Cuban Journal of Forest Sciences

CFORES

Edaphic macroinvertebrates in productive systems of Coffea arabica in Garzón, Huila, Colombia

Macroinvertebrados edáficos en sistemas productivos de Coffea arábica en Garzón, Huila, Colombia

Macroinvertebrados do solo em sistemas de produção de Coffea arabica em Garzón, Huila, Colômbia

Fernando Vargas Castro[1]* , *Gelber Rosas Patiño[1]* , *Verenice Sánchez Castillo[1]*

[1] University of the Amazon, Faculty of Engineering. Florence, Columbia.

[*] Corresponding author: fervaragro@yahoo.com

SUMMARY

Agroforestry systems are an increasingly implemented alternative for coffee production in Colombia due to the multiple socioeconomic and environmental benefits. They generate an ideal habitat for soil macrofauna. The objective of this research was to evaluate the incidence of two coffee production systems on the population behavior of edaphic macroinvertebrates. In order to do this, the composition, richness, abundance and vertical

distribution of soil macroinvertebrate families in Secondary Forest (Bs), Coffee Agroforestry Systems (SAFc) and Coffee Monoculture (Mc) systems were evaluated in four strata (leaf litter, 0-10 cm, 10-20 cm and 20-30 cm). 22 orders and 53 families of edaphic macroinvertebrates were identified, presenting the highest abundance of Lumbricidae, Formicidae, Porcellionidae and the lowest of Forficulidae, Geophilidae and Polydesmidae, with Bs > SAFc > Mc, except Forficulidae, Polydesmidae and Porcellionidae, which were found in greater abundance in Mc than in SAFc; in all systems the abundance was higher in the first 10 cm of the soil ($p<0.05$). Wealth showed a similar behavior, although without statistically significant effects. Although there are soil macroinvertebrates that are tolerant to the disturbances caused by forest cover changes to establish coffee production systems, some families of macroinvertebrates are susceptible to these cover changes, which makes them potential indicators of soil disturbances.

Keywords: abundance, coffee, edaphic fauna, richness, agroforestry system

RESUMEN

Los sistemas agroforestales son una alternativa cada vez más implementada para la producción de café en Colombia debido a los múltiples beneficios socioeconómicos y ambientales. En ellos, se genera un hábitat ideal para la macrofauna del suelo. El objetivo de esta investigación fue evaluar la incidencia de dos sistemas productivos de café sobre el comportamiento poblacional de los macroinvertebrados edáficos. Para ello, se evaluó la composición, riqueza, abundancia y distribución vertical de las familias de macroinvertebrados del suelo en sistemas de Bosque secundario (B.s), Sistemas agroforestales de café (S.A.F.c) y en Monocultivo de café (M.c), en cuatro estratos (hojarasca, 0-10 cm, 10-20 cm y 20-30 cm). Se identificaron 22 órdenes y 53 familias de macroinvertebrados edáficos, presentándose la mayor abundancia de Lumbricidae, Formicidae, Porcellionidae y la menor de Forficulidae, Geophilidae y Polydesmidae siendo B.s > S.A.F.c > M.c, salvo Forficulidae, Polydesmidae y Porcellionidae que se encontraron en mayor abundancia en M.c que en S.A.F.c; en todos los sistemas la abundancia fue mayor en los primeros 10 cm del suelo ($p<0,05$). La riqueza mostró un comportamiento similar,

aunque sin efectos estadísticamente significativos. Si bien hay macroinvertebrados del suelo tolerantes a las perturbaciones ocasionadas por los cambios de cobertura boscosa para establecer sistemas productivos de café, algunas familias de macroinvertebrados son susceptibles a estos cambios de cobertura lo que las convierte en indicadores potenciales de alteraciones en el suelo.

Palabras clave: abundancia, café, fauna edáfica, riqueza, sistema agroforestal.

RESUMO

Os sistemas agroflorestais são uma alternativa cada vez mais implementada para a produção de café na Colômbia devido aos múltiplos benefícios socioeconômicos e ambientais. Eles criam um habitat ideal para a macrofauna do solo. O objetivo desta pesquisa foi avaliar o impacto de dois sistemas de produção de café no comportamento populacional de macroinvertebrados edáficos. Para tanto, foram avaliadas a composição, riqueza, abundância e distribuição vertical de famílias de macroinvertebrados do solo em sistemas florestais secundários (B.s), sistemas agroflorestais cafeeiros (S.A.F.c) e em monocultura de café (M.c), em quatro estratos (folha serapilheira, 0- 10 cm, 10-20 cm e 20-30 cm). Foram identificadas 22 ordens e 53 famílias de macroinvertebrados edáficos, sendo a maior abundância de Lumbricidae, Formicidae, Porcellionidae e a menor de Forficulidae, Geophilidae e Polydesmidae sendo B.s > S.A.F.c > M.c, exceto Forficulidae, Polydesmidae e Porcellionidae que foram encontrados em maior abundância em Mc do que em S.A.F.c; Em todos os sistemas a abundância foi maior nos primeiros 10 cm do solo (p<0,05). A riqueza apresentou comportamento semelhante, embora sem efeitos estatisticamente significativos. Embora existam macroinvertebrados do solo que são tolerantes às perturbações causadas pelas alterações na cobertura florestal para estabelecer sistemas de produção de café, algumas famílias de macroinvertebrados são suscetíveis a essas alterações na cobertura, o que os torna potenciais indicadores de alterações no solo.

Palavras-chave: abundância, café, fauna edáfica, riqueza, sistema agroflorestal.

INTRODUCTION

Coffee (Coffea *arabica* L.) is an example of the agricultural crops that have been developed in Colombia since the 18th century to the present. Currently, the departments of Huila, Nariño and Cauca make up the new 'Coffee Axis'. The cultivated surfaces have grown 63.6 % in the last 13 years, which leads to a greater expansion of the local agricultural territory, compromising the soil resource. Thanks to its agricultural vocation and coffee tradition, the department of Huila has established itself in recent years as the main coffee producer in Colombia (Cerquera *et al.,* 2020).

The transformation of native landscapes due to the intensification of coffee monocultures has been one of the main causes of the loss of biodiversity in high Andean ecosystems. Edaphic macroinvertebrates, which are soil invertebrates larger than 2 mm, can play an important role as bioindicators. Its abundance, taxonomic richness and vertical distribution vary depending on the vegetation cover, the different uses and management of the soil, as well as seasonal variations (Doblas *et al.,* 2009) ; Cabrera *et al.,* 2017 ; Velásquez and Lavelle, 2019).

Agroforestry systems (crop and tree association) represent an opportunity for coffee production with sustainability criteria. These systems are positively correlated with biodiversity Campera *et al.* (2022) and the abundance of soil macrofauna (Rojas *et al.,* 2021) . In contrast, in coffee monocultures bioindicator organisms predominate, that indicates imbalance and disturbance in the soil (Rodríguez *et al.,* 2019) .

The objective of this research is to evaluate the incidence of two coffee production systems on the composition, richness, abundance and vertical distribution of edaphic macroinvertebrates in the municipality of Garzón, Huila, Colombia.

MATERIALS AND METHODS

Study zone

It is located 15 km east of the municipality of Garzón - Huila (Colombia). Nine farms with an average area of 1.0 ha were identified. These were located between the coordinates 02º20'52" north latitude and 75º54'17" west longitude of Greenwich, at an altitude of 1,460 to

1,668 masl. All the farms are within the Premontane Humid Forest life zone. (Bh-P) according to the Holdridge classification. Average temperatures between 18 °C and 24 °C predominate and annual rainfall ranges between 2,000 and 3,500 mm. The soils of the area are superficial to deep, well drained, slightly acid and of moderate fertility (IGAC, 1994 an 2014).

Systems evaluated

Coffee monocultures (MC) were evaluated with a planting distance of 1.2 mx 1.8 m and a density of 4,630 trees per hectare, agroforestry systems of coffee and plantain (Musa paradisiaca L.) (SAFC), established at a distance of 1.2 mx 1.8 m and 5.6 mx 3 m, respectively, and areas of secondary forest (BS) moderately intervened as positive control. The coffee plantations corresponded to plantations of the Catimor variety, established 11 years ago, two years after the last stumping (total pruning of the stems 30 centimeters from the ground to stimulate the regrowth of new stems).

The agronomic management of MC and SAFC was carried out by the producers following the recommendations of the technical assistants in the area, thus: applications of 100 cm3 of glyphosate in 20 L of water to control weeds, twice a year and pruning with a scythe every four months. Pest control was carried out through applications of pesticides based on Phenylpyrazole, Chlorpyrifos and Thiamethoxam + Ciproconazole, in doses of 25 ml per 20 L of water, with annual applications in SAFC and biannual in MC. Fertilization was performed with urea, diammonium phosphate (DAP) and calcium oxide (CaO). In each case, a dose of 50 grams per plant was used, every four months.

The secondary forest (Bs) is approximately 40 years old; Ararat and Prager (2002) found in these forests in the area, species such as *Goupia glabra* A. (white cedar), *Cedrela odorata* L. (pink cedar), *Erythrina poeppigiana* W. (cachingo), *Persea caerulea* R&P (aguacatillo), *Chrysophyllum* cainito L. (caimo), Inga marginata W. (guamo) and Jacaranda copaia A. (gualandai).

Establishment of the design and sampling in the field

A Randomized Complete Blocks (BCA) design was established in a factorial arrangement with four (4) replicates. Factor A corresponded to the evaluated systems (Mc, SAFc and Bs)

and factor B to the four invertebrate sampling depths (leaf litter, 0-10 cm, 10-20 cm and 20-30 cm).

The samplings were carried out in the month of October 2018 (there was a collection permit, according to Resolution 01140 of 2016), in the rainy season, before starting the second significant coffee harvest of the year to avoid anthropic disturbances.

The edaphic macroinvertebrates were collected using the method suggested by Velasquez and Lavelle, (2019). In each system, three monoliths (25 x 25 cm) or subsamples per replicate were collected; the monoliths were divided into four strata: litter, 0-10, 10-20 and 20-30 cm. For the collection of edaphic macroinvertebrates, they used entomological tweezers and brushes. These were preserved in 70 % alcohol, with the exception of the worms, which were preserved in vials with 5 % formalin. Subsequently, they were transferred to the Entomology Laboratory of the University of the Amazon (LEUA) for their characterization at the order and family level. The taxonomic keys and descriptions of Ruiz *et al.* (2008) and Borror *et al.* (1992) were used.

Response variables and analysis of biological data

For the analysis of macroinvertebrates, the values of richness (number of families), specific abundance (individuals m $^{-2}$), density (number of individuals m $^{-2}$) and vertical distribution of the macroinvertebrates were determined as a function of abundance in each profile or soil layer. The overall results in each of the systems were calculated and presented.

In addition, the assumptions of normality and homogeneity of the variances of the data were validated by means of an exploratory residual analysis (QQ plot, Shapiro-Wilk test, and plot of predicted values against residuals). The data that presented a normal distribution and homogeneity of variance (richness) were analyzed using Fisher's LSD test ($p < 0.05$) and the data that did not present a normal distribution were analyzed using the non-parametric Kruskall-Waill test. ($p < 0.05$).

A multivariate analysis was used in order to reduce the information and facilitate its interpretation. In the case of diversity, a correspondence analysis (CA) was carried out based on the presence - absence of soil macrofauna families. This allowed us to identify those families that were exclusive or shared between systems. All analyzes were performed with the InfoStat software, version 2018.

RESULTS AND DISCUSSION

Composition of the richness and abundance of edaphic macroinvertebrates.

The taxonomic richness was represented by two phylums, seven classes, 22 orders and 53 families of edaphic macroinvertebrates. The greatest richness was found in Bs, followed by SAFc and Mc. Despite this, the evaluated systems did not present statistically significant differences (p>0.072) in the richness of taxonomic groups (Table 1). This type of behavior may correspond to a sampling effort or insufficient statistical power; however, these results present a trend in which richness decreases as the degree of disturbance and differences in vegetation increase, as occurs with high Bs heterogeneity and Mc homogeneity The foregoing coincides with reports by Delgado *et al.* (2011) and Cabrera *et al.* (2011) who indicate that the richness of species is higher in the forest and in agroforestry systems than in production systems without the presence of trees, thanks to the diversity of the vegetation, the availability of food for the species, the complex structure of the vegetation that provides habitat sites and offers better protection than in simpler agricultural systems. Rojas *et al.* (2021) also affirm that coffee agroecosystems with complex vegetation help maintain a high richness of macroinvertebrates, which allows a greater similarity with the forest, as is the case of SAFc (Table 1).

Table 1. - Abundance (individuals m $^{-2}$) and richness of soil macrofauna in coffee production systems (Mc and SAFc) and in secondary forest (Bs) in the department of Huila

Family	Mc	SAFc	B.s	*p-value†*	*p-value††*
Amaurobiidae	1.33 ± 1.33	2.67 ±1.8	-	ns	
Anisolabididae	1.33 ± 1.33	5.33 ±5.33	-	ns	
Araneidae	2.67 ±2.67	-	-		
Bdellidae	-	-	5.33 ±1.54		
Cantharidae	-	1.33 ± 1.33	-		
Carabidae	4 ± 2.28	1.33 ±2.28	10.67 ± 4.55	ns	ns
Cheliferidae	-	-	5.33 ± 1.54		
Chthoniidae	-	1.33 ± 1.33	-		
Cixiidae	1.33 ± 1.33	-	-		
Clubionidae	-	2.67 ± 2.67	-		
Coccinellidae	-	1.33 ± 1.19	5.33 ± 2.37		ns
Chrysomelidae	8 ± 6.95	10.67 ± 6.95	5.33 ± 13.9	ns	ns

Cryptopidae	8 ± 3.96	10.67 ± 3.96	16 ± 7.93	ns	ns
Curculionidae	-	8 ± 3.68	-		
Cybaeidae	1.33 ± 1.33	2.67 ± 1.8	-	ns	
Cydnidae	-	5.33 ± 4.1	10.67 ± 10.67		ns
Dictynidae	12 ± 9.26	4 ± 2.09	-	ns	
Ectobiidae	8 ± 6.3	9.33 ± 6.3	42.67 ± 12.59	ns	ns
Elateridae	1.33 ± 1.33	4 ± 2.87	-	ns	
Forficulidae	1.33B ± 1.19	-	10.67 **A** ± 2.37		**
Formicidae	205.33b ± 75.99	325.33 **to** ± 75.99	138.67 ± 151.99	*	ns
Geometridae	2.67 ± 1.8	-	-		
Geophilidae	1.33B ± 3.33	1.33B ± 3.33	21.33 **A** ± 6.67	ns	*
Gryllidae	-	-	10.67 ± 1.54		
Hubbardiidae	2.67 ± 2.67	-	-		
Isotomidae	21.33 ± 8.22	5.33 ± 8.22	5.33 ± 16.44	ns	ns
Julidae	-	-	10.67 ± 1.54		
Labiduridae	6.67 ± 5.38	16 ± 16	-	ns	
Largidae	-	8 ± 2.83	-		
Lepidopsocidae	1.33 ± 1.33	-	-		
Linyphiidae	17.33 ± 8.77	25.33 ± 8.77	10.67 ± 17.54	ns	ns
Lumbricidae	165.33 **bB** ± 43.38	352 **BC** ± 43.38	666.67 **A** ± 133.7	**	*
Lycosidae	1.33 ± 1.33	-	-		
Mycetophagidae	2.67 ± 1.8	5.33 ± 3.01	-	ns	
Nabidae	1.33 ± 1.33	1.33 ± 1.33	-	ns	
Noctuidae	5.33 ± 2.27	17.33 ± 6.67	-	ns	
Nymphalidae	13.33 ± 13.33	5.33 ± 5.33	-	ns	
Parajulidae	-	17.33 ± 17.33	-		
Pentatomidae	1.33 ± 1.33	-	-		
Pisauriidae	-	13.33 ± 4.33	-		
Polydesmidae	8B ± 3.17	2.67 **B** ± 3.17	21.33 **A** ± 6.35	ns	*
Porcellionidae	13.33B ± 7.68	10.67B ± 7.68	80A ± 15.36	ns	*
Ptiliidae	-	5.33 ± 4.10	-		
Salticidae	-	-	5.33 ± 5.33		
Scarabaeidae	8 ± 8.36	13.33 ± 8.36	48 ± 16.72	ns	ns
Siphonotidae	-	8 ± 8	-		
Spirobolidae	-	1.33 ± 1.19	5.33 ± 2.37		ns

Staphylinidae	45.33 ± 14	52 ± 14	53.33 ± 28.01	ns	ns
Superstitioniidae	-	-	5.33 ± 1.54		
Tetragnathidae	2.67 ± 3.16	6.67 ± 3.16	5.33 ± 6.32	ns	ns
Theridiidae	4 ± 4.35	8 ± 4.35	16 ± 8.69	ns	ns
Trogositidae	-	1.33 ± 1.33	-		
Trombidiidae	1.33 ± 1.33	-	-		
Total abundance	586.67 **bB** ± 130.41	969.33 **aA** ± 130.41	1216 **A** ± 260.81	*	*
Wealth	8.58 ± 0.84	10.17 ± 0.84	13 ± 1.69	ns	ns

* = P < 0.05; ** = P < 0.01 ; ns = not significant. † corresponds to comparisons between production systems; ††
corresponds to the comparisons between Bs, Mc and SAFc

Means ± standard error. Means followed by the same lowercase letter do not differ significantly between Mc and SAFc; and means followed by the same capital letter do not differ significantly between Bs, Mc and SAFc according to Fisher's LSD test p<0.05.

Correspondence analysis (Figure 1) showed that eight families (Araneidae, Lycosidae, Hubbardiidae, Trombidiidae, Cixiidae, Pentatomidae, Geometridae and Lepidopsocidae) were associated with a single system, the Mc; ten families (Clubionidae, Pisauriidae, Chthoniidae, Parajulidae, Siphonotidae, Cantharidae, Curculionidae, Ptiliidae, Trogositidae and Largidae) were only recorded in SAFc, while Salticidae, Superstitioniidae, Cheliferidae, Bdellidae, Julidae and Gryllidae were only recorded in Bs (Figure 1). The low representativeness of the reported families indicates that they are more susceptible to environmental disturbances. Families associated with Mc and SAFc were also recorded (Table 1 and Figure 1), this may be due to the fact that *C. arabica* is found covering most of the soil, providing a similar habitat in the two ideal systems for these organisms (Campera *et al.* , 2022) .
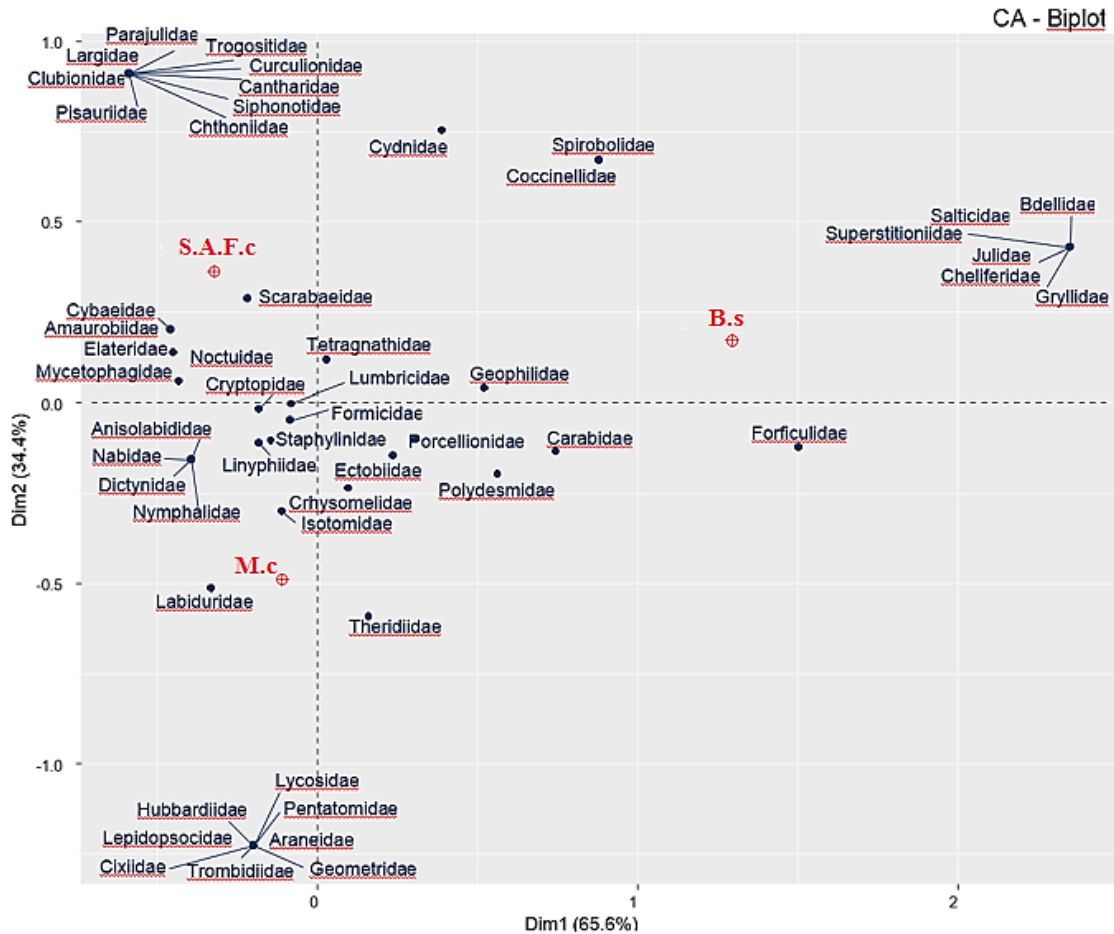
Fig. 1. - Correspondence analysis of soil macrofauna in coffee productive systems and secondary forest of Garzón, Huila

Abundance of individuals per system

22.320 individuals m^{-2} were recorded (Figure 2), with a general average of 826.7 individuals m^{-2} per monolith. The highest abundance on average occurred in B.s, followed by S.A.F.c, these two systems being statistically similar, but presenting significant differences with Mc (p<0.014) (Table 1).
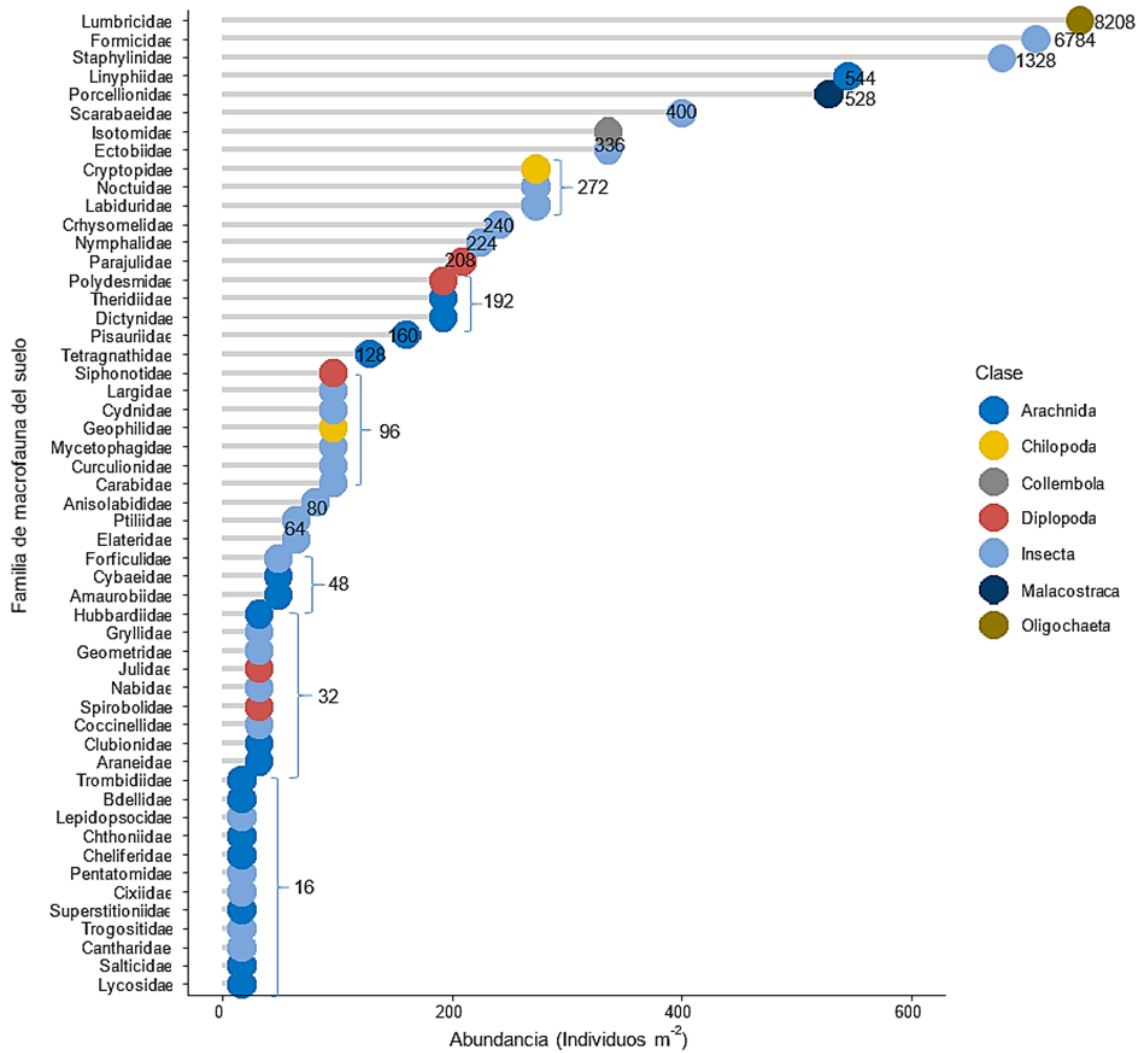
Fig. 2. - Total abundance of soil macrofauna (at family level) in coffee production systems and secondary forest

There were differences ($p<0.049$) between the coffee production systems (Table 1, Figure 2), showing that the macroinvertebrate communities present in the soil use systems are determined by the availability of resources for their survival and the levels of soil intervention in the development of agricultural activities. The results show that there is a direct positive relationship between less disturbed systems with the abundance of edaphic macroinvertebrates, as argued by other authors (Delgado *et al.,* 2011).

In this sense, it is suggested that the main factor influencing the pattern of abundance was plant heterogeneity; the result is due to the fact that the diversification of productive systems with other plant species improves the abundance of macroinvertebrates (Delgado *et al.,* 2011), although these effects are also conditioned by the application of insecticides and fertilizers.

The taxonomic families that presented the highest abundance in the three systems were: Lumbricidae, Formicidae, Staphylinidae, Porcellionidae, Scarabaeidae and Ectobiidae. In the same way, Rojas *et al.* (2021) found that in most of the macrofauna found in Colombian coffee systems, earthworms and ants dominate in abundance. These six (6) families represented 80.7% of the edaphic macroinvertebrates identified throughout the study, while the "Other" groups corresponding to 47 families represented 19.3% of the taxonomic groups as they presented low density in the systems evaluated (> 2%).

However, only three families (Lumbricidae, Formicidae and Porcellionidae) of the most abundant and three of the "other" category (Forficulidae, Geophilidae and Polydesmidae) presented significant differences ($p < 0.01$), evidencing a potential use as bioindicators of soil quality and anthropic disturbances in coffee systems. The abundance of Lumbricidae presented significant statistical differences between the evaluated systems, reaching the highest value in Bs, followed by SAFc and lower abundance in Mc ($p < 0.01$) (Table 1). This taxonomic order is characterized by participating in the regulation of the dynamics of organic matter and the biogeochemical cycle of nutrients, in the neutralization of toxins generated by agrochemical products and in the modification of the soil structure.

On the other hand, the families of Geophilidae, Polydesmidae and Porcellionidae were statistically similar within the same families in both SAFc and Mc, however, significant differences were found compared to Bs (Table 1), with $p < 0.031$, $p < 0.045$ and $p < 0.036$ respectively. This is due to the fact that these families require humid environments because of their loss of water, an attribute that Bs provides.

Regarding the Formicidae family, it presented greater abundance in the SAFc compared to the Mc with significant differences being found between them ($p < 0.046$) (Table 1). The Forficulidae family presented greater abundance in Bs compared to Mc, finding significant

differences between them (p<0.001) (Table 1); mainly because they are organisms that are sensitive to land use because they often live in deep tunnels (Cabrera, 2011).

The Others group corresponds to the remaining 47 family groups that individually contribute less than 2 % each. The abundance of individuals in S.A.F.c did not present statistical differences with B.s, a similar result was presented by Delgado *et al.,* (2011) in a coffee-banana agroforestry system, showing that the macrofauna present in the different land use systems is determined by the availability of resources for their survival and by the intensity of agricultural activities, which suggests that agroforestry systems with coffee can be a viable option to conserve the abundance of edaphic macroinvertebrates.

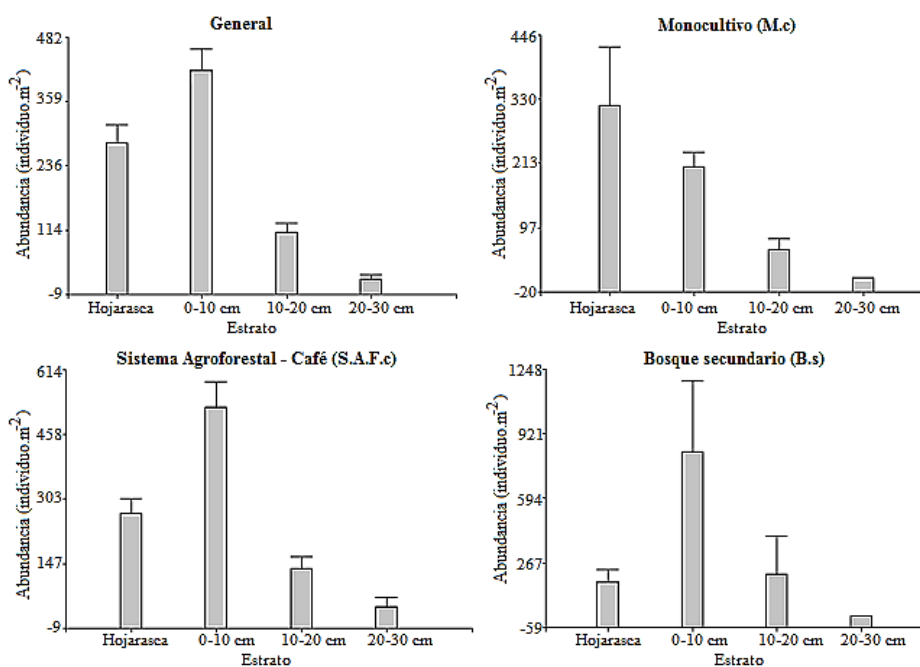*Vertical distribution of the abundance of macroinvertebrates in general and for each system*

Fig. 3. - *Vertical distribution of soil macrofauna in forest and coffee production systems in Garzón, Huila*

General

The greatest abundance was found in the 0-10 cm stratum, with significant differences with respect to the litter stratum and other depths (Figure 3); this agrees with the findings of Olayemi *et al.,* (2022) who establish that the macrofauna is confined to the upper part, in the

first centimeters of the soil. Similarly, there were significant differences in the litter in relation to the depths of 10-20 cm and 20-30 cm. These last two strata were statistically similar to each other.

M.c

Greater abundance was found in the litter layer, probably due to the greater contribution of litter in the superficial part, thus influencing the formation of a more favorable habitat for the development of these organisms. However, it is statistically similar to the depth of 0-10 cm, nevertheless, there was a statistically significant difference in litter with respect to the strata of 10-20 cm and 20-30 cm; also, between the 0-10 cm stratum compared to the 20-30 cm stratum (Figure 3). This decrease in macrofauna in the deep strata may be due to the fact that as the soil profile deepens, the porosity, oxygen and organic matter content that provides habitat and food decrease (Vanolli *et al., 2023)*.

The foregoing supports what was mentioned by Armbrecht and Perfecto (2001), that the coffee monoculture is an exemplary case of how the intensification of agriculture negatively affects tropical biodiversity, because by reducing the presence of shade trees, fauna associated with crops also diminishes. In part, this is explained by the decrease in the structural complexity of the crop and, therefore, of the ecological niches of the fauna resident in it (Rodríguez *et al.,* 2019). In this context of simplification, it is possible to study how the interspecific relationships between the macroinvertebrates that inhabit agroecosystems are affected and how these relationships can favor or harm the interests of the farmer.

S.A.F.c.

Greater abundance was found in the 0-10 cm stratum, presenting statistically significant differences with respect to the litter stratum and other depths. Similarly, there were significant differences in the litter in relation to the depths of 10-20 cm and 20-30 cm; these last two depths, despite having different abundances, were statistically similar (Figure 3). Doblas (2009) point out that one of the causes that leads to a greater presence of organisms in the first strata (superficial and 0-10 cm) is due to the amount of organic matter due to the plant cover which provides biomass and generates microhabitats favorable for the life of the macrofauna. Duran *et al.* (2023), suggest that the greater structural complexity and botanical composition of agroforestry systems promote the richness and diversity of the edaphic

macrofauna by improving the physical conditions, the organic matter content of the soil, enhancing this by improving its processes of aggregation and porosity.

B.s

The stratum that presented the greatest abundance was 0-10 cm deep (Figure 3). This behavior may be related to the soil that is formed by the addition of leaf litter, in addition, the presence of the tree in the systems makes temperatures and the impact of rain decrease compared to open land, constituting alternatives to achieve the colonization (Lavelle *et al.*, 2022).

CONCLUSIONS

The abundance and distribution of the edaphic macrofauna are highly sensitive attributes when the forest is replaced by coffee production systems. However, the implementation of coffee cultivation in agroforestry systems emerges as an important strategy for the conservation of these organisms.

The most abundant families (Lumbricidae, Formicidae and Porcellionidae) and less abundant (Forficulidae, Geophilidae and Polydesmidae) present a high susceptibility to changes in coverage in the systems.

In the coffee agroforestry system, the greatest diversity of macroinvertebrates is observed in the first 10 cm of soil, while in the monoculture the greatest diversity is found in the litter.

THANKS

BIBLIOGRAPHIC REFERENCES

ARARAT, M.C. y PRAGER, M., 2002. Efecto de cinco manejos agroecológicos de un Andisol (*Typic Dystrandept*) sobre la macrofauna en el municipio Piendamó, departamento del Cauca, Colombia. Acta Económica. vol 51, (3/4) 121-129. Disponible en:

https://revistas.unal.edu.co/index.php/acta_agronomica/article/view/47796/48
927

ARMBRECHT, I. y PERFECTO, I., 2001. Diversidad de artrópodos en los agroecosistemas cafeteros. Universidad de El Salvador. Facultad de Ciencias Agronómicas, *Revista Protección Vegetal,* 12 (2): 11-16. Disponible en: http://hormigas.univalle.edu.co/pdf/2001ArtropodosCafetales.pdf

BORROR, D.J., TRIPLEHORN, C.A. y JOHNSON, N.F., 1992. *An introduction to the study of insects* [en línea]. 6ta. Estados Unidos: Sunders College Publishing. [consulta: 9 junio 2023]. ISBN 9780030253973. Disponible en: https://latam.casadellibro.com/libro-an-introduction-to-the-study-of-insects-6th-ed/9780030253973/831454.

CABRERA DÁVILA, G., SOCARRÁS RIVERO, A., HERNÁNDEZ VIGOA, G., PONCE DE LEÓN, D., MENÉNDEZ RIVERO, Y. y SÁNCHEZ RENDÓN, J., 2017. Evaluación de la macrofauna como indicador del estado de salud en siete sistemas de uso de la tierra, en Cuba/Evaluation of the macrofauna as indicator of the health status in seven land use systems, in Cuba. *Pastos y Forrajes* [en línea], vol. 40, no. 2, Disponible en:
https://www.researchgate.net/publication/320191245_Evaluacion_de_la_macrofa una_como_indicador_del_estado_de_salud_en_siete_sistemas_de_uso_de_la_tierra _en_CubaEvaluation_of_the_macrofauna_as_indicator_of_the_health_status_in_se ven_land_use_systems_in_.

CABRERA, G., ROBAINA, N. y PONCE DE LEÓN, D., 2011. Composición funcional de la macrofauna edáfica en cuatro usos de la tierra en las provincias de Artemisa y Mayabeque, Cuba. *Pastos y Forrajes* [en línea], vol. 34, no. 3, Disponible en: https://www.redalyc.org/pdf/2691/269121083008.pdf.

CAMPERA, M., BUDIADI, B., BUŠINA, T., FATHONI, B., DERMODY, J., NIJMAN, V., IMRON, M. y NEKARIS, K.A., 2022. Abundance and richness of invertebrates in shade-grown versus sun-exposed coffee home gardens in Indonesia. *Agroforestry Systems* [en línea], vol. 96, no. 5-6, DOI 10.1007/s10457-022-00744-9. Disponible en:

https://www.researchgate.net/publication/360606929_Abundance_and_richness_ of_invertebrates_in_shade-grown_versus_sun- exposed_coffee_home_gardens_in_Indonesia.

CERQUERA LOSADA, Ó.H., PÉREZ GÓMEZ, V.H. y SIERRA CHAVARRO, J., 2020. Análisis de la competitividad de las exportaciones del café del Huila. *Tendencias* [en línea], vol. 21, no. 2, [consulta: 12 junio 2023]. ISSN 0124-8693, 2539-0554. Disponible en: https://dialnet.unirioja.es/servlet/articulo?codigo=7646596.

DELGADO MIRANDA, G., BURBANO, A. y SILVA PARRA, A., 2011. Evaluación de la macrofauna del suelo asociada a diferentes sistemas con café Coffea arabiga L. *Revista de Ciencias Agrícolas* [en línea], vol. 28, no. 1, [consulta: 12 junio 2023]. ISSN 2256-2273, 0120-0135. Disponible en: https://dialnet.unirioja.es/servlet/articulo?codigo=5104119.

DOBLAS MIRANDA, E., SÁNCHEZ PIÑERO, F. y GONZÁLEZ MEGÍAS, A., 2009. Vertical distribution of soil macrofauna in an arid ecosystem: Are litter and belowground compartmentalized habitats? *Pedobiologia* [en línea], vol. 52, no. 6, [consulta: 12 junio 2023]. ISSN 0031-4056. DOI 10.1016/j.pedobi.2008.11.006. Disponible en: https://www.sciencedirect.com/science/article/pii/S0031405609000043.

DURAN, B. E.H., ANGEL, S. Y.K., BERMÚDEZ, M.F. y SUÁREZ, J.C., 2023. Agroforestry systems generate changes in soil macrofauna and soil physical quality relationship in the northwestern Colombian Amazon. *Agroforest Syst* 97, 927–938. https://doi.org/10.1007/s10457-023-00838-y

INSTITUTO GEOGRÁFICO AGUSTÍN CODAZZI. 1994. Estudio General de suelos del Departamento del Huila, Santafé de Bogotá.

INSTITUTO GEOGRÁFICO AGUSTÍN CODAZZI., 2014. Estudio general de suelos y zonificación de tierras departamento de Caquetá, escala 1.100.000. Bogotá. 410p.

LAVELLE, P., MATHIEU, J., SPAIN, A., BROWN, G., FRAGOSO, C., LAPIED, E., DE AQUINO, A., BAROIS, I., BARRIOS, E., BARROS, M. E., BEDANO, J. C.,

BLANCHART, E., CAULFIELD, M., CHAGUEZA, Y., DAI, J., DECAËNS, T., DOMINGUEZ, A., DOMINGUEZ, Y., FEIJOO, A., … SUPP, S., 2022. Soil macroinvertebrate communities: A world-wide assessment. *Global Ecology and Biogeography*, 31, 1261–1276. https://doi.org/10.1111/geb.13492

OLAYEMI, P.O., SCHNEEKLOTH, J. P., WALLENSTEIN, M.D., TRIVEDI, P., CALDERÓN, F.J., CORWIN, J. y FONTE, S. J., 2022. Soil macrofauna and microbial communities respond in similar ways to management drivers in an irrigated maize system of Colorado (USA), *Applied Soil Ecology*, Volume 178. https://doi.org/10.1016/j.apsoil.2022.104562.

ROBAINA RODRÍGUEZ, N., MÁRQUEZ, S.M. y RESTREPO, L.F., 2019. The edaphic macrofauna in three components of the coffee plant arrangement associated with different management typologies, Antioquia, Colombia. *Revista de la Facultad de Ciencias Agrarias UNCuyo* [en línea], vol. 51, no. 2, Disponible en: https://bibliotecas.uncuyo.edu.ar/explorador3/Record/I11-R107article-2597/Description#tabnav.

RODRÍGUEZ, N. R., MÁRQUEZ, S. M. y RESTREPO, L. F. 2019. The edaphic macrofauna in three components of the coffee plant arrangement associated with different management typologies, Antioquia, Colombia. *Revista de la Facultad de Ciencias Agrarias UNCuyo*, vol. 51 no. 2, pp. 78-88. https://revistas.uncu.edu.ar/ojs3/index.php/RFCA/article/view/2597

ROJAS MÚNERA, D.M., FEIJOO MARTÍNEZ, A., MOLINA RICO, L.J., ZÚÑIGA, M.C. y QUINTERO, H., 2021. Differential impact of altitude and a plantain cultivation system on soil macroinvertebrates in the Colombian Coffee Region. *Applied Soil Ecology* [en línea], vol. 164, [consulta: 13 junio 2023]. ISSN 0929-1393. DOI 10.1016/j.apsoil.2021.103931. Disponible en: https://www.sciencedirect.com/science/article/pii/S0929139321000524.

RUIZ, N. y LAVELLE, P., 2008. *Soil macrofauna field manual. Technical level* [en línea]. Roma: FAO. [consulta: 13 junio 2023]. Disponible en: https://docplayer.net/159975720-Soil-macrofauna-field-manual-technical-level.html.

VANOLLI, B. S., PEREIRA, A. P.A., FRANCO, A. L.C. y CHERUBIN, M. R., 2023. Edaphic and epigeic macrofauna responses to land use change in Brazil, *European Journal of Soil Biology*, Volume 117. https://doi.org/10.1016/j.ejsobi.2023.103514.

VELÁSQUEZ, E. y LAVELLE, P., 2019. Soil macrofauna as an indicator for evaluating soil based ecosystem services in agricultural landscapes. *Acta Oecologica* [en línea], vol. 100, [consulta: 13 junio 2023]. ISSN 1146-609X. DOI 10.1016/j.actao.2019.103446. Disponible en: https://www.sciencedirect.com/science/article/pii/S1146609X18302613.

Conflict of interests:

The authors declare not to have any interest conflicts.

Contribution of the authors:

The authors FVC, GRP and VSC have participated in the design and development of the research, data analysis and writing of the manuscript, in a proportion of 33% for each author for the achievement of the article.