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Quantifying soil macrofauna in a Colombian watershed

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Summary. From April to September 1994, macrofauna density, total biomass, and species diversity of earthworms were measured across a range of land use types in the Cabuyal River watershed. The methodology recommended by the Tropical Soil Biology and Fertility Program (TSBF) was used. Macrofauna density, biomass, and diversity of earthworm species varied considerably across land use types, and depths. Principal component analysis yielded three factors that accounted for 71.8% of the total variance in macrofauna density. High taxonomic units values occur in the Andean forest (98 observed), decreasing dramatically in pastures (ranging from 28 to 13) and farm lands (ranging from 31 to 18).

Key words: Cabuyal, river watershed, earthworms, land use, soil macrofauna, diversity

Introduction

Invertebrates are major determinants of soil processes in tropical ecosystems. Key groups such as earthworms, termites, ants, and litter-feeding arthropods have been shown to affect the physical structure of the soil and influence nutrient dynamics through their effects on immobilisation and humification (Anderson & Flanagan 1989; Lavelle et al. 1992; Lavelle et al. 1994).

Only recently have studies been conducted on the importance of macroinvertebrates in paleotropical and neotropical regions and the impact that environmental disturbance limited to land use systems has on them (Collins 1980; Lavelle & Kohlmann 1984; Lavelle & Pashanasi 1989; Decaëns et al. 1994).

CIAT's Hillsides Program has been researching on four issues, one of which seeks to (1) develop land use alternatives that preserve the soil's biodiversity while improving fertility, and (2) use soil macrofauna as indicators of disturbance. This study compared the diversity, abundance, and biomass of soil macrofauna in hillside areas under ten different land uses.

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Materials and Methods

Study sites

The study was carried out in the Cabuyal River watershed, in the Colombian Andes. The watershed covers 7,000 ha and is located about 120 km from Cali (from 76° 33' W to 76° 30' W and 2° 42' N to 2° 52' N). Samples were taken in the intermediate (1,450-1,550 m) and upper (2,000-2,200 m) parts of the watershed. The study was conducted between April and September, during the 1994 dry season, at 10 sites that differed according to land type and land use frequency:
1. Secondary forest (SF); **2.** 40-year-old forest (S40); **3.** Forest of more than 40 years (S40+); **4.** Fallow (Bracken undergrowth, BU); **5.** Traditional coffee crop (CC); **6.** Pine plantations (PP); **7.** Cassava associated with beans and maize (CA); **8.** Kikuyu grass (*Pennisetum clandestinum*) (KG). **9.** Yaragua grass (*Melinis minutiflora*) (YG); **10.** *Brachiaria humidicola* pastures (BP).

Methods

Samples were taken, following the methodology of the TSBF Program (Anderson & Ingram 1993). Invertebrates were grouped into taxonomics units (TU) (Table 1), and their density and biomass were measured. Earthworms were kept in 5% formaldehyde and the other invertebrates, in 70% alcohol. 23 taxonomic units from 10 sites were subjected to principal component analysis (PCA,SAS version 609). The type of vegetation and land use were determined.

Table 1. Major correlations between factors extracted in the PCA of macroinvertebrate density

Taxonomic Units	Factor I (43.6%)	Factor II (15.4%)	Factor III (12.8%)
Diversity	0.9	-0.14	0.32
Termites	0.95	0.05	0.12
Myriapoda	0.88	0.004	-0.32
Diptera	0.88	0.04	-0.14
Arachnida	0.96	0.09	0.06
Lepidoptera	0.95	0.01	0.15
Isopoda	0.9	0.34	-0.09
Mollusca	0.92	-0.14	0.08
Hirudinea	0.95	0.06	0.17
Epigeic earthworms	-0.17	0.83	0.08
Endogeic earthworms	-0.13	0.72	-0.15
P.corethrurus	-0.18	0.72	0.52
Oligohumic endogeic	0.1	-0.58	-0.16
Coleoptera	0.26	-0.77	0.12
Blattidae	0.24	0.31	0.25
Ants	-0.08	-0.45	0.66
Mermithidae	-0.10	-0.21	0.71

Results

Three factors accounted for 71.8% of variance in total macrofauna (Table 1). Factor I accounted for 43.6% and was interpreted as the effect of dense vegetation and surface soil mulch. The diversity of macroinvertebrates was high- termites, myriapoda, arachnida, diptera, lepidoptera, isopoda, dermaptera, mollusca and hirudinea. Factor II, accounted for 15.4% of variance, and was allocated as the effect of felling and burning. Sites are characterized by the presence of numerous roots and shade, serial successions, perennial crops and pastures of kikuyu grass. Its diversity was intermediate-epigeic, endogeic and oligohumic endogeic, including *Pontoscolex corethrurus*, coleoptera, and blattidae. Factor III accounted for 12.8% of variance and was interpreted as the effect of erosion, separating those sites, prepared with animal traction, that presented high soil deterioration and low diversity, abundance, and biomass of soil macrofauna. Ants, *P. corethrurus* and Mermithidae predominated.

Secondary forest possess great taxonomic richness (98 TU) and high population densities (6,790 individuals/m²) and biomass (98.6 g/m²). Coleoptera communities form the greatest biomass component (52.2%), followed by termites (13.2%) and earthworms (12.5%). The diversity of earthworms was high, with 9 species: *Martiodrilus savanicola, M. agricola, Martiodrilus sp., Glossodrilus sp., Onoreodrilus sp., Periscolex sp., Thamnodrilus sp., Dichogaster sp.* and an unidentified species.

Forest (S40) and (S40+) had similar values for diversity (27 and 31 species, respectively), although they differed in population density (2,056 and 3,932 individuals/m²) and biomass (27.04 and 91.42 g/m²).The greatest biomass component was formed by earthworms (S40, 81%; S40+, 26.6%) and coleoptera (S40, 10.4%; S40+, 20.6%). The diversity of earthworms was high for both sites. S40 hosted 7 species: *M. heterostichon, Glossodrilus sp., Periscolex sp., P. corethrurus, Dichogaster sp., Amynthas gracilis,* and *Periscolex sp.*, whereas S40+ had 5 species: *Martiodrilus sp., M. agricola, Thamnodrilus sp., Periscolex sp., A. corticis* and *Dichogaster sp.* Land use types CC, CA, and PP differed in fauna density (3,352; 1,187 and 870 individuals/m², respectively); both CC and CA had high biomass (115.7 and 78.9 g/m², respectively), whereas PP had the lowest value of all sites (3.2 g/m²). Compared with SF, diversity was low (CC, 31; CA, 18; and PP, 15 taxonomic units).

Invertebrate numbers were greater in the 0-10 and 10-20 cm layers. In CC and CA, biomass was dominated by earthworms (79.5% and 80.8%, respectively). Four native (*M. savanicola, Periscolex sp., P. corethrurus, A. gracilis*) and one exotic (*P. corethrurus*) earthworm species were concentrated in the top 10 cm (62.1% in CE and 40.9% in CA), followed by Coleoptera (8.9% and 17.1%, respectively). Populations were low in CP, with coleoptera predominating (73.98%). Only one earthworm species (*Glossodrilus sp.*) was prevalent in the top 10 cm of the soil (40.9%). Fauna was restricted to top 10 cm of the soil in KG (78.4%), YG (62.9%) and BP (52.1%), and respective values for species richness were 20,28 and 13 TU. Density fluctuated betweeen 2,038 individuals/m² for KG and 6,443 and 1,965 individuals/m² for YG and BP, respectively; ants predominated especially in YG (*Ectatoma tuberculatum, Dolichoderus sp., Hypoponera sp., Solenopsis sp. and Tranopelta sp.*) and KG (*Linepithema sp., Pheidole sp., Neivamyrmex sp., Acropyga sp.*) Biomass values (g/m²) were 67.9 for KG, 33,9 for YG, and 73.4 for BP, with earthworms and coleoptera making the greatest biomass contribution in the cases of KG (83.4%, 13.8%) and BP (77.9%, 16%), while coleoptera and ants made the greatest contribution in YP (64% and 21.5%). In KG, nine earthworm species were found: *Martiodrilus sp., M. agricola, M. savanicola, Glossodrilus sp., Thamnodrilus sp., Dichogaster sp., A. gracilis, A. corticis* and *Dendrobaena octaedra*; four in YG: *P. corethrurus, Glossodrilus sp., Periscolex sp.* and *Dichogaster, sp.*; and one in BP (*P. corethrurus*). The highest earthworm incidence occurred in the top 10 cm of the soil for all three pastures: KG, 53.1%; YG, 63.3% and BP, 73,8%. The values for bracken undergrowth (BU) were intermediate between the previous two groups. Diversity was low (19 TU), population density was high (4,464 individuals/m²), and biomass was low (26.28 g/m²). Earthworms (64%) and ants (17%) made the greatest contribution to biomass. Soil fauna was concentrated in the layers 0-10 cm (44.6%) and 10–20 cm (37.9%). Five earthworms species (*Martiodrilus sp., Thamnodrilus sp., Glossodrilus sp., A. corticis* and *D. octaedra*) were found.

Discussion

Our results indicated variation in diversity, abundance and functional structure of soil fauna communities, according to land use type in the Cabuyal River watershed. Species richnes decreases according to soil degradation, e.g. in SF from 98 TU and nine species of earthworm to 13 and one respectively in BP In sites with natural succession there is a tendency to recover biodiversity, e.g. from 19 TU and five earthworms species to 31 TU and five earthworms species in S40+. The CC system showed high TU and earthworm species numbers compared with the succession systems, while the respective numbers in the CA were low (18 and one, respectively). Nine earthworms species and 20 TU were found in KG. Several indicator or-

Table 2. Density (ind./m2) and biomass (g/m2) of soil macrofauna and earthworms at different localities

Site	Type of Vegetation	Macrofauna Biomass	Macrofauna Density	Reference	Earthworms Biomass	Earthworms Density
Colombia	Secondary forest (SF)	98.6	6,790	This study	12.3	210
Colombia	Gallery forest	13.6	4,294	Decaëns et al. 1994	4.7	251
Colombia	Traditional cofee crop (CC)	115.7	3,352	This study	92	498
Colombia	Cassava associated (CA)	78.9	1,187	This study	63.8	637
Mexico	Tropical rain forest	16.4–18.9	888–3,011	Lavelle et al. 1984	9.8–10.7	8–132
Peru	Tropical rain forest	24.1–53.9	4,099–4,303	Lavelle et al. 1989	11.9–28.2	85–120
Sarawak	Tropical forest	2.4–6.8	663–2,579	Collins, 1980	0,4–1	24–42
Colombia	P. clandestinum (KG)	67.9	2,507	This study	56.6	438
Colombia	Savanna	15.3	1,830	Decaëns et al. 1994	4.8	157
Colombia	Pinus patula (PP)	3.2	870	This study	0.13	29
Colombia	Traditional pastures	8–16.8	698–2,029	Decaëns et al. 1994	4.5–13.8	32–192
Peru	Traditional pastures	82.3–121.2	1,768–2,347	Lavelle et al. 1989	78–116.4	474–573
Colombia	Introduced pastures	28.8–62.5	1,541–2,267	Decaëns et al. 1994	22.9–51.1	139–213
Peru	Introduced pastures	110.9–159.2	922–1,546	Lavelle et al. 1989	103.2–153	546–740
Mexico	Introduced pastures	–	–	Lavelle et al. 1981	35.8–55.5	620–948
Colombia	B. humidicola (BP)	73.4	1,965	This study	57.2	363
Colombia	High-input crops	3.2–4.3	429–592	Decaëns et al. 1994	0.5–2.3	18–27
Peru	High-input crops	3.1	730	Lavelle et Pashanasi 1989	1.5	14

ganisms were differentiated in disturbed environments: for earthworms, these were *A. corticis, A. gracilis, D. octaedra* and *P. corethrurus*. For coleoptera, these were *Dichotomius aff. septentrionalis, Heterogomphus chevrolatti, Oxisternom conspicillatum,* and *Passalus sp.*

In environments with surface mulch, epigeic, and oligohumic endogeic organisms dominated, while in herbaceous environments they were mostly epigeic. The density and biomass of SF were higher than those of other tropical environments of Mexico (Lavelle et al. 1981; Lavelle & Kohlmann 1984), Nigeria (Magde 1969), Sarawak (Collins 1980), Peru (Lavelle & Pashanasi 1989), and Carimagua, Colombia (Decaëns et al. 1994) with values up to 7 times higher (Table 2).

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