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# Comparative evaluation of local and scientific knowledge on soil characteristics in agroecosystems of the Oziel Alves III Settlement Project, DF

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## ABSTRACT

The objective of this work was to verify similarities and differences between local and scientific knowledge by interrelating local and scientific indicators of soil quality. The research was based on the "InPaC-S" and "Scientific Validation of Empirical Indicators" methods. The study was carried out in the Oziel Alves III Settlement (DF) in nine areas: three with successional agroforestry management in the initial stage, three with successional agroforestry management in the secondary stage, and three with conventional management. Semi-structured interviews and a scientific validation workshop were conducted with farmers and Embrapa researchers. 143 ethnoindicators were raised: 74 for soil fertility, 45 for water availability in the soil, 15 for soil compaction, and 9 for soil biology. Of this total, 92 (64%) were fully or partially validated by the researchers, 14 (10%) were classified as "potential research objects," and 37 (26%) were not validated. The ethnoindicators were reorganized, showing that 43% were related to the characteristics of cultivated plants, 23% to soil biota, 19% to soil properties, and 15% to spontaneous plants. Settled lands using an agroforestry management system tripled the frequency of ethnoindicators in comparison to those with conventional management, with the exception of ethnoindicators related to roots or plant vigor.

**Index terms:** agroforestry system, ethnopedology, knowledge dialogue.

# Avaliação comparativa dos conhecimentos locais e científicos sobre características do solo em agroecossistemas do Projeto de Assentamento Oziel Alves III, DF

## RESUMO

O objetivo deste trabalho foi verificar similaridades e diferenças entre conhecimento local e científico, inter-relacionando indicadores locais e científicos de qualidade do solo. A pesquisa se baseou nos métodos "InPaC-S" e "Validação Científica dos Indicadores Empíricos". O estudo foi realizado no Assentamento Oziel Alves III (DF), em nove áreas: três com manejo agroflorestal sucessional na fase inicial, três com manejo agroflorestal sucessional em estágio secundário e três com manejo convencional. Foram realizadas entrevistas semiestruturadas e oficina de validação científica com agricultores e pesquisadoras da Embrapa. 143 etnoindicadores

**Ideias centrais**

- Interação entre conhecimento científico e local na pesquisa de etnoindicadores de qualidade do solo.
- Validação científica significativa dos etnoindicadores de qualidade do solo.
- Etnoindicadores reorganizados demonstraram predomínio dos relacionados às características das plantas cultivadas.
- Frequência significativamente maior de etnoindicadores originários de agricultores com manejo agroflorestal em relação aos com sistema de manejo convencional.
- Foi levantada ampla gama de etnoindicadores, estando o maior número relacionado com a fertilidade do solo.

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foram levantados: 74 para fertilidade do solo, 45 para disponibilidade de água no solo, 15 para compactação de solo e 09 para biologia do solo. Deste total, 92 (64%) foram validados total ou parcialmente pelos pesquisadores, 14 (10%) foram classificados como "objeto potencial de pesquisa" e 37 (26%) não foram validados. Os etnoindicadores foram reorganizados, mostrando que 43% estavam relacionados às características das plantas cultivadas, 23% à biota do solo, 19% às propriedades do solo e 15% às plantas espontâneas. Os assentados com sistema de manejo agroflorestal triplicaram, pelo menos, a frequência de etnoindicadores pesquisados em relação aos com manejo convencional, com exceção dos etnoindicadores relacionados com raízes ou vigor das plantas.

**Termos para indexação:** sistema agroflorestal, etnopedologia, diálogo de conhecimentos.

# INTRODUCTION

The relationship between scientific knowledge and local knowledge is becoming increasingly visible as science is a fundamental form of knowledge that can validate ethnoknowledge and receive new research objects (Meneses, 2014; Mattos et al., 2019).

Dialogue between scientific knowledge and local knowledge, with the aim of identifying, recovering, and valuing traditional knowledge about soils, helps generate environmental, productive, and cultural information that is important for scientific analyses and interpretations (Matos et al., 2014; Beatriz-Melo, 2019).

In order to value social practices and production methods characteristic to rural communities, it is necessary to carry out a continuous process of systematization and study of local knowledge and its validation through scientific analysis (Nivagara, 2018).

Considering the intrinsic associations between different forms of knowledge in the evaluation of soil characteristics, ethnopedology conceives that local pedological knowledge is constituted in the daily activity of family farming, with approaches that are gaining new approaches and expanding the conceptual scope (Araújo et al., 2013).

The comparative approach establishes similarities and differences between ethnoknowledge and scientific knowledge, which include documentation, understanding, and interaction with local approaches to perception. It also involves soil classification and evaluation of its properties and processes, soil-plant interrelationships, and more recently, soil quality indicators used by farmers (Barrera-Bassols & Zinck, 2003; Barrios et al., 2006).

Including the perspective of social actors when building and selecting indicators evaluated by scientific criteria strengthens the dialogue between research and local knowledge (Mattos et al., 2019). As a result, methodologies are increasingly adopting these methodologies as this dialogue plays an important role in research studies and helps researchers and other participants immersed in problematic situations learn more (Picheth et al., 2016).

Agroecology is inserted in this dynamic and complex context and is a reflection of the historical connection between farmers and researchers, whose approach includes emphasis on the interrelationships between agrosystem components and the dynamics of ecological processes, in addition to being a comprehensive study of all environmental and human elements (Scarabeli & Mançano, 2020).

Agroecology values the local knowledge systems of natural assets. How they are used, and thus facilitates the dialogue between scientific and local knowledge, create opportunities for further construction and expansion (Cacho et al., 2018).

Building a dialogue promoted by the agroecological approach and soil science, through ethnopedology, promotes the investigation of local terms used by farmers and can also provide the socialization of interpretations between scientific and local knowledge, thus producing new knowledge with a greater potential for application and sustainability (Carvalho, 2016).

In this sense, the objective of this work was to verify the relationship between science and the knowledge of settled farmers, more specifically, the similarities and differences between scientific and empirical knowledge about the physical, chemical, and biological characteristics of the soil, interrelating local indicators and soil quality scientists.

## MATERIAL AND METHODS

The research was conducted between April and August 2019 in the Oziel Alves III Settlement Project, located next to Highway BR 020, about 65 km from Brasilia-DF, between the urban centers of Planaltina-DF (approximately 25 km from Brasilia) and Formosa-GO (about 20 km from Brasilia). The participants in our research were the settlers associated with Aprospera (Association of Agroecological Producers of Alto de São Bartolomeu).

The Oziel Alves III Settlement is divided into 16 groups, organized into agricultural villages. There are a total of 168 lots (settled families) with 34 settled families associated with Aprospera, 13 of whom have official certification for organic farming.

The existing soil classes in Oziel Alves III are Red Latosol (69.57% of the total area), Red-Yellow Latosol (18.56%), Cambisol (1.80%), Gleisol (0.79%), and Quartzite Neosol (9.28%). The relief is predominantly “Smooth Wavy” (64.60%), but also features areas classified as “Flat” (26.99%), “Wavy” (7.64%), “Strong Wavy” (0.75%), and “Mountainous” (0.02%). The native vegetation consists of gradients containing samples of cerrado, cerrado sensu stricto, and denser formations such as cerradão and cerrado rock. (Emater, 2013).

The research activities were based on complementary methodologies, referred to in this study as 1) the “ICRAF Method” (International Center for Agroforestry Research), more specifically, the “InPaC-S: Participatory Integration of Knowledge on Soil Quality Indicators” (Barrios et al., 2011), and 2) the “Embrapa Method”, more specifically, the “Scientific Validation of Empirical Indicators of Environmental Services” (Mattos et al., 2019).

The ICRAF method was aimed at the participatory methodologies carried out in the field, specifically in the mobilization, in the dynamics of the workshop presenting the research proposal, and in the workshop of systematization of the ethnoindicators raised on the field.

The Embrapa method was used to select the themes to be worked on, to prepare semi-structured interviews, as well as for guided tours through the production areas and the workshop of interpretation and scientific validation of the empirical knowledge of the ethnoindicators surveyed in the field. This method included evaluating the conformity between the local and scientific indicators surveyed in the different production systems in the Oziel Alves III settlement.

Both methods employed activities to demonstrate that empirical, local, or popular knowledge about soil quality indicators has scientific validity, and that empirical forms of observation and interpretation of soil qualities have the potential to identify research objects. Thus, the Embrapa and ICRAF methods were used to complement each stage of the research.

Two initial events were held at the Oziel Alves III settlement (mobilization meeting on 06/26/2019 and workshop on 07/10/2019), both of which presented the research methods and case studies to the Aprospera associated settlers. These meetings were used to define the themes of this study, particularly the soil properties that would be evaluated in the fieldwork, as well as the criteria for selecting the study areas.

The soil properties presented and accepted for the assessment of soil quality were:

1. Soil chemistry – soil fertility (high or low)

2. Physical-hydric – availability of water in the soil; soil compacting

3. Biological (life in the soil) – soil macro and microorganisms

The selection criteria for the areas of study, which addressed practical details of the production systems were:

1. Similar soil types (Red Latosol or Red-Yellow Latosol)

2. Types of management systems – areas (lots) of nine farming families who are available and interested in continuing the work using the following management systems detailed below.

a) successive agroforestry management system - initial stage (up to three years of implementation) - 1/3 of cases (areas of three settlers);

b) successive agroforestry management system - secondary stage (more advanced, with more than three years of implantation) - 1/3 of cases (areas of three settlers);

c) conventional management system – 1/3 of cases (areas of three settlers) – located in the same agricultural villages as the Aprospera settlers.

The agroforestry management system stages were classified according to the descriptions presented by Miccolis et al. (2016) and Couto (2017).

Thus, in the initial stage of the agroforestry system, lines were found with the presence of trees and fruits (banana, coffee, papaya, eucalyptus, mutamba, palm trees, pineapple, among others) and between the lines there was the presence of vegetables and annual and biannual crops. (lettuce, carrots, chives, cabbage, beets, arugula, mustard, cassava, sweet potatoes, corn, among others).

The "secondary stage" of the agroforestry system was predominantly composed of medium-cycle perennial species (eucalyptus, citrus, soursop, embaúba, jabuticaba, mutamba, mastic, annatto, banana, avocado, coffee, guava, among others).

In the second phase, guided tours were conducted in the production systems of each batch, accompanied by the application of semi-structured interviews. A systematization workshop was then held at PA Oziel Alves III to review the ethnoindicators with the settlers who were participating in field activities.

The third phase took place in a scientific validation workshop held at Embrapa Cerrados, where ethnoindicators were assessed with four settlers who participated in the project, a doctoral student in ecology, an ecology professor from UnB, and seven researchers from "EMBRAPA Cerrados".

The participants were divided into thematic groups (chemistry, physics, and soil biology) and each ethnoindicator was classified as either YES (validated), NO (not validated), YES, WITH CONDITIONS (validated with conditions, i.e., as long as other ethnoindicators or manifest phenomena were observed) and R&D OBJECT (potential research object for indicators with no scientific information).

Classification of the ethnoindicators was built on consensus and the farmers played a fundamental part in these discussions, in addition to eliminating any possible misinterpretations of responses recorded in the field.

## RESULTS AND DISCUSSION

### Breadth and integration of farmers' knowledge about soil quality

In the survey, 143 ethnoindicators of soil quality were surveyed and systematized with the settlers (with scientific and local terms). More than half of the ethnoindicators referred to soil fertility (74 ethnoindicators of soil chemistry), followed by ethnoindicators of water availability (45 ethnoindicators), soil compaction (15 physical-hydric soil ethnoindicators), and soil life indicators (09 ethnoindicators of soil biology).

Some of the 18 ethnoindicators of low soil fertility (Table 1) were the presence of termites (*Coptotermes formosanu* - four quotes), the yellow color of the soil ("yellow earth, lighter"; three quotes), and the presence of *Urochloa decumbens* ("decreases as soil becomes more fertile"; two quotes).

There were 56 ethnoindicators (Table 1) of high fertility, including darker soil color ("blacker"; 7 citations), higher organic matter content (5 citations); the presence of *Bidens pilosa* ("*indicates that the land has improved*" or is "*well fertilized*"; 4 citations"), *Phyllophaga* spp. (boró/coró; 4 citations), *Pheretima hawayana* (earthworms; 3 citations) and *Ageratum conyzoides* (mentrasto; 3 citations).

21 ethnoindicators were cited for the presence of water in the soil (Table 1). The emphasis was on the existence of *Pheretima hawayana* (earthworm; five citations), on the "*fresh*" soil, to the point that when "*pressing the ground*, *water does not come out in the hand*" (four citations); the opposite was mentioned for excess water in the soil when performing the same procedure, "*mines water in hand*" (two citations).

As for the ethnoindicators related to the scarcity of water in the soil (14 ethnoindicators; Table 1), the lack of plant vigor stood out, particularly "*the deforestation of the plants*" (three citations) or the "*top leaves*" of peppers or tomatoes (two citations).

Among the 15 soil physical ethnoindicators were dense soil (four citations, such as "*hard, rough soil, with difficulty digging*") or the opposite for non-compacted soils, "*soft, fluffier soil*" (two citations), in addition to the presence of more organic matter (seven citations).

Regarding soil biology (Table 1), nine ethnoindicators were identified, with frequent citations of Pheretima hawayana (earthworm; two citations), indicating the existence of life in the soil.

**Table 1.** Number and description of ethnoindicators related to soil chemistry (low and high fertility), soil water availability (presence of water, water scarcity, excess water, and deep water), soil physics (non-compaction and soil compaction), and soil biology (macro and microorganisms) surveyed with Oziel Alves III farmers.

| Ethnoindicators - Soil chemistry (74) | |
|---|---|
| Low fertility (18) | - Color (yellow earth, red earth), smell (odorless soil), and soil consistency (loose soil, similar to sand);<br>- Plant color (yellowish plant), plant vigor (plant does not develop; thinner stems and leaves; bell pepper flowering falls off; bell pepper falls off while still small); and fruit with nutritional calcium deficiency (peppers and tomatoes with a dark skins);<br>- Presence of herbs, shrubs and/or trees – *Urochloa decumbens* (Brachiaria);<br>- Presence of macro-organisms and microorganisms - *Coptotermes formosanu* (termites), *Atta* spp. (saúva ant), *Tetranychus evansi* (mite) and *Oidiopsis tauric* (powdery mildew). |
| High fertility (56) | - Soil color and scent (dark soil, with more scent);<br>- Organic matter and soil cover – the presence of more organic matter and soil cover, incorporation of organic matter, area without burning (increased mulch); soil dries up and does not become loose (not compact, as it is in the northeast); |
| | - Plant Vigor - *Plant with vigor ("up to the bush*"), "*beautiful plant, produces well*" (broccoli, cabbage, flower cough, cough), *rapid development* (lettuce, cabbage, flower cough), produces over a longer time (cabbage); *thicker leaf* (*more prominent*); very beautiful *tomato bulb, with thin hairs on the stem and large leaves; pepper produces more fruits;*<br>- Plant color – the dark green color of cultivated plants, "*very green leaves*" (lettuce, broccoli, cabbage, cauliflower, spinach, crab, guava, jackfruit, and corn);<br>- Root color - white root (brachiaria, mustard, and an unconventional food plant);<br>- Root size - "*larger size*" root; |

Continued...

**Table 1.** Continuation.

| | |
|---|---|
| High fertility (56) | - Presence of herbs, shrubs, and/or trees - *Portulaca oleracea* (common purslane), *Physalis* spp. (canapu), *Acanthospermum hispidum* (butterbur), *Amaranthus* spp. (cariru/carurú), *Crotalaria* spp., *Cassia occidentalis* (fedegoso), *Cajanus cajan* (pigeon bean), *Chenopodium Ambrosioides* (mastruz/herba de santa maria), *Ageratum conyzoides* (mentrasto/casadinha), *Bauhinia fortifica* (paw), *Bidens pilosa* (black beggartick), *Sonchus oleraceus* (milkweed), *Emilia sonchifolia* (false milkweed), "*weeds do not appear*" and "*Brachiaria (Urochloa decumbens) is decreasing in the agroforestry system*";<br>- Presence of macro-organisms and microorganisms - cockroach (scientific name not identified), *Phyllophaga spp.* (june beetle), *Solenopis Saevissima* (fire ant), *Pheretima hawayana* (earthworm), *Diaphania spp.* (wireworm, due to more organic matter), *Agrotis epsilon* (screwworm) and earthworm (presence of organic matter, scientific name was not identified), and nematodes (general citation, not possible to correlate with the scientific name). |
| Ethnoindicators - Water availability in the soil (45) | |
| Available water (21) | - Soil scent (the earth has a smell), soil moisture (humid/fresh soil; the soil is pressed and "*water does not come out of the hand*"), presence of soil cover;<br>- Plant vigor - Pepper with vigor, larger "*head*" and garlic root (soil slope, taking water and nutrients);<br>- Characteristics of the roots - white, flexible; soil sticks to the root (when pulling plant from soil);<br>- Soil moisture - Banana (*Musa* spp.) preserves more moisture;<br>- Presence of herbs, bushes and/or trees - *Bidens pilosa* (black-jack – "grows anywhere there is moisture"), *Amaranthus* spp. (cariru/caruru);<br>- Presence of macro-organisms and microorganisms - More abundant life in the soil, presence of spiders (general citation, not possible to correlate with the scientific name) and beetles (general citation, not possible to correlate with the scientific name) under the banana, and microorganisms in the banana clumps, *Lagria villosa* (beetle), *Phyllophaga spp.* (scarab beetle), *Solenopis Saevissima* (fire ant), *Pheretima hawayana* (earthworm), and frog (general citation, not possible to correlate to the scientific name). |
| Water shortage (14) | - Soil consistency - Loose soil, similar to dry sand (sandy soil);<br>- Soil drying - Cracked soil (northeast);<br>- Presence of macro-organisms and microorganisms - Soil has less life than humid regions (e.g. between the rows of passion fruit);<br>- Plant Vigor - plant drying;<br>- Fruit color - peppers with blackened skin due to water not reaching the bottom;<br>- Roots - smooth root ("the earth does not stick to the root when pulling the plant"), weakened and hard;<br>- Typical characteristics of the plants - Fruit trees (mango) survive with less water, *Cajanus cajan,* and *Ricinus communis* (pigeon pea and castor beans survive the lack of rain). |
| Excess water (4) | - Soil Moisture - *Squeeze the soil and water comes out in hand (mine water in my hand)*;<br>- Plant Color - yellow plant;<br>- Plant vigor - weak plant;<br>- Plant diseases (symptoms) - *Xanthomonas campestres* (bacterial spot) on the pepper leaf (*spot on the pepper*); *Phytophthora capsici* (chili wilt - "*fungus near the root of the stem*"). |
| Deepwater (6) | - Popular knowledge - *When two iron sticks (held in hands, one parallel to the other) begin to vibrate and cross each other indicates underground water*;<br>- Presence of herbs, bushes, and/or trees - Presence of *Vernonanthura phosphorica* (roasting white fish), *Cecropia spp.* (embaúba) green even in the dry season (and without irrigation), *Eucalyptus spp.* (eucalyptus) root is deeper and draws water well;<br>- Presence of macro-organisms and microorganisms - *Coptotermes formosanu (termite - indicates water "vein"); "areas where clouds of swallow birds fly close to the ground is indication that there is deepwater"*. |
| Ethnoindicators soil physicists (15) | |
| No compression (10) | - Soil with more organic matter; presence of soil cover; soft, fluffy soil; soil is not "crumbled";<br>- Roots - Deepest root in harrowed soil; deeper rooted plants - *Crotalaria pumila* and *Canavalia ensiformis* (crotalaria and jack bean); root comes out of soil and develops easily - *Cajanus cajan* and *Manihot esculenta* (bean and cassava). |
| Soil compaction (5) | - Hard soil, very rough; difficulty digging the soil; cracked soil ("In the northeast, areas where the land is very dry, the soil becomes cracked, almost compacted");<br>- Plant development - Plant grows slowly and weakly;<br>- Crooked root – The root of the plant curls up, and does not penetrate (does not develop). |

Continued...

**Table 1.** Continuation.

| Biological Ethnoindicators (9) | |
|---|---|
| Soil macroorganisms (8) | - Presence of organic matter and soil cover; wet soil has more life than dry (e.g. between irrigated rows of passion fruit );<br>- Presence of macro-organisms - beetles under the *Musa* spp. (banana) "*hunt for moisture*"; *Phyllophaga* spp. (boró/coró); *Solenopsis* spp. (fire ant) under the banana; *Atta* spp. (saúva) or *Acromyrmex* spp. (quenquen); slug (general citation, not possible to correlate to the scientific name); *Pheretima hawayana* (earthworm). |
| Soil microorganisms (1) | - Presence of microorganisms in the clumps of *Musa* spp. (banana) - gather water and take it into the soil. |

### Scientific bases and local knowledge in the evaluation of ethnoindicators of soil quality

The 143 ethnoindicators surveyed were evaluated in the scientific validation workshop as follows (Table 2). 32 (22%) were classified as "YES" (validated, without reservations); 60 (42%) as "YES, WITH CONDITIONS" (correlation with other soil quality indicators that must be observed); 14 (10%) as "R&D OBJECT" (indicator without scientific information to be refuted or validated – potential research object); and 37 ethnoindicators (26%) categorized as "NO" (with no scientific validation).

By using the Embrapa method we were able to validate 92 ethnoindicators (64%) in the classifications YES (validated) or YES, WITH CONDITIONS (validated under conditions). This is close to the rate of 63% obtained by Mattos et al. (2019) for the same classification in a study conducted in the Cerrado biome.

**Table 2.** Results of the validation workshop for chemical, physical-water, and biological ethnoindicators of soil quality.

| Ethnoindicators of soil quality | Validation of ethnoindicators (Number of ethnoindicators) | | | | | |
|---|---|---|---|---|---|---|
| | Yes | Yes with conditions | No | R&D object | Subtotal (Yes and with conditions) | Total |
| Chemical Ethnoindicators | 11 | 27 | 24 | 12 | 38 | 74 (52%) |
| Low fertility | 2 | 5 | 8 | 3 | 7 | 18 |
| High fertility | 9 | 22 | 16 | 9 | 31 | 56 |
| Water Ethnoindicators | 8 | 27 | 8 | 2 | 35 | 45 (31%) |
| Water in the Soil | 1 | 20 | 0 | 0 | 21 | 21 |
| Water shortage | 5 | 6 | 3 | 0 | 11 | 14 |
| Excess Water | 1 | 0 | 3 | 0 | 1 | 4 |
| Deep water | 1 | 1 | 2 | 2 | 2 | 6 |
| Physical Ethnoindicators | 8 | 5 | 2 | 0 | 13 | 15 (10%) |
| Soil compaction | 1 | 2 | 2 | 0 | 3 | 5 |
| No compaction | 7 | 3 | 0 | 0 | 10 | 10 |
| Physical-Water Subtotal | 16 | 32 | 10 | 2 | 48 | 60 (42%) |
| Biological Ethnoindicators ("Life in Soil") | 5 | 1 | 3 | 0 | 6 | 9 (6%) |
| Soil microorganisms | 0 | 1 | 0 | 0 | 1 | 1 |
| Soil macro-organisms | 5 | 0 | 3 | 0 | 5 | 8 |
| Total | 32 | 60 | 37 | 14 | 92 | 143 |
| Percentage | 22% | 42% | 26% | 10% | 64% | |

The reorganization of soil fertility ethnoindicators (soil chemistry), soil compacting and water (soil water physics), and soil life (soul biology) gave us a different view of the 143 soil quality ethnoindicators (Table 3):

1. Cultivated plants (development, vigor, withering, plant and root color) – 62 ethnoindicators (43% of the total);

2. Soil biota – 33 ethnoindicators (23% of the total);

3. Soil properties (organic matter, texture, consistency, moisture, soil color and smell) – 27 ethnoindicators (19% of the total);

4. Spontaneous plants – 21 ethnoindicators (15% of the total).

**Table 3.** Relationship between chemical, biological, and physical-water ethnoindicators of soil quality.

| Soil quality Ethnoindicators | Number of Ethnoindicators | | | | Total |
|---|---|---|---|---|---|
| | Chemicals | Biological | Physical – Water | | |
| | Fertility | Life in soil | Compression | Water in the soil | |
| 1. Characteristics of cultivated plants | 36 | 0 | 8 | 18 | 62 (43%) |
| Development/vigor | 19 | 0 | 1 | 6 | 26 |
| Plant color | 13 | 0 | 0 | 3 | 16 |
| Plant root | 4 | 0 | 7 | 9 | 20 |
| 2. Soil biota | 12 | 8 | 0 | 13 | 33 (23%) |
| 3. Soil Properties | 10 | 1 | 7 | 9 | 27 (19%) |
| Organic matter and soil cover | 3 | 1 | 1 | 1 | 6 |
| Soil texture | 2 | 0 | 0 | 0 | 2 |
| Soil consistency | 0 | 0 | 6 | 0 | 6 |
| Soil moisture | 0 | 0 | 0 | 7 | 7 |
| Soil color and smell | 5 | 0 | 0 | 1 | 6 |
| 4. Spontaneous plants | 16 | 0 | 0 | 5 | 21 (15%) |
| Total | 74 | 9 | 15 | 45 | 143 |

The wide scope and integration of knowledge stood out in ethnoindicators for organic matter and soil cover (Table 3). These were correlated with (high) fertility, soil biology (soil life), water availability, and non-compact soils. All these indicators (6) were also validated (YES or WITH CONDITION).

This ethnoknowledge related to organic matter is corroborated by studies that consider it to be an ideal indicator for assessing soil quality. This is based on the fact that several functions and biological, physical, and chemical processes that occur in the soil are directly related to the presence of organic material. (Pulleman et al., 2000).

The theoretical-conceptual basis also confirms that constant dead biomass cover in the soil affects the biological diversity and temperature of the soil, thus reducing evaporation and increasing the storage capacity and infiltration of water into the ground. Conversely, removing the dead biomass cover, as well as turning the soil, can destabilize aggregates and expose the carbon in organic matter to microbial oxidation, which is released into the atmosphere in the form of $CO_2$ (Cherubin et al., 2017).

Ethnoindicators for “plant roots” (20 ethnoindicators, 16 validated as YES or WITH CONDITIONS) were not just associated with soil biology such as “white plant roots”, their greater development, size, and depth (high fertility and non-compaction), or the opposite, a “weakened” root (water scarcity).

The plant root, according to Primavesi (2009), is a multiple indicator of soil conditions as it indicates compaction and consolidation, correct management of organic matter, excess or lack of water, and nutritional deficiencies.

Soil biota (33 ethnoindicators; 18 validated as YES or WITH CONDITION) was related to fertility (12 ethnoindicators) and soil water availability (13 ethnoindicators), in addition to being connected to the existence of life in the soil (eight ethnoindicators). Similarly, earthworms (Pheretima hawayana; high fertility, life and water in the soil), microorganisms and "*small beetles*" in banana trees (water and life in the soil), tree frogs (*Phyllomedusa spp*.), spiders and armored catfish (*Lagria villosa* - water on the ground), and leaf-cutting ants (*Atta spp*. - low fertility) were all validated (YES or WITH CONDITION).

These associations are in line with studies that demonstrate how soil organisms actively participate in the chemical, physical and biological processes of the soil (Rousseau et al., 2013).

Despite insufficient scientific validation of ethnoindicators (21 ethnoindicators, 13 not validated), spontaneous plants had three ethnoindicators classified as research objects, specifically the plants that indicate fertile soil, such as mastruz (*Chenopodium Ambrosioides*) and mentrast (*Ageratum conyzoide*s).

There are spontaneous plants with positive allelopathy, such as mastruz (*Chenopodium Ambrosioides*), which has root exudates that stimulate the growth of some crops, maize being one example (Kalh, 1987), or which indicate organic matter in the soil, like mint (*Ageratum conyzoides*).

Native and spontaneous plants emerge to correct mineral deficiencies and excesses, compaction, and stagnant water as they try to restore an optimal condition of greater biological productivity (Primavesi, 2017).

Soil organisms stand out as research objects and have ethnoindicators of fertility (six) and availability of deep water in the soil (one), such as the termite (*Coptotermes formosanu* - low fertility and deep water in the soil).

Termite activity in the soil changes the physical properties of the soil, the distribution and nature of organic matter, the availability of nutrients, and affects plant growth (Gholami & Riazi, 2012).

### Systemic view of farmers with an agroforestry management system

The results referring to the frequency of responses by farmers in the researched management systems (successional agroforestry management system – initial and secondary and conventional stages) showed a quantitative and qualitative difference in terms of the diversity and frequencies of ethnoindicators of soil quality (Figure 1).

The (six) farmers who adopted an agroforestry management system had triple the number of responses as the (three) farmers who adopted conventional management, the only exception being ethnoindicators related to roots and plant vigor.

The best performance for chemical and physical parameters of soil quality in agroforestry systems highlights the beneficial effects of agroforestry management. They are capable of increasing nutrient cycling (Aguiar et al., 2014; Froufe et al., 2020), the content of organic matter (Sacramento et al., 2013) and soil structure (Stöker et al., 2020).

The presence of perennial species (trees) generates multiple benefits, which include creating more favorable microclimates for plant production (decrease in temperature, increase in humidity), the periodic contribution of biomass to the soil, ultimately improving its quality, and the diversification of production (Lasco et al., 2014).

Of note was the number of citations of ethnoindicators related to spontaneous plants (n=25) and soil biota (n =36) by farmers with agroforestry management. There was even a correlation between the same organism and different soil properties, which shows the farmers' broad and integrated view of soil quality variables.

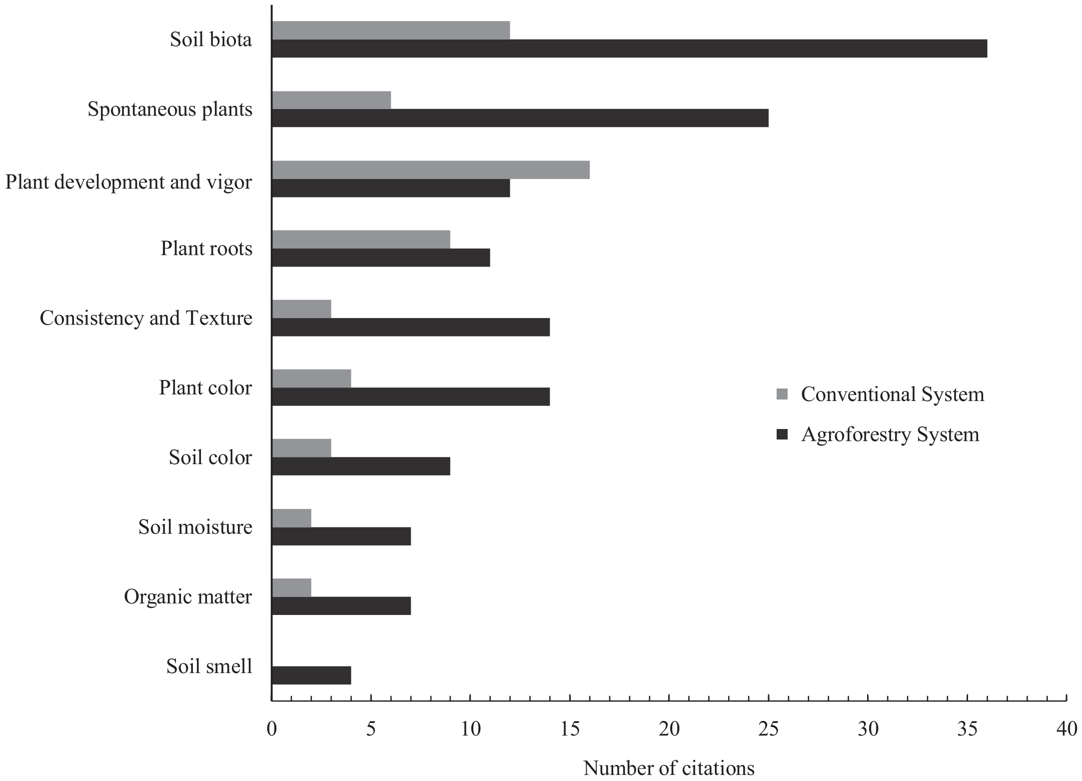

**Figure 1.** Frequency of responses (number of citations) of farmers who use agroforestry and conventional management systems, in relation to ethnoindicators of soil quality.

Broad assessments that simultaneously group physical-water, chemical, and biological properties provide a dynamic view of how soil responds to transitions and changes in management as many of these processes and attributes are interrelated. According to Mendes et al. (2018), the best indicators combine the effects of several attributes in production processes.

This distinctive way of building a relationship between human beings and the natural environment represents a shift from appropriation and exploitation to a more harmonious and mutualistic relationship, one in which humans and nature interact, cooperate, and benefit from each other (Fontes et al., 2013).

This more accurate and complete knowledge of soil quality indicators from family farmers in this study who use agroforestry management (compared to family farmers who use conventional systems) is also beneficial to science as it leads to new observations and perceptions. It is also important that the scientific process helps to validate knowledge, as well as challenge itself with new research objects (Mattos et al., 2019).

## CONCLUSIONS

The significant proportion of scientific validation of soil quality ethnoindicators demonstrated the importance of the dialogue of knowledge between farmers and scientists. This dialogue is recurrent at PA Oziel Alves III, due to both the proximity (physical and institutional) and the exchange with non-governmental organizations and teaching, research and extension institutions, strengthening the interaction between academic theory and peasant practice.

Farmers' integrated knowledge about soil quality was verified in the correlation of several ethnoindicators with different chemical, physical-water and biological properties of the soil, with emphasis on those settled with agroforestry management systems, due to the complexity of such systems allows more observations of the ecosystem functions that are manifested.

Despite the limitations of the geographic and numerical scope of the research, the results also demonstrated the possibility of new research based on knowledge that has not yet been validated or proven scientific information, with emphasis on ethnoindicators obtained correlated to soil biota and spontaneous plants, which reinforces the relevance of the interaction of knowledge for both family farming and science, and, in general, for the qualification of public policies.

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