Scientific Paper

Evaluation of agroecological systems through biological indicators of the soil quality: edaphic mesofauna

Ana Socarrás and I. Izquierdo

Instituto de Ecología y Sistemática, CITMA
Carretera de Varona Km 3½, Capdevila, Boyeros, A.P. 8029, C.P. 10800. La Habana, Cuba.
email anameri@ecologia.cu

ABSTRACT: In a farm with livestock production-agriculture integrated management, located in Cangrejeras, Artemisa province, the impact of agroecological methods was evaluated through the variation of the soil mesofauna,. Three management systems were selected: pastureland area, designated as control area, which had been established for more than 20 years; forage area, planted in mosaic form, with small plots of perennial crops, and subject to an organic manure treatment; and polycrop area, with a rotation system of short-cycle crops and application of compost. The samplings were conducted six and eight years after making the transformations in the forage and crop areas, in both seasons. Five samples were taken in each system, at a depth of 0-10 cm, according to a completely randomized design. In general, in the forage and pastureland areas, regarding the Oribatida/Astigmata, Oribatida/Prostigmata and Astigmata/Mesostigmata ratios (in both seasons and years of transformation), the edaphic groups that constitute indicators of soil stability and fertility prevailed (Oribatida and Mesostigmata), as they are favored by the incorporation of organic matter and a higher soil cover, which stimulates the mesofauna to recover higher stability conditions. In the polycrop area the groups which are indicators of the soil instability and infertility (Astigmata and Prostigmata) prevailed, because the crop rotation and the management of the agroecological techniques did not guarantee yet the conditions that benefit the establishment of the other groups.

Key words: soil fertility, soil management, soil organisms

INTRODUCTION

Agroecology –beyond the system production– proposes a strategy to design agroecosystems which are productive, resilient, stable and sustainable. According to Tarrasón (2008), to evaluate the sustainability of the management of an agroecosystem, the definition of the soil status (capacities and properties) and its evolution should be taken into consideration, through the evaluation of soil quality. Agroecological practices remarkably influence the development of highly diversified edaphic organism communities (Flores, 2009). In turn, the edaphic fauna –especially, the soil mesofauna– is strongly involved in several important processes that allow a functional soil, such as: fragmentation and decomposition of the organic material, nutrient recycling and availability, water and air filtration, degradation of contaminants, formation of the soil structure and stability of the ecosystem and the related trophic networks (Chocobar, 2010). On the other hand, such organisms are sensitive to anthropogenic disturbances, in time scales, which are relevant for soil management and they are useful to determine its degree of affectation due to human activity (Bedano, 2011).

The edaphic mesofauna, from one particular species to communities, and their biological processes, has been proposed as an indicator of soil quality. Different groups of soil mites have different responses to the managements applied to it: while Oribatida species are more susceptible to soil management practices, Astigmata and Prostigmata can be very numerous in agricultural and livestock production soils, because their populations are benefitted as a result of the anthropic activity (Behan, 1999). Hermosilla *et al*. (1974) proposed the use of the relation between the density of different taxa with opposite ecological functions as an indicator of the degree of soil degradation and anthropization. Bedano (2011) stated that the diversity of edaphic communities is a useful tool to monitor soil quality in time, along with the physical and chemical indicators.

The objective of this work was to evaluate, through the relations or the balances among the different mesofauna groups, the effect of the agroecological practices applied in two transformed systems, as compared with the traditional pastureland that gave origin to them.

MATERIALS AND METHODS

The study was conducted in a one-hectare agroecological farm, located in the Cangrejeras locality (Artemisa province, Cuba), in which livestock production (75 %) and agricultural activity (25 %) are integrated. Its soil is typical Ferralitic Red, equivalent to a Ferralsol, according to the FAO-UNESCO classification (Hernández *et al.*, 1999). Table 1 shows its physical and chemical characteristics for each of the evaluated areas.

Treatments and design

Evaluated areas within the farm

The cultivated pastureland (P) was designated as control area, with a low stocking rate. It had been established for more than 20 years, without organic amendments. The plant community that prevailed was *Megathyrsus maximus* (Jacq.) B.K. Simon and S.W.L. Jacobs, *Cynodon nlemfuensis* Vanderyst and *Teramnus uncinatus* L. Sw.

The forage (F) was originated from the pasture area; it was subject to a management system with application of compost, made from plant residues and manure, and established with cover forage (*Saccharum officinarum* ssp., *Pennisetum* sp. y *Leucaena leucocephala* (Lam.) de Wit).

The polycrop (C) also came from the pasture area, in which, in addition to the organic treatment mentioned in F, the rotation of short-cycle crops was practiced, mainly: cassava (*Manihot esculenta),* maize *(Zea mays),* banana (*Musa* spp.), beans (*Phaseolus vulgaris*), squash (*Cucurbita melopepo* L.), sweet potato *(Ipomoea batata* L. Lam), tomato (*Lycopersicon esculentum* Mill) and spinach *(Spinacia oleracea* L.).

The treatments were constituted by the three above-described areas (the last two had been established for eight years). In each one, five soil samples were taken at only one depth level (0-10 cm), with a cylinder of 5 cm diameter and 10 cm depth, according to a completely randomized design. Sampling was conducted six and eight years after the transformation of the areas (forage and crop): three samplings in the rainy season (May, July and October) and three in the dry season (December, February and March), in both years.

Procedure. The extraction of the edaphic fauna was carried out for seven days, with Tullgren funnels, and no artificial source of light and heat was used. Afterwards, the individuals were counted and separated, through a stereoscopic microscope, and they were preserved in alcohol at 70 %. Then, they were identified, according to the classification proposed by Brusca and Brusca (2003) and Krantz (2009), up to the family category. For the selection of the biological indicators, the ecological characteristics of the organisms present were taken into consideration and some criteria proposed by other researchers (Hermosilla *et al*., 1974; Behan, 1999; Bedano *et al*., 2001) were adopted.

Statistical analysis. The values of average density (No. ind.m^{-2}) of each taxon were processed through a simple classification analysis, which included a factorial arrangement of the treatments, the years of transformation and the season.

RESULTS AND DISCUSSION

Oribatida/Astigmata ratio or balance

It has been stated that there is a certain relation between Oribatida and Astigmata, because while one increases, the other decreases; hence the importance of the ratio to measure the degree of imbalance between the edaphic biocenoses. In the pastureland and forage areas, in both seasons and at six and eight years, this ratio became higher than one and Oribatida –mites which are indicators of soil stability and fertility– prevailed. In the polycrop area, six years after the transformation took place and in both seasons of the year, the ratio was

Table 1. Physical and chemical data of the first 10 cm of soil.

Area	pH (H_2O)	OM (%)	AD (g cm^{-3})	WHC (%)
Pasture (P)	6,0	3,65	1,34	50,0
Forage (F)	6,5	5,14	1,06	60,0
Crop (C)	6,4	4,14	1,16	54,0

OM: organic matter, AD: apparent density, WHC: water holding capacity.
Source: (Izquierdo *et al*., 2004).

observed to be dangerously close to one, because the values of Astigmata –group indicator of disturbances of the edaphic medium– were close to those of Oribatida. In this area, eight years after its transformation and in the rainy season, the ratio favored the group indicator of instability and infertility; while in the dry season it was close to one, which showed an imbalance of the groups that integrate the soil mesofauna (fig. 1). On the other hand, this area had moderate values of AD, WHC and OM (table 1); this indicates that when the area is subject to more tillage and a lower soil cover, i.e., there is an affectation because of the agricultural management; it shows affectations in its physical, chemical and biological properties. This causes imbalance, instability and, thus, scarce conditions for the development of the edaphic fauna. Hermosilla *et al*. (1974), Bedano *et al*. (2001), Socarrás and Robaina (2008), among other authors, confirm the capacity of the Oribatida/Astigmata ratio as indicator of the soil quality.

Oribatida/Prostigmata ratio or balance

The Oribatida/Prostigmata ratio allows to know the existing degree of infertility and imbalance in an area, which is mainly expressed in the low organic content and the low values of calcium carbonate and humidity (Flores *et al*., 2008). The results obtained in the studied farm, with an agroecological management, corroborated that the balance of the groups served as bioindicator of the soil conditions. Six years after transformation, in the pasture and forage areas, the majority presence of Oribatida was observed in both seasons of the year; while in the polycrop area a value much closer to one was obtained, but with predominance of Oribatida, which should constitute an alert for decision-makers. In the evaluated areas, eight years after the transformations, similar results were obtained in the rainy season, which contributed humidity levels that could have had a beneficial influence. Nevertheless, in the dry season, in the polycrop area, Prostigmata prevailed numerically (fig. 2). With the use of this indicator it was corroborated that the polycrop area showed disturbance in the edaphic medium and, thus, in the establishment of the soil fauna communities. In Cuba, Bedano *et al*. (2001), Socarrás and Robaina (2011) and Socarrás (2013) have used the Oribatida/Prostigmata ratio or balance in forests, reclaimed areas and agroecosystems.

Astigmata/Mesostigmata ratio or balance

Bedano *et al*. (2001) established the Astigmata/Mesostigmata ratio as effective to predict the instability of the edaphic medium. If there is a strong presence

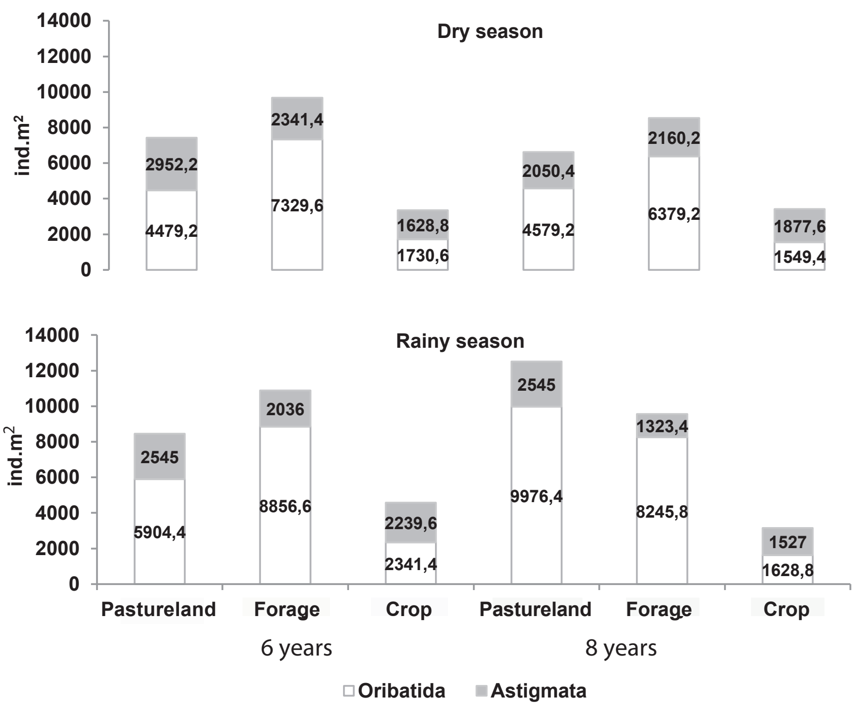

Fig. 1. Oribatida/Astigmata ratio at six and eight years, in the dry and rainy seasons.

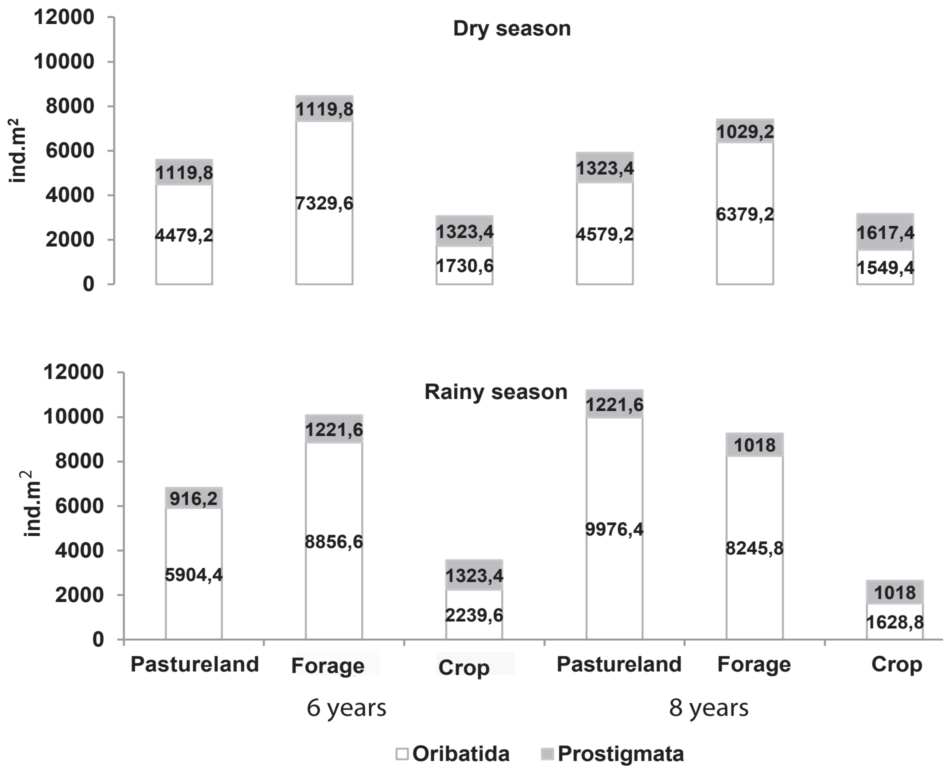

Fig. 2. Oribatida/Prostigmata ratio at six and eight years, in the dry and rainy seasons.

of the numerator group –indicator of instability–, it can be inferred that the medium is altered and disturbed. Robaina (2010) used this ratio to evaluate agroforestry systems. In this study, in all the evaluated areas, at both transformation moments and in the rainy season, the ratio was lower than one, which shows the favorable abundance of Mesostigmata –indicators of soil stability and fertility– (fig. 3). In the dry season, eight years after the occurrence of the land use change, a predominance of such group (Mesostigmata) was also observed; yet, at six years, the Astigmata prevailed in the polycrop area, which shows alteration and infertility of the edaphic medium. This ratio proved the existing disturbance in the polycrop area, where the litter contribution of the short-cycle crops is very poor and the soil remains almost all the time without plant cover; hence the need to make an urgent analysis of the agroecological methods that are applied, to reverse the situation affecting the medium quality as fast as possible.

Of special interest was the existence in the studied areas of two fauna groups: springtails (Collembola) and barklice (Psocoptera), because their presence can indicate the recovery and good quality of the edaphic medium (Flores, 2009). Collembola is a detritivorous group, indicator of balance and good edaphic conditions (humidity and OM quality), according to Siddiky *et al*. (2012), which was present in the forage areas with higher density values, suggesting a certain stability of the soil. In addition, in this area the highest OM and WHC values were reported, which guaranteed the best conditions for the development of this group of edaphic microarthropods (table 1). On the other hand, the barklice –detritivorous insects, known as the pioneers of the re-colonization of disturbed areas– were present in all the evaluated areas; but an increase in their density was observed in the dry season, which can be explained by the performance of this taxon as drought indicator. However, its constant presence in both seasons, areas and sampling years showed that the recovery of the transformed areas (polycrop and forage) had not been achieved yet and that in the pastureland (area of origin) there were disturbances which affected the desired balance in the edaphic medium.

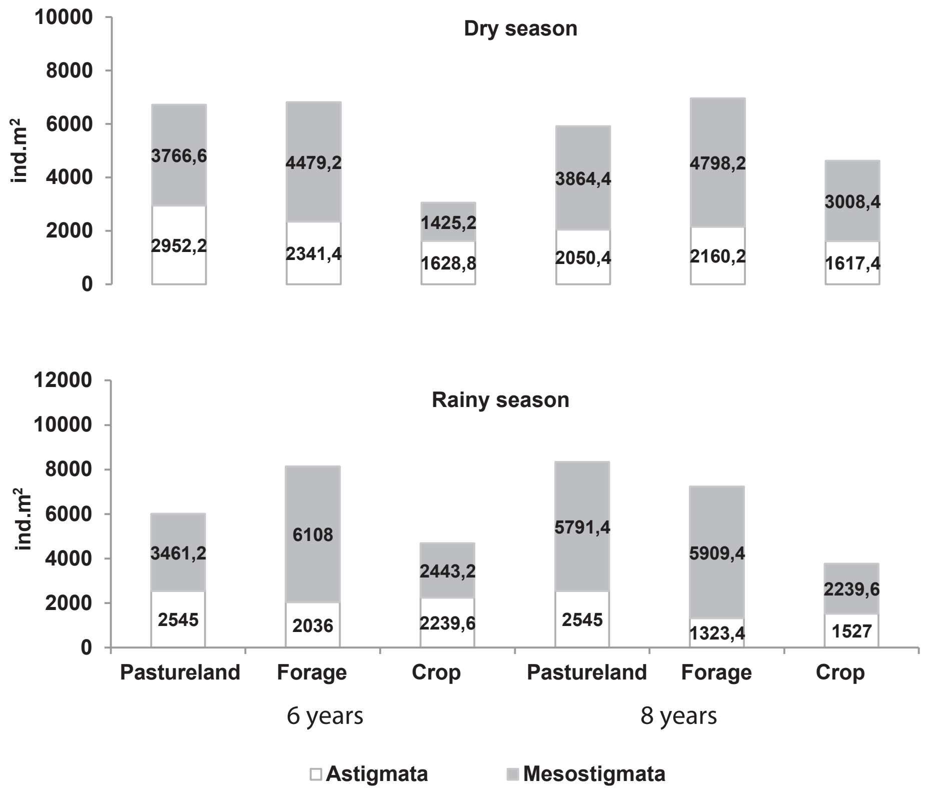

Fig. 3. Astigmata/Mesostigmata ratio at six and eight years, in the dry and rainy seasons.

Transformed area/area of origin ratio

The values of the ratio between the transformed area (forage and polycrop areas) and the one which gave it origin (pastureland), for the total of the mesofauna and for each of the groups that compose it, provide information about the resilience of the soil system, as well as the recovery of the structure and function of the mesofauna populations.

In this study, in the rainy season and in the F/P ratio, the density values of the total mesofauna and of the indicator groups of stability and fertility of the edaphic medium –Oribatida, Mesostigmata and Collembola– showed a slight decrease with time, but they always reached values higher than or very close to one; which indicates that the forage area surpassed, or was very close to reach, the values obtained for such groups in the pastureland –area that gave it origin and which represented the ecosystem without transformations– (table 2). The forage area showed higher soil cover, higher WHC, lower AD and higher OM values (table 1).

In the case of Astigmata and Prostigmata –mites which are bioindicators of the soil infertility and imbalance–, the F/P ratio reached values lower than one. Over time and in the rainy season, the density of Astigmata in the forage area was lower than that of the pastureland. In Psocoptera a similar performance was observed (table 2).

The F/P ratio in the dry season behaved as follows: although a decrease of the total mesofauna was observed, the Oribatida and Collembola, eight years after the change of land use the values were higher than one. In the case of Mesostigmata a slight increase was observed over time. This means that the values obtained for these groups in the pastureland were exceeded in the forage area. All seems to indicate that the management performed in this area improved the conditions in the edaphic medium, which was shown in the wide presence of groups that are indicators of the soil stability and fertility, as well as in the physical and chemical data (see table 1). The values of the F/P ratio for barklice –pioneers of the recovery of disturbed areas– were higher than one in the dry season, that is, the quantities of these insects in the forage area were higher than those reported in the pastureland. They are indicators of drought, for which this season of the year is propitious for the increase of their populations (table 2).

Table 2. Changes in the transformed area/pastureland ratio for the mesofauna and the groups that integrate it.

Group	Dry season				Rainy season			
	six years		eight years		six years		eight years	
	F/P	C/P	F/P	C/P	F/P	C/P	F/P	C/P
	Ind.m^{-2}							
Oribatida	1,636	0,386	1,393	0,338	1,5	0,379	0,826	0,163
Mesostigmata	1,189	0,702	1,24	0,777	1,764	0,705	1,019	0,386
Astigmata	0,793	0,793	0,914	1,053	0,8	0,92	0,52	0,6
Prostigmata	1,0	1,181	0,777	1,222	1,333	1,444	0,833	0,833
Collembola	1,812	0,875	1,49	0,81	1,333	0,619	1,111	0,666
Psocoptera	1,222	0,888	1,241	1,215	1,0	0,894	0,65	0,6
Mesofauna	1,331	0,662	1,187	0,693	1,361	0,674	0,848	0,378

The C/P ratio in the dry season, for the groups which are indicators of soil fertility and stability (Oribatida, Mesostigmata and Collembola) and the total mesofauna, showed density values lower than one and with scarce variation between the sampling years; which proved that their populations in the polycrop area had not reached the existing values in the area that gave it origin (pastureland), which had not undergone any transformations.

With regards to Astigmata and Prostigmata, eight years after the management changes were established the ratio reached values higher than one. This explains that the densities of these groups were higher than those of the pastureland, which indicates the infertility and disturbance present in the polycrop area, with moderate values of AD, OM and WHC (table 1). The behavior of the mesofauna and the groups that compose it, as well as of the physical and chemical indicators, showed the existing imbalance in this area; which was seemingly caused by an inadequate agricultural management and by the influence of the prevailing climate conditions in the dry season.

Analyzing the information provided by the ecological variables of the edaphic mesofauna community as indicator of the quality of soils affected by the agricultural practices applied in this study, it can be considered that the transformation occurred in the forage area has proven to be efficient in the recovery of the edaphic medium, due to the higher soil cover and the contribution and quality of the litter with low C:N ratio, as well as because of the contribution of dejections and organic amendments. These elements had a positive incidence on nutrient recycling, the improvement of the physical properties of the soil, the increase of the OM values and its rapid decomposition by the soil biota. In the case of the polycrop area, the sowing of short-cycle crops produced a poor and instable plant cover. In addition, the evaporation increased and there was higher desiccation, as well as alterations in the edaphic conditions. The crop rotation caused, to some extent, the disturbances linked to the cultural practice (alteration of the soil structure, removal of the roots and lower contribution of plant residues). Nevertheless, the use of introduced species can lead to the formation of diversity-poor replacement ecosystems, which reach new levels of relative stability (Bedano, 2011) which hinders the restoration of the previously existing conditions and ecosystems. It would be necessary to continue the monitoring of these areas in time, using the same criteria and indicators.

It is concluded that the density of Collembola and Psocoptera, as well as the Oribatida/Astigmata, Oribatida/Prostigmata, Astigmata/Mesostigmata and transformed area/area of origin ratios constitute good indicators of the soil quality. According to the evaluated indicators, the management performed in the forage area seems to be the most accepted agricultural practice for the conservation of the soil biological quality; while in the polycrop area a remarkable transformation has not been shown yet which drives it close to the basal state from which it comes.

Received: November 30, 2013
Accepted: January 13, 2014