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Soil macroinvertebrates under *Guadua angustifolia* Kunth in two study sites in the Colombian coffee growing region

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Abstract: The abundance, biomass and diversity of macroinvertebrates were determined in two study sites of *Guadua angustifolia* in the Department of Quindío (Quimbaya and Buenavista), Colombia. Sampling was carried out in four landuse sites; *Guadua* with high harvest (GHH), *Guadua* with low harvest (GLH), pasture (P) and forest (F). The systems under forest and pasture were used as reference points for comparison. The results showed that different soil management practices generated changes in the composition and structure of macroinvertebrate communities. Systems with high intervention (e.g. *Guadua* with high harvest) presented high biomass values and low diversity of species. The impacts generated by *Guadua* extraction and different soil management practices in short time periods, could have influenced the physical and chemical degradation of the soil, causing changes in biomass, abundance and diversity in soil macrofauna. On the contrary, systems like *Guadua* with low harvest maintained similar conditions to those of a forest and retained components of the original fauna, probably due to rich organic matter, shade and high water holding capacity of these systems.

Key words: *Guadua angustifolia*, macroinvertebrates, biomass, abundance, diversity.

INTRODUCTION

Soil macroinvertebrates play an important role in the conservation and fertility of soils. Among the numerous factors that determine the quality of soils, biological regulatory factors, mediated by soil macroinvertebrates, may be the most important (Lavelle *et al.*, 1994). Macroinvertebrates are responsible for affecting the physical and chemical properties of soil by influencing the dynamics of organic matter, nutrient cycling and plant growth (Stork and Eggleton, 1992). They also have an effect on conditions of life, abundance and structure of other soil communities (Marin, 2000). Since these organisms are extremely sensitive to changes in the environment caused by human or natural impacts, macroinvertabrate communities can be used as an additional tool for the determination of soil quality.

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In Colombia, macrofauna has been studied under different agro-ecosystems. For example, the introduction of pastures, forest species (*Pinus patula*) and annual crops (coffee, yucca, beans and corn) causes a reduction in diversity and an increment in density, presenting few species of ants and earthworms. On the other hand, it has been observed that systems with canopy covering and soil surface litter, present high diversity, density and biomass (Feijoo and Knapp, 1998). It has also been found that annual crops have dramatic effects on the population of earthworms and arthropods. The factors responsible for this phenomenon are the use of fertilizers, disappearance of soil surface humus and climatic modification caused by the pruning of the natural vegetation, together with the application of plaguicides (Decaens *et al.,* 2001). Disturbances of ecosystems eliminate numerous species, mainly those with narrow niches (Lavelle *et al.,* 1994). Plantations with leguminous trees are sustainable environments since they offer diverse resources for decomposition. However, annual cultivation practices decrease most soil fauna, and few weeks after the establishment of these cultivations, biomass rapidly decreases. On the contrary, traditional cultivation techniques can conserve local fauna.

Guadua angustifolia stands with low intervention levels create special microclimates, which are characterized by a high water holding capacity vital for development of floristic and faunistic diversity. They also play an important role in the maintenance of soil fertility as they contribute large quantities of organic matter to the soil, which is later transformed into nutrients by diverse processes of decomposition (Decaens *et al.*, 2001). In the Colombian coffee growing region, *G. angustifolia* stands are of great importance, since they promote the existence of flora and fauna. In these systems, Coleoptera and ants are the most abundant individuals.

The main objective of the present study was to estimate abundance, biomass and diversity of soil macroinvertebrates and assess their importance as indicators of agro-ecosystem quality in two study sites in the Department of Quindío, located in the coffee growing region of Colombia.

MATERIALS AND METHODS

Study sites and sampling design

Sampling was carried out in La Cascada Farm and in the Experimental Station of Paraguaicito. La Cascada is located in the municipality of Quimbaya, in the northwestern part of the Department of Quindío between 4° 35′ and 4° 40′ N latitude and between 75 ° 50′ and 75 ° 55′ E longitude. The area has an altitude of 1200 m.a.s.l. The mean annual temperature is 21 °C and mean annual precipitation is 2200 mm. The Experimental Station of Paraguaicito is located in the municipality of Buenavista, in the southwestern part of the Department of Quindío at 4° 23′ N latitude and 75 ° 44´ E longitude. It has an altitude of 1250 m.a.s.l. The mean annual temperature and precipitation are 20.9 °C and 2200 mm respectively.

To carry out the experiment, four different landuse practices were selected (pasture, forest, *Guadua* with low and high harvest). These were chosen with similar landscape and altitudinal (1100 m.a.s.l) conditions. The quantification of macroinvertebrates was done as per the methodology of Tropical Soil Biology and Fertility Program (TSBF) (Anderson and Ingram, 1993) and with surface soil gathering traps. The following abbreviations are used to identify the sampled systems:

GHH1 = *Guadua* with high harvest. GHH2 = *Guadua* with high harvest, repetition.
GLH1 = *Guadua* with low harvest. GLH2 = *Guadua* with low harvest, repetition.

In each system two replicate transects of 28 m each were traced leaving a distance of 20 m in between. Each transect was located 10 m away from the boundary of the system, and from the transect seven samples were taken at regular 4 m intervals (Fig. 1).

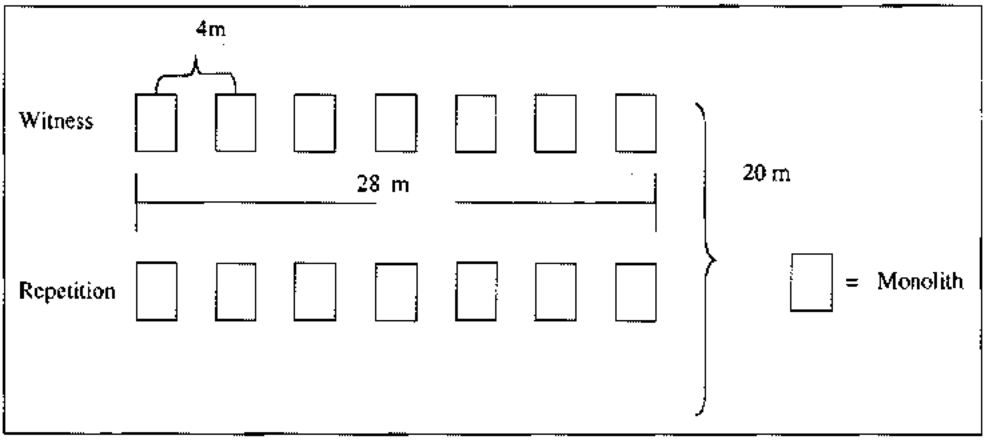

Figure 1. Design used for the definition of transects in each landuse system.

The sampling was done by isolating monoliths of 25 × 25 ×30 cm. From each monolith three layers of 10 cm each were extracted (0–10, 10–20 and of 20–30 cm) (Fig. 2). Macroinvertebrates were collected and grouped into earthworms, ants, termites, Coleoptera, Arachnida, Diplopoda, larvae of Coleoptera and other invertebrates. Their density and biomass were also determined. Earthworms were kept in 5 per cent formaldehyde and other macroinvertebrates were kept in 70 per cent alcohol. To broaden the information of social insects, sampling was also done with surface soil gathering traps. These traps were located in each system, where 81 plastic cups with alcohol were distributed in an area of 15 m^2.

RESULTS

La Cascada Farm (Quimbaya)

Abundance, biomass and diversity of macroinvertebrates using TSBF

Of the 452 individuals/m^2 × 0.3 m found with the TSBF methodology, the landuse GLH contained 286 individuals (179 in GLH1 and 107 in GLH2), contributed mainly by larvae of Coleoptera which formed 47.5 per cent. Of the total of individuals in this system, more than 75 per cent were found in the first 20 cm of soil depth. GLH presented the highest diversity with 15 taxonomic units, and the lowest biomass (26.8 g fresh weight/m^2 × 0.3 m), represented by larvae of Coleoptera (Table 1). In GHH, 166 individuals (91 in GHH1 and 75 in GHH2) were found; once again larvae of Coleoptera were the major component of this abundance (33.1%). The biomass under this system was of 28.4 g fresh weight/m^2 × 0.3 m (Table 1), where 70.7 per cent of this value was contributed by earthworms. More than 70 per cent of the total individuals inhabited the first 20 cm of the soil. GHH presented 12 taxonomic units (Figs. 2, 3).

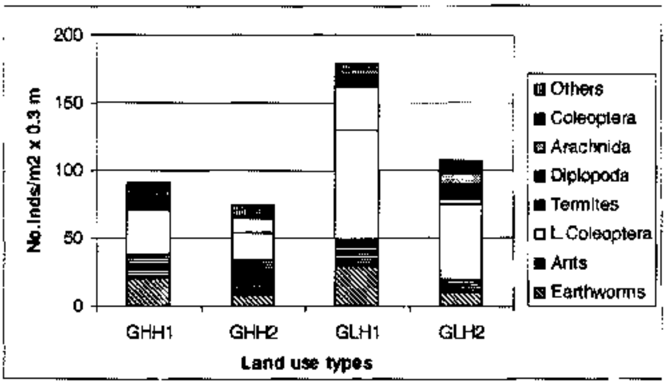

Figure 2. Abundance of macroinvertebrates with TSBF in *Guadua* with different harvest levels at La Cascada Farm.

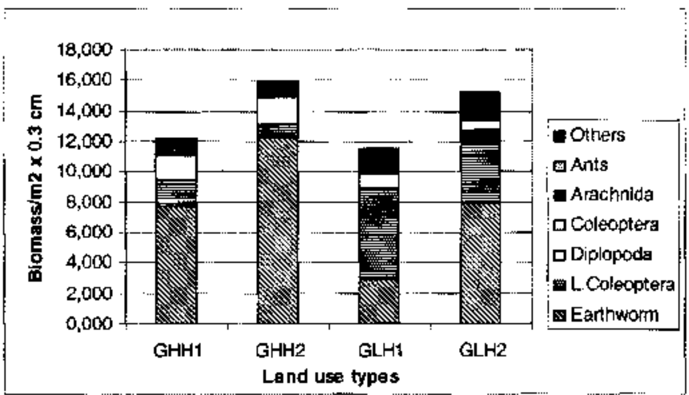

Figure 3. Biomass of macroinvertebrates with TSBF in *Guadua* with different harvest levels at La Cascada Farm.

The species diversity variable did not present significant differences in the systems under *Guadua*; diversity values for these were similar to the ones for pasture and forest. Evidently the diversity was independent of harvest levels. In general terms, earthworms contributed 54.4 per cent and 39.2 per cent of the abundance respectively in pasture and forest. For biomass in both systems, these organisms were the major component (93.9%). Larvae of Coleoptera contributed 47.5 per cent and 33.1 per cent of the abundance in the systems under *Guadua* with low and high harvest, with more than 40 per cent in GHH and 47.5 per cent in GLH, biomass was also dominated by larvae of Coleoptera (Table 1).

Abundance, biomass and diversity of macroinvertebrates using surface soil gathering traps

Of the 81 individuals found by the use of surface soil gathering traps, ants were the most abundant (with 56 indviduals/m^2 × 0.3 m), especially in GLH. Even though biomass was very similar in both systems under *Guadua*, the distribution of this variable in GHH was very even shared by ants, arachnids and crickets, while in GLH, the biomass was dominated mainly by ants. In taxonomic richness, ants found in the GLH were the most diverse group with 15 different species (Figs. 4, 5).

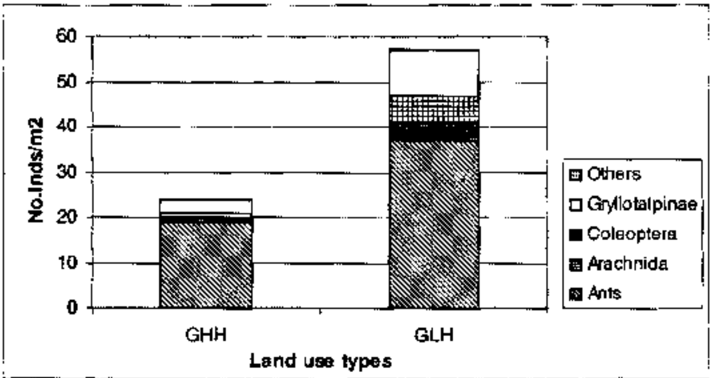

Figure 4. Abundance of macroinvertebrates with surface soil gathering traps in *Guadua* with different harvest levels at La Cascada Farm.

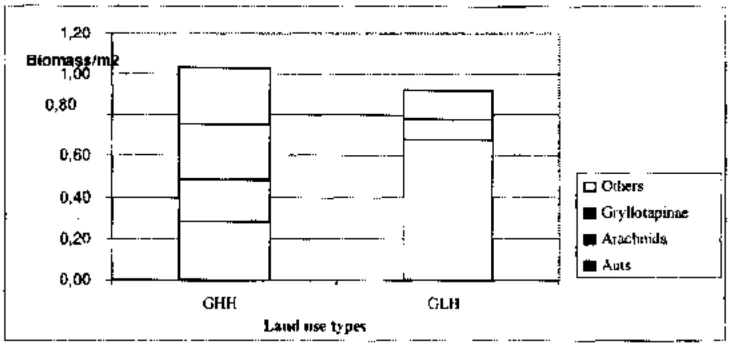

Figure 5. Biomass of macroinvertebrates with surface soil gathering traps in *Guadua* with different harvest levels at La Cascada Farm.

Experimental Station Paraguaicito (Buenavista)

Abundance, biomass and diversity of macroinvertebrates using TSBF

Both, GLH and GHH presented very similar values of abundance, with 568 (356 in GLH1 and 212 in GLH2) and 556 individuals (234 in GHH1 and 322 in GHH2). The GLH landuse system was dominated by termites (31.9%), and in biomass, earthworms contributed 67.3 per cent of the total weight. The highest diversity was found under this landuse, with 18 taxonomic units. A major part of the abundance (61.8%) and of the biomass (78.4%) was concentrated in the 0-10 cm layer. GHH presented abundance values of 556 individuals, where earthworms presented the highest values for abundance (67.8%) and biomass (90.6%). Most of the macroinvertebrates were found in the first 10 cm and 14 taxonomic units were found under this system (Figs. 6, 7).

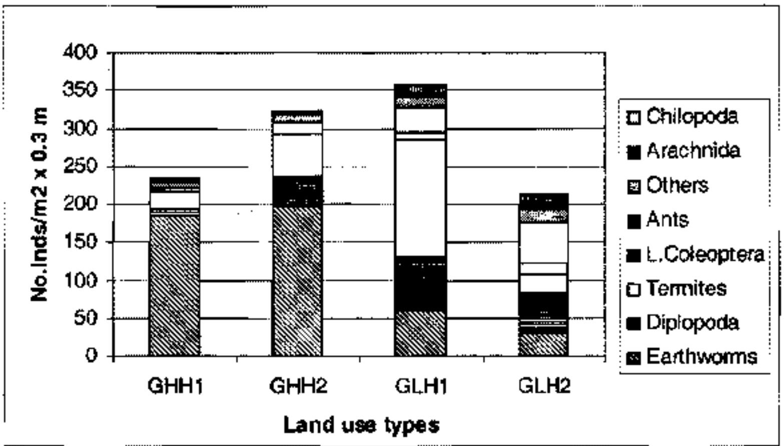

Figure 6. Abundance of macroinvertebrates with TSBF in *Guadua* with different harvest levels at the Experimental Station of Paraguaicito.

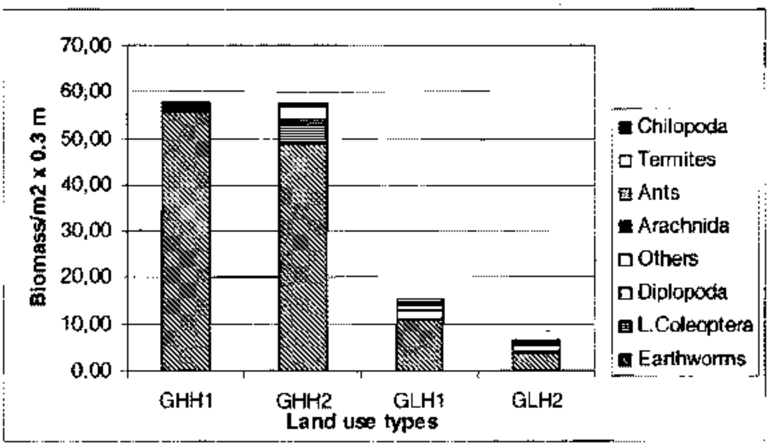

Figure 7. Biomass of macroinvertebrates with TSBF in *Guadua* with different harvest levels at the Experimental Station of Paraguaicito.

With regard to the results obtained for different landuse systems, the pasture had the highest number of individuals (651), where 43.3 per cent of the abundance was contributed by earthworms; these had also a significant representation in biomass with 76.5 per cent. In terms of diversity this system had the lowest value (9 species), while forest was the most diverse with 17 species. Forest and GLH presented similar values of diversity, with 14 taxonomic units each. It was observed that earthworms were a major component in the abundance (>42%) of the systems under pasture, forest and GHH, and they contributed with more than 67 per cent of the total biomass in all four landuses (Table 2).

Abundance, biomass and diversity of macroinvertebrates using surface soil gathering traps

Among the two landuse systems of *Guadua*, a total of 91 individuals were collected. These were represented mainly by four taxonomic groups. The GHH system presented the highest abundance (66 individuals), where ants contributed with more than 50 per cent. On the other hand, the abundance of individuals was of 25 in GLH. The biomass among the two systems was of 1.36 $g/m^2 \times 0.3$ m. The GLH system had the highest value (0.90 $g/m^2 \times 0.3$ m), contributed mainly by the group of other invertebrates. With surface soil gathering traps, the taxonomic groups that presented the highest taxonomic richness were ants and Coleoptera, with seven and six species respectively; these were found under GHH (Figs. 8, 9).

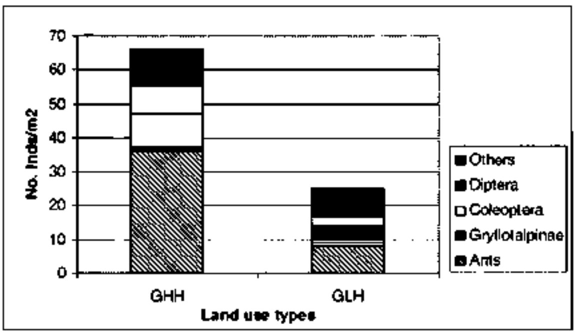

Figure 8. Abundance of macroinvertebrates with surface soil gathering traps in *Guadua* with different harvest levels at the Experimental Station of Paraguaicito.

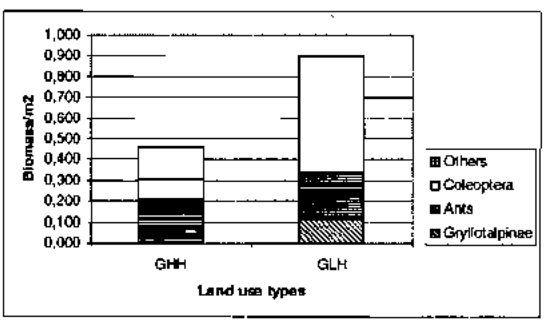

Figure 9. Biomass of macroinvertebrates with surface soil gathering traps in *Guadua* with different harvest levels at the Experimental Station of Paraguaicito.

DISCUSSION

Even though the landuse systems under *Guadua* were not characterized by a high number of individuals, they stood out for their species diversity and taxonomic richness. Higher species diversity was found under agroforestry systems than in agro-ecosystems. This can be explained by the fact that agroforestry systems simulate the forest-like structure of vegetation, provide better shade and organic matter that improves the structure of the soil and generates a micro-environmental condition which favours the formation of associations of different taxonomic groups (Netuzhilin *et al.*, 1999).

In GLH, several species of Coleoptera were identified. These were the most abundant organisms under *Guadua*. Their presence can be explained by the constant contribution of organic matter by *Guadua* stands, which served as a food source and provided favourable conditions for the establishment of their habitats. Also, these organisms benefited the eco-system by developing stable structural elements and reducing density and soil compaction (Giraldo and Sabogal, 1999).

Under GHH and GLH, the larvae of Coleoptera were the most abundant. *Guadua* roots provide an ideal environment for these macroinvertebrates (Bueno, 1998; Camero, 1999). On the other hand, Coleoptera adapt very well to this type of systems, since these offer suitable living conditions highly aerated, unflooded and uncompacted soils for them to thrive (Giraldo and Sabogal, 1999).

The presence of some soil excavating earthworm species such as *Onycochaeta elegans* and *Pontoscolex corethurus* in GHH suggests that the soil was probably hardened by the formation of micropores which hinders the passage of water and oxygen to deeper layers (Arango and Benitez, 2004). In similar studies carried out in Cuba, *O. elegans* has been recorded in ecosystems with different levels of perturbation (Martinez and Sanchez, 1994). The La Cascada Farm, where the pressure generated by the activities of harvesting could have probably caused a physical compaction of the soil and loss of its structure, thus causing changes in biomass and abundance of soil macrofauna.

The native species *Martiodrilus heterostichon*, found under GHH and GLH, is known for inhabiting sub surface soil layers (Feijoo, 2001). However, it was found near the surface in the sampled plots in La Cascada. Presence of this species close to surface is probably due to the high moisture after the rainy season, when these organisms ascend from deeper soil layers to the surface in search of soil rich in organic matter.

Of the total earthworms found under GHH, only 5 per cent were exotic and these contributed to 0.55 per cent of the biomass. Their presence can be regarded as an early warning of soil degradation. This is probably an indication that the management practices adopted in this system are creating a suitable atmosphere for the arrival of exotic species. Plantation systems contribute ample quantities of organic matter to the soil, maintain similar conditions to those of a forest and retain components of the original fauna (Bueno, 1998; Neituzhilin *et al.*, 1999; Lavelle and Fragoso, 2001). However, the level of perturbation and/or the establishment of an herbaceous stratum similar to that of a forest may provide niches that can promote the colonization of exotic species. This explains why the systems under GHH and GLH in the Experimental Station of Paraguaicito, presented similar taxonomic diversity of earthworms and the coexistence of native and exotic species.

CONCLUSIONS

Agro-ecosystems with high soil perturbations and with different types of management practices (pastures and *Guadua* stands with high levels of harvest) presented low diversity, where a few species such as earthworms and ants prevailed in abundance and biomass. While those systems with less perturbation (forest and *Guadua* stands with low levels of harvest) were very significant in their diversity of species and taxonomic richness.

Macroinvertebrates from the sampled study sites of the coffee growing region of Colombia were sensitive to environmental changes of the soil, the response to these changes were manifested in the type of species found. Different management and harvest levels of the different landuse systems generated changes in the composition and structure of the soil macrofauna.

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