International Journal Semiarid

THE USE OF PFEIFFER CHROMATOGRAPHY AS A TOOL FOR EVALUATING AGROECOLOGICAL MANAGEMENT IN AN AGRICULTURAL PROPERTY IN THE MUNICIPALLY OF BOQUEIRÃO – PB

Antônio Marques Carneiro
Master's student in Ecology Conservation from the Universidade Estadual da Paraíba (UEPB)
https://orcid.org/0000-002-6248-3971
antonio.carneiro@aluno.uepb.edu.br

Jean Oliveira Campos
Doctoral student in Geography from the Universidade Federal da Paraíba (UFPB)
https://orcid.org/0000-0002-2874-754X
jeannolliveira@gmail.com

RESUMO
A Cromatografia Circular de Pfeiffer é vista como uma ferramenta utilizada para separação física de misturas complexas com potencial para retratar de forma holística os atributos biológicos do solo, propiciando o monitoramento de manejos agroecológicos. Objetivou-se aqui avaliar a qualidade do solo de um agroecossistema de base familiar no município de Boqueirão – PB, no intuito de orientar a tomada de decisões no que diz respeito aos manejos empregados. O delineamento da pesquisa está de acordo com (Pfeiffer, 1980), e foi adaptada à óptica de condução para o campesinato. As amostras de solo foram coletadas à profundidade de 0-20cm, com trado holandês secas à sombra e triadas. Duas soluções foram utilizadas em etapas distintas da condução: dispersante (NaOH) e foto reativa (AgNO3). Foi utilizado papeis filtro JPLAB 15cm, que foram preparados para produção dos cromatogramas. As amostras passaram por um processo de agitação intercalado com período de repouso: 15min, 1h e 6h. Os resultados mostraram boas revelações dos cromas, que permitiram inferir os principais indicadores de cada área. A partir das interpretações que a cromatografia permite, verificou-se que o croma C apresenta os melhores resultados em termos de saúde do solo, uma vez que expressou alta atividade enzimática. Por outro lado, os cromas A e B não expressaram boas condições, evidenciando a necessidade de alterações no quadro de manejo.
Palavras-Chave: Saúde do solo; Etnopedologia; Agroecossistemas.

ABSTRACT
Pfeiffer Circular Chromatography is seen as a tool used for physical separation of complex mixtures with the potential to holistically portray the biological attributes of the soil, providing the monitoring of agroecological managements. The objective here was to evaluate the soil quality of a family-based agroecosystem in the municipality of Boqueirão - PB, in order to guide decision-making with regard to the managements used. The design of the research is in accordance with (Pfeiffer, 1980), and has been adapted to the conduction optics for the peasantry. Soil samples were collected at a depth of 0-20cm, with Dutch auger dried in the shade and screened. Two solutions were used in different stages of conduction: dispersant (NaOH) and photoreactive (AgNO3). JPLAB 15cm filter papers were used, which were prepared for the production of chromatograms. The samples went through a stirring process interspersed with a

rest period: 15min, 1h and 6h. The results showed good revelations of the chroma, which allowed us to infer the main indicators of each area. From the interpretations that chromatography allows, it was found that chroma C presents the best results in terms of soil health, since it expressed high enzymatic activity. On the other hand, chroma A and B did not express good conditions, evidencing the need for changes in the management condition.

Key words: Soil health; Ethnopedology; Agroecosystems.

INTRODUCTION

The experience accumulated from studies about the evaluation of soil quality has shown the significant sensitivity of biological indicators to present differences between the managements used in soils (AZIZ; MAHMOOD; ISLAM, 2013; LIU *et al*., 2015; PAZ-KAGAN et al., 2014; ROUSSEAU et al., 2013). According to Cardinale *et al.* (2012) biological attributes of the soil indicate ecological processes that promote ecosystem services. Its understanding depends on the integrated methodologies to evaluate, quantify, and map the ecosystem services generated (PRADO *et al*., 2016).

In light of this, the monitoring of soil fertility can assist farmers in making decisions about the management practices to be adopted. Thus, there is the important of simple and accessible methods of soil analysis that assist farmers in soil monitoring and decision-making on the management used (BEZERRA, 2018).

Studies developed in agricultural areas have evidenced CPP as a method capable of expressing physical, chemical, and biological indicators of the soil, because of this, for Feliciano (2018), Graciano *et al.* (2020) and Melo *et al*. (2019), CCP presents itself as an efficient tool for analyzing soil quality. It is, therefore, a low-cost technology, easy to replicate and accessible to farmers to assist in the monitoring of soil attributes resulting from the managements used. Based on that, it is evidenced as an important instrument to evaluate "soil health" (BEZERRA, 2018; FAGUNDES, 2013; RIVERA; PINHEIRO, 2011).

Through the CCP it is possible to obtain rapid guidance on soil quality (PFEIFFER, 1959). With the use of this tool, the final product is an image in a circular format in a broad and multidimensional way that reveals the soil's physical, chemical, and biological properties. The main characteristics presented in the image and that act as the basis for the evaluation are: color, shape and harmony of them (PERUMAL; ANANTHI; ARUNKUMAR, 2016; RIVERA; PINHEIRO, 2011). Socioeconomic characteristics of the properties and their forms of use are also important factors to be considered in the analysis of the results.

The Northeast region of Brazil stands out as one of the regions with the highest number of family-based agricultural properties in the country (COÊLHO, 2010). A part of them are users of agroecological management, aiming at the sustainability of the agroecosystem and thereby reducing damage to the environment. In Paraíba, in turn, agroecological management has been adopted in the various regions of the state, which has resulted in better socioeconomic and environmental conditions on the properties (ALVES; CÂNDIDO; CAROLINO, 2016). In view of this, it is necessary to continuous monitoring these conditions, aiming at the effective application of agroecological practices.

International Journal Semiarid

Given the above, this research aimed to evaluate the soil quality of a family-based agroecosystem in the municipality of Boqueirão - PB, through Pfeiffer Chromatography, in order to guide decision-making with regard to property management.

METHODOLOGY

Description of the study area

The research was developed in a family-based agroecosystem located in the municipality of Boqueirão, state of Paraíba, in the Borborema mesoregion and in the microregion of Eastern Cariri (Fig. 1).

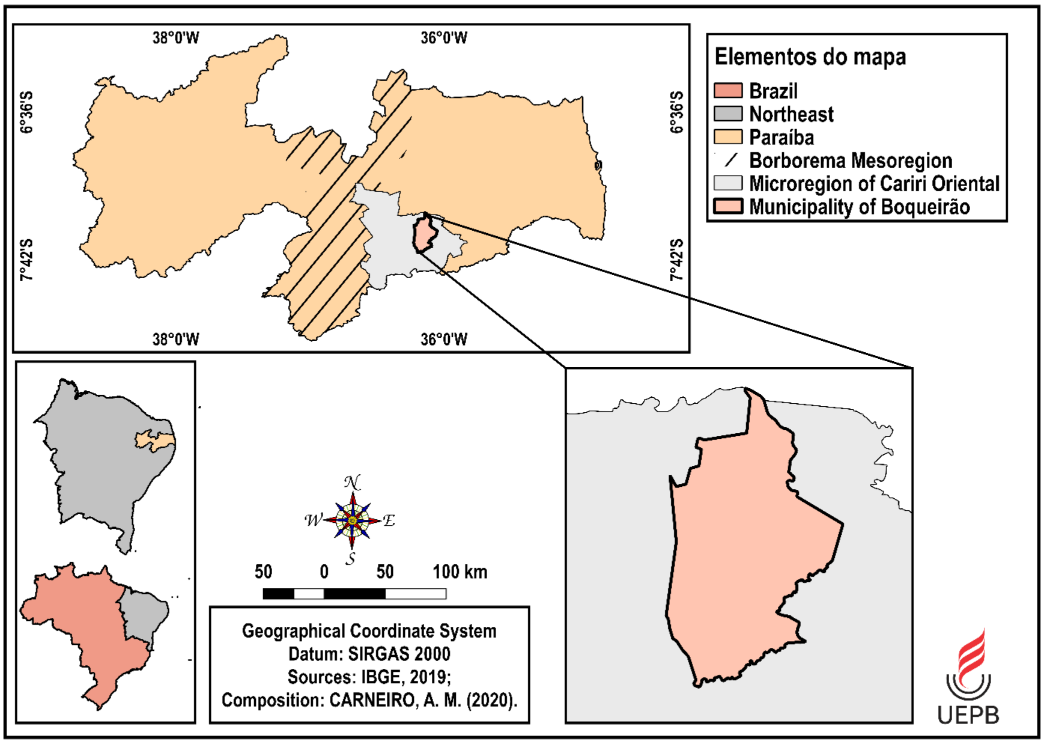

Figure 1: Location of the municipality of Boqueirão in the state of Paraíba
Source: Own authorship.

With a population of 16,888 inhabitants, the municipality in 2018 reached the PIB per capita of R$ 11,674.69 (IBGE, 2011, 2020). However, the core of the economy of the semi-arid zones is family farming, since this activity is based on popular knowledge and techniques, contributing decisively to the reproduction of an expressive portion of the local population. This research is fostered within the Rural Extension Center (NERA) and the Technological Vocational Center (CVT).

Data collection

The collection of soil samples for Pfeiffer Chromatography were carried out on a rural property: Sítio Rodeadouro; currently in agroecological transition in the municipality of Boqueirão-PB. Deformed samples were collected at a depth of 0-20 cm with the aid of Dutch auger, properly identified and dried in the shade. The collection areas were defined as: Forest, Degraded Area, and Cultivated Area in the process of recovery after the intervention of agroecological management.

Pfeiffer Chromatography

All the steps of conducting the technique and interpreting the chromatograms are in accordance with Pfeiffer (1980), adapted by Rivera and Pinheiro (2011). However, the methodology was modified thinking about the use of this tool by family farmers. To this end, all the laboratory utensils seen in the methodological description of chromatography were replaced by easily accessible materials, such as: Plastic pot lids or PET bottles, bottle caps, wooden pestles, plastic sieves, for better accessibility for the farmer substituting laboratory glassware.

Samples preparation

The soil samples were dried in the shade for a period that varies with the condition of the soil (slightly humid soils: one to two days; more humid soils: one week). The samples were sieved and macerated using a wooden pestle (rinsed dried at each maceration) until they reached a powder consistency (talc). Then, they were properly sieved (using a 2mm sieve) and weighed five grams (5g) in disposable plastic cups for the addition of reagents (Fig.2).

The reagents used in Pfeiffer Chromatography are: 1) dispersant: NaOH (Sodium Hydroxide at a volume of 1%); and 2) photo reactive: $AgNO_3$ (Silver Nitrate at volume 0.5%).

The first reagent was added to the plastic cup containing the heavy and sieved soil and to solubilize/suspend the particles, the samples were shaken clockwise (six times) and counterclockwise (six times) alternately (6x←→6x), repeating this process six times at three distinct moments, with an interval of 15 minutes and 1 hour. Subsequently the last agitation carried out after a 1-hour rest, the samples should be left to stand for a minimum interval of 6 hours.

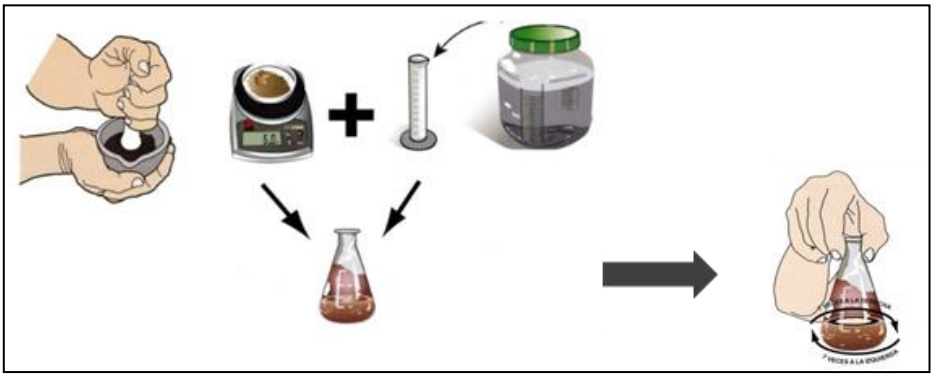

Figure 2: Preparation of soil samples.
Source: Rivera and Pinheiro (2011).

Filter papers preparation

During the rest interval for 6 hours of the soil solution, it proceeded the chromas preparation/impregnation. In the filter papers of the qualitative type of rapid filtration (JP 41, Black Belt, 15cm Ø, porosity 23μm) 3 demarcations were made: 0cm, 4cm and 6cm (from center to edge) with the aid of a needle. These marks are important for the control of the chromatography in two steps.

Then capillaries were made, using the same paper, cut into 2cm x 2cm and inserted into the middle marking of the filter paper. This apparatus was placed on a plastic cap containing 3mL of solution 2, leaving only the capillary in contact with it (Fig.3). After the solution rise by capillarity and reached the marking of 4cm, the apparatus was disassembled and the filter papers were dried in the dark for three hours until the moment of the second impregnation (DOMINGUES et al., 2018; RIVERA; PINHEIRO, 2011).

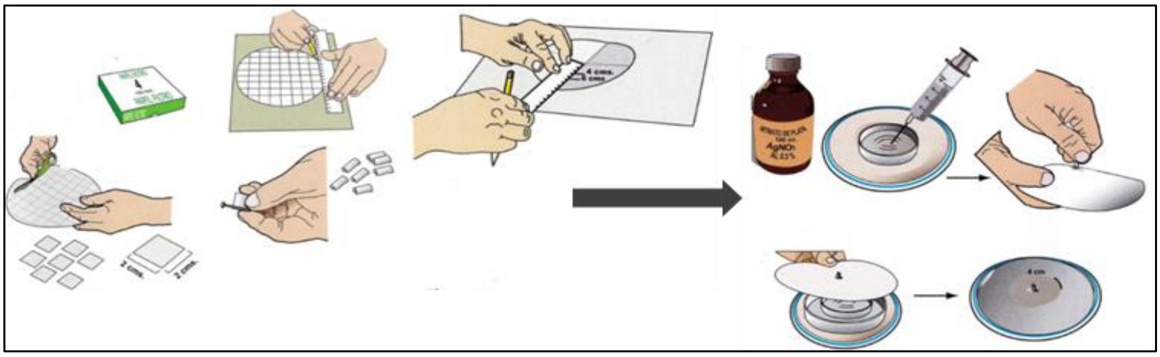

Figure 3: Preparation of filter paper and impregnation with Silver Nitrate.
Source: Adapted from Rivera e Pinheiro (2011).

Chromatograms revelation

After the six-hour interval, was carefully removed, with a syringe, 3mL of the supernatant of the solution with soil and placed in a plastic cap.

It was assembled a new apparatus with a clean capillary and the filter paper previously impregnated with solution 2 and was placed over the cap allowing contact between the solution and the capillary. After the supernatant reached the 6 cm mark on the filter paper (Fig. 4) the apparatus was disassembled and the filter paper placed in indirect light for the revelation of the chroma. This process can vary from 3 to 10 days, but on the first day it is already possible to see the pattern of colors and shapes.

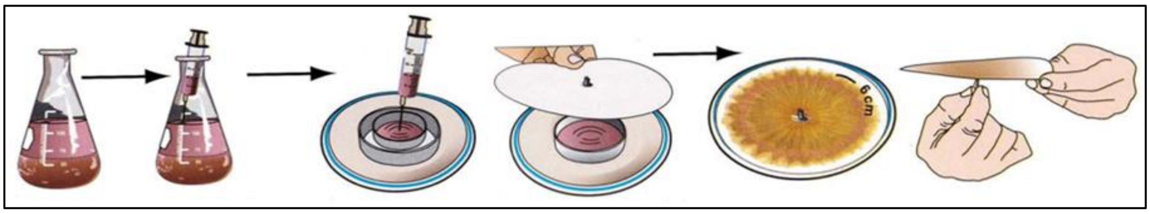

Figure 4: Development of the samples in the chromatograms.
Source: Adapted from Rivera e Pinheiro (2011).

Chromatograms interpretation

All the patterns obtained in the chromatograms after finally revealed, consisted of four characteristic zones of an ideal chromatogram (Fig. 5): ZC (Central Zone); ZM (Medial or Internal Zone, also known as Mineral Zone), ZE (External Zone) and ZP (Peripheral Zone) of which can be seen forms taken in rays whereby the displacement of particles that culminate in channels (Fig. 6).

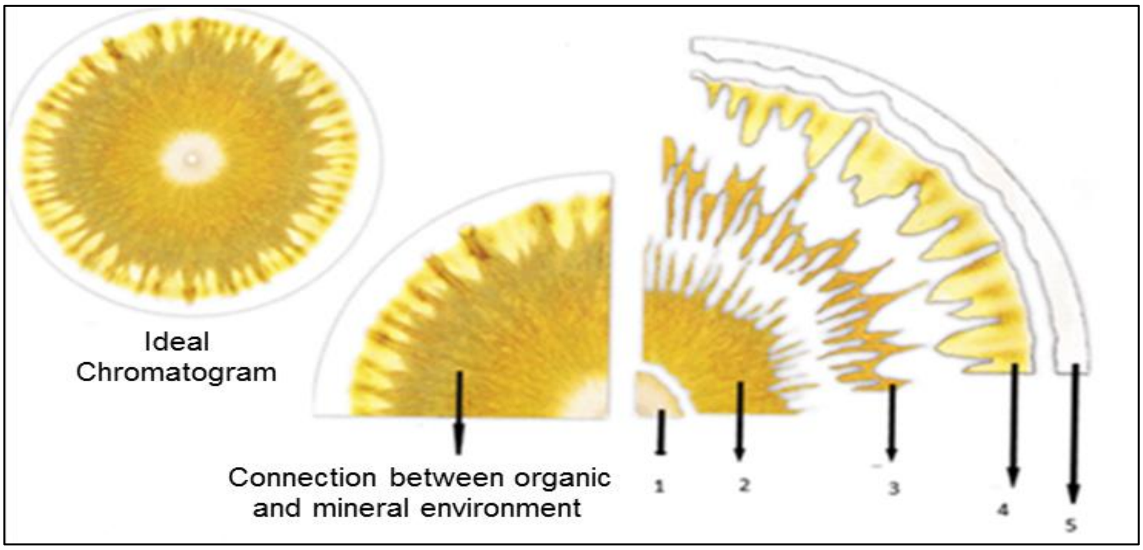

Figure 5: Illustration of an ideal chromatogram and its zones: (1) Central Zone, (2) Internal Zone, (3) Intermediate Zone, (4) External Zone, (5) Peripheral Zone.
Source: Adapted from Rivera e Pinheiro (2011).

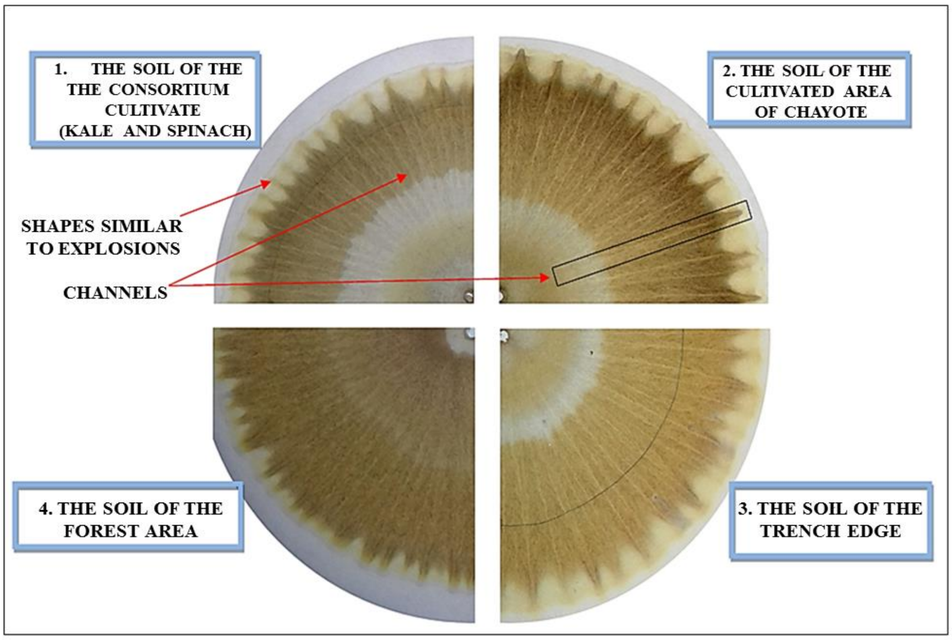

Figure 6: Shapes taken through channels.
Source*:* Own authorship.

RESULTS AND DISCUSSION

The Pfeiffer chromatography is characterized as a method of describing the soil quality, because it allows identifying the performance of soil biology and its interaction with physics, and the soil chemistry (structure and mineralization of MOS).

Thus, chromatography is evaluated by means of chemical, physical and biological reactions, and may be related to the ecological aspects of the place (BEZERRA, 2018; FELICIANO, 2018; PRADO *et al*., 2016).

Case: Rodeadouro Site

The chromatograms were organized under the optic of an unhealthy soil **"A"** for a soil that is integrally healthy **"C"** (Fig. 7). Chromatogram **A** (forest) are areas that are usually intended for grazing animals, which goes against the image of a preserved area that we become aware of. Thus, the configuration of the patterns of colors and shapes (rings and channels) are presented differently from the areas: cultivated, degraded, or defined in a state of recovery.

Chroma **A** is presented in a homogeneous way that makes it impossible to identify the other zones, this conformation is not seen in chromas **B** and **C**. The forest soil, had a little dark color, a characteristic of soils with little availability of MO, and therefore, identified as compacted, even though this effect is naturally occurring, can be intensified by the action of animal foraging. Given the characterization of the place, the low availability of oxygen and water does not favor many of the microbial processes important for soil fertility.

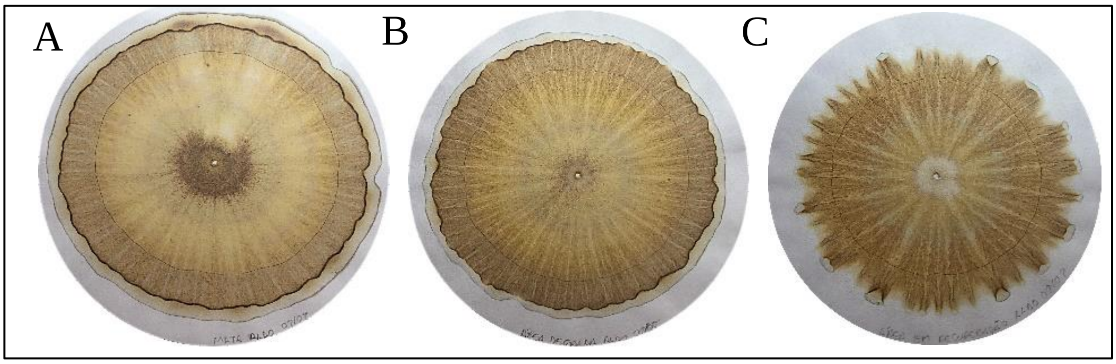

Figure 7: Chromatograms of soil samples from the Rodeadouro site: **A (forest); B (degraded area); C (recovered cultivated area).**
Source*:* Own authorship.

The dark color pattern of the central zone (ZC) is due to the reaction of the soil solution + NaOH with $AgNO_3$ that for Pinheiro, (2011), the organic and/or mineral substances carried by NaOH (solution 1) undergo a rapid action with AgNO3 (solution 2), forming AgOH *(Silver Hydroxide)* and later Ag_2O *(Silver Oxide).* If the soil does not have aerobic metabolism due to the low availability of electron acceptors, it will accumulate toxic substances to the organisms present in the rhizosphere.

If we identify such coloration in the ZC, it is due to the result of the lack of oxidation of minerals, fermentative or respiratory action (BEZERRA, 2018; DOMINGUES *et al*., 2018; FELICIANO, 2018; SIQUEIRA; MARQUES; FRANCO, 2017).

When compared, chroma **A** is showed distinct from chroma **B** and **C** (Fig. 7) given the absence of the intermediate zone, as well as the almost imperceptible external zone, the small channels in this zone do not integrate with the others of the chromatogram, denoting in chroma **A** a homogeneous pattern highlighted by Rivera and Pinheiro (2011) as indicative of the low vital quality of the soil.

Also in the extraction of the samples, when the 6 cm mark is reached by the displacement of the Soil + NaOH solution, even if it is disassembled the apparatus in which the solution is found, the discharge continues in detriment of the capillarity effect, so, the displacement of the particles is not interrupted, and this effect continues to occur, revealing itself on the filter paper the final zone of the chromatogram (external zone).

Chroma **A**, therefore, does not present a distinguishable pattern as in Fig. 5 in its external zone, due to the inefficiency of microbial metabolism on organic matter in the soil. The causes of this configuration, are related to the dynamics in which the area is placed, with the Forest being an unpreserved area, separate to the management and used, almost exclusively for grazing the animals of the property.

Such activity culminates in a decrease of the local vegetation, pressure from the animal's paws that intensify the soil compaction process, and as a consequence there will be a decrease in metabolic processes important for the decomposition of organic matter, promoted by the aerobic metabolism of the soil microbiota. Therefore, if there is not enough oxygen availability, it occurs a deflation of the macro/microbiota.

The ideal activity of microorganisms in the soil, argued by Siqueira, Marques and Franco (2017) expresses complex substances of high molecular weight active in the soil that in the chromatogram tend to reveal forms similar to: clouds; petals and waves that characterize the Enzymatic Zone (ZE).

Bezerra (2018) explains that the configuration of this zone is due to the biological value and nutritional reserves revealing the vitality of the soils. Chroma **A**, however, does not have a similar characteristic that can infer the acuity of the forest area, and is therefore a place of low vital quality.

The radial pattern of chroma **B** is also presented differently according to chromatograms **A** and **C** (Fig. 7). The external zone which deals with the enzymatic condition, revealed in the chromatogram a smooth edge, referring to low biological activity in the soil, in contrast, it is possible to notice a heterogeneous pattern of the zones in the chromatogram **B**.

Chromatogram **B** (Fig. 7) represents a soil sample collected below a mesquite plant (*Prosopis juliflora* (Sw.) DC.). The soil presented characteristics similar to those seen in the forest area, over the soil structure. The chroma showed a darker color pattern than chroma **A**, due to the integration of organic matter, the incorporation occurs, possibly, through the decomposing of the Algaroba leaves.

Such indications may explain the radial pattern and heterogeneity of the zones. Comparing chroma **B** with chroma **A**, it can be seen that the central zone of both chromatograms is distinct, in color and size, this is a visual characteristic that can be easily observed (Fig. 7A and Fig. 7B).

The recovering area (**C**) of the Sítio Rodeadouro, (integrated ecological cultivation area), the following cultivars were identified: papaya, manioc, potatoes, among others planted together.

The practice of intercropping is an agroecological strategy of soil management, due to the intraspecific ecological relationship there will be a beneficiation of flora, and the soil microfauna. In the chromatogram, we interpret this relationship by observing the radiation (characteristics of the ramification) that occurs in the form of arrowhead and/or "arrows" superimposed in a more or less noticeable way, which can be from the central zone to the end of the chroma, which is colored with a golden-yellow tone and the more diverse and harmoniously integrated with the other zones, the greater is the mineralogical quality and soil life (BEZERRA, 2018; FELICIANO, 2018; RIVERA; PINHEIRO, 2011).

The Internal Zone of chroma **C** (Fig. 7C) is shown well integrated with the other zones, starting from the central zone, to the external zone, being punctuated by Pinheiro (2011), as the primary and secondary metabolism, due to the width and extension of the channels. In this way, can be visualized tiny arrowheads that start from the central to the external zone and are superimposed on each other (BEZERRA, 2018).

The conformation taken at the completion of the chromatogram (external and peripheral zone) greatly explains the life of the soil, thus, the chroma **C** presents a good diversity of shapes similar to explosions in clouds that reflects the high enzymatic activity of the collected soil, which is still reinforced in the integrality of the zones in which the conditions are revealed through the shapes and colors presented in the chromatographic analysis.

FINAL REMARKS

It is concluded that area C presents the best results in terms of soil quality, since the chroma analysis indicated high biological activity. At the same time, the reality observed highlights the importance of agroecological management implemented in the area for the maintenance of soil health.

On the other hand, chroma A and B did not present good conditions in soil health, which demonstrates that the areas analyzed need changes in the management framework. For that matter, the use of adequate management, aimed at soil conservation, can lead these areas to experience better conditions. Finally, Pfeiffer Chromatography is considered a holistic tool, easy to access and low cost, which becomes important for the autonomy of the peasantry in monitoring the agricultural property.

REFERENCES

ALVES, A. P.; CÂNDIDO, G. A.; CAROLINO, J. A. Sustentabilidade em Agroecossistemas Familiares: Uma aplicação do MESMIS junto a produtores de hortifrutigranjeiros na microrregião de Sapé-PB. *In*: CÂNDIDO, G. A.; LIRA, W. S. (org.). **Indicadores de Sustentabilidade para Agroecossistemas: Aplicações em diversos tipos de cultivo e práticas agrícolas no estado da Paraíba**. Campina Grande: EDUEPB, 2016. p. 161–204.

AZIZ, I.; MAHMOOD, T.; ISLAM, K. R. Effect of long term no-till and conventional tillage practices on soil quality. **Soil and Tillage Research**, v. 131, p. 28–35, 2013. Disponível em: http://dx.doi.org/10.1016/j.still.2013.03.002. Acesso em: 4 abr. 2021.

BEZERRA, P. L. **Implantação de sistemas agroflorestais na agricultura familiar: um caminho para a transição agroecológica**. 2018. Dissertação (Mestrado em Agroecologia e Desenvolvimento Rural) - Universidade Federal de São Carlos - UFSCar, Araras, 2018.

CARDINALE, B. J.; DUFFY, J. E.; GONZALEZ, A.; HOOPER, D. U.; PERRINGS, C.; VENAIL, P.; NARWANI, A.; MACE, G. M.; TILMAN, D.; WARDLE, D. A.; KINZIG, A. P.; DAILY, G. C.; LOREAU, M.; GRACE, J. B.; LARIGAUDERIE, A.; SRIVASTAVA, D. S.; NAEEM, S. Biodiversity loss and its impact on humanity. **Nature**, v. 486, n. 7401, p. 59–67, 2012. Disponível em: http://www.nature.com/articles/nature11148. Acesso em: 20 abr. 2021.

COÊLHO, J. D. **Informe rural ETENE: Agricultura familiar no Nordeste**. Fortaleza: Banco do Nordeste, 2010.

DOMINGUES, S.; FAEDO, L.; FARINA, É.; CONTINI, R.; GABARDO, G.; BONADIMAN, A. Revisão da cromatografia de pfeiffer como método de avalição qualitativa de solos. **Revista da 15a Jornada de Pós graduação e Pesquisa**, v. 15, n. 15, p. 1471–1479, 2018. Disponível em: http://revista.urcamp.tche.br/index.php/rcjpgp/article/view/2921/2030. Acesso em: 5 maio. 2021.

FAGUNDES, A. V. W. Cromatografia como indicador da saúde do solo. **Cadernos de Agroecologia**, Porto Alegre, v. 8, n. 2, p. 1–4, 2013. Disponível em: http://revistas.aba-agroecologia.org.br/index.php/cad/article/view/14447/9307. Acesso em: 10 jun. 2021.

FELICIANO, C. A. **Avaliação da qualidade do solo em dois diferentes sistemas de manejo orgânico e convencional**. 2018. Dissertação (Mestrado em Desenvolvimento Territorial e Meio Ambiente) - Universidade de Araraquara - UNIARA, Araraquara, 2018.

GRACIANO, I.; MATSUMOTO, L. S.; DEMÉTRIO, G. B.; PEIXOTO, E. C. T. M. Evaluating Pfeiffer Chromatography for Its Validation as an Indicator of Soil Quality. **Journal of Agricultural Studies**, v. 8, n. 3, p. 420–446, 2020. Disponível em: http://www.macrothink.org/journal/index.php/jas/article/view/16336. Acesso em: 4 jun. 2021.

IBGE. **Censo Demográfico 2010: Características da população e dos domicílios**. Rio de Janeiro: IBGE, 2011.

IBGE. **Produto Interno Bruto dos Municípios 2018**. Rio de Janeiro: IBGE, 2020.

LIU, Z.; ZHOU, W.; LI, S.; HE, P.; LIANG, G.; LV, J.; JIN, H. Assessing soil quality of gleyed paddy soils with different productivities in subtropical China. **CATENA**, v. 133, p. 293–302, 2015. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S0341816215300369. Acesso em: 15 abr. 2021.

MELO, D. M. A. de; REIS, E. F. dos; COARACY, T. do N.; SILVA, W. A. O. da; ARAÚJO, A. E. Cromatografia de pfeiffer como indicadora agroecológica da qualidade do solo em agroecossistemas. **Revista Craibeiras de Agroecologia**, v. 4, n. 1, p. e7653, 2019. Disponível em: https://www.seer.ufal.br/index.php/era/article/view/7653. Acesso em: 2 jun. 2021.

PAZ-KAGAN, T.; SHACHAK, M.; ZAADY, E.; KARNIELI, A. Evaluation of ecosystem responses to land-use change using soil quality and primary productivity in a semi-arid area, Israel. **Agriculture, Ecosystems & Environment**, v. 193, p. 9–24, 2014. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S0167880914002412. Acesso em: 28 maio. 2021.

PERUMAL, K.; ANANTHI, S.; ARUNKUMAR, J. Innovative and simplest alternative analytical technology (AAT) for testing soil nutrients. **Journal of Soil Science Research**, v. 1, n. 1, p. 22–31, 2016. Disponível em: https://www.tsijournals.com/abstract/innovative-and-simplest-alternative-analytical-technologyaat-for-testing-soil-nutrients-9352.html. Acesso em: 15 maio. 2021.

PFEIFFER, E. Eine qualitative chromatographische Methode zur Bestimmung biologischer Werte. **Lebendige Erde**, v. 5, p. 205, 1959.

PFEIFFER, E. **Chromatography Applied to Quality Testing: The Art and Science of Composting**. Wyoming, Rhode Island: Bio-Dynamic Literature, 1980.

PRADO, R. B.; FIDALGO, E. C. C.; MONTEIRO, J. M. G.; SCHULER, A. E.; VEZZANI, F. M.; GARCIA, J. R.; OLIVEIRA, A. P. de; VIANA, J. H. M.; PEDREIRA, B. da C. C. G.; MENDES, I. de C.; REATTO, A.; PARRON, L. M.; CLEMENTE, E. de P.; DONAGEMMA, G. K.; TURETTA, A. P. D.; SIMÕES, M. Current overview and potential applications of the soil ecosystem services approach in Brazil. **Pesquisa Agropecuária Brasileira**, v. 51, n. 9, p. 1021–1038, 2016. Disponível em: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0100-204X2016000901021&lng=en&tlng=en. Acesso em: 25 maio. 2021.

RIVERA, J. R.; PINHEIRO, S. **Cromatografía: imagenes de vida y destrucción del suelo**. Colômbia, Cali: Impressora Feriva, 2011.

ROUSSEAU, L.; FONTE, S. J.; TÉLLEZ, O.; VAN DER HOEK, R.; LAVELLE, P. Soil macrofauna as indicators of soil quality and land use impacts in smallholder agroecosystems of western Nicaragua. **Ecological Indicators**, v. 27, p. 71–82, 2013. Disponível em: https://linkinghub.elsevier.com/retrieve/pii/S1470160X12004086. Acesso em: 25 fev. 2021.

SIQUEIRA, J. B.; MARQUES, G. dos S.; FRANCO, F. S. Construção de Conhecimento Agroecológico Através da Experimentação da Cromatografia de Pfeiffer, uma Análise Qualitativa dos Solos. **Cadernos de Agroecologia**, v. 11, n. 2, 2017. Disponível em: http://revistas.aba-agroecologia.org.br/index.php/cad/article/view/21618. Acesso em: 15

mar. 2021.