Agroecological characterization of Sacha Inchi *(Plukenetia volubilis* Linneo*)* crop production system in Arauquita, Colombia

Caracterización agroecológica del sistema productivo de Sacha Inchi (*Plukenetia volubilis* Linneo) en Arauquita, Colombia

Caracterização agroecológica do sistema produtivo de Sacha Inchi (*Plukenetia volubilis* Linneo) em Arauquita, Colômbia

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Abstract

The Sacha Inchi or Inca peanut (*Plukenetia volubilis* Linneo) is an oily plant native to the Amazon, consumed by indigenous people since ancient times and recognized for its great contribution of essential fatty acids, antioxidants and proteins, being potentially attractive as a legal agricultural alternative for the reincorporation of insurgent groups. The objective of the research was to characterize the productive system of Sacha Inchi in the municipality of Arauquita, Colombia. Fifty farmers were selected (40 peasants and 10 ex-combatants of the FARC-EP), using an intentional non-probabilistic sampling. The information was collected through a questionnaire and two participatory workshops aimed at identifying limitations and potentialities of the agroecological and productive system. Data were analyzed using descriptive and multivariate statistics. The classification analysis allowed partitioning the set of farmers, based on socioeconomic and environmental characteristics necessary to guide extension plans. The results showed that the most used agroecological practices are: soil conservation, application of lime, use of compost as fertilizer, use of certified seed and direct sowing. Low crop rotation and limited use of phytosanitary products were evidenced. The participatory workshops made it possible to identify crop limitations such as low productivity, few marketing channels and lack of knowledge of some agroecological techniques necessary to improve its productivity. Agroecological practices must be reinforced and expanded through extension programs to achieve recognition as agroecological producers, since this crop is a highly viable alternative for the municipality of Arauquita, within the framework of the peace agreement.

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Resumen

El Sacha Inchi o maní del Inca (*Plukenetia volubilis* Linneo) es una planta oleaginosa originaria de la Amazonía, consumida por los indígenas desde la antigüedad y reconocida por su gran aporte de ácidos grasos esenciales, antioxidantes y proteínas, siendo potencialmente atractiva como alternativa agrícola lícita para la reincorporación de grupos insurgentes. La investigación tuvo como objetivo caracterizar el sistema productivo de Sacha Inchi en el municipio de Arauquita, Colombia. Se seleccionaron 50 agricultores (40 campesinos y 10 excombatientes de las FARC-EP), empleando un muestreo no probabilístico intencional. La información fue recolectada mediante un cuestionario y dos talleres participativos dirigidos a identificar limitantes y potencialidades del sistema agroecológico y productivo. Los datos se analizaron mediante estadística descriptiva y multivariada. El análisis de clasificación permitió particionar el conjunto de agricultores, con base a características socioeconómicas y ambientales necesario para orientar planes de extensión. Los resultados mostraron que las prácticas agroecológicas más utilizadas son: conservación de suelos, aplicación de cal, empleo de compost como fertilizante, uso de semilla certificada y siembra directa. Se evidenció baja rotación de cultivos y uso limitado de productos fitosanitarios. Los talleres participativos permitieron identificar limitantes del cultivo como baja productividad, pocos canales de comercialización y desconocimiento de algunas técnicas agroecológicas necesarias para mejorar la productividad del mismo. Las prácticas agroecológicas deben ser reforzadas y ampliadas mediante programas de extensión para lograr el reconocimiento como productores agroecológicos, ya que este cultivo, es una alternativa altamente viable para el municipio de Arauquita, en el marco del acuerdo de paz.

Palabras clave: maní del Inca, factores socioeconómicos, factores ambientales, análisis de correspondencias múltiples (AMC).

Resumo

O amendoim Sacha Inchi ou Inca (*Plukenetia volubilis* Linneo) é uma planta oleosa nativa da Amazônia, consumida pelos indígenas desde a antiguidade e reconhecida por sua grande contribuição de ácidos graxos essenciais, antioxidantes e proteínas, sendo potencialmente atrativa como alternativa agrícola legal para a reincorporação de grupos insurgentes. O objetivo da pesquisa foi caracterizar o sistema produtivo de Sacha Inchi no município de Arauquita, Colômbia. Foram selecionados 50 agricultores (40 camponeses e 10 ex-combatentes das FARC-EP), por amostragem não probabilística intencional. As informações foram coletadas por meio de questionário e duas oficinas participativas com o objetivo de identificar limitações e potencialidades do sistema agroecológico e produtivo. Os dados foram analisados por meio de estatística descritiva e multivariada. A análise de classificação permitiu particionar o conjunto de agricultores, com base nas características socioeconômicas e ambientais necessárias para orientar os planos de extensão. Os resultados mostraram que as práticas agroecológicas mais utilizadas são: conservação do solo, aplicação de calcário, uso de composto como fertilizante, uso de semente certificada e semeadura direta. Evidenciou-se baixa rotação de culturas e uso limitado de produtos fitossanitários. As oficinas participativas permitiram identificar limitações da cultura como baixa produtividade, poucos canais de comercialização e desconhecimento de algumas técnicas agroecológicas necessárias para melhorar sua produtividade. As práticas agroecológicas devem ser reforçadas e ampliadas por meio de programas de extensão para obter o reconhecimento como produtores agroecológicos, uma vez que esta cultura é uma alternativa altamente viável para o município de Arauquita, no âmbito do acordo de paz.

Palabras-chave: Amendoim Inca, fatores socioeconômicos, fatores ambientais, análise de correspondência múltipla (MCA).

Introduction

Conventional agricultural production has been affected by the indiscriminate use of agrochemicals and fertilizers, because of globalization and industrial growth policies, as a strategy to increase productivity, leading to an agricultural production model, acquired from the green revolution, which promotes monoculture, together with the use of technological packages and a large amount of non-renewable fossil energy (Martinez-Centeno and Huerta, 2018). In this sense, it is necessary to generate elements aimed at conserving the resources used in traditional local agriculture that, in turn, explore modern ecological knowledge and methods.

These elements can be configured through agroecology, a science that applies ecological concepts and principles to design and manage sustainable agroecosystems (Gliessman, 2000), which must integrate the broad and multifactorial concept of sustainable development, to meet the needs of the present, indefinitely, without compromising the satisfaction of future needs (Torres-Jaramillo *et al*., 2021). In addition, a sustainable production model must face the challenges of traditional agriculture, studying the risks generated in production, including environmental risks as a precondition (Saltos *et al*., 2020).

In this context, emerges Sacha Inchi (*P. volubilis* L.), a climbing oily plant of the Plukenetia genus that grows in Latin American countries such as Peru, Bolivia, Venezuela and Ecuador (Alayón and Echeverri, 2016), consumed by ancestral indigenous populations and whose cultivation it is feasible under a model of sustainable agroecological production, even more so when 12 of the 19 species worldwide are found in their native state in different places of the Colombian Orino-Amazon (Ayala, 2016), reporting crops in departments such as the Caquetá, Putumayo, Antioquia, Valle del Cauca, among others, with 1,100 hectares planted, production of 2,418.6 tons and yields between 2 and 6 $t.ha^{-1}$ in 2018 (MINAGRICULTURA, 2019).

In addition, being a promising species, it can be a viable alternative in the substitution of coca cultivation in vulnerable regions, in the post-conflict framework, by presenting similar cultivation models (Muñoz, 2019), easy adaptation and propagation to different ecological conditions, acceptable production and high nutritional quality of the oil (Caicedo and Certuche, 2019).

Sacha Inchi contains a high concentration of polyunsaturated essential fatty acids of the omega 3, 6 and 9 family, mainly α-linoleic (C18:3) and linoleic (C18:2), which range between 79 % to 84 % of the total content of the oil, together with a high content of tocopherols and antioxidants (Manco, 2006; Gutiérrez *et al*., 2011). These characteristics can positively impact the health of the Latin American population by preventing the onset of cardiovascular diseases, where the consumption of cardioprotective agents like olive oil is low (Alayón and Echeverri, 2016).

In the case of the municipality of Arauquita - Colombia, there are producers of Sacha Inchi belonging to a peasant economy, with agricultural practices that require revision so that they can reach levels

of agronomic productivity that allow them to improve their quality of life. Therefore, the objective of this research was to agroecologically characterize the productive units of Sacha Inchi of the Arauquita municipality, in addition, socioeconomic and environmental aspects were considered to group them and critical factors were identified to formulate extension plans for producers of this crop.

Materials and methods

This research uses a mixed methodological approach, combining strategies for obtaining quantitative and qualitative data, with their respective analyzes (Tashakkori and Teddlie, 2009). This approach can be controversial in terms of scientific coherence, but when implemented correctly it can be a powerful tool for describing, understanding and explaining the observed phenomena (Núñez, 2017).

Description of the study area

The research was conducted in the municipality of Arauquita (07°01'39" N and 71°25'55" W), Arauca, Colombia, during the year 2021. The environmental conditions are: 155 m altitude, average temperature of 28 °C, average annual rainfall of 2255 mm and a relative humidity of 76 %. Sacha Inchi producers are located in 20 villages: Filipinas, Gaitán Caranal, San Isidro, Las Bancas, La Ossa, El Vivero, Carretero, La Chigüira, Las Acacias, Mata Oscura, Puerto Nuevo, La Paz, Guamalito, El Encanto, Los Almendros, Gaviotas, Aguachica, Santander, El Futuro and El Amparo (figure 1).

Figure 1. Map of the villages in Arauquita where Sacha Inchi is grown, adapted from the Google Earth satellite map.

Sample and sampling

To select the sample, a non-probabilistic "intentional" sampling was applied, where the terms of inclusion were with informed consent, which were dedicated to the cultivation of Sacha Inchi (*P. volubilis* L.) in the region and that were affiliated to any association in the municipality. Fifty farmers were included, distributed as follows: (15) associated to "Sacha Arauquita", (15) to "Sacha Caño Limón", (10) to "Sacha Caricari" and the remaining (10) ex-combatants of the former FARC-EP organization belonging to the association "FILIMARPAZ UEAI ZOMAC SAS" - company dedicated to the cultivation of tropical and subtropical fruits, all were visited and interviewed in their farms for the application of the questionnaire.

Information collection techniques

For characterization and groupings by multivariate statistical methods, the information from the survey was used with the application of a questionnaire (57 questions with multiple and open answers), where variables and subvariables were established in three dimensions (socioeconomic, environmental and agroecological), which are described in table 1.

Table 1. Dimensions, variables and subvariables under study.

Variables	Subvariables
Socioeconomic dimension	
Owner	Name of the producer, age, sex, marital status, school grade, membership in an association, evaluation of basic services, source of higher income
Property	Name of the property, georeferencing, district, municipality, department, type of property, area of the property, topography.
Economic efficiency	Productivity, production costs, marketing, monthly net income.
Farmer Self-Sufficiency	External inputs, food self-sufficiency.
Sociocultural relationship	Producer satisfaction, producer quality of life
Environmental dimension	
Crop	Established crops, cultivated area, type of crop.
Soil	Loss due to erosion, productivity and conservation of soil life.
Water	Quality, quantity, sources for cultivation, protection and soil conservation
Waste disposal	Crop residue management and domestic waste management
Agroecological Dimension	
Knowledge	Native seeds, natural resource, biofertilizers, biodiversity, seed conservation, integrated pest management, trap plants, biological pest control, light traps for insects, genetically modified seeds, food safety, nitrogen fixers, phosphosolubilizers, efficient microorganisms, entomophagous (predators), phytopesticide, entomopathogen, antagonist.
Practices	Soil conservation, weed control, types of fertilizer, seed varieties, type of crop on your property, types of tillage, crop rotation and phytosanitary use.

Crop production critical factors were identified through two participatory workshops and work groups with the producers, analyzing the system internal (strengths and weaknesses) and external (opportunities and threats) environment, where the limitations and potentialities of the cultivation of Sacha Inchi were determined.

Information analysis techniques

the Questionnaire information was analyzed using descriptive statistics to perform characterizations. Socioeconomic and environmental grouping were constructed by multivariate statistical techniques: multiple correspondence analysis (MCA) and classification analysis (Hair *et al*., 2004). The information obtained

from the questionnaires was cross-checked with that obtained from the participatory workshops to identify the main limitations that affect production and the causes that prevent the implementation of good agroecological practices in cultivation. All the opinions were summarized in DOFA matrices to elaborate solution proposals for the different needs (Masera *et al*., 1999).

Results and discussion

The FAO (2018) argues that farmers are the people who have the tools to practice agroecology in their territories, where the solution is generated by combining the advancement of science and the traditional, practical and local knowledge of the producers. Agroecology studies the relationship of the different components of the agroecosystem; as a practical aspect, it seeks to make agricultural systems sustainable, optimize and stabilize production, and as a multifunctional social movement, it reinforces agriculture, culture and the economic viability of rural areas.

Agroecological characterization

From the diagnosis on the knowledge and agroecological practices carried out by the producers of Sacha Inchi, it was observed that more than 60 % of the producers know about native seeds, natural resources, biofertilizers and biodiversity (blue bars, figure 2); however, less than 40 % of the producers are unaware of issues such as seed conservation, integrated pest management, trap plants, food safety, among others, and are totally unaware of terms such as phytopesticides, entomopathogens and antagonists (red bars, figure 2).

Regarding agroecological practices, it was observed that more than 80 % of the producers surveyed apply them to their crops, these being soil conservation with lime as fertilizer, pest control using plant cover, the use of compost as fertilizer, the maintenance of permanent crops, direct sowing as a tillage method and the use of certified seed. On the other hand, few producers (8 %) practice crop rotation, while only 54 % use phytosanitary products (figure 3).

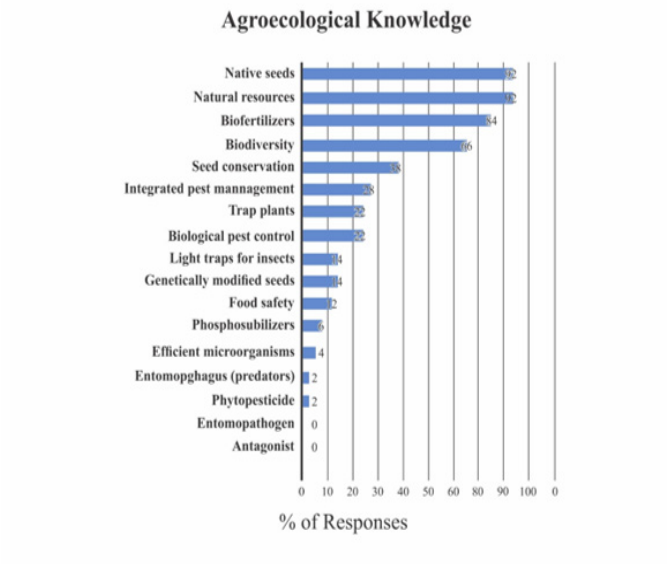

Figure 2. Agroecological knowledge of Sacha Inchi producers.

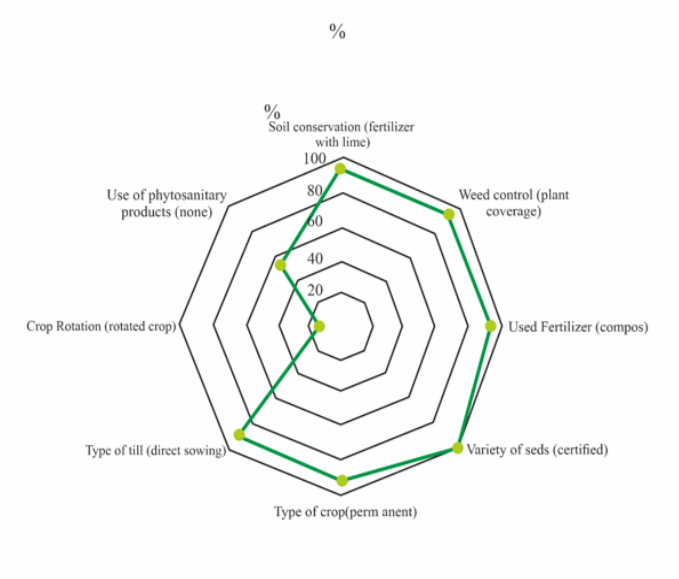

Figure 3. Agroecological practices of Sacha Inchi (*Plukenetia volubilis L.*) producers.

In terms of the subvariables analyzed, the producers of the Sacha Inchi crop need to transform the current production system, incorporating clear objectives of sustainable development. The FAO (2018) establishes 10 elements that allow reaching this north, defining the characteristics that frame the agroecological system, the basic practices and the innovation criteria (diversity, synergies, efficiency, resilience, recycling and the joint creation and exchange of knowledge), the own context of the system (human and social values, food culture and traditions) and those that describe and build a favorable environment (circular and solidarity economy and responsible governance), elements of agroecology that are interrelated and interdependent.

Socioeconomic characterization of Sacha Inchi production systems

In relation to the planted area, an approximate average extension of 1 ± 0.94 ha was found, with a crop establishment time of 1.48 ± 0.5 years, the average annual production was 2.5 ± 0.5 t.ha^{-1} and a yield that represents 42 % of what was reported by MINAGRICULTURA (2019) for the departments of Caquetá (6 t.ha^{-1}.year^{-1}), Valle del Cauca (5 t.ha^{-1}.year^{-1}) and Boyacá (5.8 t.ha^{-1}.year^{-1}).

The average annual production income was $17,681,250 ± 4,873,270, with annual production expenses equal to $6,682,214.92 ± 1,239,135, made up of the items: labor, fertilizers, agricultural inputs, collection and freight, the two being first, the ones with the greatest weight, 70 % of the total costs are invested in labor and the purchase of inputs. The exercise yielded an annual average net income of $12,646,622 ± 3,187,845.

The largest source of income for producers comes from agriculture (68 %) and livestock (32 %). All agreed that the cultivation of Sacha Inchi was profitable since the product is continuously harvested, generates profits in a short time and is sold quickly, but the labor and cost of inputs has increased significantly in recent years.

Most of the producers (98 %) evaluated the Sacha Inchi as being of good quality. The only distribution channel is the regional

market and the limitations to produce Sacha Inchi were sales and processing of the grain, among others. These results confirm what was observed by Garcés (2021), since the intervention of the state is necessary in terms of providing basic conditions for rural populations and facilitating access to financial, educational and technological resources, which allow them to be productive and self-sufficient.

Grouping of Sacha Inchi production systems

For the groupings of the Sacha Inchi production systems, the socioeconomic and environmental dimensions were considered.

Socioeconomic grouping

Next, the first factorial plane derived from a classification analysis carried out on the coordinates of the Multiple Correspondence Analysis (MCA) is presented. In this case, socioeconomic indicators were considered, and the classification variable was marital status. In figure 4, three groupings represented by ovals of blue, red and green colors are identified.

Group 1. It is observed that a large part of the producers (represented with numbers) inside and outside the blue oval (54 %), indicates that the majority are in a free union, are male, have an average age of 53 years, are affiliated to Sacha Arauquita, her main source of income(fi) comes from agriculture and livestock, her school grade is high school, the material of her house is brick-block, all affiliated with SISBEN, the health services (ss), they are evaluated as regular, drinking water (ap) and electric energy (ee) are evaluated as regular. The sewage service (al), the gas service (sg) and the internet service (in) were rated as poor.

Group 2. The second group corresponds to the group of producers who are inside the pink oval (30 %). Producers who are married were concentrated there, most of them male, with an average age of 55 years, associated with "Sacha Caño Limón" and "Sacha Arauquita", their school grade is incomplete primary, the sources of higher income are the livestock and agriculture, health services and drinking water rated it as good. Similarly to group 1, gas, sewage and internet services were evaluated as deficient.

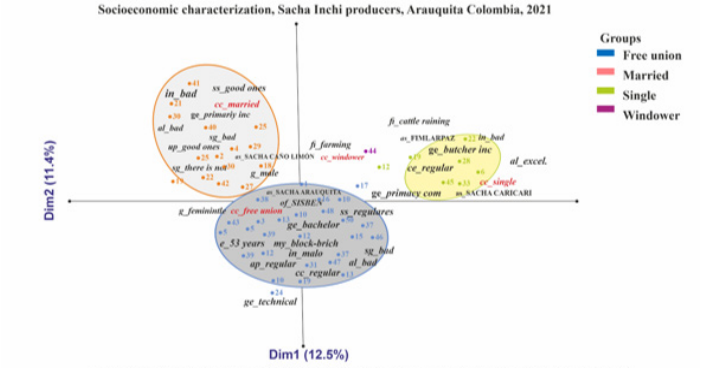

Figure 4. AMC factorial foreground with socioeconomic indicators.

Group 3. This group of people concentrated in the green oval (14 %), are characterized by being single, with an average age of 57 years, the source of the highest income is agriculture and livestock, and they are associated with Sacha Caricari and to Filmarpaz. Their school grade is complete elementary school and incomplete high school, electrical energy services were rated as regular, internet services were poor, and sewerage (16 %) was rated as excellent.

Environmental grouping

The second factorial map shows some environmental indicators (figure 5). Two large groups represented by colored ovals are identified in the graph, based on a classification analysis by soil productivity (ps), carried out on the MCA coordinates. The groupings obtained with the most relevant aspects are described below.

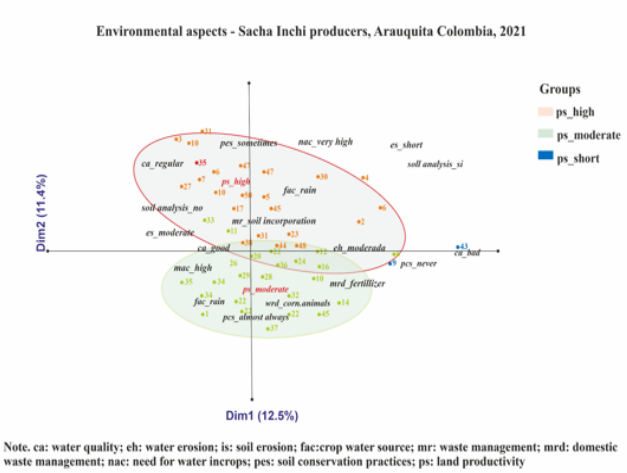

Figure 5. Second MCA factorial plane with environmental indicators.

Group 1. Corresponds to 50 % of the producers who are concentrated in the green oval, who state that the productivity of the land (ps) is moderate, carry out soil conservation practices (pcs) almost always; do not do soil analysis, water erosion (eh) is evaluated as moderate, water quality (ca) is considered good, the need for water for crops (nac) is high, the source of water for crops (fac) are the rains, the management of crop residues (mr) are incorporated into the same properties and the domestic residues (mrd) are converted into fertilizers or used for animal feed.

Group 2. A second group is represented by the pink oval, (46 % of the producers), this group is characterized by considering soil productivity (ps) as high, water erosion (eh) as low; the quality of the water (ca) is considered regular; show that the need for water for crops (nac) is very high, just like group 1, the source of water for crops is rain.

Critical factors of the agroecological production of Sacha Inchi

The different factors that can positively or negatively affect the development of concerted plans with the producers were seen in the participatory workshops and analyzed through a DOFA. The weaknesses found were focused on the lack of economic capital to increase the cultivated areas, as well as the lack of equipment for seed processing. Producers do not have business training, leading to a lack of criteria for decision-making at the business level, depending entirely on the decisions made by actors such as the Sacha-Colombia Cooperative. The need to train several of the producers in good agricultural practices and in the industrial processes that can be carried out with the seeds, as well as for the management of pests and diseases and soil edaphic conditions, was observed.

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Empirical knowledge, family labor, the great nutritional value of the seed, fertile land of alluvial origin, associated producers and own land were identified as Strengths. These strengths must be strengthened through the socialization of the business management proposal of the producers towards the different actors of the productive chain, reinforcing agricultural strategies and guidelines, which allow the producers to deepen their knowledge on issues such as the selection and production of seeds, marketing and commercialization strategies, aimed at achieving a product with denomination of origin.

Regarding Opportunities, there is access to government support programs, the existence of a potential demand for products derived from the cultivation of Sacha Inchi, in national and international markets. It is important to seek technical assistance and training, by linking universities, research centers and other active knowledge-generating actors involved in the production chain. The seed and its derived products must also be characterized compositionally, allowing the existence of specialized production niches in the area to be established. It is important to reinforce the marketing plans for derived products, integrating these environmental sustainability criteria. For example, the amount of environmental carbon captured by Sacha Inchi crops.

Among the threats detected is that the quality of education at the municipal level is regular, there is no periodic technical assistance, which allows producers to deal with problems such as the attack of pests and diseases at the root level, costs of cultivation implementation. Also, the lack of an organic agriculture certification for the farms and the management of the internal control system leads to the application of chemical products, which generate residuality, affecting the commercialization of the seed for its industrial use and human consumption.

Conclusions

Through the agroecological characterization, it was observed that many Sacha Inchi (*P. volubilis* L.) producers carry out agroecological practices aimed at soil conservation, pest control, the use of compost as fertilizer and the use of certified seed. However, elements such as low crop rotation and the lack of alternatives to the use of agrochemicals show the need to incorporate Good Agricultural Practice techniques into the Sacha Inchi production system in Arauquita, aimed at incorporating the necessary elements to make of this a sustainable agroecological system. Their knowledge of some agroecological concepts that they apply must be reinforced and expanded through extension programs designed by different actors involved in the production chain, leading to their training and recognition as agroecological producers.

Socioeconomic grouping evidenced the need to improve access to and quality of basic services for producers such as health, education, and public services, and grouping by environmental indicators showed adequate conditions in terms of soil quality and waste management. However, it is necessary to evaluate aspects such as water erosion, low crop rotation, and water quality and availability.

Even though the area of the Sacha Inchi (*P. volubilis* L.) crops characterized is small compared to other references in the country, the opportunity for expansion is high, given the productive yields observed, being necessary to guarantee access to financial resources, generate seed transformation processes and strengthen technical and business training processes, linking actors such as universities and training centers (SENA) and research, which together with producers generate new knowledge on cultivation and a vision for the generation of agricultural companies .

Under the current context of the country, with the implementation of the peace agreements and the need to offer productive alternatives to coca cultivation, Sacha Inchi is presented as a highly viable crop for the municipality of Arauquita, requiring compositional characterization of the seed and its by-products, establishing the characteristics of the productive system that is developed in Arauquita, which would generate advantages to be commercialized or used by other actors that can be linked to the productive chain.

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