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Ethnoedaphology as an Integrating Process between Academy and Peasant Knowledge in the Productive System of Coffee (*Coffea arabica* L.) of Southwestern Colombia

Iván A. Delgado-Vargas, Hugo Ferney Leonel, Ángela A. Molina-Moreno, Nicolás Ojeda Chávez, Paula A. Pinta Paz

Faculty of Agricultural Sciences, University of Nariño, Pasto, Colombia
Email: *ivan.delgado@udenar.edu.co

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Abstract

Community knowledge about agricultural land and its management constitutes a complex system of wisdom, with universal principles and categories similar or complementary to those used by modern soil science. However, soil management is only recognized from the point of view of agronomy and academia, covering problems in rural areas at the time of adopting agricultural alternatives. For this reason, peasant knowledge was characterized and related to scientific knowledge, in the valuation of land properties in the coffee (*Coffea arabica* L.) production system. The study was carried out in four villages in the municipality of Buesaco (Nariño, Colombia), with humid pre-mountain forest conditions, an average temperature of 18˚C, annual rainfall of 1400 mm, and an altitude of 1959 m. The study was carried out in the municipality of Buesaco (Nariño, Colombia). Through field visits, priority was given to farms with coffee production systems under different types of shade. A semi-structured survey was applied to learn about the social, environmental, productive, ancestral, and cultural components, with the application of participatory methodologies allowed to learn about traditional management and practices in the soil component. The results allowed us to identify four types of production systems from coffee without shade to coffee in association with different multipurpose woody perennials and mosses. Diverse dynamics of crop and land management are presented. Several references were found to differentiate land types such as color, texture, production and fertility, being characteristics that are associated to classify soil quality and make management decisions and type of fertilization. Through the perception of the farmers, six land classes with different characteristics were identified, relating the characterization with what was obtained in the chemical analysis of lands. It can be concluded that the perception of coffee growers, dark shades in the land representing better quality than light shaded soils, both associated with characteristics such as quantity of organic matter, presence of weeds, growth and development of the crop, perceptions that coincide with the variables of scientific knowledge such as availability of nutrients, organic matter, pH and texture.

Keywords

Ethnoedaphology, Local Knowledge, Scientific Knowledge, Local Referents, Land Properties, Coffee Cultivation

1. Introduction

Soli is a natural, dynamic and highly complex component whose chemical, physical and biological properties interact with each other, maintaining a balance that allows the adequate development of agrobiodiverse ecosystems [1] [2]. However, as a resource, it is limited to meeting the growing demand of the population and its food needs, contributing to its degradation due to the effects of climate change and anthropic activities such as the use of unsustainable agricultural practices, causing erosion, sedimentation of rivers, loss of water sources, loss of vegetation cover and loss of biodiversity [3].

The diversity of agricultural practices by farmers presents a social, cultural and ethnic richness specific to every region, however, mechanization and technological packages tend to homogenize production, thus losing traditions and customs, as well as native crops and seeds [4]. So, the local knowledge of farmers constitutes a complex system of wisdom, which arises from experience, which has allowed them to face the challenges that arise in their environment [5], this knowledge presents universal principles and categories similar or complementary to those used by modern soil science [6].

In Colombia, the knowledge of agricultural lands has generally been handled from the agronomic study, through the evaluation of physical and chemical properties in laboratory, covering the problems encountered from this perspective [7], due to the lack of communication between technicians and producers, most of the time the views and knowledge of the local population are neglected and modern scientific knowledge is imposed as the only valid [8] [9]. The approach to the knowledge of rural communities in general and, in particular, to the local knowledge of soil, has been called Ethnoedaphology or peasant land classification, which studies the perception of soil properties, its nomenclature, relationship with ecological factors and its management in agriculture [7] [10], which is catalogued as a science that comprises the knowledge that a community has acquired by relating to the soil resource.

Thus, the need to promote the integration of peasant knowledge and scientific knowledge focused on the soil resource, its forms of evaluation and its application in the coffee sector, of the Department of Nariño, which is made up by 64 municipalities, of which 41 are coffee producers [11]. In Nariño region, producers attribute the impacts of the soil on production systems due to a change in heat intensity and rainfall patterns. These temperature changes are evidenced by more frequent frosts during the months of July, August, January and February, due to the relatively dry conditions associated with the influence of El Niño phenomenon and the increase in precipitations for the inter-Andean region in the case of the La Niña phenomenon [12] [13].

By the previous, present study has as purpose, highlighting land local knowledge and generating positive interaction between academy and community to the recovery and academy the land in the coffee productive system in the municipality of Buesaco and with coffee growers benefiting from the project Macro of Minciencias call for applications 818 - 2018 named "Analysis of extreme events of associated with climate variability and change for the implementation of adaptation strategies in agricultural production systems in Nariño".

2. Methods and Materials

2.1. Study Site

The study was realized in the municipality of Buesaco, located at a distance of 36 kilometers from Pasto; Nariño-Colombia [14]; with an altitude of 1.959 m.s.n.m; an average temperature 18 C, average annual precipitation of 1.400 mm, with a life zone of Humid forest pre-mountain [15]. According to Argoti and Belalcazar [16], the sidewalks Medina-Espejo, Hatillo-Medina; Veracruz and Juanambú have favorable geographic and agro-ecological conditions for coffee with multipurpose woody perennials and agricultural crops (**Figure 1**).

2.2. Sample Size Determination

The size of the sample was obtained through a database provided by Agropecuarian technique Assistant Municipality Unit (UMATA) of the municipality of Buesaco, with a size of population of 570 families; based on representativeness of 90% of confidence and because the population is finite [17], sample size was determined of 41 coffee producers families (with a 90% confidence level) thought the following formula

$$n = \left(NZ^2 pq\right) / \left(\left(N-1\right)E^2 + Z^2 pq\right)$$

where:

n = size of sample search.

N = size of population or Universe (570).

Z_α^2 = Statistic Parameter that depends on confidence level (NC) (90%).

e = Max error estimation accepted (10%).

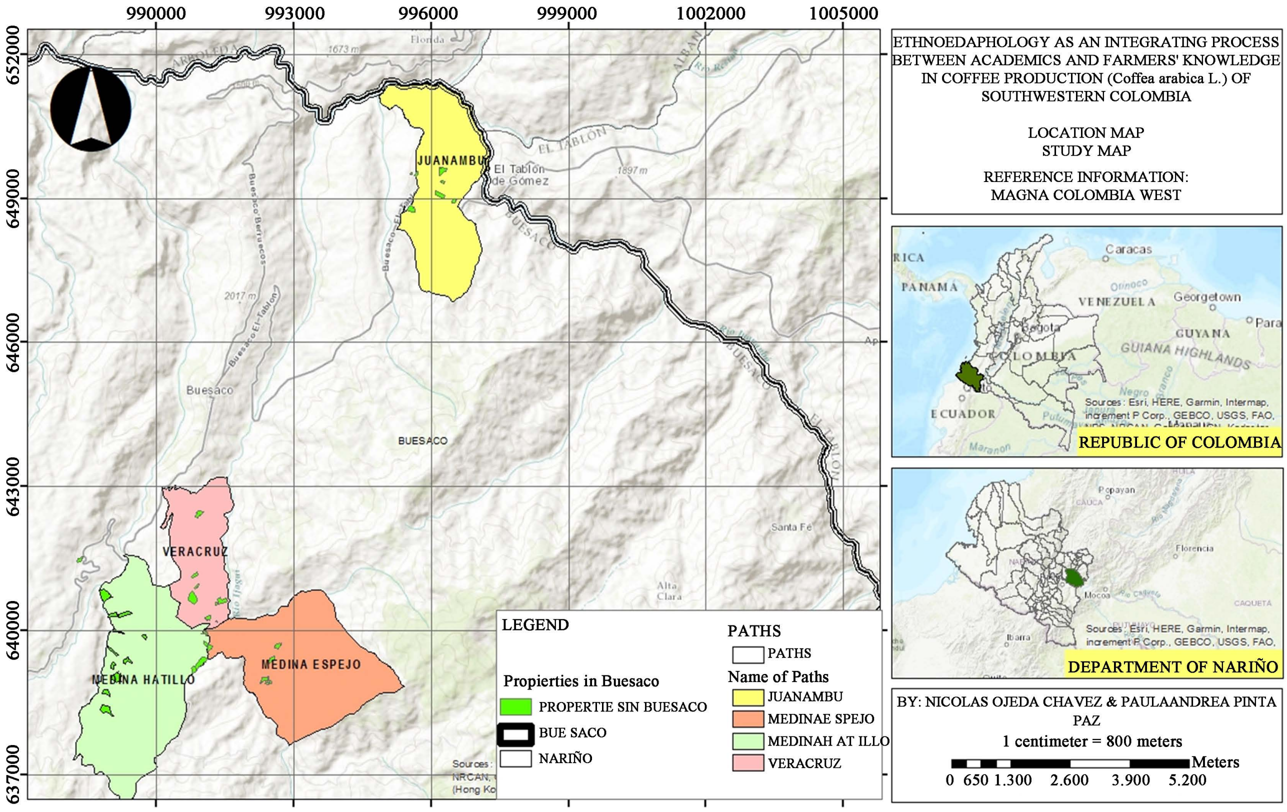

Figure 1. Municipality location; Juanambú; Hatillo-Medina, Medina-Espejo and Veracruz: Buesaco (Nariño).

p = probability that happens the studied (success) (50%).

$q = (1 - p)$ = probability that do not happen the studied event (50%).

The distribution was realized in the following way: Hatillo Medina: 11; Veracruz: 11; Juanambú: 9 y Medina Espejo: 10 families. The following selection criteria were taken into account: to be coffee producers, to live on a sidewalk for at least 10 years, and availability of time for the participatory workshops. We worked with Participatory Action Research Methodology, allowing the community to be principal part to the study, where the coffee producers have the opportunity to expose their ideas and knowledge. Methodology with qualitative focus, which has the intentions and purposes, the actions of the social actors involved the different procedures that develop and the achievements they reach [18].

2.3. Characterization of Local Knowledge and Management of Coffee Harvest

For the biophysical characterization of the coffee production system, visits were made to farms, where the production system and its management were observed, and a semi-structured survey was applied to farmers on aspects related to land, farm area, species associated with coffee, farmers' knowledge on soil management, species association, land preparation practices, among others [19].

2.4. Classification and Identification of Local Indicators of Land Quality

Through the use of practice guides to the characterization of soil and land [20] five properties of land were collected and evaluated; Thus, a relationship was established between the farmer and the professional, seeking the exchange of knowledge about the soil. By means of social mapping [7], maps of each farm were made to learn about the diverse knowledge in crop and soil management [21]. It was established to establish six typologies of soils, recognized by farmers, of good, regular and poor quality, as they are construction that arises from the integration of the professional and the farmer.

For soil sampling, the following selection criteria were taken into account: degree of slope, type of vegetation (age of the crop) and previous management (fertilization and soil preparation). The type of sampling in each production system, was zig zag, obtaining 15 to 20 soil subsamples, which were subsequently homogenized to extract a soil sample of one kilogram [22]. The soil samples were taken to the Soil and Agricultural Inputs Laboratory of the Universidad de Nariño, where variables associated with chemical and physical characteristics of the soil were determined (**Table 1**).

Table 1. Soil chemical and physical parameters evaluated in land laboratory.

Parameter	Chemical Parameters	
	Methods	**Techcnique**
pH, Potentiometer land relation: water (1:1)	NTC 5264	Potenciometric
Organic matter	Walkley-Black (Colorimétrico) NTC 5403	spectrophotometric uv-vis
Phosphorus Available	Bray II y Kurtz NTC 5350	Spectrophotometric uv-vis
Cation Exchange capacity (CEC)	CH_3COONH_4 1NpH7 NTC 5268	Volumetric
Exchange calcium Exchange magnesium Exchange potassium	CH_3COONH_4 1NpH7 NTC 5349	Atomic Absorption Spectrophotometry
Exchange aluminum	Extraction KCL 1N NTC 5263	Volumetric
Iron available Manganese available Coper available Zinc available	DTPA-NTC 5526	Atomic Absorption Spectrophotometry
Boron available	Hot water NTC 5404	Spectrophotometric uv-vis
Total nitrogen	Based on organic matter	Calculation
Oxidizable organic carbon	Walkley-Black (Colorimetric) NTC5403	Spectrophotometric uv-vis
Sulfur available	$(Ca(H_2PO_4)_2 \cdot H_2O$, 008 M NTC 5402	Spectrophotometric uv-vis
	Physical parameters	
Texture	By touch	
Apparent density	Graduated cylinder	

Source: Land and Agricultural Inputs Laboratory of the University of Nariño. Delgado y Chávez [23].

The interpretation of the laboratory analyses was carried out, with the levels or ranges of each variable [24] and the corresponding rapprochement between the knowledge of farmers and academia, based on the analysis of the information.

2.5. Statistical Analysis

A Multiple Correspondence Analysis (MCA) was performed, with which correlations between variables were established. In addition, a classification analysis was performed. The qualitative information was processed statistically using the SPAD program, version 5.6.

3. Results and Discussion

3.1. Characterization of Local Knowledge of the Coffee Production System

By means of the Multiple Correspondence Analysis—MCA, it was characterized to understand the dynamics of the coffee agroecosystems. The majority of coffee growers have their own land (V1 = 1) (32 farms), with an area ranging from 1 to 2 hectares (V2 = 1) (17 farms), in agreement with that registered for the coffee ecotope 220[a] where the municipalities of La Unión and Buesaco are located, 74.4% of the farms have less than 3 hectares and predominantly the cultivate *C. arabica* [11]. Four types of coffee production systems (V3) were found: 1) coffee in association with canopy shade of some perennial woody perennials and mosses (V3 = 2) (27 farms); 2) coffee in association with canopy shade of multipurpose perennial woody perennials (V3 = 1) (10 farms); 3) coffee in association with mosses (V3 = 3) (2 farms); 4) coffee without canopy shade (V3 = 4) (2 farms).

In the plots, between two to three established coffee varieties (V6 = 2) (24 farms) are evident: Castillo variety (V7 = 1) (33 farms), Caturra variety (V10 = 1) (19 farms) and Colombia variety (V11 = 1) (15 farms), being the varieties most cultivated by farmers in Nariño (Colombia and Castillo) due to their tolerance to rust (*Hemileia vastatrix* Berk. & Broome) [25]. Seventy percent of the farm's present coffee in association with multipurpose woody perennials, from 3 to 5 species (V4 = 2), where orange (*Citrus sinensis* (L.) Osbeck), lemon (*Citrus limon* (L.) Osbeck), mandarin (*Citrus reticulata* L.), monkey tamarind (*Inga edulis* Mart), loquat (*Manilkara huberi* (Ducke) Standl), avocado (*Persea americana* Mill. Var Hass), banana (*Musa paradisiaca* L.), banana (*Musa* spp.), and guineo (*Musa* spp.). The presence of fruit trees provides the farmer with an additional alternative for family food security and the remaining product for sale [11]. The shade coffee system is a model of sustainable development that provides goods and services such as soil protection and conservation, nutrient recycling, and habitat for different organisms, among others [26] [27].

Among the management activities, weeding was found, which was done on a monthly basis (V15 = 3) (18 farms); the waste is incorporated as organic fertilizer, On the other hand, a practice that did not perform on a regular basis is the harvest rotation (V16 = 2) (27-farmers). Delgado-Vargas [27] mentions that is feasible done with transitory crops such as corn, Bush beans and table tomatoes, in order to diversify and obtain income in periods of establishment or renovation of coffee plantation up to the period before the first flowering.

For pest recognition, 48% of farmers (V21 = 1) (20 farms) identified the CBB (*Hypothenemus hampei*). However, the farmers stated that they did not present considerable damage to the production system. This is due to the relationship between CBB infestation and altitude, with the insect's development being greater between 1.200 and 1.300 m above sea level, and temperatures above 21˚C [28]. Constantino [28] regarding diseases, 51% of farmers (V20 = 1) (21 farms) recognized rust (*Hemileia vastatrix*) as a problem during production, and the community stated that they manage it by applying copper oxychloride.

As a fertilization method, 95% of the farmers use agrochemical fertilizers with applications from 20 ± 60 gr/plant (seedling and sowing stage) and 100 ± 120 gr/plant (growth and production stage) in the months of March and November (V17 = 1) (39 farms). The fertilization process derives from the knowledge and experience acquired that allows inferring the doses required by the crop depending on its phenological stage. On the other hand, 63% of the population applies organic fertilization (V18 = 2) (26 farms), by means of vermicompost and biopreparations (V19 = 3) (18 farms).

Therefore, 75 % of the coffee growers do not know the real nutritional's requirements and do not have into account or do not have a previous land analysis (V22 = 2) (V23 = 4) (31 farms) Since the technique part, a land analysis is recommended to know the weaknesses of nutritive elements, according to the age of the productive system, that allows doing corrective applications or amendments [29]. However, the perception of coffee grows establish that the practice and experience have allowed adapting to different situations, recognizing how "Good" the land of fertility (V24 = 1) (21 farms) and it is associated with the production (V25 = 1) (16 farmers) and presence of macrofauna (V26 = 1) (26 farmers) main of worms in the land. The family Lumbricicidae helps to improve the properties of physis helping the formation of aggregates, water retention, mineralization of organic material, infiltration of water, development of roofs and serves as indicators of biological quality of soils [30].

In the same way the farmers acknowledge deficiencies of nutrients in the crops (V27 = 1) (22 farmers) mainly by the color of the leaves, fallow leaves, stains on the roof's necrosis and deformities, among others (V28 = 4) (19 farmers) the growing of crops and the low productivity, which is directly commensurate to the edaphic mineral nutrition [24].

In relation to associativity, 75% of the farmers do not belong to an association (V29 = 2) (31 farms), however, they state that association is important to obtain benefits, such as marketing and training, because it allows them to know and adopt measures to face climate variability and change (V30 = 2) (22 farms), and to know soil management and conservation practices (V32 = 1) (35 farms). This is a rural development strategy implemented by the communities that allow them to achieve better social, environmental and economic results [31] [32].

3.2. Identification of Local Soil Indicators

Through the Participatory Action Research process, it was possible to understand the farmers' vision of how to value the soil resource, taking into account characteristics such as color, texture, organic matter, porosity, humidity, and pH besides the production and location, as references that allow them to differentiate one soil from another and qualify their quality, in this way, the farmer recognizes the management practices that should be carried out on his farm for a certain type of soil. Subsequently, collective maps were constructed to identify the different types of "soil" (local term for soil resource) identified by the farmers, depending on the location on the farm, slope and use, categorized as good, fair and poor (**Table 2**).

In this way, the exchange and dialogue of knowledge was essential for the differentiation and identification of six types of soil Aguilar [33] in a related study said that key informants, through field visits and inspection by visual and tactile means, took into account the physical characteristics of the soil, as structure, texture, stoniness, depth and color, with the above, eight types of soil were identified (black, red cascajillo, cascajillo, yellow cascajillo, barrial, red barrial, polvillo and tepetape).

The Multiple Correspondence Analysis (MCA), allowed inferring the most significant variables of local knowledge of lands, where the type of black land (V1 = 1) predominates (40 farms), cataloged as good quality (V7 = 1) (38 farms), associated with characteristics such as color (V13 = 1) (13 farms), which allows

Table 2. Farmers' perceptions of soil types and quality, Buesaco, Nariño.

Municipality	Farm	Owner	Kind of land	Quantity of land	Local land references
Medina Espejo	El Chirimoyo	Bolívar Jojoa	Tierra Negra	Well	Location, black color, good production, good organic matter content.
			Tierra Cascajosa	Bad	Yellow color, difficult workability, poor drainage, low production, low organic matter content, stoniness, short life cycle.
Juanambú	El Guayabo	Benito Bolaños	Tierra greda	Bad	Gray color, poor drainage, clayey texture, short crop growing cycle.
Veracruz	Loma Gorda	Guillermo Valencia	Tierra café	Regular	Brown color, regular production, low nutrient availability, clay texture.
Juanambú	El Mango	Sonia Urbano	Tierra azul	Good	Blue color, good nutrient content, easy workability, moisture retention, good production.
Hatillo Medina	Buena Vista	Carlos Pantoja	Tierra combinada	Regular	Color, regular production, good organic matter content.

the farmer to differentiate those areas of his farm where the growth and development of crops are more favorable. The fertility reference (V67 = 1) (38 farms), is associated with the presence of weeds such as pacunga (*Bidens pilosa*), bread with cheese (*Galinsoga parviflora* Cav), turnip (*Brassica alba* Boiss) and horsetail (*Equisetum arvense* L.), allowing a high availability of nutrients (V85 = 1) (38 farms) and organic matter (V37 = 1) (36 farms), which is mainly associated with the decomposition of leaf litter in the land, moisture retention (V79 = 1) (34 farms), good rooting (V73 = 1) (30 farms), and texture (V25 = 2) (27 farms), described by them as loose, sandy, loamy and soft to the touch.

Color is of great importance as it is considered an indicator of fertility [34]. The type of black land is classified according to edaphic characteristics, particularities recognized by coffee growers, they are deep, friable lands, with high moisture retention, considered the best productivity [35], which is directly related to high organic matter content, as opposed to light, reddish or yellow lands, which are considered limiting for crop production [36].

This kind of soil could be rescued mentioned by the coffee farmer Guillermo Valencia to Veracruz municipality "the black soil kept more humidity because is like a sponge, that retains and absorb, at the same time has major organic matter and roofs, indicates that soil is loose because in solid soil there is no roof" Mr. Carlos Pantoja to the sidewalk Hatillo-Medina said that "there are plants as Pacunga and Pan con Queso that when decay it helps to the soil and the touch perceive it as released and granny, to good production to the different harvest".

Another type of land identified by farmers is gravelly land (V5 = 1) (33 farms), with a clayey texture (V29 = 3) (32 farms), which makes it difficult to work and manage crop establishment activities due to its stony texture; it is differentiated by its yellowish color (V17 = 4) (29 farms) and is frequently located in the upper parts of the farms (V23 = 1) (27 farms). Organic matter is low (V41 = 3) (25 farms), and the application of organic manure and fertilizers are required to improve its fertility and make coffee growth possible. Characteristics that classify it as poor-quality soil (V11 = 3) (22 farms), due to its low production (V53 = 3) (22 farms) and therefore represent losses for the farmer, due to its hard textures, waterlogging during the rainy season; brittle soil in the summertime, poor root development, short life cycle and lower production [35], according to farmers, "The yellow color of these soils, is an indicator of the poor nutrition they give and the low production capacity" [7].

Other relevant properties are soil pH (V35 = 2) (28 farms), identified by acidity indicator plants (V36 = 1) (31 farms), such as fern (*Pteridium aquilinum* (L.) Kuhn), which evidences poor soil "bad" or "little productive", with a yellow soil color, for which, it is necessary the application of agricultural amendments and tillage activities [37] [38]. Organic matter (V31 = 4) (22 farms), is associated with organic residues, which, through decomposition processes, release nutrients to crops, it is identified by the presence of leaf litter in soil, crop residues, weeds, among others. Therefore, farmers recognize the influence of OM in water retention; improvement of soil physical, chemical and biological properties, among others [39] [40].

Coffee growers recognize the benefits of perennial woody agroecosystems in association with coffee, standing out the incorporation of leaf litter, microclimate for coffee plants, land improvements to the fertility of soil due to nutrient cycling, porosity due to the presence of roots and earthworms, that facilitate aeration and nutrient input, and reducing the development of weeds [41]. This can be maintained through good agricultural practices, the use of organic fertilizers, land cover, minimum tillage, planting of polycultures, among others [42].

3.3. Classification of Local Knowledge of Soils

The Multiple Correspondence Analysis (MCA) presents 3 groups (**Figure 2**): The first group conformed by 12 farms (29.26%) presenting 88.89% with brown soil (V4 = 1), 100% of the farmers mention that the availability of nutrients of the brown soil is regular (V88 = 2) and it is located in the lower part of the farms (V22 = 3), 88. 89% state that it is a land of regular fertility (V70 = 2), it is differentiated by its brown color (V16 = 3), has regular production (V52 = 2) and is classified as of regular quality (V10 = 2), 87.50% of the population identifies it as a land of regular humidity retention (V82 = 2) and regular organic matter content (V40 = 2); About this kind of soil the coffee farmer Federico Diaz said that "to the touch it feels drier, having a regular production by lack of nutrients" and the coffee farmer Elizabeth Rivera has observed "that the coffee does not develop in a good way and has fallen of fruits and shelves".

Group two, made up of 25 farms, (60.97%) presents a gravelly soil type (V5 = 1), with 78.79%, low levels of organic matter with 80% (V41 = 3) and clayey texture with 78.13% (V29 = 3). Group three, formed by four farms (9.75%), 100% have blue soil (V2 = 1), located in the lower part of the farms (V20 = 3), with

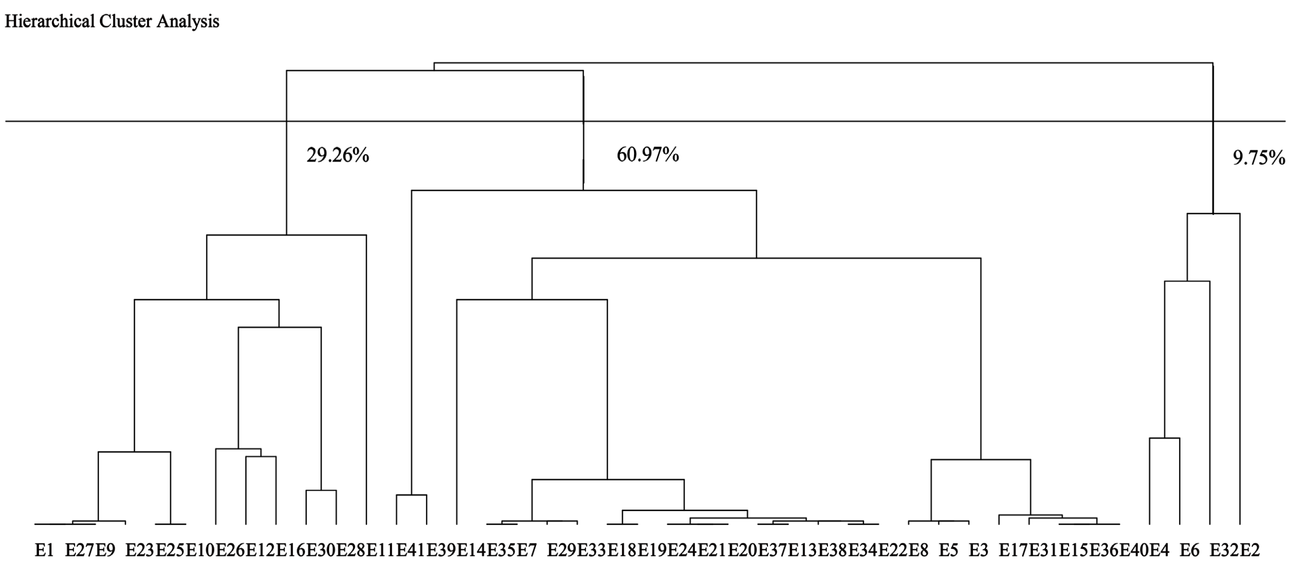

Figure 2. MCL dendrogram of the farms evaluated of local knowledge of soils.

clayey texture (V26 = 3), good quality soil (V8 = 1), high level of organic matter (V38 = 1), good production (V50 = 1), good fertility (V68 = 1), good moisture retention (V80 = 1) and good availability of nutrients (V86 = 1). About the blue soil the coffee farmer Sonia Urbano mentioned that "lets to retained the humidity, has good quality and is fertile faced in the coffee production".

Ortiz [7] through a cluster of farms, found three groups with 11 types of lands referenced by farmers, by their characteristics, are considered of good quality, such as black and clay land; lands of regular quality, denominated as loose land, wagon, parched and terrace and lands of poor quality; in it are those denominated by farmers as forest land, muddy, stony, yellow and edge.

3.4. Laboratory Analysis of Land Physical and Chemical Properties

According to the parameters of Soil Lab (**Table 1**), the physical and chemical variables of lands, the interpretation of land analysis for coffee cultivation proposed by CENICAFE [24] was taken as a reference, 10 representative variables were found: The K content is within the required range (greater than 0.4 cmol$^+$/kg) (V4 = 3) (36 farms). Its concentration in andisol soils, is moderately high, stimulates root growth and improves crop resistance to diseases [43]. However, when higher contents are present, it affects production up to 8% [44].

P levels in the lands analyzed are low (less than 10 mg/kg) (V2 = 1) (24 farms). In soils of the Andean region of Colombia, deficiencies of this element are quite common, with average values of 7.2 mg/kg due to its low disponibility, making it one of the most limiting elements in agricultural production, in addition to the high capacity of phosphorus fixation from fertilizers or soluble sources, especially by adsorption processes that limit the efficiency of phosphorus fertilizers [45].

The presence of Al with a value of less than 0.5 cmol$^+$/kg (V5 = 1) (40 farms), presents low values, being a characteristic of soils derived from volcanic ashes in Colombia, which allows not finding severe symptoms of toxicity for plants [43], and does not represent problems for the establishment of the coffee production system. The pH presented values higher than 5.5. Low levels of Zn (1.5 mg/kg) and medium levels of Cu (1.0 to 3.0 mg/kg) are present. As reported by Montoya-Salazar [46], acidity in soils derived from volcanic ash generates problems of availability of nutrients such as P, but benefits the availability of others such as Zn and Cu, which explains the results obtained in this research.

As for B content, values of less than 0.2 mg/kg were found (V9 = 1) (28 farms). In general, in lands with low OM, the lack of B is more frequent and the deficiency of this element can reduce production [43] [47]. Fe presents high values of 50 mg/kg (V6 = 3) (29 farms). Arteaga [48] reported the behavior of chemical variables of land subjected to different uses, high Fe contents (>50 mg/kg), which respond to the nature of areas of volcanic influence, due to the participation of iron oxides and hydroxides that are the product of the weathering of igneous rocks.

In relation to Cation Exchange Capacity (CEC), average levels of 15 to 25 cmol/kg were recorded (V3 = 2) (27 farms). This property is a determinant of soil fertility, it constitutes a temporary reserve of exchangeable bases, therefore, a higher CEC helps reduce losses of elements such as Ca^{2+}, Mg^{2+} and K^{+} by leaching, making fertilization more efficient [24].

3.5. Classification of Land Scientific Knowledge

With respect to the scientific knowledge of the land in the coffee production system of Buesaco, three groups were inferred (**Figure 3**). The first group is made up of 25 farms (60.97%) of the total number of farms studied, 85.71% of the farms have a low level of boron (B) (V9 = 1) and 85% have a low level of zinc (Zn) (V8 = 1). The second group is made up of two farms (4.87%), with 100% of the them having a sandy clay loam (FAa) soil texture (V10 = 6). The third group is made up of 14 farms (34.14%) of them, where 100% of the farms are characterized by having a soil with a high level of Zinc (Zn) (V8 = 3), with a loamy loam (FL) texture (V10 = 7), with a high level of boron (B) (V9 = 3).

The first and second groups show similar results in terms of chemical and physical soil properties, as described above, with the exception of the third group that shows variability with respect to the levels of Zn and B, farms with pH levels higher than 5.5. When the pH is lower than 5.5, there is a low presence of Zn, Cu and B, which explains the high levels of microelements in this research [43].

3.6. Relationship between Ethnoedaphological and Scientific Knowledge

The Classification Analysis for qualitative variables of ethnoedaphological knowledge and scientific knowledge (**Table 3**), shows the grouping of the study farms. The land analysis is a tool used by the academy to characterize land

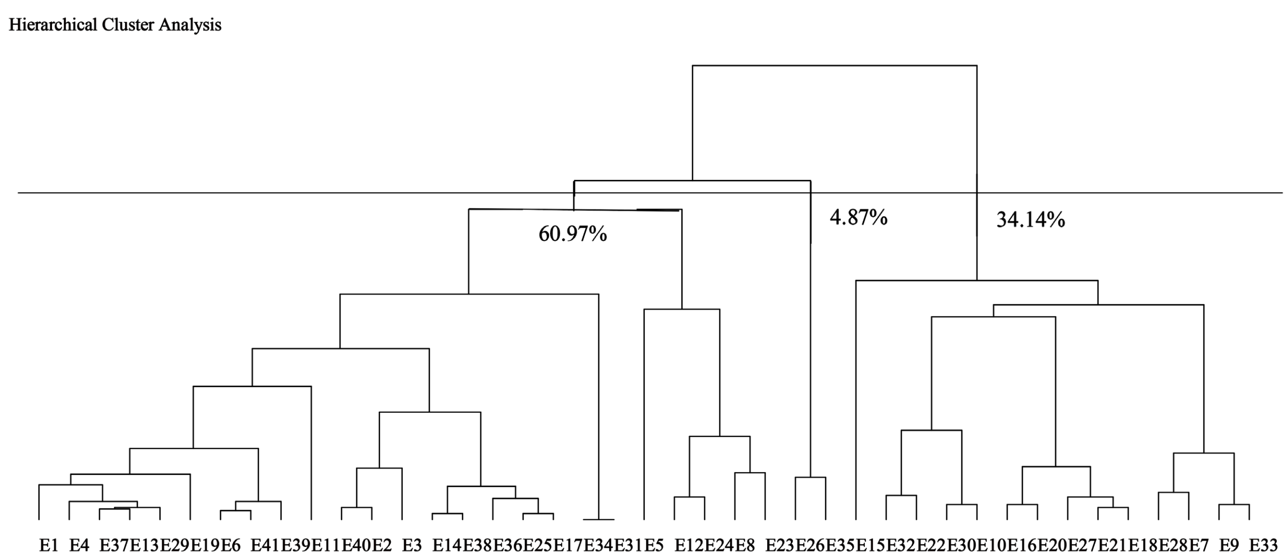

Figure 3. Dendogram to ACM of the farmers with productive system of coffee, of scientific knowledge of lands.

Table 3. Relationship between qualitative variables of local knowledge and scientific knowledge.

Groups	Farm	Kinks of land	Local variable knowledge	Scientific knowledge variables
Group 1	E23	Black land	Quality, color, location, texture, organic matter, yield, biological activity, fertility, rooting, moisture retention, nutrient availability, pH, drainage, effective depth, associated species benefits	Al medium, K high, pH medium, B low, CIC medium, Fe high, Cu medium, P medium, Zn low, Texture A
Group 2	E35	Gravelly land	Quality, color, location, texture, organic matter, species association, organic matter, yield, fertility, moisture retention, nutrient availability	Low Al, high K, high pH, high B, low B, medium CEC, medium Fe, low Cu, low P, low Zn, FAa Texture
Group 3	E32	Black land	Quality, color, location, texture, yield, yield, fertility, moisture retention, nutrient availability	Al low, K high, pH high, B medium, CIC medium, Fe medium, Cu medium, P low, Zn medium, Texture FA

properties, as well as the perception of farmers and the referents, which allow them to differentiate soil typologies, which agree for the group of good and bad quality soils, black soil type and gravelly, which allows inferring that the perception of farmers is correct since it coincides with the results obtained in the laboratory analysis. The farms with the most representative characteristics E23, E35, E32 were selected and the soil typologies were established, with their respective associated references and the characteristics of each soil analysis, as shown below:

With the consolidated information, three groups are formed with two types of soils identified by the farmers. The first and third groups indicate the physicochemical characteristics that are considered of good quality, for the typology and references of Tierra Negra, and the second group includes the typology and characteristics of soils that are classified as poor quality, gravelly soil. Soils that, according to physicochemical analysis and local knowledge analysis, are of good quality, are characterized by having properties with adequate edaphic factors for coffee cultivation, in variables related to fertile soils, such as pH, Cu, P, B, Fe, Zn, and FA texture [24] [47].

In the category of poor-quality soils, there is gravelly soil, with inadequate edaphic levels for cultivation, in variables such as pH, Al, K, B, CIC, Cu, P, Zn, elements that, at these levels, represent problems for coffee development, especially pH [24] [47].

According to bulk density, presented values between 0.84 and 1.15 g/cm^3 coincide with those reported by Salamanca [48], and correspond to high levels, because they are volcanic ash-derived soils that are charactered by presented a lower MO content. The increase in DA, as a consequence of compaction, decreases macroporosity and aeration, increases mechanical resistance to penetration, affects the normal absorption of nutrients and water, impedes microbial activity, reduces infiltration, and induces changes in soil structure and functional behavior [49].

The productivity of the coffee crop depends on the interaction of various factors, from the human component, the proper management of the physical, chemical and biological properties which condition root growth and nutrient absorption, therefore, knowing them becomes the fundamental support for adequate nutrition [24]. With the above, it is demonstrated that the perception of the farmers of the Municipality of Buesaco, is valid, due to the fact that the categorization and identification of referents associated with the investigated soils are based on the experience, culture, traditions and local knowledge obtained, in the management and observation of coffee production [50].

The variables that contributed most to the characterization of the soils are pH, K, P, Al, CIC, Cu, Fe, B, Zn and Texture, when compared with the perception of the coffee grower, coincide in the levels of nutrient availability, organic matter, quality, production, fertility, texture and pH through the identification of acidity indicator plants. Therefore, the ethnoedaphological approach constitutes an important input when differentiating and evaluating soils in such a way that the farmer plays an important role in recognizing the quality of soils and generating references according to color, production, location, biological activity, fertility, moisture retention, nutrient availability, porosity, porosity and pH, nutrient availability, porosity, pH, acidity indicator plants, organic matter, among others, which allows him to classify soils into three groups, good, regular and bad, and to propose appropriate management practices, such as chemical and organic fertilization, application of organic amendments, irrigation, erosion control (living barriers), among others [7] [33] [34].

Ntongani [51] and Hernández-Hernández [52], state that achieving sustainable land management does not depend solely on the technical knowledge of the processes and functions of agroecosystems, but it is necessary to develop interactive communication and learning tools that incorporate technical understandings generated by scientific research, and the knowledge of producers, their expectations and criteria, which are decisive when making decisions related to agricultural practices adjusted to their agroecological and socioeconomic reality.

4. Conclusions

The extension process establishes within the Participatory Action Research to generate integration and exchange of agricultural knowledge, academy, to identify local indicators of soils, which let to determine some variables as color, texture, porosity, pH, and organic matter.

The ethnoedaphological approach was an important input for differentiating and evaluating the soils Aldo the farmers, recognizing soil quality and generating the classification of six soil types that made it possible to understand the various agricultural practices in the region.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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