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ARTICLE

Agro-ecological transition in rural settlement in Chapada dos Veadeiros

Transição agroecológica em assentamento rural na Chapada dos Veadeiros

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Abstract: The sustainability of organic production and the agroecological transition of farmers in the Chapada dos Veadeiros region was evaluated using the Environmental Impact Assessment System of Agricultural Technological Innovations (AMBITEC-AGRO). The evaluation process consisted of three stages: 1st survey and data collection, 2nd application of questionnaires and 3rd individual interviews. Data were entered into electronic spreadsheets, generating quantitative results of the impacts of activities carried out on rural properties. The indicators of the data obtained are organized in weighting matrices and automatically transformed into impact indices expressed graphically. These indexes resulted in the Percentage of Impact of Technologies - PIT, which characterizes the percentage gain of technology for each of the criteria of the environmental, economic and social dimensions of the productive units. For the environmental dimension, the PIT showed a reduction of -3.73%, where the general index of impact of the activity was 0.95 and after the transition to organic and/or agroecological production it went to 1.29, with a difference of 0.34. In the economic dimension, the PIT was 7.70%, the employment variable with 0.73 and income with 3.89 were the ones that most contributed to this percentage. In the social dimension, the PIT was 7.19%, the most prominent criteria being the consumer with an average of 3.74 and health with an average of 2.99. In this sense, the transition to organic and/or agroecological management, mainly due to the reduction of environmental impacts, provided greater sustainability for agricultural activities in the region.

Keywords: agroecology, organic, sustainability, AMBITEC-AGRO.

Resumo: A sustentabilidade da produção orgânica e a transição agroecológica dos agricultores da região da Chapada dos Veadeiros foi avaliada, utilizando-se o Sistema de Avaliação de Impactos Ambientais de Inovações Tecnológicas Agropecuárias (AMBITEC-AGRO). O processo de avaliação consistiu de três etapas: primeira: levantamento e coleta de dados; segunda: aplicação dos questionários e terceira: entrevistas individuais. Os dados foram inseridos em planilhas eletrônicas, gerando resultados quantitativos dos impactos das atividades desenvolvidas nas propriedades rurais. Os indicadores dos dados obtidos são organizados em matrizes de ponderação e, automaticamente, transformados em índices de impacto, expressos graficamente. Esses índices resultaram no Percentual de Impacto das Tecnologias (PIT), que caracteriza o ganho percentual da tecnologia para cada um dos critérios das dimensões ambiental, econômica e social das unidades produtivas. Para a dimensão ambiental, o PIT apresentou uma redução de -3,73%, onde o índice geral de impacto da atividade era de 0,95 e, depois da transição para a produção orgânica e/ou de base agroecológica passou para 1,29, com uma diferença de 0,34. Na dimensão econômica, o PIT foi de 7,70%, a variável emprego, 0,73, e renda com, 3,89, foram as que mais contribuíram para esse percentual. Na dimensão social, o PIT foi de 7,19%; os critérios com maior destaque foram o do consumidor com média de 3,74, e saúde, com média de 2,99. Nesse sentido, a transição para o manejo orgânico e/ou de base agroecológica, principalmente pela redução dos impactos ambientais, proporcionou maior sustentabilidade para as atividades agropecuárias da região.

Palavras-chave: agroecologia, orgânico, sustentabilidade, AMBITEC-AGRO.

1 INTRODUCTION

Sustainable agricultural production emerges as a model aimed at promoting integration among biological, geochemical, physical, and productive processes, as well as social components involving political, economic, and cultural aspects. This change is not only about greening production but also about positively changing agri-food systems, aiming for food security and socio-environmental sustainability.

Agroecological transition seeks to produce food with fewer environmental impacts and to preserve environmental resources for future generations. Therefore, it cannot be confused solely with the conversion to organic systems that only aim at replacing inputs (Caporal, 2009, 2020).

According to Altieri (2004), agroecological transition aids in converting a conventional system into an organic and/or agroecological production system, passing through different stages, both within and outside the production system, depending on the distance the productive system is from sustainability (Empresa Brasileira de Pesquisa Agropecuária, 2006).

Gliessman (2016) defines agroecology as a way to redesign food systems to achieve ecological, economic, and social sustainability. The same author states that this transition is divided into 5 levels. Level 1: reduction of agrochemical uses and increased efficiency in the production process. Level 2: substitution of intensive external input products and environmentally degrading practices with more renewable ones, based on natural and environmentally healthier products. Level 3: redesigning the agro-ecosystem and the set of ecological processes. Level 4: establishing a direct connection between food producers and consumers. Level 5: involves global changes that go beyond the food system to the nature of culture, civilization, progress, and human development.

According to Abreu et al. (2012), in recent years, a dichotomy has been established between products from agroecological-based agriculture and certified organic agriculture. The former is being expanded among family farmers, driven by public policies and social movements. Certified organic agriculture mainly develops in the business sector, being marketed in specific stores, supermarket chains, and organic product fairs.

Lima et al. (2020) consider that in recent years, from 2000 to 2017, organic production and consumption have grown considerably. During this period, the area of organic crops increased by 365%, and production jumped from 15 million hectares to 69.8 million hectares; 51% of the total organic production area is in Oceania, followed by Europe (21%), Latin America (11%), Asia (9%), North America (5%), and finally Africa (3%).

Leach et al. (2020) state that the current situation of food systems is concerning, and urgent calls for change are being made. In this regard, public policies for this sector need to advance and should consider environmental preservation and social justice. According to Sambuichi et al. (2017), the standardization and institutionalization of public policies have positioned Brazil as one of the countries that have advanced in the production and commercialization of organic products. In 2003, Law 10,831, which regulates organic agriculture, was approved, and served to guide the production and commercialization of organic products, culminating in Ministerial Ordinance No 52, dated March 15, 2021 (Brasil, 2021).

According to Santos et al. (2014), organic and/or agroecological production has shown promise in family farming and has been an alternative to conventional agriculture, providing sustainability for rural families. This has strengthened family farming and contributed to the retention of families in rural areas. However, there are still several obstacles that deserve attention and need to be overcome. Technical assistance and difficulty accessing credit are some of the problems reported. Therefore, the creation of public policies is essential for the growth of this sector.

Brugg & Dallacosta (2017) describe that diversification is one of the main characteristics of organic and/or agroecological agriculture, as well as family farming. The reasons why family farmers adopt this cultivation practice are related to reducing risks and uncertainties regarding income. This diversification can be even greater when there is integration between animal and plant production, providing products that can be marketed year-round, and better living conditions for family farmers.

According to Soares et al. (2011), organic and/or agroecological agriculture can be a way to increase productivity, diversify production, and better distribute income from the productive unit throughout the year, as well as minimize the impact on natural resources in Brazil. Furthermore, diversifying production contributes to greater security and ensures the sustainability of the activity. In this sense, research is being conducted with the aim of assisting farmers in achieving more sustainable agriculture. However, according to Rodrigues et al. (2006), when technologies are introduced into agricultural properties, they have impacts on the complex nature of socio-cultural and environmental interactions, which imply uncertainties about the possible repercussions of the innovation implemented.

To evaluate these impacts and guide the adoption of agricultural technological innovations, the Brazilian Agricultural Research Corporation (EMBRAPA) has used the AMBITEC-AGRO System, which is a tool applicable to environmental certification processes, contributing to sustainable rural development (Soares et al., 2021b). According to Rodrigues & Rodrigues (2007), the method for appropriate evaluation must be suitable for guiding the choice of activities, technologies, and management practices according to the potentialities and constraints of rural space use and its appropriation of sustainable development goals - SDGs.

Farmers in the municipality of Alto Paraíso, located in the Chapada dos Veadeiros region, in the state of Goiás, are innovating and starting to implement organic agriculture practices based on agroecological principles. In this region, which includes part of the Chapada dos Veadeiros National Park (PNCV) and the surrounding buffer zones, there are settlement projects of agrarian reform, family farmers, and highly skilled rural producers. Agricultural activities carried out in the buffer zones of the Park impact the fauna, flora, and natural resources of the preserved sites (Costa et al., 2022). Therefore, the agroecological transition of producers to sustainable production models is fundamental for the sustainability of local production systems.

The objective of this study was to analyze sustainability in the process of agroecological transition to organic production, measuring the socioeconomic and environmental impacts of producers in the Chapada dos Veadeiros in the municipality of Alto Paraíso-GO.

2 THEORETICAL BACKGROUND

2.1 Organic agriculture and agroecological transition

In Brazil, large-scale agriculture coexists with intensive pesticide use and heavy machinery, alongside other forms of agriculture with limited access to technologies. In this case, the Brazilian land structure consists of both small and large properties, employing intensive or extensive practices, with varying degrees of fertilizer, pesticide, machinery, and other technology usage (Jesus, 2005).

The same author also states that the techniques of the Green Revolution and large-scale production did not achieve the objectives of their creators, as they led to greater environmental degradation and did not solve the problem of hunger. These factors contributed to the expansion of organic and agroecological-based agriculture, which proposes a productive practice aimed at sustainable development.

Movements that criticized the indiscriminate use of pesticides and environmental degradation began to gain more visibility in Brazil from the 1980s. These movements contributed to the development of less impactful agriculture, which gained various denominations over time. This became popularly known as organic and agroecological-based agriculture and has advanced worldwide, both in production and commercialization, significantly impacting the agricultural sector's economy in several countries.

According to Figueiredo & Soares (2012), there is significant intentional and unintentional confusion between organic products and other products, such as green products, agroecological products, rustic products, colonial products, and others. It is important to highlight that organic products have official regulation from the Ministry of Agriculture, Livestock and Supply (MAPA), while these others do not (Soares et al., 2021a). Therefore, any ecological, biodynamic, natural, regenerative, biological, agroecological product is referred to as organic product (Brasil, 2003) as long as they are certified or come from producers linked to social control organizations (OCS) and have their production, processing, storage, transportation, and commercialization processes governed by Law 10,831/2003 (Brasil, 2003) and Ordinance 52 (Brasil, 2021).

Abreu et al. (2012) emphasizes that the analysis between ecological-based systems and organic production should not be polarized, where one opposes the other, as both approaches converge and present significant contributions to the social, economic, and environmental dimensions, thus promoting the search for more sustainable production systems. Currently, there is an observable convergence between the two at the level of public policies, as described in the National Policy on Agroecology and Organic Production Systems, of 2012. This same trend can be found in public policies of different Brazilian states, highlighting the importance of agriculture models that differ from conventional systems.

According to Willer et al. (2021), recent data presented by the International Federation of Organic Agriculture Movements (FiBL/IFOAM) show that the demand for these products has been mainly driven by the United States and European countries, such as Germany and France, as well as by China. It is observed that since the year 2000, the average annual growth in retail sales of organic products worldwide has exceeded 11%. In Brazil, the organic segment generated 5.8 billion reais in 2020, a 30% increase compared to 2019 (Lima et al., 2020).

For Buainain (2006), the major challenge is not to maintain production growth but to expand the consumption of these products to poorer layers of society and consumers with less concern for environmental preservation. Overcoming this challenge requires consumer awareness, lowering prices, and the creation of more public policies.

2.2 Organic and agroecological-based production from family farming

Family farmers who have embraced more sustainable production engage in strategies that go beyond purely economic values, including environmental, cultural, social, and religious factors that directly influence the property's infrastructure, both in agricultural area occupation and in crop and livestock choices. Thus, it is important to highlight that in Brazil, there is a predominance of more sustainable integrated systems (Khatounian, 2001).

Abramovay (1998) asserts that the main challenge for family agricultural production units is related to means that can guarantee participation in dynamic and competitive markets since they require technological innovations, and families have limited choices to commercialize their products. Furthermore, obtaining credit to purchase inputs and accessing information are also obstacles for the sector. Overcoming these challenges and accessing formal agricultural credit can contribute to increasing families' income to emancipate themselves from the clientelist dependency to which they are subjected, opening up possibilities to develop new production systems such as organic and/or agroecological-based agriculture and gain new markets.

Santos et al. (2014) demonstrate that organic and/or agroecological-based agriculture enables family farmers to achieve socio-economic sustainability in their activities, providing opportunities for these families to develop necessary survival conditions. Therefore, transitioning to this type of system helps improve the living conditions of these farmers and contributes to sustainability.

2.3 Sustainability indicators and tools for assessment and impacts

In the case of organic and/or agroecological-based agriculture that follows the principles of sustainable development, indicators, according to Schultz et al. (2010), should be based on the following dimensions: ecological: conservation and improvement of natural resources, reduction of pesticide use and non-renewable resources; social: improvement in the quality of life of the population and basic service provision; economic: improvement in family income, financial stability, and productivity; cultural: valorization of local culture, recovery and respect for cultural habits and diversity; political: collective organization, participation spaces, and collective construction of alternatives for problem-solving and development; and ethical: individuals' responsibility towards environmental preservation, adherence to new values, fraternity, and solidarity in relationships.

Cândido et al. (2015) state that there are several sustainability assessment methods tailored to agriculture, with the most popular being IDEA (Indicauters de Durabilité des Exploitations Agricoles) and MESMIS (Framework for Evaluating Management Systems Incorporating Sustainability Indicators), which, despite structural differences, converge in analyzing agricultural production activities through various indicators aiming for sustainability.

In addition to these, there is the Environmental Impact Assessment System for Agricultural Technological Innovations (AMBITEC), created by the Brazilian Agricultural Research Corporation (EMBRAPA), which serves to assess the sustainability of systems and technologies employed (Soares & Rodrigues, 2013).

According to Soares & Rodrigues (2013), AMBITEC is composed of a simple hierarchical structure, starting from a more local sphere, i.e., the cultivation field or the entire production unit, and can be extended to surrounding ecological systems, at the scale of the rural landscape of the region or in the hydrographic microbasin. This measurement system is based on sustainability assessment methods widely described in current literature and can be applied in organic and agroecological-based agriculture.

Irias et al. (2004) affirm that the AMBITEC method features practicality, low cost, and simplicity in application and interpretation of results. The tool's objective is to generate indicators that can assist in promoting sustainable development of agricultural activities, seeking the adoption of new technologies and practices that minimize negative impacts on environmental quality while promoting economic profitability and social development.

It is evident that there is a variety of tools to assess the sustainability of agricultural activities. However, Galharte & Crestana (2010) describe that the choice of parameters and the measurement, evaluation, and interpretation of data must be transparent and clear, without leaving doubtful points in the principles used during the assessment process. Therefore, when constructing and selecting sustainability assessment methods, their applicability, understanding, costs, and whether they truly integrate economic, social, and environmental factors from different places must be taken into consideration.

AMBITEC consists of a practical system that, according to Rodrigues et al. (2002), is ready to be applied on rural properties through interviews and surveys directed to farmers responsible for introducing new technologies in their production processes. The system is composed of a computer platform that is easily accessible and applicable at a low cost. Additionally, the system is standardized in terms of quantifications but is also flexible, allowing it to adapt to specific usage situations.

3 METHODOLOGY

3.1 Characterization of producers and the study area

The Citizenship Territory of Chapada dos Veadeiros is located in the Northeast of Goiás, where the municipalities of Alto Paraíso de Goiás, Campos Belos, Cavalcante, Colinas do Sul, Monte Alegre de Goiás, Nova Roma, São João D'Aliança, and Teresina de Goiás are situated, gaining prominence with more sustainable production practices (Costa et al., 2022). This region is also known for the natural beauty of the Chapada dos Veadeiros National Park. The Chico Mendes Institute for Biodiversity Conservation informs that the park was created on January 11, 1961, by President Juscelino Kubitschek, through Decree 49,875. Initially, it was named the Tocantins National Park and covered an area of 625,000 hectares of protected conservation land. The justification for the park's creation was the protection of areas of natural wealth. In 1972, a redelineation was carried out by the Decree 70,492. In 1981, another redelineation was done with Decrees 86,173 and 86,596, and finally, in 1990, land demarcation was completed with Decree 99,279 (Costa et al., 2022).

The evaluated productive units are in the region of Cidade da Fraternidade, and some producers are agrarian reform settlers in different municipalities of the region. The settlement began with the arrival of the Landless Rural Workers Movement (MST) in 2013. During this period, just over 300 families formed the Sílvio Rodrigues Settlement Project, which currently comprises 119 properties ranging from twenty to thirty hectares. The settlement is located within the limits of the municipality of Alto Paraíso de Goiás, which, despite its natural wealth, is classified as a corridor of social misery in the state due to poverty conditions and a low Human Development Index (HDI).

Ten rural producers classified as family farmers, who are transitioning to organic production, were evaluated. Their properties are located in the Tocantinzinho river basin region in Alto Paraíso de Goiás. Regarding the regularity of production units, all of them have already received land ownership titles (Table 1).

Despite transitioning to integrated organic production systems, the systems are characterized as agroecological-based. The interviewed farmers do not yet have organic certification; they are developing their activities in integrated production systems, involving both plant and animal origins, which are marketed at local fairs and other commercial establishments in the region. Recently, the Participatory Organic Conformity Assessment Body (OPAC/AGE) has been conducting a participatory certification process for 32 producers in the Chapada dos Veadeiros, in the municipalities of Colinas do Sul, Cavalcante, São João d'Aliança, and Alto Paraíso de Goiás, since late 2022. Visits and interviews were conducted with representatives of family production units in the first half of November 2021, where each property served as a sample unit for socio-economic and environmental impact assessment. Through these visits, initially, introductory data were collected about the characterization of rural properties, such as the property's name, administrator, respondent's name, address, duration of the agroecological transition, crops planted, and total area of the property (Chart 1).

Chart 1 – Characterization of agricultural activities on family rural properties (AF) in the Silvio Rodrigues-Alto Paraíso-GO settlement

Producers	Total property area	Start of activity	Activities on the property
AF 1	18,2 ha	1992	Cultivation in the garden and garden with cassava, sugarcane, pineapple, sweet potato, silver and dwarf bananas, dry rice, lemon, orange, guava, lime, jackfruit, mango, jabuticaba[1], acerola[2], acaí[3], guariroba[4], coffee, cotton, pitanga[5], lettuce, carrot, beetroot, cabbage, tomato, eggplant, okra, mangarito, yam, arrowroot, chili pepper, garlic, onion. Breeding a dairy herd (17 animals: 2 lactating cows, 8 heifers, 7 calves. Raising chickens (20 laying birds) and fish (tilapia).
AF 2	156 ha	1987	Livestock farming activities including beef cattle, dairy cattle, and chickens. Cultivation of cassava and crafting slate stone handicrafts for commercialization.
AF 3	74 ha	2020	Dairy and beef cattle breeding activities, fish farming. Vegetable, corn, banana and cassava crops.
AF 4	33 ha	2003	Corn, pumpkin, beans, cassava crops. vegetable garden (lettuce, arugula, cabbage, carrots, radishes). Dairy cattle (18 animals), chickens (70 laying birds) and 2 pigs are raised.
AF 5	23 ha	1993	Dairy cattle, guinea fowl, horses and cassava, sugar cane and banana farming activities.
AF 6	24,8 ha	2007	Subsistence vegetable garden, conventional corn, cabotiá pumpkin, dairy cattle.
AF 7	121 ha	1950	Exclusive and extensive breeding of beef cattle without knowledge of the total number of heads.
AF 8	5 ha	2017	Poultry and pig farming. Vegetable cultivation.
AF 9	24 ha	2019	They produce goat's milk (fresh and cured cheese), yogurt, ricotta, dulce de leche), vegetables (leek, carrot, beetroot, onion, garlic, cabbage, cauliflower), corn, beans, oranges, jabuticaba.
AF10	18,5	2003	Cultivation of a 2 ha field with green beans, beans, corn, pumpkin, cassava. 1 ha of vegetable garden with cultivation of zucchini, carrots, beets, sweet potatoes, cauliflower, broccoli, leeks, parsley, cabbage, coriander, chives, flowers (angel carnation and carrot flower). Raising 27 animals - 4 lactation with 20 liters of milk/ day. 8 calves and heifers, 3 heifers, 5 males (1 year old), 7 males (3 being 1.5 years old and 4 males being 2 years old.

Source: Authors.

[1] The jabuticaba, also known as the Brazilian grape tree, is a fruit-bearing tree native to Brazil. Its scientific name is Plinia cauliflora, and it belongs to the Myrtaceae family.

[2] Acerola is a fruit native to tropical regions of the Americas, particularly South America, Central America, and the Caribbean. Scientifically known as Malpighia emarginata, it is also commonly referred to as the Barbados cherry or West Indian cherry.

[3] Acaí is a fruit native to the Amazon rainforest in Brazil, scientifically known as Euterpe oleracea. It is a small, dark purple berry that grows in clusters on the acaí palm tree.

[4] Guariroba, also known as the Brazilian palm or Syagrus oleracea, is a species of palm native to Brazil. It typically grows in the cerrado biome, a tropical savanna region.

[5] Pitanga, scientifically known as Eugenia uniflora, is a tropical fruit native to Brazil and other regions of South America. It is commonly referred to as Surinam cherry or Brazilian cherry.

3.2 Assessment of Environmental and Socioeconomic Impacts

The data collection of environmental and socio-economic impacts began with field information gathering conducted alongside producers on their rural properties, aided by notebooks, through interviews with those responsible for the rural establishments. The method used was the Environmental Impact Assessment System for Agricultural Technological Innovations (AMBITEC-AGRO) (Soares & Rodrigues, 2013).

Ambitec Agro is a program consisting of a set of electronic spreadsheets (MS-EXCEL®) comprised of a series of environmental and socio-economic indicators. The application of the tool included the development of an on-site interview with the producer, aimed at assessing their perception based on their experiences and experiences regarding the impacts generated by the agroecological transition to organic production systems. The data collection process was carried out in two stages and included the completion of two different spreadsheets from the Ambitec system. Initially, the producer answered questions related to their previous situation (ex post), when their production activities were conventional; and, in the second stage, their perception of the current situation was evaluated, during the agroecological transition process to the organic production system (ex post). Both stages were carried out on the same day, with only differentiation regarding the two forms of production.

The Ambitec system in the assessment of environmental impacts consists of two general aspects to be considered: the first relates to the use of inputs and resources, and the second, to environmental quality, including indicators such as water consumption and direct and indirect land use change grouped together, given the importance of these indicators for natural resource preservation.

In economic impacts, the aspects evaluated are income and employment. The assessment of social impacts is composed of aspects such as consumer respect, health, management, and administration (Soares & Rodrigues, 2013). Each of these aspects is formed by indicators, and each indicator consists of a series of variables (Figure 1). The aspects, indicators, and variables that constitute the Ambitec impact assessment can be consecutively related (Irias et al., 2004).

Each of the variables has a weighting factor (k) indicating the weight or importance of each one. The program also includes the geographical scale of occurrence of the change in the indicator component, determining the scope of the impact, which can vary between punctual, when the effect is restricted to the technology implementation environment; local, when the effect is felt outside the technology environment but restricted to the limits of the production unit; and surrounding, when the generated impact exceeds the limits of the production unit (Rodrigues et al., 2002).

The variables of each indicator are measured based on the indicator's alteration coefficient, understood as the impact of the activity under specific management conditions for each variable. Alteration coefficients can range from -3 to +3, where +3 indicates a significant positive influence on the component; +1, moderate positive influence on the component; 0, unchanged component; -1, moderate negative influence on the component; and -3, significant negative influence on the component (Soares & Rodrigues, 2013). The alteration coefficients were inserted according to the producer's perception, who identified the degree of impact for each variable. Once the alteration coefficient is inserted, the program automatically generates the partial impact coefficient, which, when summarized, forms the total impact of the indicator.

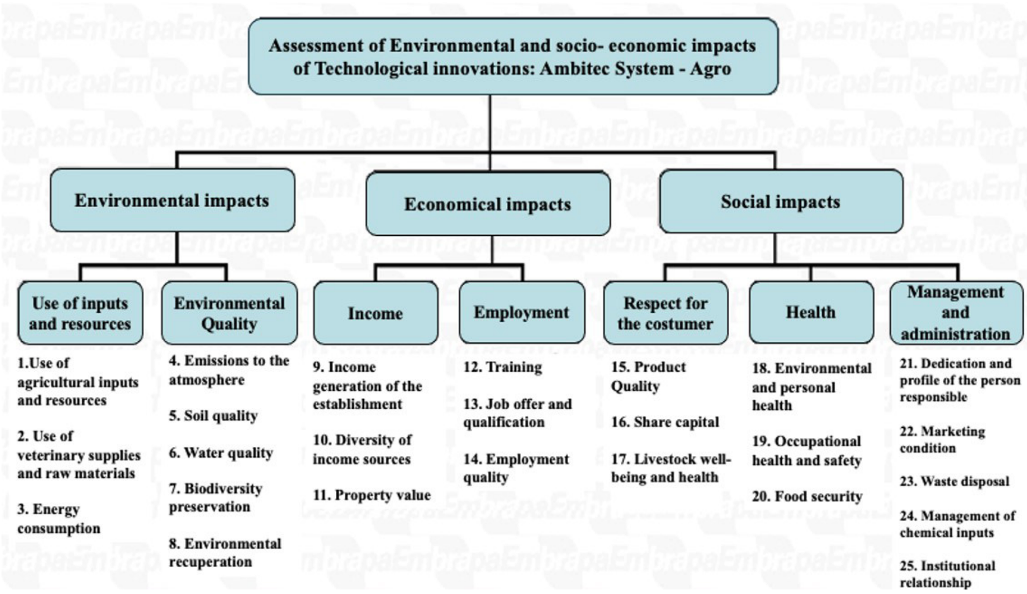

Figure 1 - Diagram of aspects, indicators, and variables for the assessment of socioeconomic and environmental impacts via the Ambitec system.
Source: Adapted from Soares & Rodrigues (2013). Translated by the author.

In the Ambitec system's results matrix, the environmental impact indicators were grouped and consolidated for each evaluated producer both before and after the technology implementation, which occurred at different times on each property, with the period varying according to each producer's entry time into the activity. These indicators have a graphical representation, generating an overall impact index ranging from +15 to -15, depending on the impact direction, whether positive or negative, respectively.

The methodology for calculating the technology impact percentage (TIP) was developed to provide a comparative analysis between the socio-economic and environmental conditions before and after the organic and/or agroecological transition. It also characterizes, in a practical way, the percentage gain of the technology for each production unit, with easy understanding for the family farmer to highlight the differences in terms of technical coefficients of the process and the changes provided by the adopted technology (Soares et al., 2015).

$$PIT_i = \left(\frac{\mu_{2i} - \mu_{1i}}{AM} \right) \times 100$$

Where:

PIT_i: Individual's Percentage of Technology Impact (TIP) i, i=1

μ_{2i}: Impact index after the introduction of technology, referring to the individual i;

μ_{1i}: Impact index before the introduction of technology, referring to the individual i;

AM: Maximum possible amplitude of the Ambitec scale (= 30).

3.3 Statistical analyzes

To assess the possible existence of significant differences for each criterion within the social, economic, and environmental dimensions (before and after), the non-parametric Wilcoxon test for paired samples was conducted at a significance level of 5%.

The individual Technology Impact Percentage (TIP) per producer (Soares et al., 2015) was also calculated. This same measure can indicate the intensity or magnitude related to these impact indices in the change between the moments. All statistical analyses were performed using the R software, version 4.2.0.

4 RESULTS AND DISCUSSION

Based on the alteration coefficients provided by the producers for each of the variables within the aspects and indicators of the system during the questionnaire application of the Ambitec-Agro method, the impact indices of the implemented technologies and the change in producers' management were calculated. These scores also resulted in the percentage of technology impact (TIP).

The 25 criteria were individually and collectively assessed, both before and during the agroecological transition process. The results from before and after are presented in Tables 1 and 2, and the differences in performance across the 25 criteria are described in Table 3.

The average performance coefficients concerning conventional management can be observed in Table 1. As described, criteria such as water consumption (μ = -2.4), use of agricultural inputs (μ = -1.8), use of veterinary inputs and raw materials (μ = -1.6), self-generation, utilization, reuse, and autonomy (μ = -0.1) received negative evaluations. These were followed by soil quality (μ = -1.6), conservation of biodiversity and environmental recovery (μ = -2.8), job qualification and availability (μ = -0.2), gender, generation, and ethnicity equity (μ = -1.6), income generation (μ = -2.8), occupational safety and health (μ = -1.4), which also received negative evaluations. The variable related to income generation had the highest negative average among all variables. Farmers reported difficulties in generating income with the conventional method.

Producers 1 and 5 had a negative General Impact Index of Activity of -1.40 and -1.19, respectively. However, the other 8 producers had a positive evaluation, with farmer number 2 standing out, who had a General Impact Index of Activity of 4.28 (Table 1).

Table 1 - Performance coefficients of the different impact criteria of the activity in the conventional system of family producers in the Silvio Rodrigues-Alto Paraíso-GO settlement

Impact criteria	Performance coefficients of family producers (AF)										
	AF1	AF2	AF3	AF4	AF5	AF6	AF7	AF8	AF9	AF10	Avarage
Change in direct land use	2.5	1.0	0.5	-0.5	1.0	0.8	2.0	2.0	-0.8	1.0	1.0
Change in indirect land use	0.0	0.5	-1.0	0.5	-0.8	-0.5	0.5	3.0	-0.5	-1.0	0.1
Water consumption	-13.0	-1.0	-2.0	9.0	-5.0	5.0	-4.0	-3.0	-3.0	-7.0	-2.4
Use of agricultural inputs	-15.0	15.0	-6.0	0.0	-5.0	-5.0	4.5	0.0	1.5	-8.0	-1.8
Use of veterinary supplies and raw materials	15.0	1.0	-12.0	-7.0	5.0	-15.0	7.5	-3.0	-7.5	0.0	-1.6
Energy consumption	-5.0	10.5	-1.5	1.5	1.0	2.0	11.5	6.0	4.5	-5.0	2.6
Own generation. use. reuse. and autonomy	0.6	0.6	0.5	0.1	0.2	-0.6	0.0	-3.9	1.1	0.2	-0.1
Emissions to the atmosphere	3.0	-0.6	-1.6	0.0	-1.0	0.0	0.4	-0.1	-0.8	1.0	0.0
Soil quality	7.5	15.0	-12.5	3.8	-5.0	-5.0	-12.5	0.0	-2.5	-5.0	-1.6
Water quality	15.0	3.0	-0.2	-0.6	0.8	6.0	0.6	9.6	-1.8	3.0	3.5

Source: Authors.

Table 1 - Continued...

Impact criteria	Performance coefficients of family producers (AF)										
	AF1	AF2	AF3	AF4	AF5	AF6	AF7	AF8	AF9	AF10	Avarage
Biodiversity conservation and environmental recovery	-3.8	-2.3	-2.0	-5.2	-1.4	-3.0	-11.1	-1.0	-1.5	3.1	-2.8
Product quality	-15.0	-3.5	5.5	-0.8	-0.3	2.5	-0.8	10.0	3.0	5.0	0.6
Share capital	-2.1	2.5	1.7	1.2	-0.1	1.6	-1.4	-0.5	1.2	-2.3	0.2
Livestock welfare and health	-1.0	12.0	13.5	5.0	-5.0	13.5	3.0	-15.0	4.3	4.5	3.5
Training	-8.3	1.5	8.3	3.8	2.8	1.5	8.3	11.3	1.3	-3.8	2.7
Qualification and job offer	0.8	2.6	0.6	0.9	-0.4	-7.2	0.0	-0.5	0.5	0.8	-0.2
Quality of job/ occupation	0.0	5.8	1.0	0.0	2.3	4.0	0.0	0.5	0.0	-6.0	0.8
Equity between genders. generations. ethnicities	-2.5	5.6	10.0	-2.5	-6.3	-15.0	8.8	-12.5	7.5	-8.8	-1.6
Income generation	-4.0	6.0	0.0	-7.0	-15.0	-15.0	-4.0	15.0	1.0	-5.0	-2.8
Property value	-10.5	6.5	13.0	5.0	5.0	-10.5	5.5	8.0	0.0	-5.0	1.7
Occupational health and Safety	1.5	-5.0	-1.5	0.0	1.5	-0.8	-5.0	0.0	-5.0	0.0	-1.4
Food safety	-3.0	3.0	2.4	1.0	0.4	3.0	1.0	-3.0	3.0	1.0	0.9
Dedication and profile of the person responsible	-8.3	8.3	10.8	8.3	-4.3	9.8	8.3	8.5	2.8	-1.0	4.3
Marketing condition	-1.3	3.8	6.5	4.5	1.3	5.3	0.8	-1.8	4.8	3.5	2.7
Waste disposal	0.0	2.0	3.0	4.0	-2.0	8.0	-2.0	-6.0	13.0	-2.0	1.8
Chemical input management	0.0	0.0	3.8	0.0	1.0	1.0	0.0	0.0	0.0	5.0	1.1
Institutional relationship	0.0	11.3	11.3	0.0	0.0	2.5	0.0	1.3	-3.8	0.0	2.3
General Activity Impact Index	**-1.40**	**4.28**	**0.91**	**1.34**	**-1.19**	**0.09**	**1.65**	**1.87**	**0.66**	**1.28**	0.9

Source: Authors.

The average performance coefficients of the producers after the agroecological transition process can be observed in Table 2. During this period, farmers made management changes and invested in more sustainable practices aiming for less impactful production and greater profitability. The average for the variable Biodiversity Conservation and Environmental Recovery was μ = 2.5 (Table 2), indicating a positive assessment among farmers who reported investing in conservation practices over time. Farmers reported reducing deforestation, wildfires, and the opening of new areas for production on their properties.

However, some coefficients such as water consumption (μ = -5.0) and water quality (μ = -1.8) (Table 2) continued to have negative evaluations and did not show changes to achieve a positive average. It is important to note that water quality also received a negative evaluation after the transition, a situation explained by farmers as a consequence of conventional soybean planting in the vicinity of the evaluated properties. Farmers reported the application of pesticides in soybean fields and that these products were being carried by rainwater to the watercourses in the region.

As shown in Table 2, it is noticeable that after the management change and agroecological transition, all farmers experienced an increase in the average. As demonstrated, the General Impact Index of Activity for all 10 farmers had a positive average, with farmer number 2 standing out with μ = 2.65 and producer number 10 with μ = 2.81. Regarding the overall average related to Activity Impact Criteria, the variable property value stood out after the agroecological transition, with an average value of μ = 8.7.

The findings of Gusman Muñoz et al. (2022) reveal similar characteristics and an increase in the average during the agroecological transition on family farming properties in the Federal District. Actions were taken to maximize the use of available resources, adopt practices in favor of sustainability, optimize spaces, use agroecological technologies, utilize foods with high nutritional value, and engage in ethical and responsible marketing. Thus, the analyzed initiatives work towards improving the social, economic, and environmental conditions of their areas.

The variable water consumption, which had a negative coefficient of performance average (μ = -2.4), increased to μ = -5.0 after the agroecological transition. In this case, it is evident that there was a reduction in water consumption on the property. This may have occurred due to the low availability of water for consumption on the rural property during the agroecological transition period. Farmers reported difficulties regarding the quantity of water available for personal consumption and also for rural activities after soybeans began to be cultivated on other properties in the region, which turns this issue into a land problem.

Table 2 – Performance coefficients of the different activity impact criteria in the agroecological transition period of family producers in the Sílvio Rodrigues-Alto Paraíso-GO settlement.

Impact criteria	Performance coefficients of family producers (AF)										
	AF1	AF2	AF3	AF4	AF5	AF6	AF7	AF8	AF9	AF10	Avarage
Change in direct land use	0.0	0.5	2.3	0.0	1.3	-0.3	-0.3	0.0	1.8	6.3	1.2
Change in indirect land use	0.0	-0.3	1.5	-0.8	-2.3	-4.3	0.0	-4.5	0.0	-8.8	-1.9
Water consumption	-4.0	-9.0	-6.0	-9.0	-12.0	-4.0	4.0	2.0	0.0	-12.0	-5.0
Use of agricultural inputs	9.5	-5.0	12.0	0.0	0.0	8.0	-4.5	0.0	-0.5	10.5	3.0
Use of veterinary supplies and raw materials	3.0	-9.5	4.5	-9.0	-7.0	15.0	1.5	-7.5	0.0	6.0	-0.3
Energy consumption	6.0	-9.5	-12.0	-10.5	-7.0	-12.0	-7.0	-7.0	-7.5	-9.5	-7.6
Own generation. use. reuse. and autonomy	1.4	-0.6	0.2	0.9	-0.5	0.6	0.0	-1.2	0.0	0.2	0.1
Emissions to the atmosphere	-1.8	-0.2	0.0	0.0	-2.2	0.0	-1.2	-0.3	0.3	-1.6	-0.7
Soil quality	-7.5	-15.0	12.5	3.8	3.8	12.5	11.3	0.0	0.0	7.5	2.9
Water quality	-9.0	-1.6	0.6	-0.6	0.4	-7.6	-0.6	-1.2	1.6	-0.2	-1.8
Biodiversity conservation and environmental recovery	3.8	1.1	0.4	2.6	0.8	5.0	10.4	0.3	0.1	0.3	2.5
Product quality	12.0	2.3	0.0	10.8	1.5	11.3	2.3	7.5	0.0	0.5	4.8
Share capital	5.3	-0.4	0.0	0.2	1.1	3.6	0.6	1.5	0.4	6.8	1.9
Livestock welfare and health	12.0	-0.8	0.0	15.0	0.0	0.0	2.3	15.0	0.0	11.5	5.5
Training	5.3	0.0	0.0	1.3	8.3	6.8	-3.8	0.0	-1.3	3.8	2.0
Qualification and job offer	-1.5	-0.3	0.0	0.3	0.4	7.2	0.0	0.5	0.0	-0.7	0.6
Quality of job/occupation	0.0	0.3	0.0	0.0	6.8	-12.0	0.0	-6.0	0.0	6.0	-0.5
Equity between genders. generations. ethnicities	-5.6	-0.6	0.0	8.8	7.5	6.9	-5.6	8.8	0.0	12.5	3.3
Income generation	3.0	-2.0	0.0	15.0	11.0	9.0	3.0	1.0	4.0	9.0	5.3
Property value	6.0	6.0	0.0	15.0	15.0	10.5	8.0	8.8	7.5	10.0	8.7
Occupational health and Safety	-3.8	-0.8	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	-0.3
Food safety	3.0	0.0	0.0	3.0	2.4	0.0	3.0	3.0	0.0	3.0	1.7
Dedication and profile of the person responsible	6.3	0.0	0.0	0.0	9.3	0.0	0.0	5.8	1.0	3.3	2.6
Marketing condition	4.5	0.0	0.0	4.5	1.3	0.0	2.3	4.5	-1.8	10.5	2.6
Waste disposal	10.0	-1.0	0.0	12.0	2.0	0.0	3.0	12.0	1.0	6.0	4.5
Chemical input management	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Institutional relationship	3.8	-8.8	0.0	0.0	0.0	0.0	0.0	3.8	1.3	12.5	1.3
General Activity Impact Index	**1.76**	**2.65**	**0.75**	**1.30**	**1.13**	**1.25**	**0.29**	**0.83**	**0.16**	**2.81**	1.3

Source: Authors.

The overall average quality of the farmers' products, even without statistical significance, increased quantitatively, as evidenced in Table 3. In this sense, it was possible to verify that the change in management, as well as the implementation of agroecological-based agriculture, led to better product quality.

The overall average of the activity impact index according to all farmers' perceptions of themselves was μ = 0.9 (Table 1) in conventional production, increasing to μ = 1.3 after the agroecological transition process (Table 2). The average performance of the group of 10 farmers by environmental, social, and economic dimensions and by criteria within the dimensions is presented in Table 3. In the environmental dimension, the criterion of energy consumption impact was significant (P<0.5). This variable reached a coefficient of μ = -10.15 and showed the highest average variation in the environmental dimension. This criterion showed a reduction during the agroecological transition of the production units.

However, in the economic dimension, there were two criteria of activity impact that had the highest average variation of coefficients (P<0.5). Biodiversity conservation and environmental recovery reached an average of μ = 5.28, and the property value had an average of μ = 6.98, significantly contributing to this dimension.

The technology impact percentage (TIP), which characterizes the percentage gain of the technology for each production unit, was evaluated in environmental, economic, and social dimensions. It is evident that the overall average during conventional management was μ = 0.95, and after the transition to organic and/or agroecological-based production, it increased to μ = 1.29, with a difference of μ = 0.34.

In the environmental PIT, the average was -3.73, indicating a decrease in environmental impacts. In this component, the negative value represents a decrease in environmental impacts. The variables that contributed the most to this reduction were water consumption (-2.60) and energy (-10.15). This reduction in impacts in the environmental dimension reveals that the transition provided greater sustainability for the evaluated groups of producers. In the economic dimension, the PIT was 7.70, with the employment variable μ = 0.73 and income with μ = 3.89 being the most contributing factors to this percentage. In the social dimension, the PIT was 7.19, with the criteria of consumer respect with an average of μ = 3.74 and health with an average of μ = 2.99 standing out.

Table 3 – Average performance coefficients between the conventional production system and the agroecological transition of the 10 family farmers from the Sílvio Rodrigues-Alto Paraíso-GO settlement.

Dimension	Activity impact criteria	Before	After	Avarage variation
Socio-environmental	Water consumption	-2.4	-5	-2.60
Socio-environmental	Energy consumption	2.55	-7.6	-10.15*
Socio-environmental	Livestock welfare and health	3,475	5.5	2.03
Socio-environmental	Quality of job/occupation	0.75	-0.5	-1.25
Socio-environmental	Food safety	0.88	1.74	0.86
Socio-environmental	Dedication and profile of the person responsible	4.3	2.55	-1.75
Socio-environmental	Marketing condition	2,725	2,575	-0.15
Socio-environmental	Waste disposal	1.8	4.5	2.70
Economic	Use of agricultural inputs	-1.8	3	4.80
Economic	Own generation, use, reuse and autonomy	-0.145	0.095	0.24
Economic	Soil quality	-1,625	2,875	4.50

*Indicates statistical significance using the non-parametric Wilcoxon test, at a probability level of 5%.
Source: Authors.

Table 3 - Continued...

Dimension	Activity impact criteria	Before	After	Avarage variation
Economic	Biodiversity conservation and environmental recovery	-2.8	2,465	5.28*
Economic	Property value	1.7	8,675	6.98*
Economic	Occupational health and Safety	-1,425	-0.3	1.13
Social	Change in direct land use	0.95	1.15	0.20
Social	Change in indirect land use	0.075	-1,925	-2.00
Social	Use of veterinary supplies and raw materials	-1.6	-0.3	1.30
Social	Emissions to the atmosphere	0.03	-0.7	-0.73
Social	Water quality	3.54	-1.82	-5.36
Social	Product quality	0.575	4.8	4.23
Social	Share capital	0.175	1,895	1.72
Social	Training	2.65	2,025	-0.63
Social	Qualification and job offer	-0.205	0.59	0.8
Social	Equity between genders, generations, ethnicities	-1,5625	3.25	4.81
Social	Income generation	-2.8	5.3	8.10
Social	Chemical input management	1,075	0	-1.08
Social	Institutional relationship	2.25	1.25	-1.00
General Activity Impact Index		0.95	1.29	0.34

*Indicates statistical significance using the non-parametric Wilcoxon test, at a probability level of 5%.
Source: Authors.

These results are consistent with those found by Oliveira et al. (2014) when comparing ecological and socio-environmental impact indices in milk production systems between conventional and organic methods. It was found that both systems presented significant values differently. Out of the 25 analyzed indicators, 19 had results that contributed to the improvement of the transition from conventional to organic. In this sense, the average overall impact result of the conventional system was μ = -0.55, while the organic system was μ = 3.82. Thus, the results reveal that the transition from the conventional to the organic system was efficient.

Analyzing the socioeconomic impacts of agroecological management in the caatinga, Barreto et al. (2013) found that the implementation of technologies and the use of agroecological-based management provided improvements for the rural activities of the evaluated producers. This analysis reveals that practically all the studied activities were diversified and presented positive economic, social, and environmental impacts.

Gusman Muñoz et al. (2020) analyzed the Environmental Impacts of the Implementation of the Integrated and Sustainable Agroecological Production System (Pais) in Family Units in the Federal District with the assistance of AMBITEC-AGRO and evidenced improvements in environmental indices. The results reveal a reduction in the use of external inputs, resources, and veterinary products, as well as improvements in soil quality.

In line with the results of this study and the aforementioned authors, the evaluation conducted by Gonçalves (2020) of an integrated production system in agroecological transition, similar to the present work, demonstrates a decrease in external and synthetic inputs. However, the landscape and structural reorganization of crops fell short of expectations; redesign is one of the main mechanisms for evaluating the level of agroecological transition.

When evaluating the transition to agroecology, Santos (2016) found that the main difficulties are related to water availability, spontaneous plant and insect management, maintenance of animal health, and financial resources for investment. Problems such as lack of conditions for productive structuring and internal organization limits, such as indebtedness and lack of labor, were also observed. In the present study, most of these difficulties were also reported by farmers. They believe that many of these problems could be overcome, especially through technical assistance and rural extension services, which are nonexistent in the locality.

Access to credit is also a bottleneck that limits financial resources for investments for producers to overcome limitations in accessing technologies because, according to Gomes (2022), there is a need to review credit lines, making them more attractive and less bureaucratic for producers, considering their particularities and the organic and/or agroecological production system. It is also worth mentioning that the lowest values found in the evaluation of units in agroecological transition were for the criteria of Water Consumption (μ = -2.60) and Energy (μ = -10.15), Water Quality (μ = -5.36), and Indirect Land Use (μ = -2.00). In this case, with access to credit lines, farmers could invest in new energy sources, water quality, and land use. Farmers reported that both the quantity and quality of water worsened with the advancement of soybean planting in the region.

In the first two criteria, negative values become beneficial, improving the system's efficiency, as they indicate both a reduction in water and energy consumption of production units. On the other hand, the reduction in water quality and changes in indirect land use have the opposite effect when the criteria present negative values.

Regarding water quality, most interviewed farmers reported that in recent years, soybean planting has increased in the region, and large producers in this sector use pesticides in this cultivation. According to farmers' reports, this practice has contaminated the water in the region.

As for the criterion of Change in Indirect Land Use, according to Gazzoni (2014), the identification of changes in this criterion for agricultural purposes can occur in two situations: a) when there is a replacement of a pasture area or agricultural exploitation by another crop, with the original use resumed in another area originally not dedicated to agriculture; b) when a new use for a certain agricultural product arises that triggers price increases, resulting in greater demand for agricultural land in non-traditional locations.

In the case of this study, situations that would be beneficial for producers, indicated by the negative value in the 'Change in Indirect Land Use' criterion, were not reported when large pasture areas could be replaced by new crops or when there is demand for a product in the region.

However, what would lead to price increases would be the achievement of organic certification, which has already begun in the region through the formation of a participatory conformity assessment body. OPAC/AGE has been conducting a participatory certification process for 32 producers in the Chapada dos Veadeiros since late 2022, in the municipalities of Colinas do Sul, Cavalcante, São João d'Aliança, and Alto Paraíso de Goiás.

5 CONCLUSIONS

The group of ten farmers who opted for the agroecological transition presented satisfactory values for environmental, economic and social indicators. However, the degree of sustainability achieved was different between producers due to the different conditions of each when implementing organic and/or agroecological-based management.

The average percentage of technology impact (PIT) from conventional agriculture to the agroecological transition in the economic dimension was 7.70%, in the social dimension was

7.19% and environmental was -3.73% reflecting the increase in socioeconomic impacts and reduction of environmental impacts.

Bottlenecks were identified such as the lack of technical assistance and rural extension, financial resources for investments and difficulties in finding labor, hindering the agroecological transition in the region.

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