Soil macrofauna community of amazonian agroforestry systems

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Introduction

In the Brazilian Amazon region, the total deforested area until 1997 was 53 Mio. hectares (INPE, 1998). Approximately 95% of this area was occupied by pastures, half of which were considered degraded (Fearnside and Barbosa, 1998) as indicated by a partial or total disappearance of the forrage plants. The degradation of these pastures can be attributed to the poor management of the vegetative cover, pest attack, low chemical soil fertility especially with regard to available P, the degradation of the soil structure and the reduction of the diversity of the soil macroinvertebrates.

The soil macrofauna exerts a vital function with respect to soil structure and nutrient cycling in tropical ecosystems (Oades, 1993). The regulation of the mineralization of soil organic matter by the macroinvertebrates occurs through the selective activation of the dormant microflora in the soil in distinct temporal and spatial patterns (Wardle and Lavelle, 1997).

The structure and abundance of the soil macrofauna community are very sensitive to the management of the vegetative soil cover (Lavelle et al., 1992). Lavelle and Pashanasi (1989) observed that in the Peruvian Amazon, a drastic change in the biomass and diversity of the soil macrofauna occured after the installation of pastures and annual crops. Barros (1999) observed in a chronosequence of pastures, fallows and agroforestry systems in central Amazonia that the agroforestry systems permitted the fastest regeneration of the soil fauna. Consequently, the recuperation of degraded pastures through agroforestry systems seems to be a viable option for this region.

The objective of this study was to analyze the effect of different agroforestry systems which were planted on degraded pasture land on the recolonization of the soil by the macrofauna. We also tried to identify indicator organisms for the regeneration state of the soil.

Materials and methods

The study was carried out on the experimental station of the Embrapa Amazonia Ocidental near Manaus (2°31' S, 60°01' W). The climate is humid tropical with an annual mean temperature between 24 and 26°C and annual rainfall in excess of 2000 mm, with 2 months with less than 60 mm of rain. The soil is a Xanthic Ferralsol with very clayey texture. The natural vegetation is lowland rainforest.

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The experimental area had been used as pasture during approximately 5 years after forest clearing and planting with *Brachiaria humidicola*. Because of poor management (e.g. no weeding and fertilization), the areas were abandoned thereafter and developed a fallow vegetation during 4 to 6 years.

The experiment was established in three randomized blocks with 5 treatments each. Plot size was 60 x 50 m. Four of the treatments were different agroforestry systems, and the fifth treatments was the control which remained under fallow. The three blocks differed slightly in their history, block I having been used as pasture for 4 years, block II for 5 years and block III for 8 years.

The first treatment (agrosilvocultural system 1, AS1) was a palm based system composed of cupuacu (*Theobroma grandiflorum*), pupunha (*Bactris gasipaes*), acai (*Euterpe oleracea*) and the forest tree *Columbrina glandulosa*. During the first years, a rotation of rice, cassava and mucuna (*Mucuna pruriens*) was sown.

The second treatment (agrosilvocultural system 2, AS 2) was a fruit tree based system composed of the following tree species: cupuacu, inga (*Inga edulis*), mahogany (*Swietenia macrophylla*), Brazil nut (*Bertholletia excelsa*), acerola (*Malphigia emarginata*), papaya (*Carica papaya*), jenipapo (*Genipa americana*), teak (*Tectona grandis*), passion fruit (*Passiflora edulis*) and araca-boi (*Eugenia stipitata*). Between the trees, the same food and cover crops were sown as in AS1 during the first years.

The treatments 3 and 4 were agrosylvopastoral systems with the same planting design, but differed in the input level: high input (HI) with mechanized soil preparation, liming and regular application of NPK fertilizer; and low input (LI) with manual soil preparation and fertilization with P only. The tree species used were inga, mahogany and parica (*Schizolobium amazonicum*), planted in triple rows at 20 m distance between the rows. During the first years, the space between the trees was sown with maize, cowpea and cassava in HI, and with rice, cassava and mucuna in LI. Afterwards, a fodder legume (*Desmodium ovalifolium*) was planted between the tree rows.

The soil macrofauna was studied in 1995, when the experiment was 3 years old. According to the TSBF methodology (Anderson and Ingram, 1993), soil pits of 25 x 25 x 25 cm were excavated, and the soil was separated into litter (if present), 0-5 cm, 5-10 cm and 10-25 cm. The macrofauna was hand-sorted, identified to the order level, counted and weighed. Separate, replicated collections were made under the different tree species and under the fodder crop in the four agroforestry systems and in the fallow.

The data set was analyzed in three ways: 1) comparison of the total soil macrofauna in the different agroforestry systems; 2) comparison of the total soil macrofauna under the different tree species within each system; and 3) analysis of the distribution of selected macrofauna groups within the systems.

Results and discussion

Systems comparison

Faunal density (ind. m^{-2}) and biomass (g m^{-2}) did not differ significantly between the systems. However, the richness (groups per system) was significantly higher in the silvopastoral systems HI (13 groups) and LI (12 groups), which were similar to the fallow (12 groups), than in the agrosilvicultural systems AS1 (7 groups) and AS2 (8 groups). These results point to the importance of a fodder or cover crop for the initial establishment of a diverse soil fauna after clearing an area for agricultural use. Independently of the number of tree species present, the most important factors determining the diversity of the soil fauna during the establishment phase of the systems seemed to be the creation of a favourable microclimate and the litter additions to the soil through the ground cover.

The vertical distribution of the soil organisms reflected the fact that in the systems AS1 and AS2 there was very little litter on the soil during the first 3 years. The systems HI and LI, in contrast, had a similar faunal density in the litter layer as the fallow, with 338, 205 and 352 ind. m^{-2}, respectively. In the upper 5 cm of soil, there were 807 and 693 ind. m^{-2}, respectively, in HI and LI. Significantly lower values were found in AS1 and AS2 with 225 and 290 ind. m^{-2}, respectively. In HI and LI, 42% and 44% of the fauna until 25 cm soil depth were concentrated at 0-5 cm depth, as compared to 20% and 22% in AS1 and AS2, respectively. These results illustrate again the importance of the cover crop for the colonization of the superficial soil horizons by the fauna which contributes to the decomposition and incorporation of the litter into the soil.

Effects of individual tree species within the agroforestry systems

Within the systems HI and LI, we compared the fauna under the tree rows and under the *Desmodium* fodder crop between the rows. There was a non-significant tendency that the soil under the trees had a higher faunal density and biomass than under the *Desmodium*, but the soil under the *Desmodium* had more fauna groups. There was no significant difference between the two positions within the systems with respect to the vertical distribution of the fauna in the soil.

Within AS2, the fauna under four tree species was collected separately: Brazil nut, mahogany, cupuacu and passion fruit. The fauna biomass under Brazil nut (70 g m^{-2}) and mahogany (50 g m^{-2}) tended to be higher than under cupuacu (10 g m^{-2}) and passion fruit (4 g m^{-2}, $p=0.089$), indicating that trees with relatively fast growth favour the development of the soil macrofauna. There were however no significant differences between the tree species with respect to fauna density and richness. The distribution of the fauna in the soil was more superficial under passion fruit and mahogany than under cupuacu and Brazil nut.

In the system AS1, the soil under peachpalm had a significantly higher fauna density than the soil under cupuacu, with 4402 and 524 ind. m^{-2}, respectively ($p=0.005$). This confirms the conclusion that fast-growing tree species such as peachpalm have a more favourable effect on the initial development of the soil fauna in the system than slow-growing species like cupuacu. Under cupuacu, the fauna had a more superficial distribution than under peachpalm, with 34% of the fauna in 0-5 cm depth under cupuacu as compared to 5% under peachpalm ($p=0.058$). This difference may be related to the strong root development of the peachpalm.

Influence of tree species on selected fauna groups

Among the litter feeders, diplopods and isopods showed a response to the input level in the silvopastoral systems HI and LI. For diplopods, the density and biomass levels under the *Desmodium* were 169 ind. m^{-2} and 3.4 g m^{-2}, respectively, in HI and 82 ind. m^{-2} and 1.4 g m^{-2}, respectively, in LI. For isopods, the difference between the input levels was even more pronounced, with 510 ind. m^{-2} and 3.8 g m^{-2}, respectively, under the *Desmodium* in HI and 142 ind. m^{-2} and 1.2 g m^{-2}, respectively, in LI.

The earthworms were also affected by the input level, but the effect could mainly be observed under the tree rows. The density and biomass values for the earthworms were 152 ind. m^{-2} and 12 g m^{-2}, respectively, in the system HI as compared to 67 ind. m^{-2} and 4 g m^{-2}, respectively, in the system LI.

We speculate that the effect of the input level on these fauna groups was mainly indirect and was principally mediated by the faster growth of the plants in the HI plots with consequently increased litter production and improvement of the microclimate in the litter layer and the topsoil.

Under the trees in the agrosilvicultural system AS2 diplopods were missing and isopods were only present under passion fruit. The absence of a litter layer (with the exception of passion fruit where a sparse litter layer had already developed) is the obvious reason for the absence of these groups which live in and feed on the litter. Predators such as spiders and chilopods were also practically absent in this system for the same reason, as they feed on litter-dwellers such as mites and spring-tails.

Earthworms were found under all the four tree species in AS2 with the lowest concentrations under passion fruit. All the earthworms encountered belonged to the endogeous group (i.e. living in the soil), with oligo-humic types under Brazil nut and cupuacu and poly-humic types under mahogany and passion fruit. The former group is less demanding in terms of soil organic matter, and their distribution under the four tree species may reflect the lower quality of the hard Brazil nut and cupuacu leaf litter as compared with the softer magogany and passion fruit leaves.

In the system AS1 isopods were already present, presumably as an effect of the presence on the soil of the harvest residues from the peachpalms for heart of palm production. The isopod density was similar under peachpalm and cupuacu, but the much higher biomass under peachpalm (5.5 g m^{-2}) than under cupuacu (0.2 g m^{-2}) showed that different isopod species with differing body size dominated under the two tree species.

Comparing the soil under cupuacu in the two agrosilvicultural systems, a higher number of fauna groups was found in AS1 (10) than in AS2 (5). In AS2, the diplopods, isopods, gastropods, symphila and hemiptera were absent. Also, there were approximately 4 times more earthworms in AS1 than in AS2. In AS1 these were poly-humic species which lived close to the soil surface (72% at 0-10 cm), and in AS2 they were oligo-humic species living deeper in the soil (32% at 0-10 cm). This difference may reflect the improvement of the living conditions for demanding species by the heart of palm harvest which left a layer of high-quality harvest residues on the soil.

Conclusions

The investigation of the soil fauna communities of four agroforestry systems in central Amazonia allowed to identify some factors which may contribute to a rapid establishment of the fauna after land clearing for agricultural use. Of particular importance seem to be a permanent soil cover, e.g. through cover or fodder crops, and the development of a litter layer. Their presence resulted in a higher diversity of the soil fauna in the silvopastoral than in the agrosilvicultural systems in this study. Within the agroforestry systems, tree species differed in their effect on the soil fauna.

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