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# Invertebrate soil macrofauna under different ground cover plants in the no-till system in the Cerrado

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ABSTRACT

This work was aimed at evaluating the invertebrate macrofauna community in the soil, by means of its abundance and richness of groups under different plant covers in the no-till system. Evaluations were performed at the experimental field of Embrapa Agropecuária Oeste, in the municipal district of Dourados-MS, on a Typic Hapludox under conventional, no-till, and natural systems. Samplings were performed in December 2000, June 2001, January 2002, and June 2002. Five soil monoliths measuring 0.25 × 0.25 m width and 0.30 m depth were sampled along a transect. Turnip residues before a corn crop (turnip/corn) and soybean residues before wheat and turnip crops (soybean/wheat and soybean/turnip) provided positive effects on the density and diversity of the edaphic macrofauna community.


## 1. Introduction

Since its introduction in Brazil, in the beginning of the 70's, the no-till system (NTS) has been valued on the part of growers with regard to the importance of maintaining crop residues (trash) for soil protection. An understanding of the real value of trash in the no-till system was one of the factors that determined the success of the new system under tropical and subtropical conditions. At present, Brazil has about 20 million hectares under no-till [8], and 25% of this area is found in the Cerrado region, where in recent years the system has been adopted by more and more growers, especially in Goiás, Mato Grosso, and Mato Grosso do Sul.

Crop residues are precursors of soil organic matter; biological processes are triggered after their incorporation, with effects on the physical and chemical properties of the soil, which contribute to nutrient cycling efficiency and to maintain and/or increase organic matter contents in the soil. The decomposition of organic residues, a key process for nutrient cycling, is essentially a biological process, with the participation of the soil's microflora and fauna. Among the animals that make up the soil's fauna, the edaphic macrofauna comprises the largest invertebrates that dwell in the soil (body diameter >2 mm), including groups such as ants, coleopterans, spiders, worms, centipedes, termites, diplopods, etc. [19,28].

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The edaphic macrofauna plays an essential role in the fragmentation and incorporation of organic matter into the soil, thus creating favorable conditions for the decomposing action of microorganisms [3]. The activities of these organisms lead to the creation of biogenic structures (galleries, nests, chambers, and fecal pellets), which influence the aggregation, hydraulic properties, and fate of soil organic matter [19,25]. In turn, these structures influence the composition, abundance, and diversity of other soil organisms [10]. In addition, these organisms contribute toward the vertical mobility of assimilable nutrients, thus being beneficial to the root systems of plants [6,15], and can also be the vectors of symbiotic microorganisms of plants, such as nitrogen-fixing organisms and mycorrhizal fungi; they can also digest pathogen microorganisms in a selective way [5]. Therefore, the abundance and diversity of the soil's invertebrate macrofauna community are important factors for primary production sustainability in natural ecosystems and in agroecosystems derived from them [11].

The soil's invertebrate macrofauna communities respond to the various anthropic interventions made in the environment. These responses are especially related to plant cover modifications, which directly determine the quantity and quality of the organic resource [11]. Several papers have highlighted the hypothesis that the density and diversity of the edaphic macrofauna community, as well as the presence of a given group of organisms in a system, can be used as soil quality bioindicators [2,7,9,21,22]. Therefore, evaluating the conservation management of the soil's invertebrate macrofauna community is an important step in seeking the sustainability of tropical agroecosystems. Thus, the present work's objective was to evaluate the soil's invertebrate macrofauna community under different ground cover plants in the no-till system, using a conventional and a natural system as references.

## 2. Materials and methods

The research was conducted in the period from 2000 to 2002 in the experimental field of Embrapa Agropecuária Oeste, municipal district of Dourados-MS (22° 14′ 00″ south latitude and 54° 49′ 00″ longitude west of Greenwich), under a soil classified as a Typic Hapludox, with mean clay contents of 70%. The climate in the region is Aw, according to Köppen classification, with a hot and rainy season in the summer and a moderately dry season in the winter. The agroclimatic data for monthly precipitation (mm) and temperature (°C) during the study period are presented in Fig. 1.

The fields sampled in this experiment were established in 1995, with intensive production systems and alternative systems for the region, characterized as follows: *conventional system (CS)* – consists in the cultivation of soybean in the summer and oat in the fall/winter, with the soil tilled with disc harrows and the use of pre-emergence residual herbicides, occupying a 2.0-ha plot; *no-till system (NTS)* – no-till agriculture, with corn and soybean as summer crops, intercalated with turnip/oat/wheat/during the fall/winter, so as to contain the sequences: turnip/corn/oat (t/c/o); oat/soybean/wheat (o/s/w), and wheat/soybean/turnip (w/s/t), occupying a 2.8-ha plot each. The wheat and oat crops are used for grain production, and the forage turnip is used to produce straw. In this system, post-emergence herbicides and all technologies available for the region are employed, such as integrated pest management, in order to obtain high grain yields and to reduce system losses; and, *natural system (forest)* – a forest fragment consisting of native species, next to the experiment area, used as a reference of the original soil condition.

The evaluations were performed in four periods: December/2000, June/2001, January/2002, and June/2002 (corresponding to two summer and two winter crops). The samplings were performed, in each system, about 15 days after the summer and winter crops were planted. Five soil monoliths measuring 0.25 × 0.25 m width and 0.30 m depth were sampled along a transect [1]. The soil invertebrate macrofauna specimens, i.e., organisms larger than 10 mm in length and/or with a body diameter greater than 2 mm, were extracted and stored in a 70% alcohol solution. The identification, counting and weighing of the organisms was performed in the laboratory with a stereoscopic microscope, at the level of great

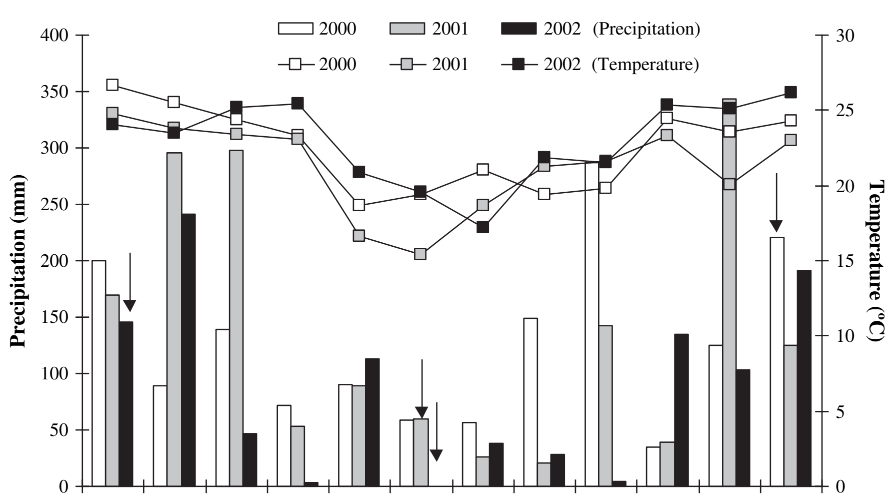


**Fig. 1 – Precipitation and mean monthly temperature at the Agroclimatic Station of Embrapa Agropecuária Oeste for the years 2000, 2001, and 2002. Arrows indicate the months when edaphic macrofauna samplings were taken.**

taxonomic groups; the families Formicidae and Enchytraeidae were identified separately.

Soil samples consisting of five replicates at the 0–30 cm depth were also collected from the studied systems; the samples were sent to the Soil Physics and Chemistry Laboratory of Embrapa Agropecuária Oeste for chemical characterization, according to Embrapa/SCNLS [13] (Table 1).

Because of their heterogeneity, the macrofauna data obtained ($x$) were transformed to log ($x+1$) and then submitted to analysis of variance; means were compared by Tukey test at the 5% level ($p < 0.05$). A coefficient of correlation test was performed for the richness data as a function of organic matter contents. The richness data and the data on the main groups of the edaphic macrofauna were submitted to principal components multivariate analysis in order to qualitatively evaluate the degree of soil change between the different production systems and in relation to the natural system, using the SPAD software [20].

**Table 2 – Total density (ind $m^{-2}$) of the soil invertebrate macrofauna community under a conventional (CS), a no-till (NTS), and a natural (NS) cropping system**

| Systems | Seasons | | | | |
|---|---|---|---|---|---|
| | Dec/00 | Jun/01 | Jan/02 | Jun/02 | Means |
| CS | 899 | 890 | 301 | 557 | 662 c |
| NTS (t/c/o)[1] | 2336 | 1091 | 1043 | 928 | 1350 b |
| NTS (o/s/w)[2] | 435 | 2246 | 227 | 1635 | 1136 bc |
| NTS (w/s/t)[3] | 554 | 1184 | 282 | 1763 | 946 bc |
| NS | 2278 | 1494 | 5430 | 4192 | 3349 a |
| Means | 1300 a | 1381 a | 1457 a | 1815 a | – |

Means recorded with different letters, within the same row and column, are contrasting by Tukey test at 5%.
1 NTS (t/c/o): corn grown in succession to forage turnip, and oat in succession to corn.
2 NTS (o/s/w): soybean grown in succession to oat, and wheat in succession to soybean.
3 NTS (w/s/t): soybean grown in succession to wheat, and turnip in succession to soybean.

## 3. Results and discussion

According to the data presented in Tables 2 and 3, significant differences ($p > 0.05$) were observed for total density and richness of groups in the soil invertebrate macrofauna community among the systems under study. The forest fragment system (NS) showed the highest total density and richness of groups when compared with the other systems. Among the agroecosystems, a higher total density was found in the no-till system with a turnip/corn/oat succession when compared with the conventional system. The turnip/corn succession should be highlighted in this system, with about 2336 (Dec/2000) and 1043 ind./$m^2$ (Jan/2002) (Table 2). In the no-till systems containing oat/soybean/wheat and wheat/soybean/turnip successions, even though no significant differences were found in relation to the conventional system, the soybean/wheat (2246 and 1635 ind./$m^2$) and soybean/turnip (1184 and 1763 ind./$m^2$) successions are worth noting. In the no-till systems cultivated with residues from the previous crop, especially when a greater incorporation of nitrogen occurred, via either the soybean or the turnip, greater total density values were verified [26] (Table 2); when the incorporation occurred via the grasses, which have a higher C/N ratio [29], the total density values were smaller.

Among the NTS management systems, the richness of groups values were similar, but significantly higher than in the conventional system ($p < 0.05$). A positive and significant correlation ($r = 0.65$; $p < 0.05$) was detected between richness of groups values and soil organic matter contents, indicating that the soil chemical characteristics and the type of vegetation contribute favorably toward maintaining the soil's invertebrate macrofauna community values for density and richness of groups.

The soil's macrofauna invertebrate groups Coleoptera, Chilopoda, Arachnida, Enchytraeidae, Coleoptera Larvae, and Formicidae were found at higher densities in the no-till system with the turnip/corn/oat succession (Table 3), even though no significant differences were found between cultivation systems ($p > 0.05$). For Isoptera, however, the highest density was observed in the no-till system with the oat/soybean/wheat succession. The community of social insects (Formicidae and Isoptera) was responsible for more than 40% of the total density in the cultivated systems, with ants in the summer and ants and termites in the winter. The density values for Oligochaeta were significantly similar between management systems in the NTS (t/c/o, o/s/w, and w/s/t), but were significantly superior in relation to the conventional system. These organisms have been described as the soil's ecological engineers, because the biogenic structures produced by them are important in the system, representing sites where some essential processes take place, such as microbial activity stimulation, soil structure formation, and organic matter dynamics [16–18]. Some adult or larval organisms were of sporadic occurrence, and were recorded in some properties as single individuals, classified either as "other" or "other larvae".

**Table 1 – Soil chemical characterization at the 0–30 cm depth under a conventional (CS), a no-till (NTS), and a natural (NS) cropping system**

| Systems | pH | P | K | Ca | Mg | Al | OM |
|---|---|---|---|---|---|---|---|
| | $H_2O$ | mg $dm^{-3}$ | | cmolc $dm^{-3}$ | | | g $kg^{-1}$ |
| CS | 5.1 c | 11.2 b | 0.4 ab | 3.0 c | 1.1 c | 1.2 a | 26.4 b |
| NTS (t/c/o)[1] | 5.3 b | 14.8 a | 0.3 b | 4.1 b | 1.8 b | 0.5 c | 26.3 b |
| NTS (o/s/w)[2] | 5.2 bc | 17.4 a | 0.4 ab | 3.5 bc | 1.4 bc | 0.9 ab | 26.0 b |
| NTS (w/s/t)[3] | 5.3 b | 17.5 a | 0.3 b | 3.8 bc | 1.6 b | 0.7 bc | 26.5 b |
| NS | 6.0 a | 1.7 c | 0.5 a | 9.7 a | 2.7 a | 0.1 d | 47.8 a |

Mean values of four evaluation seasons. Means recorded with different letters, within the same column, are contrasting by Tukey test at 5%.
1 NTS (t/c/o): corn grown in succession to forage turnip, and oat in succession to corn.
2 NTS (o/s/w): soybean grown in succession to oat, and wheat in succession to soybean.
3 NTS (w/s/t): soybean grown in succession to wheat, and turnip in succession to soybean.

**Table 3 – Density of individuals (ind $m^{-2}$) and richness (no. of groups) of the soil's invertebrate macrofauna under a conventional (CS), a no-till (NTS), and a natural (NS) cropping system**

| Macrofauna | Systems | | | | |
|---|---|---|---|---|---|
| | CS | NTS (t/c/o)[1] | NTS (o/s/w)[2] | NTS (w/s/t)[3] | NS |
| Arachnida | 2 (±1.3) b | 14 (±2.9) ab | 10 (±8.1) ab | 9 (±2.7) ab | 19 (±5.6) a |
| Coleoptera | 21 (±4.9) a | 83 (±19.5) a | 32 (±8.1) a | 22 (±8.1) a | 173 (±121.0) a |
| Chilopoda | 12 (±5.0) b | 18 (±9.8) b | 10 (±6.2) b | 11 (±3.3) b | 47 (±13.0) a |
| Oligochaeta | 22 (±8.1) c | 50 (±12.4) b | 104 (±21.3) ab | 73 (±26.8) b | 120 (±17.0) a |
| Enchytraeidae | 3 (±1.9) b | 80 (±69.0) b | 23 (±15.9) b | 30 (±10.5) b | 1818 (±393.4) a |
| Formicidae | 199 (±59.4) a | 810 (±189.6) a | 194 (±170.0) a | 304 (±34.8) a | 513 (±170.4) a |
| Isoptera | 275 (±122.3) a | 54 (±119.0) a | 625 (±22.6) a | 349 (±331.0) a | 173 (±150.5) a |
| Coleoptera Larvae | 94 (±17.6) ab | 106 (±26.1) ab | 80 (±16.8) b | 66 (±19.2) b | 183 (±33.6) a |
| Other larvae | 10 (±6.1) b | 45 (±13.1) ab | 19 (±19.9) b | 58 (±51.7) ab | 84 (±51.1) a |
| Other invertebrate | 22 (±6.9) c | 88 (±28.8) b | 39 (±11.4) c | 25 (±7.0) c | 219 (±25.6) a |
| Richness | 11 c | 16 b | 15 b | 14 b | 20 a |

Mean values of 4 evaluation seasons. The data enclosed in parentheses refer to the standard error. Means recorded with different letters, within the same row, are contrasting by Tukey test at 5%.
1 NTS (t/c/o): corn grown in succession to forage turnip and oat in succession to corn.
2 NTS (o/s/w): soybean grown in succession to oat, and wheat in succession to soybean.
3 NTS (w/s/t): soybean grown in succession to wheat, and turnip in succession to soybean.

With regard to total biomass, statistical differences ($P < 0.05$) could be observed between the systems (Table 4). The forest fragment showed the highest total biomass value in relation to the other systems, together with a high nutrient status and continuous organic matter inflow (Table 1), as indicated by Fragoso and Lavelle [14], which does not occur in agricultural systems. Among the cropped systems, the highest total biomass was observed in the no-till system with the wheat/soybean/turnip succession, with a strong contribution from the groups Oligochaeta, Enchytraeidae, Coleoptera Larvae, and Formicidae. The other groups showed greater biomass in the no-till system with the turnip/corn/oat succession. With the exception of the conventional system, an increase in total biomass was observed in all other systems from the summer toward the winter, attributed mainly to the occurrence of Coleoptera larvae (Portuguese: *corós*) in view of their biological cycle [24].

The principal components analysis (PCA) is presented as per cropping season in Fig. 2. The first two principal components were considered in the interpretation of results; the first component explained 37.98 and 65.78%, while the second explained 21.05 and 19.09% of the total variability of the data for the 2000/2001 and 2001/2002 cropping seasons, respectively.

The first principal component (Axis I) separated the no-till system with the soybean/turnip and soybean/wheat successions from the other systems cultivated in the two cropping seasons. Isoptera was the main group associated with this separation in the two consecutive years, while Oligochaeta was only observed in the 2000/2001 season. At the time of

**Table 4 – Biomass of individuals (mg $m^{-2}$) of the soil's invertebrate macrofauna under a conventional (CS), a no-till (NTS), and a natural (NS) cropping system**

| Macrofauna | Systems | | | | |
|---|---|---|---|---|---|
| | CS | NTS (t/c/o)[1] | NTS (o/s/w)[2] | NTS (w/s/t)[3] | NS |
| Arachnida | 0.2 (±0.2) b | 38.6 (±20.7) b | 20.1 (±4.5) b | 10.2 (±11.8) b | 666.3 (±640.6) a |
| Coleoptera | 100.6 (±25.0) b | 790.1 (±230.4) b | 417.2 (±378.5) b | 754.4 (±160.6) b | 1843.4 (±835.9) a |
| Chilopoda | 50.6 (±27.6) ab | 78.2 (±38.4) a | 5.8 (±35.6) b | 48.3 (±4.4) ab | 63.6 (±21.7) ab |
| Oligochaeta | 146.6 (±65.8) b | 676.5 (±165.7) a | 373.0 (±150.5) a | 746.9 (±135.0) a | 1195.3 (±266.6) a |
| Enchytraeidae | 0.6 (±0.4) b | 16.8 (±13.6) b | 6.3 (±36.4) b | 41.0 (±3.4) b | 1405.9 (±255.9) a |
| Formicidae | 211.1 (±77.1) a | 427.4 (±174.8) a | 152.7 (±146.7) a | 559.8 (±29.7) a | 237.9 (±104.2) a |
| Isoptera | 423.8 (±193.8) a | 677.4 (±356.6) a | 630.6 (±29.7) a | 89.8 (±306.2) a | 658.9 (±615.9) a |
| Coleoptera Larvae | 2737.8 (±968.1) ab | 2063.4 (±532.2) abc | 731.5 (±372.9) c | 2926.3 (±214.8) ab | 4046.0 (±1060.0) a |
| Other larvae | 60.6 (±31.0) b | 235.4 (±135.5) ab | 83.4 (±40.8) ab | 92.8 (±43.1) ab | 607.5 (±293.0) a |
| Other invertebrate | 233.4 (±192.2) b | 197.2 (±67.0) b | 431.3 (±100.5) b | 309.4 (±247.2) b | 2017.8 (±621.5) a |
| Total | 3964.6 (±1010.8) bc | 5200.9 (±840.8) bc | 2852.1 (±1657.3) c | 5578.9 (±633.6) b | 12,742.6 (±1548.1) a |

Mean values of 4 evaluation seasons. The data enclosed in parentheses refer to the standard error. Means recorded with different letters, within the same row, are contrasting by Tukey test at 5%.
1 NTS (t/c/o): corn grown in succession to forage turnip and oat in succession to corn.
2 NTS (o/s/w): soybean grown in succession to oat, and wheat in succession to soybean.
3 NTS (w/s/t): soybean grown in succession to wheat, and turnip in succession to soybean.

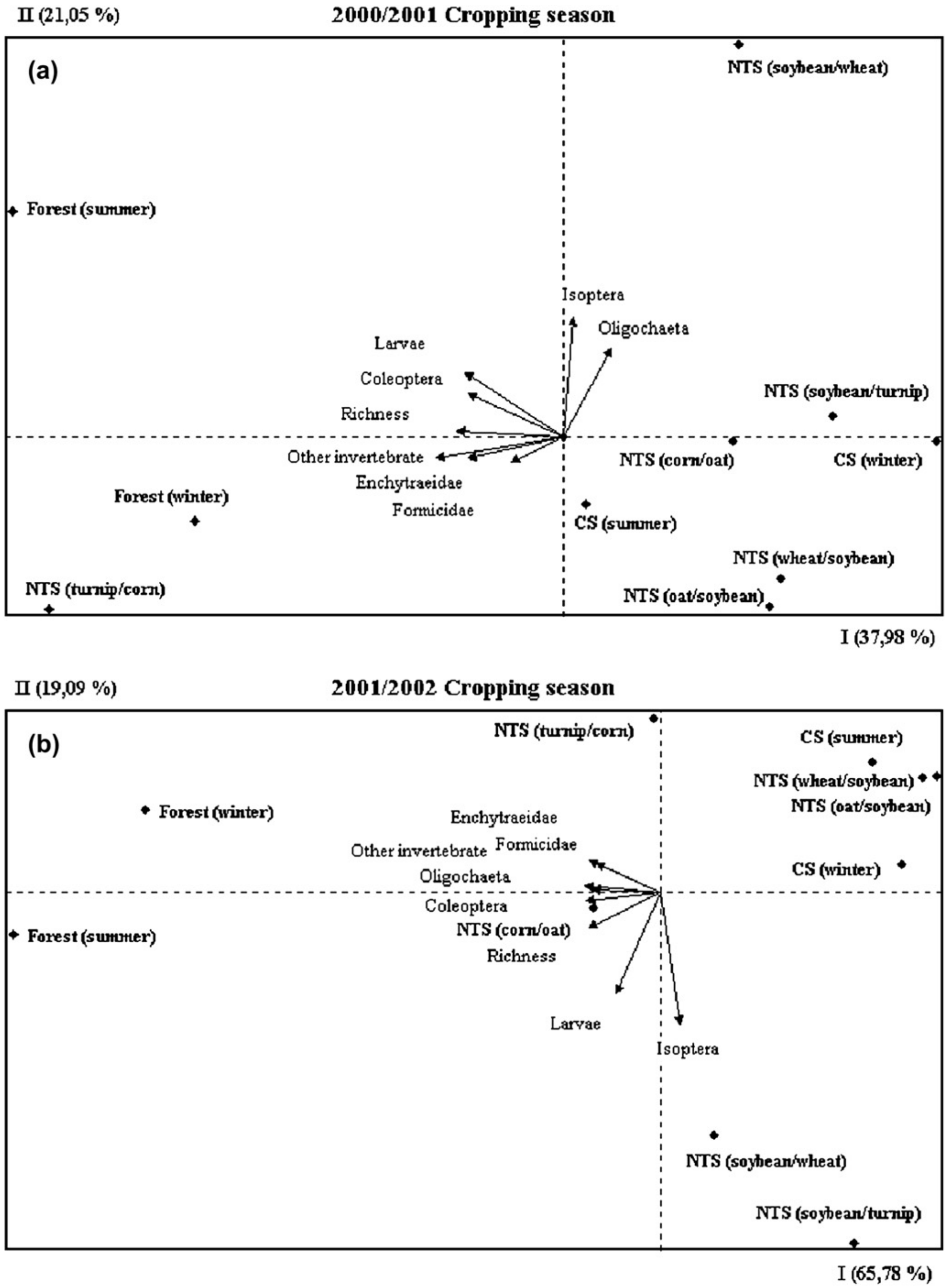


**Fig. 2 – Principal components analysis (PCA) for the most important groups of the soil's invertebrate macrofauna community under a conventional (CS), a no-till (NTS), and a natural system (forest). NTS (turnip/corn): corn grown in succession to turnip; NTS (oat/soybean, and wheat/soybean): soybean grown in succession to oat and wheat; NTS (corn/oat): oat grown in succession to corn; NTS (soybean/wheat and soybean/turnip): wheat and turnip grown in succession to soybean.**

the evaluations, the soybean trash was at a very advanced decomposition stage, showing a great amount of pod shells and stems, which are highly lignified materials, favoring the occurrence of termites. This group is usually related to organic matter with a high C/N ratio, benefiting from the association with nitrogen-fixing microorganisms [19].

It can also be observed that this component separated the natural system evaluated in the summer from the system evaluated in the winter, indicating an influence of the season. The no-till system with the corn/oat succession in the 2001/2002 cropping season is located in the center of the plane, since it presented intermediate biotic characteristics.

The second component (Axis II) associated the forest fragment and the no-till system with the turnip/corn succession, and separated these from the other cultivated systems, obeying the same distribution pattern both in the 2000/2001 and in the 2001/2002 cropping seasons, due to the greater richness and abundance of the macrofauna in these systems.

The Oligochaeta group responded positively to the no-till system with the turnip/corn succession; in the first year this effect was more pronounced for Enchytraeidae, and in the second it was stronger for the other Oligochaeta. Some authors suggest antagonistic effects between Enchytraeidae and other Oligochaeta groups; in a natural system, greater opportunities exist for the occupation of differentiated niches [12]. Tanck et al. [27] verified that no-till promoted a greater density of Oligochaeta, since it provides a better environment for the survival and reproduction of these organisms. Enchytraeidae was one of the groups that was prominent in this grouping, with a high abundance in the forest, reaching more than 60% in the 2001/2002 summer, as a consequence of the fact that this is a more favorable environment in terms of temperature and humidity, and provides better organic matter quality and abundance [12,19].

The no-till system represents a more complex agroecosystem ecologically than the conventional system, which allows a greater abundance of predatory groups [4,23], such as Chilopoda and Arachnida, observed in the summer and winter cropping seasons. However, many differences exist with respect to the crop successions.

## 4. Conclusions

Based on the results obtained, and on the conditions under which the work was developed, it can be concluded that:

1. The turnip residues before growing corn in summer (turnip/corn) provide conditions for the establishment and development of the most diverse invertebrate macrofauna community, most similar to that found in forest areas. The Oligochaeta group responded positively to the no-till system with the turnip/corn rotation; in the first year this effect was more pronounced for Enchytraeidae, and in the second it was stronger for the other Oligochaeta.
2. The soybean crop residues before growing wheat and turnip in winter (soybean/wheat and soybean/turnip), after decomposition, favored the occurrence of termites.
3. In no-till systems with continued grass trash successions, the macrofauna community showed correspondence with the conventional system.
4. The no-till system, in relation to the conventional system in general, provided greater abundance of predatory groups, such as Chilopoda and Arachnida.
5. Crop rotation with leguminous and gramineous species can be a good choice for farmers to guarantee soil biofunctionality.

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