# The edaphic macrofauna in three components of the coffee plant arrangement associated with different management typologies, Antioquia, Colombia

## La macrofauna edáfica en tres componentes del arreglo vegetal cafetero asociada con diferentes tipologías de manejo, Antioquia, Colombia

Nayla Robaina Rodríguez, Sara María Márquez, Luis Fernando Restrepo

Originales: *Recepción:* 12/10/2016 - *Aceptación:* 28/06/2017

**Abstract**

The balance and sustainability of coffee agroecosystems in southwestern Antioquia depend on the interactions and synergisms that take place above and below the ground. Within these, the functional groups of edaphic macrofauna constitute bio-indicators of soil quality. The present research on coffee systems evaluates the edaphic macrofauna in three components of the plant arrangement, under different management typologies. The study was carried out in the San Gregorio, La Soledad, La Clara and Egypt townships of Santa Rita in the municipality of Andes, Antioquia. The assessment of the edaphic macrofauna was carried out by random stratified sampling under coffee canopy, under banana canopy and in the furrow, in three zones of the slope of each productive system. A general linear model, multivariate techniques of Manovas and Biplot were used as statistical methods. The greatest interaction of the macrofauna groups was presented in the order of the systems: Transition II (Use of organic inputs)>Transition I (Rationalization of synthetic inputs)>Conventional (Use of chemical inputs), and by plant arrangement components in the order Banana>Coffee>Furrow.

**Keywords**
Agroecology • agroecosystems • biota • conventional • transition

Universidad de Antioquia (UdeA). Facultad de Ciencias Agrarias. Calle 70 No. 52-21, Medellín. Colombia. nayla.robaina@gmail.com

## Resumen

El equilibrio y la sostenibilidad de los agroecosistemas cafeteros del suroeste antioqueño, dependen de las interacciones y sinergismos que se dan lugar por encima y debajo del suelo. Dentro de estas, los grupos funcionales de la macrofauna edáfica constituyen bioindicadores de la calidad del suelo. La presente investigación de los sistemas cafeteros evalúa la macrofauna edáfica en tres componentes del arreglo vegetal, bajo diferentes tipologías de manejo. El estudio se realizó en las veredas San Gregorio, La Soledad, La Clara y Egipto del corregimiento de Santa Rita en el municipio de Andes, Antioquia. Se realizó la evaluación de la macrofauna edáfica mediante un muestreo aleatorio estratificado debajo del dosel del café, debajo del dosel del plátano y en el surco, en tres zonas de la pendiente de cada sistema productivo. Se emplearon como métodos estadísticos un modelo lineal general, técnicas multivariadas de Manovas y Biplot. La mayor interacción de los grupos de la macrofauna se presentó en el orden de los sistemas: Transición II (Utilización de insumos orgánicos)>Transición I (Racionalización de insumos sintéticos)>Convencionales (Utilización de insumos químicos), y por componentes del arreglo vegetal en el orden Plátano>Café>Surco.



**Palabras claves**
Agroecología • agroecosistemas • biota • convencional • transición


## Introduction

Today, the advance of modern agriculture has transformed the natural ecosystems of plants into simplified crop systems, characterized by a high degree of imbalance in the components of the agroecosystems (21).

In Colombia's coffee growing systems, the intensification of coffee production from a social, environmental, economic and technological point of view have a negative impact on the landscape, which in turn leads to the loss of biodiversity of microorganisms, plants and animals native to different regions of the country (20, 29).

In the municipality of Andes, Southwestern Antioquia, coffee growers and organizations in the sector use conventional systems as their main productive model. These systems use monocultures, heavy machinery, fertilizers and chemical pesticides. This model threatens the biodiversity of the territory and causes serious impacts such as; contamination of water sources (19), progressive degradation of the physical and chemical properties of the soil (27), exploitation of energy sources (24), breaking of complex biological trophic networks of the soil (7, 20, 28), resistance to pests, invasive diseases and weeds (5, 16, 25), intensification in the emission of greenhouse gases and greater vulnerability to climate change (13, 21, 29).

According to Altieri and Niholls (2008); Armbretch (2016) and Vázquez and Matienzo (2010) in order to curb the ecological deterioration that has been occurring in coffee systems, the solution is to increase interactions and positive ecological synergisms between the biotic functional groups above and below the ground.

The interactions of functional groups, ensure the integrity of the agroecosystems through various synergies and ecosystem services that occur between plant diversity and the presence of multifunctional biological organisms. Services include: nutrient recycling, increased organic matter, stability of the physical and chemical properties of soil, biological control of pests and diseases. All these services together guarantee productive, sustainable, biodiverse and resilient systems (1, 14, 21).

In direct relation with the management of soil fertility, the trophic groups of the edaphic macrofauna are manifested. These are considered soil engineers (6, 16, 18, 21) as they modify agroecosystems through their action in the decomposition of organic matter and its influence on the cycle of carbon and other nutrients. They also improve porosity, permeability, infiltration and structural stability of soil aggregates (7, 8, 26).

Therefore, this research will make it possible to evaluate the functional groups of edaphic macrofauna in three components of the plant arrangement under different management systems for coffee production.

## Materials and Methods

The study area was located in the Santa Rita district of Andes municipality, Antioquia. It is located southwest of the municipality, about 12.1km. It is located at 5°39'13" N and 75°3'37" W. It presents a humid tropical temperate climate and corresponds to the life zones of premontane humid forest. In general, the climatic conditions show an average temperature between 18°C and 24°C and an average annual rainfall between 1000 and 2000 mm (19).

The investigation was carried out in 13 coffee farms of the village, located on the path lane: San Gregorio, La Soledad, La Clara and Egypt, on an altitudinal strip between 1700 and 2000 meters above sea level. The soils of the study systems have been developed from metamorphic, igneous and sedimentary rocks with volcanic ash deposits (30). They have a texture of sandy and clayey loamy soils, in some cases with high mineral content and a strongly acidic pH. They are very deep, with an organic surface horizon-mineral of dark color and beneath it, another yellow or reddish brown color, good drainage, low moisture retention and a jagged appearance is manifested. Organic matter and nutrient content vary depending on the type of management. The types of soil present in the village are Typic Dystrudepts, Typic Fulvudands and Humic Dystrudepts. Also the inclusions Lithic Dystrudepts, Oxic Dystrudepts and Typic Eutrudepts are present (15).

The study systems belong to coffee producers with more than 20 years of experience under sun exposure or diversified shade, with three and four hectare farms and different management types (27) (table 1, page 81).

The experimental design of the research started with stratified random sampling of different functional groups of the edaphic macrofauna in three components of the plant arrangement, under three management typologies.

The sampling sites analyzed during the investigation were: I (Under coffee canopy), the coffee crops presents the same height and vegetative state and with the same topographical inclination; II (Under banana canopy), the banana crops are in the fruiting stage and are associated with coffee at a distance of one meter with 50 centimeters; III (Furrow between coffee and banana), the furrow has a width of 70 centimeters, the tillage is zero and no weeds were observed. The sampling was collected in the middle of the furrow.

**Table 1.** Characterization of management typologies coffee-growing systems.

**Tabla 1.** Caracterización de las tipologías de manejo de los sistemas cafeteros.

| **Characteristics** | **Management typologies** | | |
|---|---|---|---|
| | **Conventional** | **Transition I** | **Transition II** |
| **Coffee farms** | 1, 2, 3, 4, 5 and 6 | 9, 10, 11, 12 and 13 | 7 and 8 |
| **Production systems** | Farms of intensive production based on mono-culture and in excessive use high toxicity chemical products. | Farms in an initial phase of the conversion process toward agro-ecological systems. These systems assure the progressive elimination of chemical products through rationalization and with organic fertilizers. | Farms in a second phase of the conversion process toward agro-ecological systems. They only use organic products prepared with internal products of the system such as: vermin-culture, rustic compost, bocashi, mineral soups, among others, bio-fermented products based on manure and minerals. |
| **Vegetal strate** | The low stratum presents coffee plantation and invading weeds such as (*Cynodon dactylon* L.), (*Triumfetta semitriloba* L.), (*Cyperus rotundus* L.), (*Portulaca oleracea* L.), (*Rumex obtusifolius* L.), (*Digitaria sanguinalis* L.). In medium stratum, (*Manihot esculenta* Crantz.) and (*Musa* sp. L.) were crops observed in a dispersed way and without organization in the field as a basic food of the family. | The low stratum presents coffee plantation, invading weeds such as (*Cynodon dactylon* L.) and (*Eleusine indica* L.). In medium stratum (*Manihot esculenta* Crantz.), (*Zea mays* L.), and (*Musa* sp. L.) were crops found in association with the main crop. High stratum there were found fruit trees such as: (*Persea americana* Mill.) and (*Mangifera indica* L.). | The low stratum presents coffee plantation, not invading weeds, medicinal plants such as (*Cymbopogon citratus* Stapf.), (*Aloe vera* L.), (*Rosmarinus officinalis* L.), (*Salvia officinalis* L.), (*Ocimum basilicum* L.), and (*Capsicum annuum* L.). In medium stratum, there were crops observed such as (*Manihot esculenta* Crantz.), (*Zea mays* L.), (*Phaseolus vulgaris* L.), and (*Musa* sp. L.). In high stratum, the system showed fruit and wood trees, such as (*Persea Americana* Mill.), (*Mangifera indica* L.), (*Cordia alliodora* Oken.), (*Cedrela odorata* L.), and *(Inga edulis* Mart.). |

The study of the edaphic macrofauna was carried out by coffee systems, through nine soil monoliths 25 x 25 x 30 cm deep, 20 meters apart, and distributed in three monoliths by components of the plant arrangement. In each system, the macroinvertebrates present were collected following the Methodology of the International Program "Biology and Fertility of Tropical Soil" or TSBF. Collected samples were kept in jars with 70% ethanol and 30% formaldehyde which were used to preserve the worms. Subsequently, the counting and separation of samples was carried out using a stereoscopic microscope, according to specifications of different extraction methods and taxonomic and functional identification of the macroinvertebrates (6, 7, 16).

For the interactions assessment, the general linear model (GLM) was used, where the control factors were the systems and the plant arrangements, the response variables were the detritivores, omnivores, herbivores and predators of the edaphic macrofauna. The variables were transformed based on the Box-Cox family, with the aim of establishing the optimal lambda, which would allow validating the statistical assumptions associated with the classification model. The Manova multivariate technique was also implemented, with canonical contrast of orthogonal type, in order to simultaneously evaluate all the variables under study. In addition, the Biplot technique and the descriptive process were applied in order to detect the joint relationships between all the variables studied simultaneously. The statistical packages used were SAS University Edition version 3.0.1, R and SPAD version 3.5.

## Results and Discussion

**Taxonomic and functional composition of the edaphic macrofauna.**

The taxonomic composition of macrofauna present in the three sampling sites, showed that the macroinvertebrates are represented by three Phyla (Annelida, Mollusca and Arthropoda), seven classes (Clitellata, Insecta, Diplopoda, Chilopoda, Gastropoda, Malacostraca, Arachnida), six orders (Haplotaxida, Hymenoptera, Coleoptera, Isopoda, Dermaptera and Araneae) and seven families of different orders. The functional composition of the edaphic macrofauna by components of the plant arrangement produced four trophic groups: Detritivores, Predators, Omnivores and Herbivores (table 2).

**Table 2.** Taxonomic and functional composition of the edaphic macrofauna.

**Tabla 2.** Composición taxonómica y functional de la macrofauna edáfica.

| Phyla | Common Name | Classes | Orders | Families | Functional Group |
|---|---|---|---|---|---|
| Annelida | Earthworms | Clitellata | Haplotaxida | Megascolecidae<br>Glossoscolecidae | Detritivores |
| Mollusca | Slugs and Snails | Gastropoda | - | - | Detritivores |
| Arthropoda | Millipede | Diplopoda | - | - | Detritivores |
| | Pillbugs | Malacostraca | Isopoda | - | Detritivores |
| | Beetles | Insecta | Coleoptera | Carabidae<br>Tenebrionidae<br>Scarabaeidae<br>Elateridae | Detritivores, Herbivores and Predators |
| | Earwigs | Insecta | Dermaptera | - | Detritivores |
| | Ants | Insecta | Hymenoptera | Formicidae<br>Subfamilia:<br>Myrmicinae | Omnivores |
| | Centipede | Chilopoda | - | - | Predators |
| | Spiders | Arachnida | Araneae | - | Predators |

**Statistical analysis of functional groups of edaphic macrofauna by sampling sites and management typologies**

Statistical difference was detected for the furrow zone between Transition II system, compared to the Conventional and Transition I systems, for the amount of detritivores and omnivores present ($p<0.05$). For the other combinations of management systems and sampling sites, no significant differences were detected ($p>0.05$) (table 3, page 84).

The multivariate analysis of the Manova variance, which takes into account all the variables related to macrofauna in its comparison, made it possible to detect a statistical difference ($p<0.05$) between Transition II and Conventional systems. For coffee and banana crops, no difference was found between systems in the amount of detritivores, omnivores, herbivores and predators ($p>0.05$) (table 3, page 84).

The largest number of detritivores and omnivores in the furrow of the transition II system with respect to the other systems are due to the fact that these sites have an organic management of the plantations and present a high biodiversity of microorganisms, plants and animals that cover the entire surface of the soil. Functional edaphic groups under this typology find characteristics similar to a natural ecosystem, endowed with quantity, variety and quality of plant and animal food, as well as microhabitats and resources to establish nesting sites (5, 11, 12).

Overall results in conventional systems indicate high levels of disturbance. The simplicity of these systems affects the decomposition of organic matter and nutrient recycling, as well as increasing negative impacts such as soil erosion, gradual loss of organic matter and plant cover, generate high temperatures that alter the local microclimate.

Consequently, these characteristics diminish the sustainability of coffee and lower soil quality (9).

Omnivorous populations were represented by ants, a very diverse group of food habits that find favorable conditions for reproduction and development in open coffee systems, disturbed, with few plant species, as occurs in conventional systems, where only predominantly banana cultivation. These conditions stimulate the presence of larger generalist ant species and soldiers made up of large heads and thickened bodies (3).

Omnivores participate in many key ecosystem processes, such as soil improvement, nutrient circulation and regulation of populations of herbivorous insects and predators, which explains the low populations of these groups in all systems (25).

In Transition I and II systems, these insects had greater resources available for different microhabitats and nutrients, which explains why high omnivorous populations are represented equally in these systems (4), as well as detritivores in turn, find a greater source of food to carry out physiological processes in order to improve soil properties and guarantee the fertility of the soil (5, 17, 28).

Significant differences observed in the furrow zone between systems are due to the fact that the coffee systems in Transition II, present a greater vegetable cover made up of leguminous, medicinal and weed species, which maintains a favorable microclimate in the soil, with abundant food and shelter, for the establishment of populations of detritivores and omnivores, which decreases in the Transition I and Conventional systems (11).

**Table 3.** Analysis Anovas and Manovas of the edaphic macrofauna by sampling sites and management typologies.

**Tabla 3.** Análisis Anovas y Manovas de la macrofauna edáfica por sitios de muestreo y tipologías de manejo.

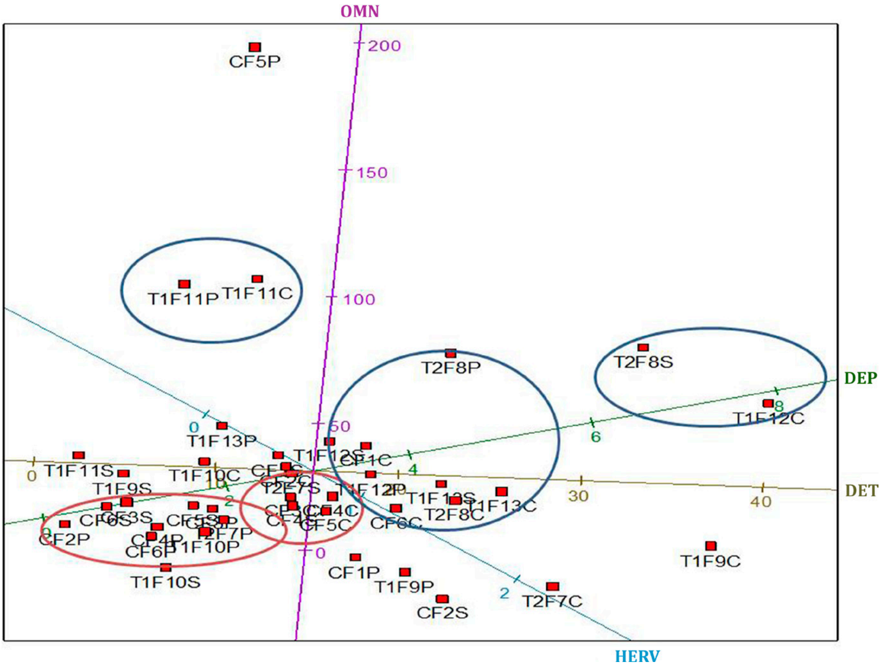
| MANAGEMENT SYSTEMS | DETRITIVORES (#Ind) | | |
|---|---|---|---|
| | MEDIA±STD | MAXIMUM | MINIMUM |
| Under coffee canopy | | | |
| CONVENTIONAL | 19.0±15.2 a | 39 | 1 |
| TRANSITION I | 24.0±13.8 a | 38 | 9 |
| TRANSITION II | 29.0±2.1 a | 30 | 27 |
| Furrow | | | |
| CONVENTIONAL | 6.0±2.6 b | 9 | 2 |
| TRANSITION I | 10.0±9.3 b | 26 | 3 |
| TRANSITION II | 30.0±9.0 a | 36 | 23 |
| Under banana canopy | | | |
| CONVENTIONAL | 6.0±4.5 a | 15 | 2 |
| TRANSITION I | 17.6±6.9 a | 26 | 10 |
| TRANSITION II | 20.0±19.0 a | 33 | 6 |
| HERBIVORES (#Ind) | | | |
| Under coffee canopy | | | |
| CONVENTIONAL | 1.0±0.8 a | 2 | 0 |
| TRANSITION I | 1.0±1.8 a | 4 | 0 |
| TRANSITION II | 2.0±2.8 a | 4 | 0 |
| Furrow | | | |
| CONVENTIONAL | 1.0±1.6 a | 4 | 0 |
| TRANSITION I | 1.0±0.8 a | 2 | 0 |
| TRANSITION II | 1.0±0.7 a | 2 | 0 |
| Under banana canopy | | | |
| CONVENTIONAL | 1.0±1.2 a | 3 | 0 |
| TRANSITION I | 1.0±0.9 a | 2 | 0 |
| TRANSITION II | 1.0±0.7 a | 1 | 0 |
| OMNIVORES (#Ind) | | | |
| Under coffee canopy | | | |
| CONVENTIONAL | 19.0±17.5 a | 47 | 1 |
| TRANSITION I | 47.0±40.4 a | 109 | 2 |
| TRANSITION II | 12.0±9.9 a | 19 | 5 |
| Furrow | | | |
| CONVENTIONAL | 12.0±8.5 b | 26 | 0 |
| TRANSITION I | 30.0±21.3 b | 59 | 0 |
| TRANSITION II | 53.0±38.1 a | 80 | 26 |
| Under banana canopy | | | |
| CONVENTIONAL | 41.0±84.4 a | 213 | 0 |
| TRANSITION I | 37.0±45.9 a | 113 | 2 |
| TRANSITION II | 45.0±42.2 a | 75 | 15 |
| PREDATORS (#Ind) | | | |
| Under coffee canopy | | | |
| CONVENTIONAL | 3.0±2.1 a | 6 | 0 |
| TRANSITION I | 5.0±2.9 a | 9 | 2 |
| TRANSITION II | 4.0±1.4 a | 5 | 3 |
| Furrow | | | |
| CONVENTIONAL | 2.8±1.7 a | 5 | 1 |
| TRANSITION I | 2.0±1.8 a | 4 | 0 |
| TRANSITION II | 5.0±3.5 a | 7 | 2 |
| Under banana canopy | | | |
| CONVENTIONAL | 2.0±1.5 a | 3 | 0 |
| TRANSITION I | 2.0±1.2 a | 4 | 1 |
| TRANSITION II | 3.0±1.4 a | 4 | 2 |
| COMPARISSON BETWEEN SAMPLING SITES | | | |
| | Coffee | Furrow | Banana |
| Wilks' Lambda | 0.6203 | 0.0338 | 0.7419 |
| Canonical | No difference | Transition II =a conventional=b | No difference |

Equal letters indicate that there is no statistically significant difference ($p > 0.05$) and different letters indicate that there is statistically significant difference ($p < 0.05$).

Letras iguales indican que no hay diferencia estadística significativa ($p > 0,05$) y letras diferentes indican que hay diferencia estadística significativa ($p < 0,05$).

The Biplot analysis simultaneously depicted the components of plant arrangement, systems and the source of the systems (finches) in association with macrofauna groups (detritivores, omnivores, herbivores, predators) (figure 1). The results show a separatist tendency of the Transition I and II systems, with respect to the Conventional ones. As well as between the results of the furrow and the banana and coffee.

Once again, the trend that separates the composition of functional groups in Transition and Conventional systems highlights the effect of managing coffee agroecosystems, where in the first instance management is organic with agro-ecological principles that conserve the components of the agroecosystems and in the second case the systems use intensive management with inadequate practices that degrade soil properties and cause the loss of functional biodiversity (22, 23, 26).




Functional groups: DET - Detritivores, HER - Herbivores, OMN - Omnivores, DEP - Predators. The codes F1, F2, F3, F4, F5 and F6 are the Conventional system (C), F7, F8 are the Transition II system (T2) and finally F9, F10, F11, F12 and F13 are the Transition I system (T1).

Grupos funcionales: DET - Detritívoros, HER - Herbívoros, OMN - Omnívoros, DEP - Depredadores. Los indicativos F1, F2, F3, F4, F5 y F6 son los sistemas Convencionales (C), F7, F8 son los sistemas en Transición II (T2) y por último F9, F10, F11, F12 y F13 son los sistemas en Transición I (T1).

**Figure 1**. Biplot of functional groups of edaphic macrofauna by sampling sites and management typologies of coffee systems.

**Figura 1**. Biplot de los grupos funcionales de la macrofauna edáfica por sitios de muestreos y tipologías de manejo de sistemas cafeteros.

With regard to soil use, the Biplot analysis confirmed that there is a greater interaction of the soil communities in the coffee and banana systems, since these systems present crops of different sizes throughout the year, offering invertebrates plant cover, fresh food, low temperatures, shelter and favorable conditions for their development and reproduction, which is evidenced in the Transition I and II systems, while there is a positive effect on the growth and reproduction of the soil. These results have coincided with different scientific research (10, 24).

## Conclusions

The functional composition of edaphic macrofauna under three components of the plant arrangement of coffee-growing systems was determined. In Conventional systems, the most abundant functional groups were predators, omnivores and herbivores; bioindicators of imbalance and disturbance of the soil, while in the Transition I and II systems the greatest abundance of detritivores was found; bioindicators of fertility and soil stability. The greater interrelationship of the functional groups of the edaphic macrofauna by management typologies was presented in the order Transition II>Transition I>Conventional, being the latter, the most disturbed systems and with low fertility, which makes them more prone to progressive degradation of soils, and by components of the plant arrangement in the order Banana>Coffee Crops>Furrows. From the agroecological approach, the functional groups of the edaphic macrofauna establish in the coffee systems interrelationships and key synergies for management above and within the soil, fundamental pillars in the restructuring and encouragement of processes between the components for agroecological conversion, towards sustainable and biodiverse systems. This research is a vital tool for agroecologists who wish to deepen in the efficiency of the biological processes that regulate the biodiversity and it is part of the agroecosystems complexity, under different management types in order to guarantee sustainability and resilience of coffee-growing systems or other agricultural sectors.

## References

1. Altieri, M. A.; Nicholls, C. I. 2008. Sistema agroecológico rápido de evaluación de calidad de suelo y salud de cultivos en el agroecosistema de café. Universidad de California. Berkeley. 1-16.
2. Armbrecht, I. 2016. Agroecología y Biodiversidad. Cali. Colombia. Editorial: Universidad del Valle. 18 p.
3. Armbrecht, I.; 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.
4. Armbrecht, I.; Gallego, M. C. 2007. Testing ant predation on the coffee berry borer in shaded and sun coffee plantations in Colombia. Entomología Experimentalis et Applicata. 124: 261-267.
5. Barbera, N.; Hilje, L.; Hanson, P.; Longino, J.; Carballo, M.; De Melo, E. 2004. Diversidad de especies de hormigas en un gradiente de cafetales orgánicos y convencionales. Manejo Integrado de Plagas y Agroecología (Costa Rica). 72: 60-71.
6. Brusca, R.; Brusca, G. J. 2003. 2° ed. Invertebrates. 966 p.

7. Cabrera, G. D. 2014. Manual práctico sobre la macrofauna edáfica como indicador biológico de la calidad del suelo, según resultados en Cuba. Fundación Rufford (RSGF, para la Conservación de la Naturaleza). 34 p.
8. Cabrera, G.; Robaina, N.; Ponce, D. L. 2011. Richness and abundance of soil macrofauna in four land uses of the Artemisa and Mayabeque provinces, Cuba. Pastos y Forrajes. 34(3): 313-330.
9. Cardona, D.; Siavosh, S. 2005. Aporte de materiales orgánicos y nutrientes en cafetales al sol y bajo sombrío de guamo. Chinchiná. Avances técnicos de Cenicafé, divulgación científica. 12 p.
10. Delgado, G.; Burbano, A.; Silva, A. P. 2011. Evaluación de la macrofauna del suelo asociada a diferentes sistemas con café (*Coffea arabica* L.). Revista de Ciencias Agrícolas. 28(1): 91-106.
11. Devi, M.; Solomon, E.; Chandru, D. 2013. Enhancement of soil fertility through agro imputs on response to cover crop of *Cratalaria Juncea* L. Microbiological research in agroecosistema Management. 175-186.
12. Farfán, V. F. 2014. Agroforestería y sistemas agroforestales con café. Federación Nacional de cafeteros-Cenicafé. Manizales. Colombia. 342 p.
13. FNC (Federación Nacional de Cafeteros de Colombia). 2014. Ensayos sobre Economía Cafetera, Editorial: Caficultura sostenible, moderna y competitiva. 128(30): 5-37.
14. Hernández-Vera, D.; Pompa-García, M.; Wehenkel, C.; Pérez-Verdín, G.; Carrillo-Parra, A. 2017. Are there any differences in carbon concentration among species of high conservation value forests in Northern Mexico? Revista de la Facultad de Ciencias Agrarias. Universidad Nacional de Cuyo. Mendoza. Argentina. 49(2): 183-192.
15. IGAC (Instituto Geográfico Agustín Codazzi). 2007. 2°ed. Estudio general de suelos y zonificación de tierras departamento de Antioquia. Subdirección de Agrología. Bogotá: Imprenta Nacional de Colombia. 595-599.
16. Lavelle, P.; Senapati, B.; Barros, E. 2003. Soil macrofauna. Trees, crops and soil fertility. Concepts and research methods. CABF Publishing. UK. 303-323.
17. Luna, G. 2009. Composición de la comunidad de hormigas a lo largo de un gradiente de intensificación agrícola en zonas de bosque Tropical Húmedo en la región Autónoma Atlántico Sur, Nicaragua. Tesis de grado en Licenciatura en Ecología y Desarrollo. Universidad Centroamericana. Nicaragua. 59 p.
18. Martínez , L. E.; Vallone, R. C.; Piccoli, P. N.; Ratto, S. E. 2018. Assessment of soil properties, plant yield and composition, after different type and applications mode of organic amendment in a vineyard of Mendoza, Argentina. Revista de la Facultad de Ciencias Agrarias. Universidad Nacional de Cuyo. Mendoza. Argentina. 50(1): 17-32.
19. Mejía, J. J. A. 2016. Plan de desarrollo. Andes: Inclusión, orden y progreso verde. Municipio de Andes. Antioquia. 17-108.
20. Min. Ambiente (Ministerio del Ambiente y Desarrollo Sostenible). 2014. Programa de las Naciones Unidas para el Desarrollo. Quinto informe nacional de biodiversidad de Colombia ante el convenio de diversidad biológica. Colombia. 101 p.
21. Nicholls, C. I.; Altieri, M. A.; Vázquez, L. 2016. Agroecology: Principles for the conversion and redesign of farming systems. Journal Ecosystem Ecograph S5: 010. Doi:10.4172/2157-7625.S5-010. 8 p.
22. Palacio, J. M. 2007. Estudio de tres diferentes usos del suelo y su efecto en la estructura y funcionalidad del ensamblaje de escarabajos coprófagos (Coleoptera- Scarabacidae) en el departamento de Antioquia-Colombia. 72 p.
23. Pardo, L.; Claudia, P.; Vélez, F.; Sevilla, E. 2006. Abundancia y biomasa de macroinvertebrados edáficos en la temporada lluviosa, en tres usos de la tierra, en Los Andes colombianos. Universidad del Valle, Grupo Empresarial Sostenible CVC. Editado para publicación en el marco de la disertación doctoral en Biología. 1-5.
24. Pimentel, D.; Hepperly, P.; Hanson, J.; Douds, D.; Seidel, R. 2005. Environmental, energetic, and Economic comparisons of organic and conventional farming systems. BioScience. 55(7): 573-582.

25. Rivera, L.; Armbrecht, I. 2005. Diversidad de tres gremios de hormigas en cafetales de sombra, de sol y bosques de Risaralda. Revista Colombiana de Entomología. 31(1): 89-96.
26. Robaina, N. 2010. Caracterización de las comunidades de la biota edáfica en los suelos de composición ferralítica de la Llanura Roja de la Habana bajo diferentes usos de la tierra. Tesis de grado de Master en Ciencias del Suelo. 4-23.
27. Robaina, N.; Vázquez, E.; Restrepo, L. F.; Márquez, S. M. 2017. Characterization and typification of coffee production systems (*Coffea arabica* L.), Andes municipality. Rev. Fac. Nac. Agron. 70(3): 8327-8339.
28. Rojas, A.; Hartman, K.; Almonacid, R. 2012. El impacto de la producción de café sobre la biodiversidad, la transformación del paisaje y las especies exóticas invasoras. En Ambiente y Desarrollo XVI. 30: 93-104.
29.UNEP (United Nations Environment Programme). 2010. Assessing the environmental impacts of consumption and production. International panel for sustainable resource management, Paris. 15 p.
30. USDA. United States Department of Agriculture. 2006. 10 ed. Keys to Soil Taxonomy. 332 p.
31. Vázquez, L. L.; Matienzo, Y. 2010. Metodología para la caracterización rápida de la diversidad biológica en las fincas, como base para el manejo agroecológico de plagas. Instituto de Investigaciones de Sanidad Vegetal (INISAV), Ministerio de la Agricultura. Ciudad de La Habana. Cuba. 1-12.

## Acknowledgments

Authors thank the economic support of the research project financed by CODI (COL0009556) - Universidad de Antioquia.

To all participant research groups and all coffee-growers in Santa Rita village in Andes municipality.