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Pedofauna diversity in traditional and agroforestry systems of the Brazilian semi-arid region

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ABSTRACT

Identifying the impact of agricultural management on soil invertebrates is still a challenge to research in the area of soil ecology. The aim of this study was to evaluate the diversity, richness, abundance and uniformity of the pedofauna in areas of traditional agroforestry systems involving burning (with intensive use, and after six and nine years of fallow) and a less-impacted system (BUSH) in the semi-arid region of Brazil. To do this, pitfall traps were installed along five transects in each system, and pedofauna diversity was analysed over seven consecutive days in the dry and rainy seasons. The collected invertebrates were classified into taxonomic groups, and their diversity, richness, abundance and uniformity were studied. During the dry season, the agroforestry systems showed low pedofauna diversity and uniformity, but with a richness similar to that of the BUSH system, whereas the traditional systems with fallow periods of six and nine years presented high diversity and uniformity. During the rainy season, the agroforestry systems had similar pedofauna abundance and richness compared to the BUSH system. The traditional fallow systems showed an abundance, richness, diversity and uniformity similar to the results under the BUSH system. Compared to the other areas, the traditional systems showed the greatest abundance and a similar richness, but less diversity and uniformity. When water is available, agroforestry systems support a diversity and uniformity of pedofauna similar to the less-impacted system.

1. Introduction

Agricultural management systems affect the soil water content, soil temperature, the incorporation of crop residue, and the physical and chemical environment, resulting in alterations to pedofaunal characteristics (Errouissi et al., 2011). However, evaluating the impact of agricultural management practices on soil invertebrates remains a challenge. In semi-arid agroecosystems, disturbances caused by extreme weather conditions, overgrazing, the burning of crop residue and monocropping have resulted in a reduction in the abundance and diversity of soil organisms (Brévault et al., 2007). In addition, the extreme arid conditions that occur in semi-arid regions during the dry season undermine the perennial plant community and cause the rapid decomposition of organic matter (Maia et al., 2007), which may directly or indirectly affect the community of soil organisms. These are limiting conditions for the presence of soil meso- and macrofauna, which become more vulnerable under agriculture management that also reduces the structure of the soil (Brévault et al., 2007). Therefore, analysing the effect of contrasting agricultural management systems on pedofauna under semi-arid conditions can help to support sustainable management practices that improve the biological quality of the soil.

Agroforestry systems are agricultural management practices that combine recent advances in plant ecology, agroecology and evolutionary biology, aiming to improve agricultural sustainability and

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Table 1
Description of the traditional and less-impacted agroforestry systems located in the area of the Fazenda Crioula Farm, Sobral, Ceará.

Area	System of cultivation	History
Agrosilvopastoral (AGRO) (1.6 ha)	The cultivation of maize (*Zea mays L.*) and sorghum (*Sorghum bicolor* L.) in alleys formed by *Leucaena* sp and gliricidia (*Gliricida sepium* (Jacq.) Steud), which, during the dry season, is used as forage for a herd of 20 female sheep or goats. During the rainy season, the aerial part of the legumes, and the material from pruning the regrowth of the trunks and shrubs, are cut and incorporated into the soil. All the manure collected from the flock is applied at planting. The annual inputs of organic residue are tree litter, biomass from pruning the leucena, gliricidia and native trees, herbaceous biomass and manure. Inputs are obtained annually from harvesting (grain and straw), and part of the leucena and gliricidia for pasture. The dominant tree families are Boraginaceae and Caesalpinaceae.	When planting, the vegetation was thinned, preserving 22% of the tree cover. A part of the useful wood was removed for domestic use and the other part was sold. The remaining woody material was laid out perpendicular to the predominant slope in the area.
Silvopastoral (SILVO) (4.8 ha)	Pasture to maintain a herd of 20 female sheep or goats. The inputs of organic residue are wood and leaves that were cut when planting, and annual inputs of litter and manure. The pasture represents the output of organic residue. The dominant tree families are Boraginaceae and Mimosoidea.	When planting, the vegetation was thinned, preserving 38% of the tree cover. A part of the useful wood was removed for domestic use and to sell. The remaining woody material was laid out perpendicular to the predominant slope in the area.
Traditional, fallow for 9 years (TRAD9) (0.8 ha)	Agricultural model adopted in the semi-arid region of Brazil that represents the practice of itinerant agriculture: the cutting and burning of vegetation with subsequent planting for two consecutive years, followed by a period of fallow. In 1998, there was deforestation and the vegetation was burned; in 1999 and 2000 maize (*Zea mays* L.) and beans (*Vigna unguilata* L. Walp) were grown, followed by a period of fallow.	After deforestation and before cultivation, the plant material was burned. During the dry season, the forage and crop residue were used as dietary supplement for a herd of 20 female sheep or goats.
Traditional fallow for 6 years (TRAD6) (0.8 ha)	Agricultural model that represents the practice of itinerant agriculture. In 2001 there was deforestation, and the vegetation was burned. In 2002, 2003, maize (*Zea mays* L.) and beans (*Vigna unguilata* L. Walp) were cultivated, followed by a period of fallow.	
Traditional (BURN) (0.8 ha)	Agricultural model that represents the practice of itinerant agriculture. In 2009, the vegetation was cut and burned with the subsequent planting of maize (*Zea mays* L.) and beans (*Vigna unguilata* L. Walp). Soil samples were collected shortly after burning.	
Less-impacted system (BUSH) (3.1 ha)	An area of preserved caatinga around 50 years old, used as a reference for the other areas.	The trees were cut down in 1981; during the extreme dry season, the animals feed on native vegetation when necessary.

Source: Maia et al. (2007).

maintaining or increasing crop production (Weiner et al., 2010), especially in semi-arid regions (Araújo Filho et al., 2001). The environmental and economic benefits tend to increase when crops and/or pasture are combined with trees and/or shrubs in spatial or temporal arrangements (Paudel et al., 2011). In general, the pedofauna is considered sensitive to changes in forest cover, however, agroforestry management practices may have less impact on pedofaunal composition than do traditional agricultural practices. Moreover, the characteristics of agroforestry systems create conditions that are more similar to natural ecosystems, providing more-optimal environmental conditions and resources for soil macro- and microorganisms (Lima et al., 2010).

Increasing plant residue on the soil surface reduces fluctuations in soil temperature and humidity, improves the soil structure, and can be used as a nutritional resource for pedofauna (Errouissi et al., 2011). In the Brazilian semi-arid region, crop residue remaining on the soil surface supports greater pedofaunal diversity and abundance than do traditional agroecosystems in which the soil is managed by deforestation and burning (Nunes et al., 2009). In addition, other studies emphasise the greater abundance, richness and diversity of the pedofauna under agroforestry management than under the traditional systems of cutting and burning the vegetation (Barros et al., 2002; Lima et al., 2010).

Under more conservative management practices, the microhabitat structure of an agroecosystem allows the coexistence of pedofaunal invertebrates with a range of survival strategies (Nunes et al., 2012) or those that provide different ecological services. Our hypothesis is that conservationist agriculture management systems that resemble the natural ecosystem, support greater diversity and more uniform pedofauna than do areas of traditional cultivation. Therefore, this study aimed to evaluate the diversity, richness, abundance and uniformity of the pedofauna between traditional agroforestry systems (agrosilvopastoral and silvopastoral), under intensive use, and after fallow periods of six and nine years, and a less-impacted system.

2. Material and methods

2.1. Study area

The study was carried out in the experimental area of the Fazenda Crioula Farm (3°41′ S and 40°20′ W) at the National Centre for Goat and Sheep Research (CNPCO) of the Brazilian Agricultural Research Corporation (EMBRAPA), located in Sobral, Ceará, Brazil. The mean annual temperature in Sobral is 27 °C, with 821 mm of rainfall (Instituto de Pesquisa e Estratégia Econômica do Ceará, 2011). In the experimental area, the mean annual precipitation over the last 10 years was 989 mm, distributed between January and June. However, 67% of the rainfall occurred between February and April (Aguiar et al., 2013). According to the Köppen classification, the climate in the region is of type BSW'h,

Table 2
Physical and chemical properties of the soil at a depth of 0–20 cm, under different systems of agricultural management. Sobral, Ceará, Brazil.

	AGRO	SILVO	TRAD9	TRAD6	BURN	BUSH
Sand (g kg^{-1})	633.0	557.0	573.0	463.0	610.0	537.0
Silt (g kg^{-1})	173.0	200.0	240.0	207.0	183.0	203.0
Clay (g kg^{-1})	193.0	243.0	187.0	330.0	207.0	260.0
Sd (g cm^{-3})	1.3	1.2	1.3	1.1	1.2	1.1
TOC (g kg^{-1})	11.3	21.7	15.7	17.2	14.7	16.5
Total N (g kg^{-1})	1.1	1.6	1.2	1.4	1.2	1.5
Available P (mg dm^{-3})	14.7	3.7	2.4	11.7	10.6	3.4
pH in water	6.8	6.4	6.2	6.7	6.9	6.5
CEC ($cmol_c$ dm^{-3})	10.7	11.4	8.5	22.1	12.6	15.2
V (%)	91.5	79.6	74.4	93.8	87.8	87.0

Sd: bulk density; TOC: total organic carbon; CEC: Cation exchange capacity.
Source: Aguiar et al. (2013).

very hot and semi-arid (BRAZIL. Ministério das Minas e Energia, 1981). The soil in the area is represented by patches of a typic Orthic Chromic Luvisol and typic Orthic Hypochromic Luvisol (Aguiar et al., 2010). The vegetation is composed of thorny deciduous savanna (Cole, 1960).

Six areas were selected, including five agroecosystems: agrosilvopastoral (AGRO); silvopastoral (SILVO); traditional with intensive use with no fallow period (BURN); traditional with six years of fallow (TRAD6) and traditional with nine years of fallow (TRAD9), and a less-impacted system (BUSH), representing the preserved Caatinga vegetation and used as reference in this study (Table 1). The physical and chemical characterisation of the soil in each area is presented in Table 2.

2.2. Sample collection

Pitfall traps were installed at ground level in each system to collect the pedofaunal organisms. The traps consisted of plastic containers, 9 cm in diameter and 11 cm in height, and were installed 10 m apart along five parallel transects in each system, with each transect representing one replication. In order to better represent the variability in the size of each area between systems, five pitfall traps were installed in each transect (25 traps) in the SILVO system Fig. 1, i.e. the larger area of 4.8 ha. For the other systems, which area varied from 0.8 to 1.6 ha, three pitfalls were installed in each transect (15 traps) Fig. 1. Although the BUSH area had an area of 3.1ha, three pitfalls were also used per transect in this system, considering that this area is in ecological balance, with no human interference. In total, 100 pitfall traps were installed.

After the installation, the pitfall traps were filled with a preservative fluid of 53% alcohol solution with 2 drops of detergent to break the surface tension of the water. The pitfalls traps remained in the area for seven days, after which the organisms were collected from the traps and transferred to a preservative solution of 70% alcohol. With the aim of representing the annual seasonality of the semi-arid region, two collections were made, one in October 2009 (dry season) and the other in March 2010 (rainy season). The organisms were identified at the level of large taxonomic groups (class, order or family), and counted using a binocular stereomicroscope. The taxonomic groups were recognised by consulting bibliographic and literary material (Dindal, 1990).

During the dry season (October 2009), the soil temperature was determined at a depth of 10 cm using a digital stem thermometer, from 08:00 to 09:00 on three consecutive days. The temperature was not determined during the rainy season due to the high soil-moisture content, which caused temperature fluctuations that compromised the measurement.

2.3. Data analysis

The total abundance for each area was evaluated considering the equation $Total\ abnd = \sum(n^\circ.\ ind/n^\circ.\ traps)/n^\circ.\ days$, where *abnd* is the abundance and *ind* the number of individuals Abundância total $= \sum((n^\circ\ \text{total de ind.})/(n^\circ\ \text{de arm.}))/n^\circ$ dias. Group abundance was determined from $Group\ abnd. = \sum(n^\circ.ind.grp/n^\circ.traps)/n^\circ.days)/n^\circ.days$, where *abnd* is the abundance and *ind* the number of individuals Abundância total $= \sum((n^\circ\ \text{total de ind.})/(n^\circ\ \text{de arm.}))/n^\circ$ dias Abundância total $= \sum((n^\circ\ \text{total de ind.})/(n^\circ\ \text{de arm.}))/n^\circ$ dias. Diversity was determined using the Shannon-Weaver index (H), defined as $H = -\sum pi\ .\log pi$, where $pi = ni/N$, where *ni* is the importance value of each group and *N* is the total of the importance values (Magurran, 2004). Uniformity was calculated according to the Pielou Index (P), defined as $P = H/\log S$, where H is the Shannon-Weaver Index and S the total number of groups in the community (Magurran, 2004).

The results for total and group abundance were submitted to analysis of variance, in which the transects were systematically distributed within the management systems (AGRO, SILVO, TRAD6, TRAD9, BURN and BUSH) to characterise a systematic design (Alvarez V. and Alvarez, 2013; Calzada Benza, 1964). Considering each transect as one replication, the mean - value of each replication was compared between systems by Tukey's test at 5%. Principal component analysis (PCA) was also applied between the soil-management systems, considering as response variables the main taxonomic groups and the sum of the less-frequent groups of pedofauna (others). The soil temperature, Shannon-Weaver diversity index, Pielou uniformity index, total richness and abundance for the dry and rainy seasons were used as explanatory variables. The principal component analysis was carried out using the R v3.6.0 software (R Development Core Team, 2019).

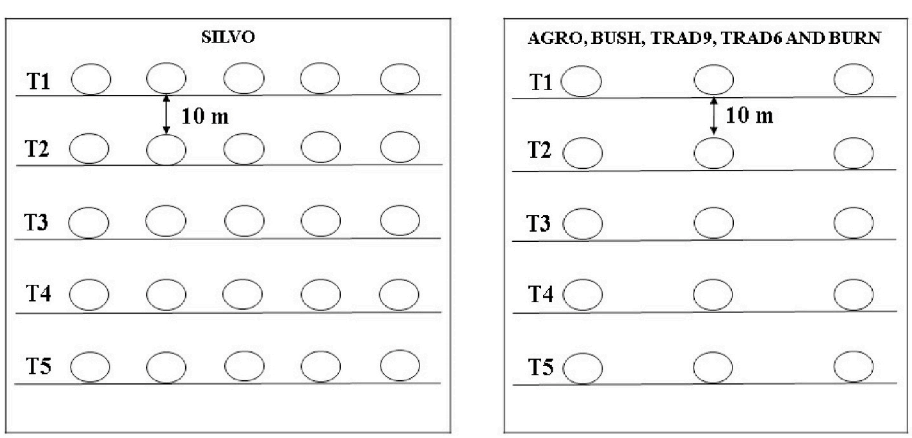

Fig. 1. Experimental design used in this study showing the five transects (T) in each system, with the oval symbols representing the pitfalls traps. AGRO: agrosilvopastoral; SILVO: silvopastoral; BUSH: less-impacted system; TRAD9: traditional, with nine years of fallow; TRAD6: traditional with six years of fallow; BURN: traditional.

Table 3
Indices of ecological diversity and soil temperature in traditional systems with and without a period of fallow, agroforestry systems and a less impacted system, during the dry and rainy seasons. Sobral, Ceará, Brazil.

Management system	Total abundance (Ind trap^{-1} day^{-1})		Total richness		Shannon Index (H′)		Pielou Index (P)		Soil temperature (°C)
	D	R	D	R	D	R	D	R	
AGRO	43^{a}	28^{b}	22^{a}	22^{a}	1.89^{c}	3.25^{a}	0.42^{c}	0.73^{a}	30.4
SILVO	26^{b}	32^{b}	21^{a}	27^{a}	1.78^{c}	2.81^{a}	0.41^{c}	0.59^{a}	30.5
BUSH	17^{bc}	24^{b}	23^{a}	22^{a}	2.46^{ab}	3.22^{a}	0.54^{ab}	0.72^{a}	28.0
TRAD9	10^{c}	31^{b}	20^{a}	27^{a}	2.89^{a}	3.18^{a}	0.67^{a}	0.67^{a}	28.0
TRAD6	21^{bc}	30^{b}	22^{a}	27^{a}	2.76^{a}	3.23^{a}	0.62^{a}	0.68^{a}	28.2
BURN	46^{a}	96^{a}	24^{a}	21^{a}	2.45^{bc}	1.68^{b}	0.53^{bc}	0.38^{b}	31.2
F-test	**	**	ns	ns	**	**	**	**	

Ind trap^{-1} day^{-1}: individuals per trap per day; D: dry; R: rainy; AGRO: agrosilvopastoral; SILVO: silvopastoral; BUSH: less-impacted; TRAD9: traditional, under fallow for 9 years; BURN: traditional; TRAD6: traditional, under fallow for 6 years. Mean values followed by the same letter in a column do not differ statistically by Tukey's test ($P < 0.05$). **Significant at 1% probability.

Table 4
Mean abundance (individuals trap^{-1} day^{-}1) for the main taxonomic groups of pedofauna collected during the rainy season under traditional and agroforestry systems, and the less-impacted system. Sobral, Ceará (n = 5).

	AGRO	SILVO	BUSH	TRAD9	TRAD6	BURN
Acari	17.40^{b}	22.68^{b}	13.13^{b}	56.33^{a}	16.86^{b}	16.07^{b}
Araneae	16.00^{a}	7.28^{b}	6.20^{b}	7.13^{b}	8.73^{b}	11.80^{ab}
Coleoptera	8.60^{bc}	4.08^{c}	8.66^{bc}	23.80^{a}	6.53^{bc}	3.06^{c}
Entomobryomorpha	18.93^{b}	22.04^{b}	27.13^{b}	9.40^{b}	31.06^{b}	89.80^{a}
Formicidae	25.40^{abc}	19.04^{bc}	18.20^{bc}	40.20^{a}	19.73^{abc}	8.20^{c}
Larva Diptera	4.00^{ab}	1.04^{b}	4.60^{ab}	10.73^{a}	8.20^{ab}	1.06^{b}
Symphypleona	60.26^{b}	92.84^{b}	50.93^{b}	26.93^{b}	65.53^{b}	478.40^{a}
Heteroptera	0.53^{b}	1.16^{b}	0.13^{b}	0.06^{b}	0.66^{b}	5.53^{a}
Orthoptera	2.53^{b}	1.56^{b}	1.06^{b}	0.60^{b}	1.46^{b}	5.66^{a}
Auchenorryncha	6.40^{b}	5.52^{b}	6.40^{b}	6.20^{b}	9.86^{b}	26.40^{a}

AGRO: agrosilvopastoral; SILVO: silvopastoral; BUSH: less-impacted system; TRAD9: traditional, including 9 years of fallow; TRAD6: traditional, including 6 years of fallow; BURN: traditional. Mean values followed by the same letter on a line do not differ statistically by Tukey's test ($P < 0.05$).

Table 5
Mean abundance (individuals trap^{-1} day^{-}1) for the main taxonomic groups of pedofauna collected during the dry season under traditional and agroforestry systems, and the less-impacted system, Sobral, Ceará (n = 5).

	AGRO	SILVO	BUSH	TRAD9	TRAD6	BURN
Acari	56.53^{a}	23.32^{ab}	1.46^{b}	2.6^{ab}	15.2^{ab}	53.53^{ab}
Araneae	6.86^{ab}	4.0^{b}	7.66^{a}	4.13^{b}	6.20^{ab}	6.4^{ab}
Coleoptera	7.06^{b}	2.24^{b}	61.0^{a}	13.26^{b}	19.60^{b}	8.73^{b}
Diptera	2.13^{c}	1.2^{c}	8.73^{ab}	5.8^{abc}	10.0^{a}	3.13^{bc}
Entomobryomorpha	160.4^{a}	108.4^{b}	9.73^{c}	12.26^{c}	32.66^{c}	133.73^{ab}
Formicidae	63.2^{a}	37.16^{ab}	18.6^{b}	22.66^{ab}	51.73^{ab}	50.66^{ab}
Dermaptera	0.46^{b}	0.16^{b}	8.46^{a}	2.60^{ab}	4.33^{ab}	0.06^{b}
Pseudoscorpionida	0.13^{b}	0.16^{b}	0^{b}	0^{b}	0^{b}	0.53^{a}

AGRO: agrosilvopastoral; SILVO: silvopastoral; BUSH: less-impacted system; TRAD9: traditional, including 9 years of fallow; TRAD6: traditional, including 6 years of fallow; BURN: traditional. Mean values followed by the same letter on a line do not differ statistically by Tukey's test ($P < 0.05$).

3. Results

During the dry season, the AGRO and SILVO systems showed low diversity and uniformity, but similar richness to that shown by BUSH (Table 3). In the areas that included fallow periods (TRAD9 and TRAD6), high diversity and uniformity were found, with the soil temperature remaining similar to that found in BUSH. In the BURN system the richness and soil temperature (+3.2 °C) were greater compared to BUSH, but the diversity and uniformity were similar.

During the rainy season, AGRO and SILVO presented an abundance similar to that of BUSH, with 28 and 32 individuals trap^{-1} day^{-1} respectively, and a richness of 22 and 27 groups (Table 3). The TRAD9 and TRAD6 systems showed similar abundance, richness, diversity and uniformity to those of the BUSH system.

Analysing the abundance of taxonomic groups, 10 different groups were found during the rainy season (Table 4) and 8 during the dry season (Table 5), while in the rainy season, there was a high abundance of Symphypleona, especially in the BURN system. During the dry season there were more individuals from the Formicidae and Entomobryomorpha groups.

The principal component analysis (PCA) made it possible to separate the different management systems during the dry and rainy seasons, considering the composition of the pedofauna (Fig. 2). Three main groups were found during the dry season, with the first composed of the BURN system only, the second of BUSH, TRAD9 and TRAD6, and the third of AGRO and SILVO (Fig. 2A). There was a predominance of the Araneae, Dermaptera, Coleoptera, Diptera, Blattodea and Psocoptera groups in the BUSH, TRAD9 and TRAD6 systems. The Thysanoptera, Acari, Heteroptera, Entomobryomorpha and Formicidae groups were more abundant in the AGRO and SILVO systems.

The relationship between the principal components during the rainy season showed that the Dermaptera, Diptera, Gastropoda, Podurомorpha and Psocoptera groups were more abundant in BUSH, AGRO and SILVO (Fig. 2B). Whereas, the most-abundant groups in TRAD9 and TRAD6 were Acari, Coleoptera, Formicidae, and Diptera larvae.

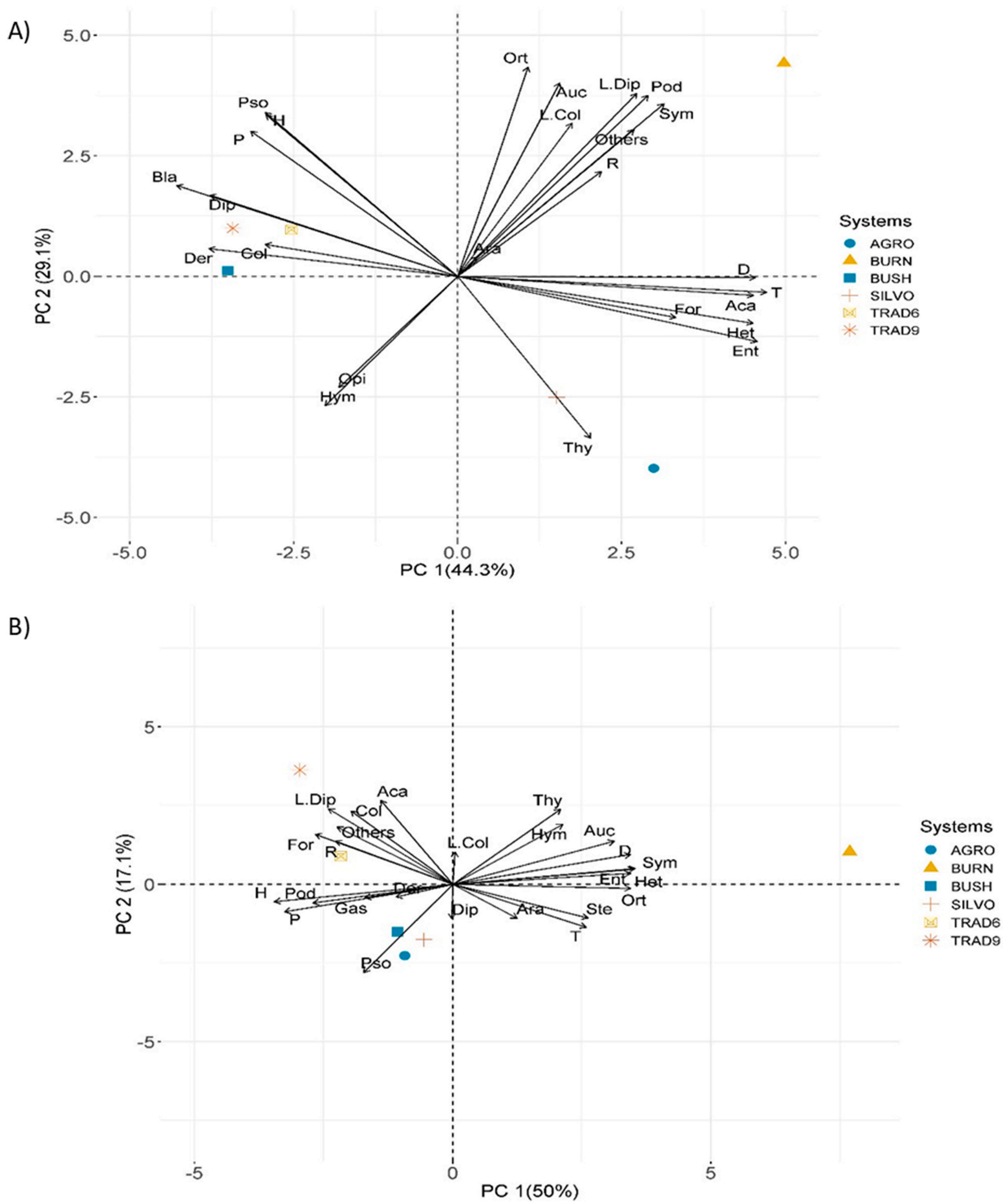

Fig. 2. Principal component analysis (PCA) between agricultural management systems, the main taxonomic groups of pedofauna and the sum of the less-frequent groups (others), during the dry (A) and rainy (B) seasons. AGRO: agrosilvopastoral; SILVO: silvopastoral; BURN: Traditional; TRAD6: traditional, including 6 years of fallow; TRAD9: traditional, including 9 years of fallow; BUSH: less-impacted system; H: Shannon-Weaver Index; P: Pielou Index; Aca: acari; Ara: araneae; Bla: blattodea; Pso: psocoptera; Ort: orthoptera; Auc: auchenorryncha; Dip: díptera; L. Dip.: larva de diptera; Pod: poduromorpha; Sym: symphypleona; L. Col: larva de coleoptera; Het: heteroptera; Ent: entomobryomorpha; For: formicidae; Gas: gastropoda; Thy: thysanoptera; Hym: hymenoptera; Opi: opilionida; Der: dermaptera; Col: coleoptera e Ste: sternorryncha

4. Discussion

This study explored the effects of contrasting agricultural management systems on the pedofauna during the dry and rainy seasons in the Brazilian semi-arid region. Deforestation and the reduction in crop residue through burning are factors that affect the microclimate, niches for shelter, and the amount and quality of resources for microorganisms, and are limiting factors that may reduce the richness, uniformity and diversity of the pedofauna community (Lima et al., 2010; Vasconcellos et al., 2010). It should be highlighted that changes in the pedofauna community can reflect on ecosystem development (Cunha Neto et al., 2012). In the present study, the higher diversity of organisms in the BUSH, TRAD9 and TRAD6 systems compared to the agroforestry systems, may be due to the greater floristic richness and biodiversity of these systems (Aguiar et al., 2013). The biodiversity in the BUSH and TRAD systems, which include fallow periods, results in an increase in the input and diversity of litter, in the release of root exudates, and in the composition and activity of soil biota and microorganisms (Paudel et al., 2011). In addition, the presence of deciduous trees in the area of BUSH allows a thick layer of leaves to form that covers the soil during drought (Nunes et al., 2008). The pedofauna is restored by the end of three years of fallow following burning (Nunes et al., 2008), corroborating the present results in the TRAD9 and TRAD6 systems. In addition, rhizosphere activity and subsequent rhizodeposition may restore the chemical and physical properties of the soil (Dias et al., 2007), favouring development of the pedofauna. Therefore, the present results indicate that traditional cultivation with a period of fallow (TRAD9 and TRAD6) can restore the composition of the pedofauna community.

The higher values for abundance in AGRO and BURN indicate that these agricultural practices may favour an increase in the number of individuals, since for some groups of pedofauna the effect of burning may not be completely devastating (Oliveira and Franklin, 1993). The low diversity and uniformity found in the AGRO system suggest the occurrence of group dominance. Although burning has an effect on many groups of organisms, it leads to recolonisation of the area, whether by individuals who manage to survive the fire by sheltering, nesting or moving to adjacent areas, or the establishment of individuals from other areas (Marini Filho, 2000). During the rainy season, the high abundance found in BURN was probably due to water availability and to the presence of nutrients derived from weeding of the herbaceous plants by the fire. After burning, there is a rapid recolonisation of the fauna with a steady increase from day 145 (Oliveira and Franklin, 1993).

The abundance and richness of the AGRO and SILVO systems were similar to the values seen in the BUSH system (Table 3), possibly associated with the presence of trees that improve the climate and the nutritional conditions of the environment (Baretta et al., 2010; Dias et al., 2007). According to Barros et al. (2002), agroforestry systems show greater abundance and diversity when compared to pasture and to fallow or annual-crop systems, probably due to the increase in organic carbon (Maia et al., 2007). The higher availability of total organic carbon and nitrogen from the roots of perennial plants under agroforestry systems, and from the dead roots of grasses under silvopastoral systems, favours microbial activity and biomass accumulation (Paudel et al., 2011; Dias et al., 2007). This process improves the stability of soil aggregation, creating a favourable environment for the pedofauna (Paudel et al., 2011). Pimentel et al. (2011) and Lima et al. (2010) also found greater diversity, uniformity, richness and abundance in pedofauna under agroforestry systems, six and ten years after implementation.

Analysing the abundance of taxonomic groups, the high values for Symphypleona during the rainy season are probably associated with the presence of grasses, as recolonisation in collembola is strongly related to the development of plant cover (Oliveira and Franklin, 1993). The identification of large numbers of Formicidae and Coleoptera during the dry season reflect their predominance in the caatinga during the period of water deficit (Nunes et al., 2012). The Formicidae group showed greater abundance in environments with more insolation (Dias et al., 2007), a characteristic favourable to its adaptation to the dry season. In addition, Formicidae may be indicative of a balanced ecosystem as regards social habits and the breakdown of work, both of which redistribute particles, nutrients and organic matter, as well as improving soil water infiltration through an increase in porosity and aeration (Baretta et al., 2010; Vasconcellos et al., 2010).

The Araneae, Dermaptera, Coleoptera, Diptera, Blattodea and Psocoptera groups are indicators of conservative agroecosystems (Cunha Neto et al., 2012), and their predominance in the BUSH, TRAD9 and TRAD6 systems demonstrates that a period of fallow is effective in restoring the pedofauna (Fig. 2). The isolation of BURN in the PCA is result of the higher abundance of Symphypleona, also seen by Oliveira and Franklin (1993) through the dominance of Collembola (Symphypleona, Poduromorpha and Entomobryomorpha). The greater number of individuals in the BURN group can be explained by the simpler systems that result from burning, compared to BUSH and other more-complex systems, optimising the survival and reproduction of more opportunistic organisms (Sales et al., 2018). Changes in water availability and soil cover, depending on the floristic composition, cause disturbances in the habitat, and result in variations in the abundance, richness, diversity and uniformity of the pedofauna. This community of invertebrates shows an adaptation to water availability that may be even more selective due to the level of modification caused by the agricultural practices.

5. Conclusions

Traditional cultivation systems in the Brazilian semi-arid region that include fallow periods of between six and nine years can restore the diversity, uniformity and richness of the pedofauna community, and their use by farmers should be encouraged.

Agroforestry systems in the semi-arid region present similar diversity and uniformity of meso- and macrofauna compared to the less-impacted system (natural Caatinga) when water is available.

The pedofauna is a useful biological indicator to represent the conservation status of agroecosystems (e.g., agroforestry systems) and intensive altered ecosystems, such as slash and burn systems.

This study shows that agricultural management systems affect the pedofauna in semi-arid ecosystems; however, further studies are needed to improve our understanding of the response of these organisms to anthropogenic action, and better orient farmers on the adoption of practices that promote agricultural production together with the conservation of soil ecology.

CRediT authorship contribution statement

Jamili Silva Fialho: Methodology, Investigation, Writing - original draft. **Anacláudia Alves Primo:** Writing - review & editing. **Maria Ivanilda de Aguiar:** Data curation. **Rafaela Batista Magalhães:** Investigation. **Lilianne dos Santos Maia:** Investigation. **Maria Elizabeth Fernandes Correia:** Supervision. **Mônica Matoso Campanha:** Resources. **Teógenes Senna de Oliveira:** Conceptualization, Project administration.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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