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Research article

Agroecological transition in family agriculture: A case study in Primavera municipality, Brazilian Amazon

Caio Cezar Ferreira de Souza[1,*], Marcos Antônio Souza dos Santos[1], Fabrício Khoury Rebello[1], Cyntia Meireles Martins[1], Maria Lúcia Bahia Lopes[2] and Antônia do Socorro Aleixo Barbosa[1]

[1] Federal Rural University of the Amazon, Tancredo Neves Avenue, Montese, 66077530, Belém, PA, Brazil
[2] University of the Amazon, Alcindo Cacela Avenue, 287, Umarizal, 66060902, Belém, PA, Brazil

* **Correspondence:** Email: caiocfdesouza@gmail.com; Tel: +5591988390145.

Abstract: Family farmers, producing a large proportion of the food consumed by the Brazilian population, seek alternative production strategies through agroecological practices owing to financial challenges. We developed an indicator system for evaluating agroecological transition potential and analyzed farmer family profiles in a Primavera Family Farmer Cooperative. Socioeconomic and productivity data were collected through questionnaires and direct observation, and an agroecological transition index was established using factor analysis. Approximately 81% of the subsistence farmers interviewed had moderate (62%) or high potential for agroecological transition (19%), had diversified production systems, and adopted a variety of sustainable agricultural practices. However, they lived with limited infrastructure and marketed products inefficiently.

Keywords: agroecology; socioeconomic analysis; agricultural practices; Pará State; factor analysis

1. Introduction

Subsistence farming plays a fundamental role in Brazil, both economically, socially, and environmentally. According to Damasceno et al. [1], the sector generates billions of reais and produces a significant portion of the food consumed by the Brazilian population, contributing to job creation and income generation in rural areas.

According to Aquino et al. [2], statistical indicators demonstrate considerable family production potential in the country and present the sector as “unique and homogeneous.” Conversely, the same authors have demonstrated that the absolute majority of the farmer families consist of low-income producers, and such a striking feature of the sector is explained by high land concentration, low technological capacity, low educational levels, in addition to lack of technical assistance programs and appropriate rural development policies.

According to Birner and Resnick [3], such unfavorable conditions for subsidence farmers prevent rural development through modernization, that is, through the exploitation of available technologies and tools, which consists of the use of external inputs such as machines and chemicals. Consequently, subsistence farmers, who produce in marginal areas without access to technologies and the support from public policymakers, seek alternative forms of production, such as production based on agroecological principles.

Agroecology is a field of study that seeks to reconcile environmental, social, economic, and cultural aspects of agricultural production, while prioritizing sustainable practices, in addition to stimulating ecological interactions through production of diverse products and application of techniques such as crop rotation, green manure, and biofertilizers, among other diverse management practices [4].

Examples of sustainable agricultural practices at a global level are integrated sustainable agronomic interventions, such as microbial inoculum, use of biochar (organic input) and reduced soil preparation, adaptive techniques to the ecosystem that have proven to be efficient in improving the productivity and socioeconomic conditions of producers [5], the use of species adapted to the local climate that help to promote sustainable agricultural production, especially in locations with limited access to inputs [6], the use of organic mulch, which protects the soil from the effects of compaction and erosion, in addition to of providing nutrients to organisms under the ground, and the sequences and rotations of crops, which promote biodiversity, attracting different types of microorganisms and inhibiting pests [7].

The study of agroecological practices could facilitate small farmer rural development, as it encourages families to stay in the countryside, in addition to facilitating the dissemination of local knowledge and encouraging independence through the production that guarantees both economic return and food security for families [8].

According to Gliessman [9], the agroecological transition is the change from conventional production systems based on unsustainable practices, such as slashing and burning, in addition to the intensive application of pesticides and fertilizers, to a system based on agroecological principles. It is a complex and gradual process involving several steps. The first step, rationalization, consists of reducing the use of external inputs, while the replacement, second level, involves exchanging external inputs and conventional practices for techniques that are less harmful to the environment, and in the last step, the redesign, the insertion of a set of ecological processes in the agroecosystem is carried out. Due to the complexity of the transition process, according to Dupré et al. [10], the status and attributes of farmers influence their choices regarding the adoption of such practices.

In this study, the concept used by Bonaudo et al. [11] of a sustainable local agricultural system, or agroecological system, in which small farmers must imitate the arrangement and functions of natural ecosystems, thus, to be considered an agroecological operation, the interrelationship of three fundamental functions, metabolic, immunological and productive. Metabolic refers to nutrient cycling and energy flow, with the need to include practices such as the use of mulch, immunological refers to the conservation of ecosystem health, which can come from alternative pest control and production the quantity of production itself competes, and an agroecological system needs to be resilient, efficient and also productive.

Consequently, the objective of the present study was to develop an agroecological transition index and analyze the profiles of family farmers who are cooperative members of the Spring Family Agricultural Cooperative (COOPRIMA), based on their socioeconomic and productivity characteristics, in order to understand the transition levels of these small farmers. The results of the study could facilitate the quantitative analysis of the agroecological transition processes in small agricultural communities in the Amazon.

2. Materials and methods

2.1. Study area

The municipality of Primavera, located in the Northeast region of Pará, with the geographic coordinates 00° 56' 36" of south latitude and 47° 07' 06" of longitude west of Greenwich, had an estimated population of 10,825 inhabitants in its municipal seat. 2019.. Public administration and industry are the major contributors to the gross domestic product of the city, with the agricultural sector accounting for only 3.19% of the gross added value in 2017 [12]. This sector is characterized by subsistence farming with production taking place in relatively small areas, and approximately 70% of the agricultural establishments in the municipality cover an area less than five hectares [13].

COOPRIMA was established in 2013, with the support of a cement company as a corporate social responsibility project, and to encourage the development of family agriculture value chains. They were established in the municipality during the same period [14]. The city hall and the Brazilian Micro and Small Business Support Service (Serviço Brasileiro de Apoio às Micro e Pequenas Empresas-SEBRAE) also contributed to the establishment of the agricultural cooperative movement. The cement production company provided an area of approximately 45 ha to serve 30 small rural producer families, in addition to financing the acquisition of material necessary for the implementation of the Integrated and Sustainable Agroecological Production (ISAP) system. SEBRAE was responsible for project execution and the municipal government was responsible for infrastructure works, such as the opening of branches and the construction of water tanks.

The ISAP system is an initiative aimed at generating income for family farmers through sustainable agricultural production. It supplies external inputs use, combining animal and crop production to preserve natural resources, in addition to promoting producer cooperation and encouraging new marketing channels [15].

At data collection time, COOPRIMA had 36 cooperative members, 23 of whom produced in the area where the ISAP was implemented, known as “agropolo”, and the other 13 were external producers who later joined with the intention of benefiting from the agroecological production stimulated by cooperative.

2.2. Data collection and analysis

The data collection was carried out in July 2018 through the administration of 21 questionnaires. Fifty-eight percent of the participants from COOPRIMA members. The respondents were subsistence farmers who were available during the data collection period. Direct observations were also carried out in the field to complement information collected via questionnaires. The questions were divided into six blocks, namely: (i) producer and family identification; (ii) infrastructure, housing, and health; (iii) land issues; (iv) information about production and marketing systems; (v) agroecological practices; and (vi) associations, technical assistance, and credit. The information was used to carry out socioeconomic characterization of the analyzed producers, in addition to the development of Agroecological Transition Index (ATI) for the farmers.

The index was developed using factor analysis in IBM SPSS Statistics 22 (IBM Corp., Armonk, NY, USA). According to Hair et al. [16], factor analysis consists of an interdependence technique aimed at defining the specific structure among variables used. In addition, according to Santana [17], factor analysis is a multivariate technique that aims to identify common factors within a set of interrelated variables in order to synthesize a large dataset; that is, it evaluates the potential of grouping *i* variables within a smaller number of *j* factors.

The factor analysis basic model, according to Dillon and Goldstein [18], can be presented in matrix form as follows:

$$X = \alpha F + \varepsilon \tag{1}$$

where, X = p-dimensional vector transposed from observed variables (characteristics), denoted by Y' = (y_1, y_2,..., y_k). α = a matrix (p, k) such that each element expresses $\alpha_{ij,}$ the correlation between y_{ij} volume and f_j factor, Λ is called a matrix of factorial loads with the number k of factors less than the number p of variables. F = q-dimensional vector transposed from unobservable variables or latent variables called common factors, denoted by F'= (f_1, f_2, ..., f_k), where k < p; and ε = p-dimensional vector composed of random variables or unique factors, that is, vector of residual components, denoted by ε'= (e_1, e_2,..., e_k).

The variables selected to represent the COOPRIMA agroecological transition of subsistence farmers were production composition, agroecological practices, access to technical assistance, and qualification courses, in addition to major income sources.

ATI development followed three key steps. The first was factor extraction using the main components method, which, according to Corrar et al. [19], is the most extensively applied method when the objective is to determine the factors explaining the most variance and the rotation application of *varimax* type factors. It allows a variable to be identified more easily using only one factor, which enhances its potential use in the interpretation of results.

Subsequently, the percentage variation explained by each factor was used to determine the weight score of each factor, which was standardized to obtain only positive values and facilitate farmer classification, since the ATI ranges from zero to one. Finally, ATI was ranked from highest to lowest calculated value, categorizing farmers as having high, moderate, and low potential for agroecological transition, according to Table 1.

Table 1. Agroecological Transition Index (ATI) classification.

Categorization	ATI
High Potential	≥ 0.70
Medium Potential	0.40 ≥ 0.69
Low Potential	< 0.40

Source: research data.

To validate the data obtained in the field interviews for the factorial analysis, the Kaiser-Meyer-Olkim (KMO) test was performed, where values less than or equal to 0.5 indicate that the sample size is inadequate. In addition, Bartlett's sphericity test was performed, to check whether there was a sufficiently high correlation among variables so that factor analysis could be performed, where a significant p-value less than the 5% significance level represents the rejection of the hypothesis that the correlation matrix is an identity matrix and therefore there is a correlation [16].

3. Results and discussion

3.1. Socioeconomic characterization of family farmers from COOPRIMA

Out of the 21 interviewed farmers, 52% were born in Primavera municipality, another 24% were born in nearby locations in Pará Northeast, and the remaining 24% were from other states or from the capital, Belém. Although most of the producers are native, 86% of the interviewees, who produce food in the defined areas for the cooperative, had lived for only six years or less at their residences. In addition, majority of the participants had worked in conventional agriculture previously in other areas, with slash and burn cultivation, which, according to Rego and Kato [20], is the main form of soil preparation strategy adopted by small-scale farmers in the Amazon.

More than half of the interviewees (57%) were women, indicating their considerable involvement in agricultural activities, which has been growing throughout the municipality, considering in 2006, only 10% of agricultural establishments in Primavera were run by women, while in 2017, the number had reached 30%, according to data from the 2017 Agricultural Census [13]. Altieri et al. [21] highlight that women are essential for biodiversity conservation, as they are a source of knowledge on seed conservation and gastronomy from their respective communities.

The age of the interviewees ranged from 31 to 68 years old, with an average age of 44.71 and standard deviation of 9.95 years. The three oldest participants were over 58 years old and were provided some form of retirement. Six people from the group received assistance from the government through the Bolsa Família program. With regard to the participation of other family members, low numbers of young people were observed participating in agricultural activity in the 19–30 years age group. Souza et al. [22], in a study in the Castanhal municipality, Pará Northeast, reported a lack of interest in young individuals in activities related to field agriculture. Troian and Breitenbach [23] argue that the exodus of young people from subsistence farming is widespread, which weakens the development potential of the sector, and raises concern over its sustainability in the future.

With regard to education, 48% of producers declared they did not complete elementary school, 14% had completed higher education, and one farmer was illiterate. Neres et al. [24], in a study with small-scale milk producers in the Tailândia municipality of Pará Northeast, found similar results with regard to level of education, alluding to the potential challenges in the adoption of technology in production systems. Regarding reliance on agriculture, 29% of the participants reported that they participate in other activities, with two individuals stating that agricultural production was not the major source of income for their families. According to Sakamoto et al. [25], pluriactive families have higher average household incomes than exclusively agricultural households, which have greater financial challenges.

Low agricultural yields were reflected in the homes visited. Only 29% of the homes had masonry walls and 48% had a clay floor. In addition, 62% of the producers did not perform any type of water treatment to the water obtained from wells, and 48% discharged their sewage in the open. Furthermore, 76% burned or buried their solid waste in the yard. The above statistics demonstrate the poor housing infrastructure of the small farmers.

3.2. Agroecological transition index

The estimated factorial model presented a KMO measure of 0.520, demonstrating sample adequacy. Regarding the Bartlett test, the p-value was less than 0.05, indicating that there was a correlation among the variables (Table 2).

After verifying data reliability, the principal component analysis allowed the extraction of two factors that explained 81% of the total variance. The commonality of all variables, which indicates the shared variance of one variable with others, and is represented by obtained factors, was greater than 0.7, demonstrating that the factors explained a significant proportion of the total variance. Table 2 lists the variables that make up each of the factors, and their respective commonalities.

Table 2. Factor load matrix after orthogonal rotation using Varimax and Communalities method.

Variables	Factor 1	Factor 2	Commonality
Major income sources	0.856	−0.106	0.744
Production composition	0.851	0.149	0.747
Access to technical assistance and qualifications	−0.134	0.941	0.903
Agroecological practices	0.580	0.715	0.847
Total Variance	45.3%	35.7%	
KMO	0.520		
Bartlett's sphericity test	Approx. Chi-square		19.551
	df		6
	Sig.		0.003

Source: research data.

The first factor explained 45.3% of the total variance and was composed of the major variables such as income sources and the nature of production, which are related to biodiversity estimates that include the planting of different species and the rearing of small animals that lead to different income potentials, so that it is referred to as production diversification.

The second factor explained 35.7% of the total variance and grouped the variables of access to technical assistance, such as the Technical Assistance and Rural Extension Company of the Pará State (EMATER), SEBRAE, in addition to qualifications, which are related to agricultural techniques, management, and agroecological practices, which refer to knowledge resources that farmers had for incorporating agroecological practices into their cultivation systems, into one group. Consequently, the factor was called agroecological knowledge. COOPRIMA encourages the use of such practices in its cropping systems among its members, with those used in Table 3 being used by farmers.

Organic compost is the result of decomposition and nutrient release from organic residues used in the fertilization of crops [26], mulch refers to the deposition of organic matter on the soil surface, intercropping and crop rotation are respectively simultaneous cultivation and alternating of different crops [7], alternate weeding consists of weeding alternate rows of a crop so as not to leave the ground completely uncovered, crowning is manual weeding in a circular fashion around a plant and windbreak is the use of vegetation to reduce wind erosion and decrease wind speed [27].

Agroforestry system is a model of sustainable land use combining an agricultural production system with a forestry production system for greater efficiency [28], rock phosphate is a phosphorus fertilizer usually produced from sedimentary rocks, manure is animal waste with great potential of nutrients used as fertilizers [29], the alternative control of pests and diseases is the use of natural compounds of fungi, bacteria, plants or plant derivatives, among others as biological control agents in detriment of conventional pesticides [30] , biofertilizers are compounds formed by microorganisms and organic materials and are an alternative to synthetic fertilizers [31] and green manure means the recycling of nutrients through the planting of certain species, such as legumes, to increase soil fertility.

Table 3. Agroecological practices used by COOPRIMA farmers.

Agroecological practices	N *	Agroecological practices	N *
Organic compost	21	Agroforestry system	4
Mulch	18	Natural phosphate	5
Alternate weeding	8	Manure	18
Crowning	19	Alternative PeD control	7
Windbreak	11	Biofertilizers	13
Crop intercropping	16	Green manure	14
Crop rotation	17		

*Number of farmers using. Source: research data.

The factor scores were obtained from the factorial load values listed in Table 2, which, were used to determine the ATI after standardization. That way, it was possible to carry out a family farmer hierarchy from COOPRIMA, organizing them in decreasing order based on the indices, according to agroecological transition potential.

Based on the data in Table 4, 19% of the farmers had a high potential for agroecological transition. The result could be attributed to the first factor, production diversification. Interviewees 16, 6, and 13, for example, managed to produce using permanent crops, temporary crops, and reared small animals, with 26, 19, and 26 different species, respectively. Consequently, they had diverse sources of income for their families. The strategy of production also offered a diversified diet, guaranteeing food security. According to Gliessman [32] and Duru et al. [33], species diversity is one of the fundamental principles of agroecology, ensuring greater resistance of cropping systems to climate change and major price fluctuations in the market.

With regard to farmer 5, access to technical assistance through the Technical Assistance and Rural Extension Company of Pará (EMATER), and to technical and managerial/organizational qualification courses, most probably led to him being the cooperative member who adopted agroecological practices the most. In addition, he emphasized during the interview that he no longer had challenges in implementing and maintaining them. Altieri et al. [21] highlight the importance of improving human capital through training and government support in the success of the agroecological transition processes.

Table 4. Factor scores and the Agroecological Transition Index (ATI).

Farmer	F1	F2	FP1	FP2	ITA	Categorization
16	1.95637	0.38229	1	0.688814	0.862784	High Potential
5	0.88957	1.84861	0.73428	1	0.851448	
6	1.65139	−0.29983	0.924035	0.544053	0.756484	
13	1.21185	0.04868	0.814554	0.618015	0.727891	
4	0.7777	0.30662	0.706415	0.672755	0.691573	Medium Potential
7	0.41158	0.8296	0.615221	0.783743	0.68953	
2	0.64034	0.05196	0.672201	0.618711	0.648615	
12	0.61008	−0.12085	0.664664	0.582037	0.62823	
10	0.06883	0.05525	0.529849	0.619409	0.56934	
18	−0.2581	0.23012	0.448416	0.65652	0.540179	
1	−0.73683	0.92674	0.329174	0.804359	0.538704	
21	−0.21692	0.05689	0.458674	0.619757	0.529703	
9	−0.2114	−0.19858	0.460049	0.565541	0.506565	
3	−0.79934	0.40623	0.313604	0.693895	0.481291	
17	−0.67569	−0.27836	0.344403	0.54861	0.434447	
19	−1.70671	1.10531	0.087594	0.842255	0.420358	
11	−0.55755	−0.70747	0.373829	0.457543	0.410742	
20	−0.48271	−0.97334	0.39247	0.401119	0.396284	Low Potential
15	−0.28761	−1.65833	0.441066	0.255749	0.359351	
14	−2.05838	0.85189	0	0.788474	0.347674	
8	−0.22647	−2.86343	0.456295	0	0.255094	
Maximum	1.95637	1.84861				
Minimum	−2.05838	−2.86343				
Weight	0.559055	0.440945				

Source: research data.

Thus, farmers with high potential for agroecological transition demonstrated that they have already started the transition process, consolidating at the second level proposed by Gliessman [9], which consists of replacing conventional practices with agroecological ones, such as intercropping and crop rotation, use of green manure, mulch, among others. However, the conclusion of the process, that is, the total redesign of the agroecosystem, or as defined by Bonaudo et al. [11] as the agroecological system that mimics the natural ecosystem, will still be a challenge for these small farmers.

Regarding producers who were classified as having low potential for agroecological transition, low levels of diversification were observed, with a concentration in specific production activities, as was the case in farmers 15 and 14, who revealed that they dedicated a large proportion of their time on bee-keeping and coriander production, respectively. In addition, producer 8, who had the worst performance in relation to agroecological knowledge, which may be related to lack of technical assistance and qualifications, implementing the least agroecological practices within his activities.

Producers evaluated with moderate agroecological transition potential, in most cases, demonstrated knowledge of the importance of diversifying production and adopting more sustainable practices based on the principles of agroecology, although they express a certain degree of rejection.

For example, 46% of them declared that the application of the techniques required is labor intensive. In addition, they were unable to produce the required organic fertilizer inputs. Consequently, they needed to search outside their properties, where inputs were scarce. This limitation was also reported by Almeida et al. [34] who observed a high dependence on foreign markets for organic compounds, this is due to inefficiency in animal management for own manure production.

Notably, 29% of farmers reported that marketing challenges were a major obstacle to the diversification of production and the adoption of agroecological practices, since options for selling products were limited and agroecological products did not attract different prices when compared to produce obtained from conventional systems.

According to some scholars, such devaluation occurs due to lack of support from the cooperatives, as reported by producers. Similarly, 33% of the interviewees did not have a commercial relationship with COOPRIMA, despite being members, maintaining the relationship only leasing out the land and selling their products to the city hall through the National School Feeding Program (Programa Nacional de Alimentação Escolar - PNAE), at fairs or directly to private customers.

Although the association of members to COOPRIMA is determined by the adoption of the agroecological production system, the cooperative has not carried out educational efforts, such as training workshops for farmers, as well as the work of publicizing what is produced by the members to consumers. very limited, making marketing difficult. Pompeu et al. [35] emphasizes in his research that cooperatives should promote the dissemination of knowledge regarding agricultural practices among their members.

In addition, 19% of the farmers reported that they still trade through middlemen, which guaranteed receipt of payment upon delivery of products, which, according to Santos et al. [8], causes them to depend on these traders. According to Vieira et al. [36], the low prices offered by middlemen are responsible for producers' dissatisfaction in the sale of products at agroforestry yards in Bonito, Pará Northeast. Sposito and Abreu [37] reinforce that such a relationship does not guarantee sustainability, leading to a return to conventional agricultural production in some cases.

4. Conclusions

Based on the socioeconomic characterization of the family farmers analyzed and the developed agroecological transition index, majority of the small-scale farmers from COOPRIMA had a moderate potential for agroecological transition, since they already exhibit fundamental characteristics such as biodiversity exploitation and the adoption of sustainable practices in their production systems. However, the application of agroecological practices has not led to significant change in the rural development of the farmers, as most of them still live in poor housing infrastructure because they are unable to obtain adequate income from agricultural activities, largely due to marketing challenges.

Therefore, solutions that could improve the production capacity of the farmers should be pursued, for example, through cooperatives, such as establishment of a partnership with the cement production company to purchase part of the produce, which would provide a mutual benefit, such as corporate image consolidation for the company and a stable source of income for the farmers. In addition, partnership would promote greater interactions among the farmers to facilitate the improvement of those who still have a low potential for agroecological transition.

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Conflict of interest

All authors declare no conflicts of interest in this paper.

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