% of the country's milk (Table 4).

	Cattle	Sheep	Goat	Total
Galiza	2.300.838	-	-	2.300.838
Spain	6.158.179	414.211	488.746	7.061.136

Table 4. Milk production in Galiza and Spain (2007) (Litres x 1000)

Dairy slurry is generated by the purification of wastewater made up of milk remains and cleaning products such as water, sodium hydroxide, and nitric acid. Generally, effluents from the agri-food industry are easily biodegradable and lack toxins (organic contaminants, heavy metals), making these effluents easy to treat with biological and, especially, microbiological methods [46]. Wastewater can be recycled as part of a closed system in which the dairy slurry produced by purification is used by farmers to fertilise fields in areas near the factory. In general, most research on industrial slurries has focused on products from facilities that purify urban wastewater, although studies were performed on dairy-industry slurry during the 1970s [47]. Likewise, in Australia, certain national programs have attempted to promote a different legislative treatment of slurry produced by the treatment of effluents from dairy factories because heavy metals and chemical contaminants are present at much lower concentrations in these effluents than in slurries from urban purification facilities [48]. In Galiza, research on the dairy industry started a decade ago. [49, 50] determined the optimum application dose for meadow soils and the consequences of this treatment for fodder production. For acidic soils and soils devoted to other uses, [51] concluded that the total concentration of heavy metals was sufficiently low to preclude any environmental risk from this source.

2.2. Materials and methods

Study area

In September 2001, a field trial was performed in which mountain terrain was transformed into a field to provide more land for agriculture. The trial was performed in Goiriz-Lugo-Galiza (northwestern Spain; latitude: 43°19’N; longitude: 7°37W’) on humic umbrisol (FAO, 1998). The mean annual temperature in the area is 11.5 ºC, and the mean annual precipitation is 1,084 mm. Most precipitation occurs during the autumn and winter (35% and 29%, respectively), and the amount of rain is the lowest during the spring (22%) and summer (14%). The vegetation on the starting soil was predominantly trees and shrubs, including *Pinus pinaster*, *Castanea sativa*, *Ulex* sp., and *Pteridium aquilinum*. After the soil was fertilised with 3 t ha^{-1} of limestone (CaO 60%), the following mixture was sown: 40 kg ha^{-1} of *Lolium perenne* L. cv. 'Tove', 20 kg ha^{-1} of *Lolium hybridum* Hausskn. cv. 'Texy', and 6 kg ha^{-1} of *Trifolium repens* L. cv. 'Huia'. Different plots were then subjected to different types of fertilisation. The trial consisted of five treatments: Control: low annual doses of mineral fertiliser, equivalent to 1/3 of the dose applied to the Mineral treatment plots, to increase the competitiveness of the sown species over the natural vegetation; Mineral: doses equivalent to 30 kg ha^{-1} of N and 45 kg ha^{-1} of P_2O_5; Cattle Manure Slurry: 50 m^3 ha^{-1}/year; Dairy Slurry: 120 m^3 ha^{-1}/year; and Broiler Litter: a single application of 4,500 kg ha^{-1} of the dehydrated product. Four randomly distributed replicates were performed for each treatment for a total of 20 experimental units of dimensions 3 x 1.3 m. These units were separated by corridors of 1.65 cm. For more information on the soil characteristics, fertiliser application and field management, see [52].

The primary characteristics of the different organic subproducts are presented in Table 5.

	DM	pH	EC	C^a	N^a %	P^b %	K^b %	Na^b %	Ca^b %	Mg^b	C/N	C/P
Cattle slurry	18,2^c	7,1	4,0	40,0	5,1	2,0	9,6	2,4	0,8	0,7	7,8	20,0
Dairy-industry sludge	20,0^c	7,1	3,4	35,6	6,2	2,1	1,1	3,2	2,2	0,4	5,7	17,0
Broiler litter	89,1^d	7,9	11,1	36,8	4,0	1,6	2,8	1,6	1,9	0,7	9,2	23,0

^{a} Determination by CNS2000 auto-analyzer and ^{b}by Atomic Absorption Spectrometric in HNO_3 70% extract solution. DM: Dry matter ^{c} (g L^{-1}) ^{d} (%). EC: Electrical conductivity (dS m^{-1}). C, N, K, Na, Ca, Mg (%). C/N, C/P, carbon/nitrogen and carbon/phosphorus rate.

Table 5. Physico-chemical characterization of different organic wastes.

Sampling and sample processing

The soil fauna was sampled in 2004 (May and November), 2005 (May and November), and 2006 (May) with pitfall traps [53]. In all, 20 traps were used per sampling season. During each sampling season, traps were collected after four days, and voucher specimens were preserved in 70% alcohol. At the laboratory, specimens were identified to upper taxonomic levels (family/order) using taxonomic keys [54, 55].

Data analysis

Initially, communities were described based on their abundance and taxonomic richness (no. of taxa present), and diversity indices were subsequently calculated based on the method of [39]. The indices calculated for the collected taxa included Simpson's diversity index (1-D), the Shannon-Wiener index (H’), the Berger-Parker index (d), the Simpson evenness index ($E_{1/D}$), and the Smith and Wilson evenness index (Evar). The data obtained were analysed with an analysis of variance (ANOVA). Logarithmic transformations were done when data departures from normal distribution and/or variance homogeneity. After the univariate descriptive analysis, a multivariate analysis was performed to attempt to group the different treatments based on the similarities of the macrofaunal community collected for each treatment. The multivariate analysis was performed with PRIMER 5.0 [55], and three factors were determined:

1. *season*, to separate spring (May 2004, May 2005, and May 2006) and autumn (November 2004 and November 2005).
2. *control*, to differentiate non-fertilised control plots (C) from fertilised plots (M, Mineral fertiliser; CS, Cattle Manure Slurry; DS, Dairy Slurry; and B, Broiler litter).
3. *fertiliser*, to differentiate non-fertilised plots (C) from plots fertilised with mineral fertiliser (M) and plots fertilised with biowaste (CS, DS, B).

In each analysis, taxa with an abundance of fewer than five individuals in all plots were not considered. The square roots of the data values were calculated, and a similarity matrix was calculated based on the Bray-Curtis coefficient [56]. A similarity analysis (ANOSIM) was performed to determine the statistical significance of the in-group discrimination. Afterwards, a SIMPER (*Similarity Percentage Breakdown*) analysis was performed to obtain the percentage contributed by each taxon to the in-group discrimination.

3. Results

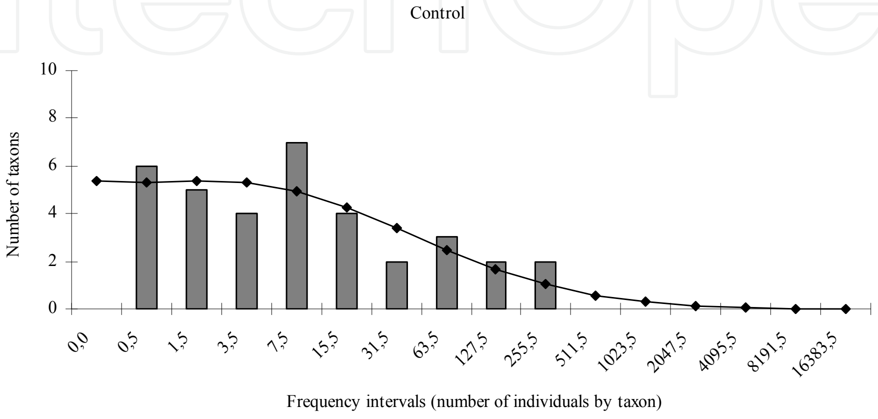
A total of 6,496 specimens were captured. These specimens belonged to 42 taxa. The dominant taxonomic groups were Araneae (23.5%), Coleoptera (21.6%), Diptera (19.8%), and Hymenoptera (6.9%). Fewer than five individuals belonging to Diplopoda, Chilopoda, Isopoda, Trichoptera, and Ephemeroptera were observed for each treatment.

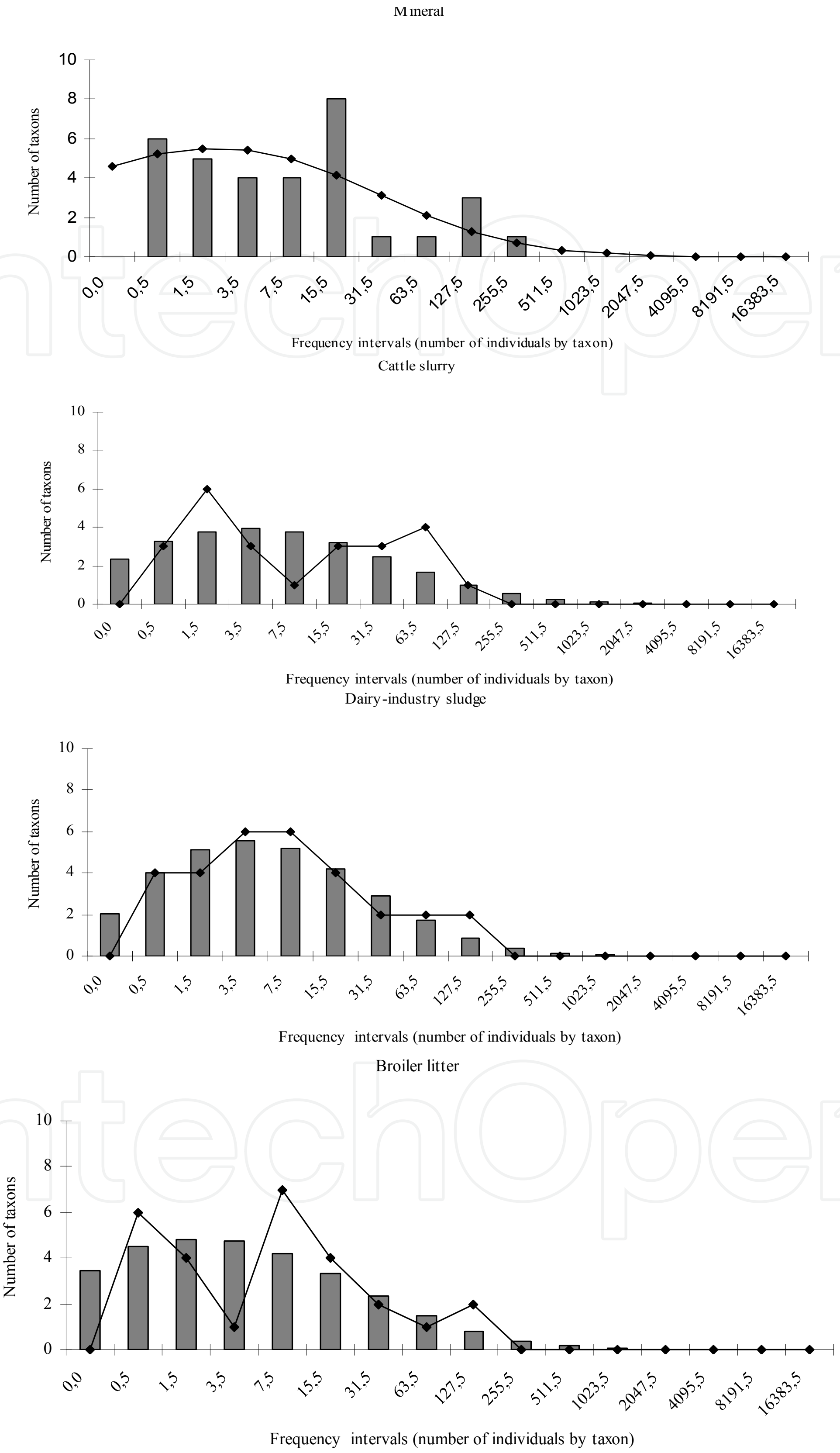
The abundance of individuals (N) and the number of taxa captured (S) varied significantly with sampling season. The Control and Mineral plots yielded a greater abundance of individuals. The Cattle Manure Slurry, Dairy Slurry, and Broiler Litter plots exhibited the lowest abundances.. Note that the abundances of individuals of Araneae, Diptera, and Coleoptera may have been influenced by both the treatment and the sampling season, with greater abundances in the spring and lower abundances in the autumn (Table 6).

	Total N		Total S			
	F	p	F	p		
Treatment	13.353	0.000	10.589	0.000		
Date	6,894	0.000	18.082	0.000		
	Aranea (N)		Coleoptera (N)		Diptera (N)	
	F	p	F	p	F	p
Treatment	8.378	0.000	15.336	0.000	6.503	0.000
Date	29.702	0.000	33.735	0.000	23.203	0.000

Table 6. Statically differences in N (abundance) and S (taxon richness) between treatments and sample season.

In the analyses of the distribution of taxon abundance (Figure 1), a better fit to the normal distribution was observed for the plots to which organic waste had been added, and a poorer fit was observed for the communities from the Mineral and Control plots. These results indicate that the addition of organic waste to the soil did not have a severe negative effect on the communities assessed in this study.





Bars: observed frequency. Dot lines: expected frequency.

Figure 1. Lognormal curves for abundance distribution (individuals/taxon) for each treatment

Indices of ecological diversity

The Simpson (1-D), Berger-Parker (d), and Shannon-Wiener (H’) indices were not affected by the fertiliser treatment. According to these indices, the addition of organic waste to the soil did not cause statistically significant changes in the number of taxa or in the abundances of the taxa in the macrofaunal communities. In contrast, the Smith and Wilson and the Simpson evenness indices (Evar and $E_{1/D}$, respectively) were more sensitive to the different fertilisers applied. However, the fluctuations between the sampling seasons were also important (Table 7).

	1-D	H'	Evar	$E_{1/D}$	d
One-way ANOVA					
May-04					
F	1,278	1,141	4,825	5,504	1,822
p	0,316	0,375	0,006	0,003	0,159
Nov-04					
F	0,414	1,241	0,504	0,585	0,233
p	0,796	0,336	0,733	0,678	0,915
May-05					
F	0,688	2,816	3,536	4,749	0,621
p	0,639	0,048	0,021	0,006	0,686
Nov-05					
F	0,821	1,060	5,667	4,647	0,725
p	0,551	0,414	0,003	0,007	0,614
May-06					
F	1,303	0,856	3,644	2,407	1,261
p	0,307	0,529	0,019	0,077	0,323
Two-Way ANOVA					
Date					
F	6,325	14,023	0,435	1,176	6,552
p	0,000	0,000	0,783	0,327	0,000
Treatment					
F	1,807	3,715	5,170	4,294	2,153
p	0,120	0,004	0,000	0,002	0,067
Interaction					
F	0,682	0,505	2,790	2,572	0,600
p	0,826	0,954	0,001	0,002	0,897

1-D: Simpson index, H′: Shannon-Wiener index, Evar: Smith-Wilson evenness index, $E_{1/D}$: Simpson evenness index, d: Berger-Parker index

Table 7. ANOVA results for ecological diversity indices.

Certain authors have demonstrated the lack of sensitivity of diversity indices relative to other methods. [57] used seven diversity indices to assess the effect of no-till farming on carabid communities and concluded that these diversity indices and models are not useful for the detection of the possible effects on carabids. [58] concluded that for differences in the values of diversity indices to be observed, the taxonomic level of identification must be deeper. However, identification to lower levels would hinder the use of diversity indices as quality indicators because sampling and identification would be more complex and costly, requiring the aid of specialists knowledgeable about the different taxonomic groups; such high-precision identification contrasts with the indicator characteristics proposed by [59]. The classification of macrofaunal communities to higher taxonomic levels is supported by studies by [60, 61] and has been used in other evaluations of the effect of agricultural practices on soil fauna [62-64]. Note that in [57] study, carabid communities were identified to the species level. However, this level of identification did not aid in the detection of a response of carabids to the disturbance. In this way, is quite difficult establish a real differentiation among treatments using only de ecological diversity indices.

Multivariate analysis

The results from the similarity analysis show that, of the four factors analysed, only the sampling season can differentiate the treatments with statistical significance (r_s = 0.638; p = 0.001) (Table 8).

General analysis			
	Season	Control	Fertilizer
r_s	0,638	0,035	-0,022
p	0,001	0,335	0,551
Pairwise test			
Spring		r_s	p
Fertilizer		0,295	0,015
	C,M	0,111	0,500
	C,O	0,535	0,009
	M,O	0,069	0,300
Fall			
Fertilizer		-0,171	0,780

Season: sampling date, Control: control vs fertilized parcels (both mineral and organic waste application), Fertilizer: control vs mineral fertilization vs organic waste application. Pairwise test: C- control, M- mineral fertilization, O- organic waste application.

Table 8. Similarity analysis results from macro-faunal communities between different sampling date and fertilization treatment

The results from the ANOVA analysis for the factor *season* (Figure 2) show that the differentiation between sampling performed during the autumn and sampling performed during the spring is statistically significant (Stress < 0.1). During the autumn, the number of specimens captured was much lower, a result that is related to the life cycle of soil organisms. During the spring, the populations of most species increase as a consequence of the higher temperature and greater availability of water and food [64, 65].

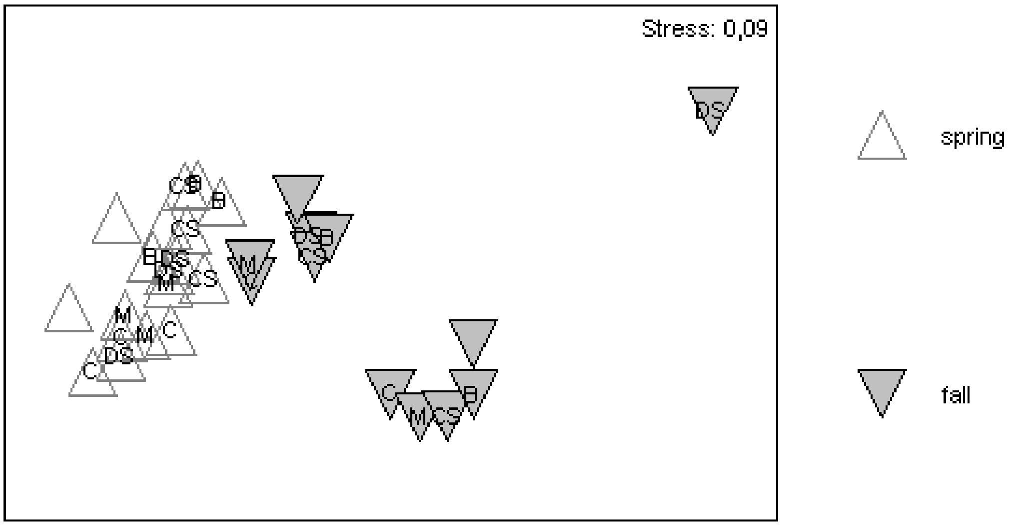


Figure 2. MDS ordination results for all dates, and all experimental parcels. C: Control, M: Mineral, DS: dairy-industry sludge, B: broiler litter, CS: Cattle slurry.

Due to the differentiation according to the sampling seasons described in the previous section, an similarity analysis was performed to separate the data from the spring and the autumn based on the factor *fertiliser*. The results were statistically significant only if the data obtained during the spring were used.

The ordination by MDS tended to separate the Dairy Slurry and Broiler litter plots from the Mineral, Cattle Slurry, and Control plots (Figure 3).

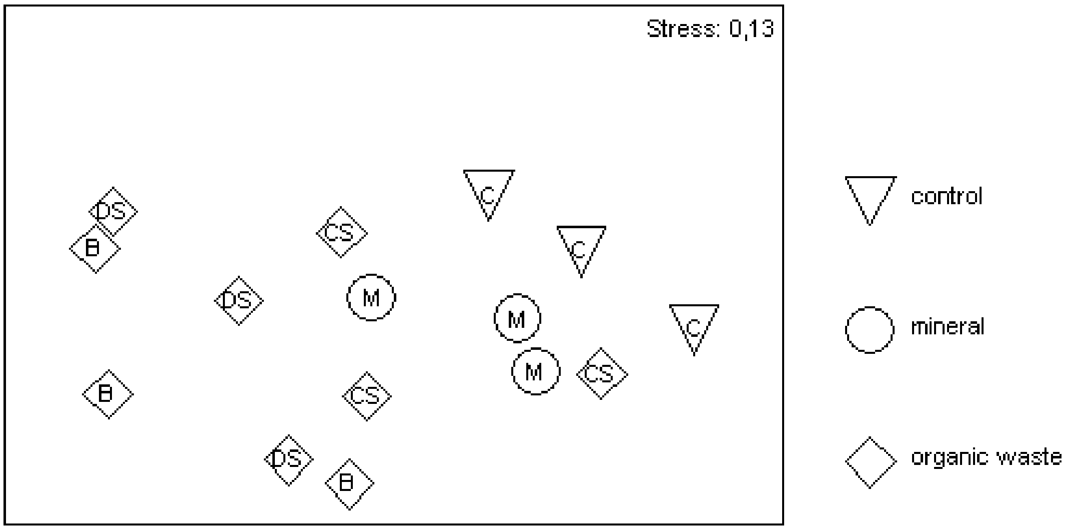


Figure 3. DMS ordination results for spring samples. C: Control, M: Mineral, DS: Dairy-industry sludge, B: Broiler litter, CS: Cattle slurry.

Carabidae and Araneae, with contributions greater than 10%, were the taxa with the greatest ability to separate the communities corresponding to the Control and Mineral plots from those corresponding to the plots treated with organic fertiliser (Table 9). These taxa include polyphagous predators, which have the ability to significantly affect the population dynamics of various phytophagous and saprophagous insects [67, 68]. These results are consistent with those of [69, 70], which demonstrate that the communities of carabids and spiders have a significant bioindicator potential. Similarly, [71] evaluated the effect of altering soil use on populations of coleopterans and spiders. These authors propose that the re-establishment of agricultural processes be monitored using these two groups.

	Average taxon abundance		Percentage of contribution
Control vs. organic waste[1]	Control	Organic waste	
Carabidae	18,33	3,47	11,03
Araneae	33,92	11,00	10,72
Diptera	26,08	9,06	8,60
Formicidae	9,67	3,50	5,43
Mineral vs. organic waste[2]	Mineral	Organic waste	
Araneae	29,25	11,00	13,12
Carabidae	10,67	3,47	10,28
Agrilimacidae	1,75	2,47	6,03
Acrididae	2,08	0,64	5,71
Apionidae	2,50	1,89	5,68
Gryllidae	1,92	0,92	5,54

Average dissimilarity: [1]42, 87%; [2]35, 33%

Table 9. Taxon abundance under different fertilizer application.

Finally, the fertiliser treatments were differentiated based on a two-way crossed similarity analysis based on sampling season and fertiliser treatment (Table 10). This analysis revealed that the presence or absence of fertiliser affected the composition of the macrofauna community. According to this analysis, the effect depends on the type of fertiliser used. For the Mineral and Cattle Slurry treatments, the effects were similar (p = 0.06). The effects of Dairy Slurry and Broiler Litter were equivalent (p = 0.271).

Factor	r_s	p
Season	0,575	0,001
Treatment	0,219	0,001
Pairwise test		
Control vs. Mineral	0,113	0,018
Control vs. Cattle slurry	0,194	0,002
Control vs. Dairy-industry sludge	0,481	0,001
Control vs. Broiler litter	0,315	0,001
Mineral vs. Cattle slurry	0,073	0,060
Mineral vs. Dairy-industry sludge	0,237	0,001
Mineral vs. Broiler litter	0,150	0,019
Cattle slurry vs. Dairy-industry sludge	0,214	0,002
Cattle slurry vs. Broiler litter	0,179	0,006
Dairy-industry sludge vs. Broiler litter	0,030	0,271

Table 10. Two factors cross-way (season x treatment) results for macro-faunal communities similarity analysis between different fertilization treatment

Further research

Based on the results obtained, it is necessary to further evaluate the response of macrofaunal communities to the addition of different types of waste used as fertilisers and/or soil restorers. With this approach, we will be able to analyse the global reaction/regeneration of the edaphic ecosystem beyond concrete and specific responses to the physico-chemical parameters. The extension of this type of research to different types of soil, different crops, and different forms of agricultural management will yield a more thorough view of the biological responses to these different factors, allowing the selection of the most appropriate taxa and indices for the monitoring of the effects of organic wastes. Our results suggest that Araneae and Carabidae should be identified to lower taxonomic levels to obtain better data on species richness and population abundance. This approach will allow a deeper evaluation of waste use.

4. Conclusions

The taxon richness and individual abundance of the soil macrofauna were lower in the plots fertilised with organic waste. However, we cannot conclude that the addition of organic waste has a severe negative effect on the communities studied. Carabidae and Araneae were the most important taxa for the separation of the groups based on the type of fertiliser used, suggesting that the application of organic waste has a positive effect on the total number of predatory arthropods. It is highly probable that this positive effect occurs because these arthropods are polyphagous and, hence, can significantly affect the population dynamics of various phytophagous and saprophagous invertebrates.

Among the organic wastes, dairy slurry and broiler litter had the same effect on the macrofaunal communities. The effect of cattle manure slurry was similar to that of the mineral fertiliser treatment.

The indices of ecological diversity were not effective for detecting differences among the different fertiliser treatments. The multivariate analysis of the macrofaunal communities was more useful, allowing the discrimination of groups and the identification of the taxa responsible for the differences among these groups.

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