



Research article

Litter decomposition by soil fauna: effect of land use in agroecosystems

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ABSTRACT

Soil fauna plays a key role in organic matter decomposition. Litter decomposition depends on the relationships of soil fauna and microorganisms as well as climate and litter quality. The decomposer community is sensitive to land use. Thus, physical-chemical disturbances, like soil tillage, can exercise important control on the soil fauna. In order to study the effect of land use and its impact on litter decomposition by soil fauna, a litter-bag experiment was conducted in the Pampa Serrana region, Azul district, Argentina. Litter-bags were made in three different mesh-sizes, allowing the access of micro, micro + meso and micro + meso + macrofauna. Four different treatments were defined: naturalized grassland and three agricultural agroecosystems under different tillage systems, i.e., conservation tillage, conventional-conservation tillage and conventional tillage. Decomposition rate and remaining litter were measured across three different seasons. We found that naturalized grassland obtained the highest decomposition rates and the least remaining litter compared to conservation and conventional tillage systems. No difference in litter decomposition was identified among agricultural agroecosystems. Micro + meso + macrofauna presented the highest decomposition rate and the lowest remaining litter of soil fauna groups, in all agroecosystems. In contrast, microfauna decomposition rate was the lowest and produced the highest remaining litter. Micro + mesofauna presented values of decomposition rate and remaining litter that differed significantly from the rest of the groups in some seasons. These results highlight the importance of soil fauna in litter decomposition and the negative effects of different land use systems on litter decomposition by soil fauna.

1. Introduction

When humans over-use environmental resources, the natural balance is disturbed, causing an intense land degradation process. Agroecosystems are disturbed by different land use practices. Land use intensity and management determine the expression of disturbances (Massobrio 2003; Massobrio and Giberti 2013). Thus, an agroecosystem is the result of a historical timeline which implies having been subjected to a selective process for years. This process has produced systems with high efficiency, processing and dissipation of the external anthropogenic energy received (Massobrio 2003; Cassani et al., 2020).

In agroecosystems, litter enters in the soil system and it is transformed into nutrients through physical, chemical and biological processes. After the production of biomass the next important process is decomposition (Wilkinson 1998). Litter decomposition mainly depends on the complex relationships between different groups of soil fauna and microorganisms

that inhabit agroecosystems as well as climate and litter quality (Swift et al., 1979; Peguero et al., 2019). Soil fauna plays a key role in organic matter decomposition (Brussaard 1997; Smith and Bradford 2003; Lavelle et al., 2006). The absence of soil fauna decreases litter decomposition rates by 30% in agroecosystems (García-Palacios et al., 2013). Mesofauna contributes to decomposition processes through litter defragmentation, thus generating an increase in the exposed surface, which promotes the action of microorganisms. They also, indirectly, affect litter decomposition by selective grazing on microbial populations (Cole et al., 2006). In addition, macrofauna creates biogenic structures that may act as incubators of microbial activities, the external rumen strategy that selectively promotes microbial activities (Lavelle et al., 2006).

Land use history can exercise important controls on decomposition due to changes in soil nutrient stock, pH, or the decomposer community (Steenwerth et al., 2002; Liiri et al., 2012; Fichtner et al., 2014). In fact, soil fauna is sensitive to land use because of physical-chemical

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disturbances (Pankhurst et al., 1997; Lavelle and Spain 2001; Sabatté et al., 2021). According to Giller et al. (1997), different agricultural practices have an important impact on litter decomposition by micro, meso and macrofauna. Soil tillage (Hendrix et al., 1992; Manetti et al., 2010; Cardinale et al., 2012) and broad-spectrum pesticides (Edwards and Thompson, 1973; Giller et al., 1997) can have important repercussion on ecosystem functioning and soil fauna biodiversity (Cardinale et al., 2012). Minimum soil disturbance and maintenance of crop residues cover on the soil surface benefit fauna and detrital soil food webs compared to management practices such as conventional tillage and bare soil (Brussaard et al., 2007). Moreover, climate is an important environmental factor responsible for the seasonal fluctuations on soil fauna individuals (Swift et al., 1979; Wall et al., 2008; Manetti et al., 2010). Soil tillage and other land management practices also affect soil organisms by affecting their food resources. In agroecosystems, the trophic interactions and flow of energy and matter within soil food webs change in response to different environmental conditions such as litter input and quality, soil structure and microclimatic conditions (Moore et al., 2005; Sabatté et al., 2021). Conventional tillage favor bacteria and their consumers over fungi and their consumers. On the other hand, conservational tillage is less detrimental to the existing soil communities of microorganisms and favors a balance between the bacterial and fungal energy channel in detrital soil food webs (Moore et al., 2004). These balanced configurations of energy channels in food webs have proved to be more stable (Moore et al., 2004).

Furthermore, Gizzi et al. (2009) found differences in mesofauna population between conventional tillage and no-tillage systems. Similar results were found by Cassani et al. (2020) in *Oribatida* and *Collembola* population metrics between naturalized grassland and agricultural sites. Also Manetti et al. (2010) and Gizzi et al. (2009) found differences in soil macrofauna population between conventional tillage and no-tillage systems.

The hypothesis of this study was “land use systems negatively affect the different groups of soil fauna, which play an important role on decomposition processes”. Thus, the objective was to evaluate the effect of land use systems on litter decomposition mediated by soil fauna, in the hilly environments of Azul district, Argentina. According to the effects of agricultural practices on soil fauna, we expected to find a higher decomposition rate in the naturalized grassland than in agricultural sites. Moreover, for agricultural sites, we expected conventional tillage to present the lowest decomposition rate. In order to identify the contribution of micro, meso and macrofauna to the decomposition process in each treatment we used litter-bags of different mesh-sizes. The litter-bags method is very useful to quantify the effect of different soil fauna groups on litter decomposition (Bradford et al., 2002; Kampichler and Bruckner 2009; Bokhorst and Wardle 2013; Castro-Huerta et al., 2015; Peguero et al., 2019; Meyer et al., 2020). As litterbags with larger mesh sizes allow the passage of all micro, meso and macrofauna, we expected litter decomposition rate to increase vs. litterbags with smaller mesh sizes. We also expected to find differences in litter decomposition rate between treatments, i.e., lower decomposition rate in agricultural sites than in naturalized grassland.

Understanding soil fauna biodiversity and its contribution to litter decomposition under different land use systems is important for agroecosystem resilience studies (Brussaard et al., 2007).

2. Materials and methods

2.1. Selection and characterization of study sites

Azul district is located in the centre of Buenos Aires province, in the Pampa Serrana region (36.13°37.27' S and 59.08°60.12' W) (Figure 1). Azul, according to Köppen classification, has humid temperate climate with oceanic influence, relatively cold winters, short and cool summers. It has an annual average of 921 mm and 14 °C of precipitation and temperature, respectively. January is the hottest month with an average

temperature of 21,8 °C and August is the coldest with an average of 7 °C. Precipitations are evenly distributed throughout the year, being heavier from October to April. Water deficits usually occur during December, January and February, where evapotranspiration exceeds precipitation (SMN 2018).

The study area was located in the hilly environment of Azul district. We selected four different agroecosystems with different land use over the past 25 years:

Naturalized grassland (NG): Closure of 25 years (from 1993 to 2018). Closed for research, where animal access and sowing were prevented. It is a naturalized grassland dominated by *Festuca arundinacea* together with *Stipa caudata*. *Bromus unioloides*, *Dactylis glomerata*, *Phalaris*, *Lolium perenne* and other *Stipa* sp. can be found in smaller proportions. Before 1993, it was a livestock area;

Conservation tillage (CT): No-till system for 25 years (from 1993 to 2018);

Conventional-Conservation tillage (C-CT): primary tillage with mouldboard plough, then secondary tillage with disk harrows and tooth harrows for 10 years (1993–2003); and then Conservation Tillage: No-till system for 15 years (2003–2018);

Conventional tillage (C): primary tillage with mouldboard plough, then secondary tillage with disk harrows and tooth harrows for 25 years (from 1993 to 2018).

Conservation tillage, Conventional-Conservation tillage and Conventional tillage Agroecosystems were currently under agricultural production, so we considered them agricultural sites. Crop rotation from 2016 to 2019 was: wheat/soybean-corn-sunflower-corn. These are typical crops for this area, with an average of 4 000 kg·per hectare⁻¹ for wheat, 3 000 kg·per hectare⁻¹ for soybean, 10 000 kg·per hectare⁻¹ for corn and 2 500 kg·per hectare⁻¹ for sunflower, confirmed by the landowner.

All sites under agriculture, given their similar crop rotation, received the same agrochemical applications over the years.

The soil present in this study was Mar Del Plata, fine-loamy, mixed (Typic Argiudoll) (INTA 1970; Soil Survey Staff 2014). It is very suitable for agriculture, according to the Land Capability Classification (Klingebiel and Montgomery 1961) and the Productivity Index (Sobral et al., 2010).

Separated by 100 m, three different sites were selected as replicates in each agroecosystem (Figure 1) (n = 3). In order to avoid the effect of the topography on soil development, humidity and temperature, replicates were selected in a transect corresponding to the same level curve at 240 m of altitude.

In the study area, macrofauna (Gizzi et al., 2009; Manetti et al., 2010) and mesofauna (Gizzi et al., 2009; Cassani et al., 2020) have been characterized for Typical Argiudols and Petrocalcic Paleudols (Soil Survey Staff 2014) under different land use systems. The macrofauna community is represented by *Oligochaeta Megadrilli*, Hymenoptera (*Formicidae*), Coleoptera (*Carabidae*, *Staphylinidae*, *Scarabaeidae*, *Curculionidae*, *Elateridae*, *Chrysomelidae* larvae, *Orthoptera*), *Diptera*, *Chilopoda* (centipedes), *Lepidoptera*, *Diplopoda* (millipedes), *Hemiptera* (*Heteroptera* nymphs and adults), *Arachnida* (spiders) and *isopoda* (*Armadillidium vulgare*, *Porcellio scaber*). Acari (*Oribatida*, *Astigmata*, *Mesostigmata* and *Prostigmata*) and *Collembola* (*Poduromorpha*, *Entomobryomorpha* and *Symphyleona*) represented the mesofauna community.

Some of these taxa are considered relevant to decomposition processes and were also found in soil food webs based on litter and detritus in typical Argiudols (Sabatté et al., 2021): *Oligochaeta*, *Coleoptera* detritivores and fungivores (*Scarabaeidae*), macrofauna decomposers (*Isopoda*, *Diplopoda*, *Diptera-Sciaridae*), mesofauna decomposers (*Acari-Oribatida*, *Collembola*), *Diptera* fungivore (*Cecidomyiidae*), *Diptera* microphage (*Chironomidae*).

2.2. Litter decomposition

Remaining litter (%RL) was quantified using decomposition bags. Each litter-bag (15 × 15 cm) was made with different mesh diameters:

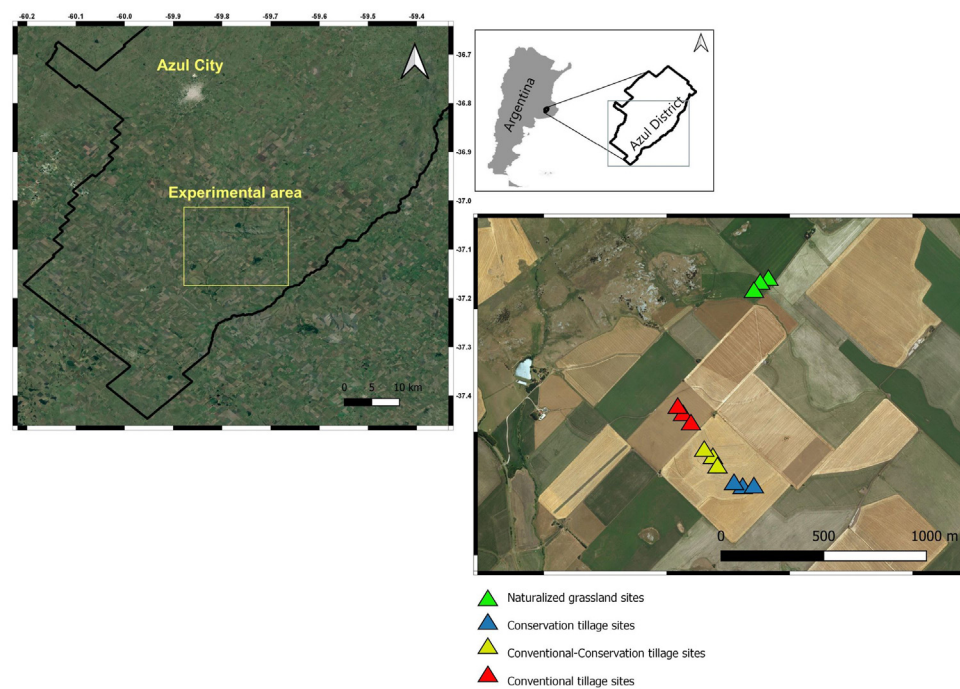


Figure 1. Experimental area located in Azul district, Buenos Aires province, Argentina (Landsat/Copernicus image. ©Google, 2020).

0.1 mm, 2 mm and 10 mm. This allowed evaluating differences according to the fauna (microfauna, micro + mesofauna, and micro + meso + macrofauna, respectively) which could cross each mesh (Bradford et al., 2002; Smith and Bradford 2003; Meyer et al., 2020). Different mesh sizes were a proxy for various types of soil fauna groups. In each bag, 6 g of dried-oven (48 h at 60 °C) wheat (*Triticum aestivum*) litter of leaves and stalks were placed, with 2–3 cm size, equivalent to 4 000 kg·per hectare⁻¹ from the 2016 harvest. The mesh size was small enough to avoid excessive loss of leaf fragments but large enough to allow access to macrofauna. Litter had a Carbon/Nitrogen ratio of 40, determined according to the methodology of Page et al. (1982) and Klute and Page (1986) for Carbon (Calcination oxidation with K₂Cr₂O₇ (1N) and H₂SO₄ (96%) and Nitrogen (Micro-Kjeldahl method).

Remaining litter was evaluated along three different seasons, where three different measurements per season were recorded:

- First season: during the summer-autumn-winter 2017 in all agroecosystems. The experiment began on January 16th and ended on August 20th. Extractions took place at 61, 129 and 216 days after the beginning of the experiment.
- Second season: during the summer-autumn-winter 2018 in Naturalized grassland and Conventional tillage agroecosystems. The experiment began on January 6th and ended on July 13th. Extractions took place at 70, 152 and 188 days after the beginning of the experiment.
- Third season: during the winter-spring 2018 in Naturalized grassland, Conservative tillage and Conventional-Conservation tillage agroecosystems. The experiment began on September 15th and ended on December 27th. Extractions took place at 33, 66 and 103 days after the beginning of the experiment.

In each season and experimental site (3 sites per agroecosystem), nine bags were randomly placed on the ground surface: three (3) 0.1 mm bags, three (3) 2 mm bags and three (3) 10 mm bags diameter mesh size. In total, 108 bags in the first season, 54 bags in the second season and 81 bags in the third season were placed. To prevent movement, the litterbags were secured to the ground using steel stakes. According to the extraction time explained above, one bag per mesh size was removed randomly. The materials

recovered from the litterbags were air-dried and carefully brushed to remove attached soil particles, and finally they were oven-dried for 48 h at 60 °C. Then the dry weight of the clean sample was documented after correcting for any increase in weight caused by soil contamination. In addition, Cassani (2020) explored climate information from the different seasons: -2016 was a dry year. Monthly precipitation did not exceed the monthly average. Thus, total annual precipitation was 757 mm, below the annual average of 921 mm; -In 2017, the precipitation scenario improved with monthly rainfall above the average. However, in October, November and December precipitation was below the monthly average. Annual precipitation was 1077 mm, below the annual average of 921 mm; -2018 began with a precipitation deficit. After April, precipitations became abundant. Annual precipitation was 1009 mm, below the annual average of 921 mm. Temperatures for the three years were always within the normal range.

2.3. Data analyses

Litter weight inside each bag, before being placed in the field at the beginning of each season, was taken as the initial litter (IL) and was used to calculate Remaining Litter (%RL). Litter weight inside each bag, after each extraction was taken as the Remaining Litter (RL).

Litter decomposition was calculated using the Remaining Litter %RL formula:

$$\%RL = \left(\frac{RL}{IL} \right) * 100 \quad (1)$$

RL: Remaining litter (g)

IL: Initial Litter (g)

Using RL and IL for each site, we calculated the mean decomposition rate (K). We applied the Olson (1963) model:

$$RL = IL \cdot e^{-K \cdot t} \quad (2)$$

RL: remaining litter (g)

IL: initial litter (g)

t: time (year)

K: decomposition rate.

This exponential model was linearized using the natural logarithm of the remaining litter (%RL) to obtain the linearized decomposition rate (k):

$$k = -\ln(RL/IL)/t \quad (3)$$

The linearized decomposition rate (k) was compared according to the agroecosystem and mesh-size for each season separately (Table 1), using an ANOVA test. When significant differences were found, the LSD Fisher test was applied for mean comparison with a 99% confidence interval ($p \leq 0.01$).

Remaining litter was measured at three different times in the same site, so we performed a repeated-measurement over time analysis, where independence assumption of observations was not fulfilled. Consequently, to analyze differences in remaining litter between agroecosystems and mesh-size in each different season, mixed models were carried out, using the Infostat® (Di Rienzo et al., 2018) interface with R v. 3.4.4 (Core Team 2017). We used the “nlme” package (Pinheiro et al., 2021) including agroecosystem, time and the interaction between agroecosystem and time (Table 2) and mesh-size, time and interaction between mesh-size and time (Table 3). Every comparison was made per season. In each model, agroecosystem, mesh size and time were considered as fixed effects while the sampling site as the random effect. We selected REML estimator with corAR1 correlations.

3. Results

3.1. Litter decomposition

3.1.1. Litter decomposition rates

Significant differences for linearized litter decomposition rate were found during the three seasons, explained by the main effects of the Agroecosystem and mesh-size (Table 1). Interaction between both factors (Agroecosystem and mesh-size) was not significant.

In the first season, Naturalized grassland presented the highest linearized litter decomposition rate. Conservation tillage and Conventional tillage agroecosystems showed similar values between them, but different from Naturalized grassland and Conventional-Conservation tillage. Conventional-Conservation tillage agroecosystem presented the lowest linearized litter decomposition rate (Figure 2A). When the linearized decomposition rate for each mesh-size was analyzed, it was observed that the microfauna and the micro + mesofauna did not differ between them; however, there was a tendency for the micro + mesofauna to have a higher rate of decomposition than the microfauna. On the other hand, both had lower linearized decomposition rates and differed significantly from micro + meso + macrofauna (Figure 2B).

During the second season, it was observed that the linearized decomposition rate by microfauna reached the lowest value and micro + meso + macrofauna the highest one. Micro + mesofauna had intermediate linearized decomposition rate (Figure 2B). Naturalized grassland had higher linearized decomposition rate than Conventional tillage (Figure 2A).

Finally, during the third season, there were no significant differences between Conservation tillage and.

Conventional-Conservation tillage agroecosystems, while they differed from Naturalized grassland, which showed the highest linearized decomposition rate (Figure 2A). Regarding mesh-size, no significant differences were found between microfauna and micro + mesofauna. Differences were found between micro + meso + macrofauna and the other two mesh-sizes, which obtained the highest linearized litter decomposition rate (Figure 2B).

3.1.2. Remaining litter

Significant differences along the three seasons for remaining litter were observed, explained by the main effects of Agroecosystem and time (Table 2). During the three seasons analysed, Naturalized grassland showed lower remaining litter values, and always differed significantly from the agricultural agroecosystems. Meanwhile, agricultural agroecosystems had no significant differences between them (Figure 3, Table 4).

Significant differences along the three seasons for remaining litter were observed, explained by the main effects of mesh-size and time (Table 3). Interaction between mesh-size and time was significant for Naturalized grassland in the first and second season. In the first season, no significant differences were found for remaining litter between microfauna and micro + mesofauna for Naturalized grassland and Conservation tillage, while they significantly differed with micro + meso + macrofauna remaining litter values. The latest treatment showed fewer values than the other two sizes (Figure 4, Table 5). Regarding Conventional-Conservation tillage, the three sizes differed significantly from each other, finding lower remaining litter values as the mesh-size increased (Figure 4, Table 5). Lastly, in Conventional tillage, microfauna differed significantly from the rest, while micro + mesofauna and micro + meso + macrofauna presented similar remaining litter values (Figure 4, Table 5). In the second season, microfauna, micro + mesofauna and micro + meso + macrofauna differed from each other for both agroecosystems (Figure 4, Table 5). Remaining litter decreased as mesh-size increased. Finally, in the third season studied, a similar pattern was found. Microfauna and micro + mesofauna exhibited similar remaining litter values and differed significantly with the micro + meso + macrofauna size, for Naturalized grassland, Conservation tillage and Conventional-Conservation tillage agroecosystem (Figure 4, Table 5). Here it can also be seen how as the mesh-size grew, remaining litter values dropped.

4. Discussion

In the present study, we evaluate the effect of land use systems on litter decomposition by soil fauna. Litter decomposition at Naturalized grassland agroecosystem was always higher than at agricultural agroecosystems. Micro + meso + macrofauna of Naturalized grassland had the highest decomposition rate and the lowest remaining litter of all agroecosystems. Smith and Bradford (2003) found similar results, working on grasslands in Silwood Park, United Kingdom in litter-bag experiment using different mesh sizes. Castro-Huerta et al. (2015) in experiments in the district of Chivilcoy, Argentina, in natural grassland sites in “Pampa Ondulada” region, obtained results similar to those in this work when analyzing the soil fauna community and its effect on litter

Table 1. Summary of ANOVA analysis examining linearized k-rate ($g \cdot year^{-1}$) in the three different seasons.

	k-rate first season		k-rate second season		k-rate third season	
	F	P-value	F	P-value	F	P-value
Model	15.620	<0.001	58.510	<0.001	28.050	<0.001
Agroecosystem	18.520	<0.001**	110.890	<0.001**	5.730	0.007**
Mesh-size	51.200	<0.001**	85.130	<0.001**	93.770	<0.001**
Agroecosystem* Mesh-size	2.310	0.067	5.700	0.018	1.730	0.167

**P < 0.01.

Table 2. Summary of mixed model analysis examining remaining litter (%) in the three different seasons. Remaining litter (%) was modelled for each of the agroecosystems for all mesh-sizes together.

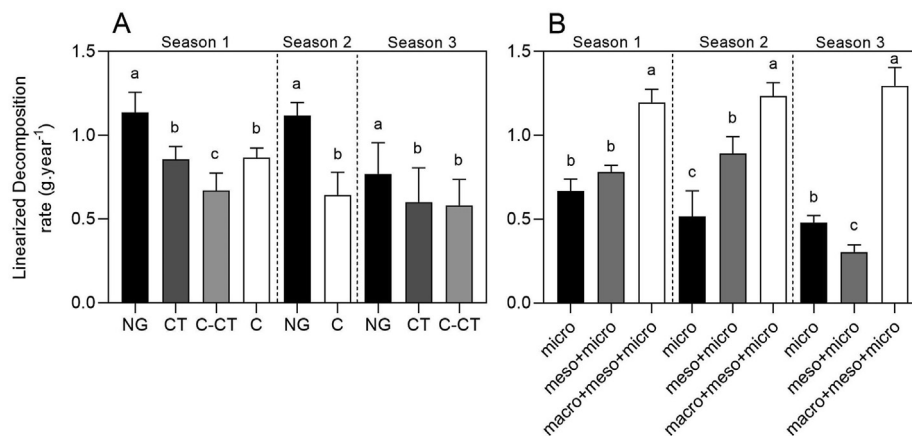
	%RL first season			numDF	%RL second season		numDF	%RL third season	
	numDF	F	P-value		F	P-value		F	P-value
(Intercept)	1	2295.32	<0.001	1	58.51	<0.001	1	28.05	<0.001
Agroecosystem	3	4.50	0.010**	3	110.89	<0.001**	3	5.73	0.007**
Time	2	25.14	<0.001**	2	85.13	<0.001**	2	93.77	<0.001**
Agroecosystem*Time	6	1.44	0.210	6	5.70	0.018	6	1.73	0.167

**p < 0.01.

Table 3. Summary of mixed model analysis examining Remaining litter (%) in the three different seasons. Remaining litter (%) was modelled for each mesh-size within each agroecosystem.

Agroecosystems		%RL first season			%RL second season			%RL third season		
		numDF	F	P-value	numDF	F	P-value	numDF	F	P-value
1	(Intercept)	1	21296.73	<0.001	1	753.05	<0.001	1	2961.09	<0.001
	Mesh-size	2	54.98	<0.001	2	13.82	<0.001	2	27.62	<0.001**
	Time	2	34.52	<0.001	2	13.88	<0.001	2	0.67	0.520
	Mesh-size*Time	4	14.67	<0.001**	4	5.66	0.004**	4	2.04	0.130
2	(Intercept)	1	1976.43	<0.001	-	-	-	1	401.72	<0.001
	Mesh-size	2	5.84	0.010**	-	-	-	2	7.88	0.010**
	Time	2	9.05	0.002**	-	-	-	2	0.80	0.480
	Mesh-size*Time	4	0.28	0.887	-	-	-	4	2.50	0.120
3	(Intercept)	1	4849.78	<0.001	-	-	-	1	24873.55	<0.001
	Mesh-size	2	19.45	<0.001**	-	-	-	2	71.46	<0.001
	Time	2	11.16	0.001**	-	-	-	2	14.46	0.002
	Mesh-size*Time	4	4.25	0.014	-	-	-	4	9.11	0.003**
4	(Intercept)	1	4428.86	<0.001	1	891.40	<0.001	-	-	-
	Mesh-size	2	9.64	0.001**	2	16.91	<0.001**	-	-	-
	Time	2	46.58	<0.001**	2	4.64	0.022	-	-	-
	Mesh-size*Time	4	0.71	0.597	4	1.16	0.359	-	-	-

**p < 0.01.

**Figure 2.** Linearized decomposition rates ($\text{g} \cdot \text{year}^{-1}$) per agroecosystem (A) and mesh-size (B) for each season. Different letters indicate significant differences ($p \leq 0.01$), only within each season.

decomposition in litter-bag experiments. According to Domínguez (2012), in grassland, the contribution of organic residues is higher than in agricultural systems. Thus, litter placed in decomposition bags does not constitute locally hot-spots in which biological activity could be concentrated and therefore increase the decomposition process.

As we moved towards agricultural agroecosystems, decomposition processes decreased. Micro + mesofauna showed different response to litter decomposition in different seasons. At first season micro +

mesofauna remaining litter values differed from the other sizes in Conventional-Conservation tillage. While in Conventional tillage, micro + mesofauna and micro + meso + macrofauna presented similar remaining litter values. At second season in Conventional tillage, micro + mesofauna remaining litter values differed from the other sizes. These results are in accordance with Castro-Huerta et al. (2015) reported. Indeed, according to Kampichler and Bruckner (2009) and García-Palacios et al. (2013), in less disturbed agroecosystems, the contribution of

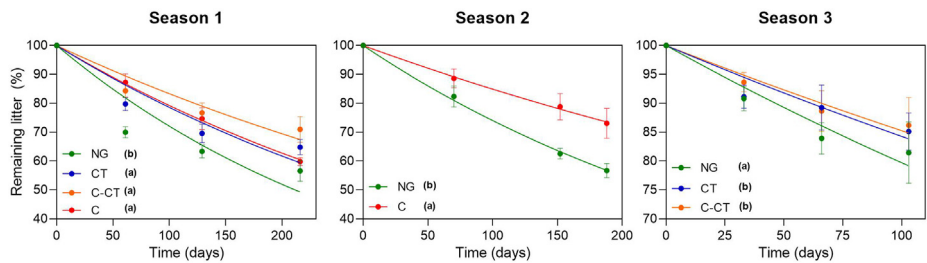


Figure 3. Remaining litter (%) as a function of time, in days, for each agroecosystem and season. R^2 for fitted predicted lines and decomposition rates (K) according to Eq. (2) are presented in Table 4 for each case. Different letters indicate significant differences ($p \leq 0.01$).

Table 4. Decomposition rate (“K” in $\text{g}\cdot\text{year}^{-1}$) of wheat litter per season and agroecosystem. Negative exponential curve and R^2 values are shown for each fauna group. Decomposition rate (K) corresponds to the loss of mass per year. Data shown as in Figure 3.

		Decomposition rate ($\text{g}\cdot\text{year}^{-1}$)	R^2
First season	Naturalized grassland NG	0.0033	0.706
	Conservation tillage CT	0.0024	0.709
	Conventional-Conservation tillage C-CT	0.0018	0.563
	Conventional tillage C	0.0023	0.821
Second season	Naturalized grassland NG	0.0030	0.863
	Conventional tillage C	0.0016	0.473
Third season	Naturalized grassland NG	0.0023	0.366
	Conservation tillage CT	0.0017	0.460
	Conventional-Conservation tillage C-CT	0.0016	0.405

micro + mesofauna to litter decomposition is lower, increasing in greater land use intensity sites.

The addition of micro + meso + macrofauna, regardless of land use, increased decomposition, although it was lower in agricultural agroecosystems. This is in accordance with Bradford et al. (2002) and Adejuyigbe et al. (2006), who affirm that the presence of mesofauna and

macrofauna accelerates the rate of litter decomposition. Moreover, Meyer et al. (2020), in litter-bag decomposition experiments in Swiss forests with different urbanization degrees, found that decomposition rate was always higher in micro + meso + macrofauna than in micro and micro + mesofauna. Those results are similar to our findings. Additionally, microfauna decomposition rate and remaining litter were always lower than micro + mesofauna and micro + meso + macrofauna, and even lower in agricultural agroecosystems. Bradford et al. (2002), Smith and Bradford (2003) and Castro-Huerta et al. (2015) documented similar results.

Cassani et al. (2020) used mesofauna indexes that relate mite's sub-order levels and are useful to indicate agroecosystem stability. They showed that in agricultural sites, mesofauna stability index was unstable, and the contrary occurred in Naturalized grassland sites, where stability reached the highest value. The present study shows that decomposition processes were higher in Naturalized grassland agroecosystems. These results may be explained by the good balance of the different groups of soil fauna that affect litter decomposition (Swift et al., 1979; Brussaard 1997; Smith and Bradford 2003; Lavelle et al., 2006; Cole et al., 2006) and because they are stable agroecosystems (Cassani et al., 2020). However, certain seasonal variations in biological activity can be caused by the climate. Lack of humidity plays a significant role in negatively affecting soil fauna activity (Manetti et al., 2010; Sabatté et al., 2021). In the first and second seasons, interactions between mesh-size and Time were observed for Naturalized grassland. This might have been caused by the deficit of humidity at some point, especially at the beginning of the

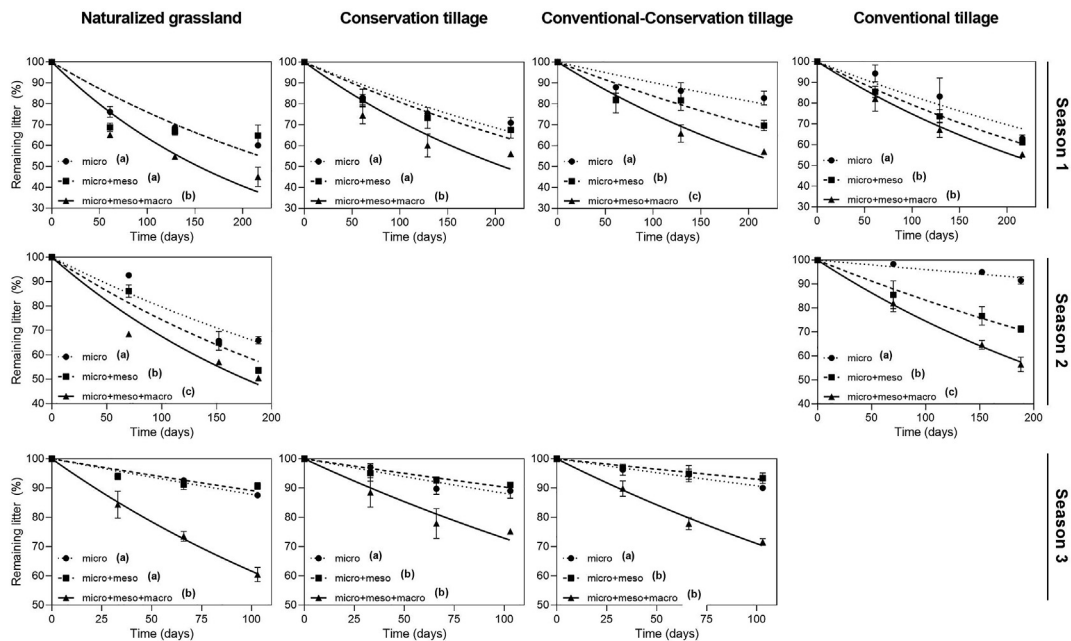


Figure 4. Remaining litter (%) as a function of time, in days, for each mesh-size within agroecosystems and seasons. R^2 for fitted predicted lines and decomposition rates (K) according to Eq. (2) are presented in Table 5 for each case. Different letters indicate significant differences ($p \leq 0.01$).

Table 5. Decomposition rate (“K” in g.year⁻¹) of wheat litter per season, agroecosystem and mesh size. Data shown as in Figure 4.

			Decomposition rate (g.year ⁻¹)	R ²
First season	Naturalized grassland NG	micro	0.0027	0.875
		meso + micro	0.0027	0.537
		macro + meso + micro	0.0045	0.876
	Conservation tillage CT	micro	0.0019	0.788
		meso + micro	0.0021	0.780
		macro + meso + micro	0.0033	0.826
	Conventional-Conservation tillage C-CT	micro	0.0010	0.552
		meso + micro	0.0018	0.662
		macro + meso + micro	0.0028	0.941
	Conventional tillage C	micro	0.0018	0.742
		meso + micro	0.0023	0.954
		macro + meso + micro	0.0029	0.911
Second season	Naturalized grassland NG	micro	0.0023	0.885
		meso + micro	0.0030	0.957
		macro + meso + micro	0.0039	0.950
	Conventional tillage C	micro	0.0004	0.776
		meso + micro	0.0018	0.811
		macro + meso + micro	0.0029	0.955
Third season	Naturalized grassland NG	micro	0.0013	0.929
		meso + micro	0.0011	0.666
		macro + meso + micro	0.0048	0.933
	Conservation tillage CT	micro	0.0013	0.829
		meso + micro	0.0010	0.812
		macro + meso + micro	0.0032	0.861
	Conventional-Conservation tillage C-CT	micro	0.0010	0.878
		meso + micro	0.0007	0.710
		macro + meso + micro	0.0034	0.970

experiment in the summer season. On the contrary, in agricultural agroecosystems, soil fauna may have been less sensitive to the lack of moisture.

Finally, stable agroecosystems, like Naturalized grassland, maximize decomposition and could decrease the use of external inputs to maintain production (Cassani et al., 2020). Therefore, new tillage systems should consider the above ideas in order to design more sustainable agricultural practices.

5. Conclusions

Differences in land use conditioned different responses to litter decomposition by soil fauna. Decomposition rates and remaining litter in Naturalized grassland were always different from other agricultural sites, showing higher values of decomposition than the rest. Micro + meso + macrofauna performed highly positively on decomposition (the highest decreases in remaining litter) in all agroecosystems, despite less total remaining litter in agricultural ones. In contrast, microfauna decomposition rate and remaining litter were always lower than the rest of soil fauna group, even lower in agricultural agroecosystems. Micro + meso-fauna response to litter decomposition differed significantly from the rest of the sizes in some seasons. These results highlight the importance of soil fauna in litter decomposition and the negative effects of different land use systems on litter decomposition by soil fauna.

Declarations

Author contribution statement

M.T. Cassani: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

M.L. Sabatté: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

M.A. Riveira Rubín: Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

A.J. Sfeir: Performed the experiments; Contributed reagents, materials, analysis tools or data.

M.J. Massobrio: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

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Data availability statement

Data included in article/supplementary material/referenced in article.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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