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ARTICLE

Impact of the Rural Agent Program on the performance of family farmers in the state of Ceará

Impacto do Programa Agente Rural sobre o desempenho dos agricultores familiares no estado do Ceará

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Abstract: Rural extension plays a significant role in rural development, acting as an instrument of economic, social, and environmental leverage. Aware of this importance, Ceará has restructured its extension services by implementing the Rural Agent Program in 2012. In this sense, this study aims to evaluate the impact of this policy on agricultural sustainability and the generation of employment and income for family farmers in the municipality of Crato, Ceará, in 2021. The data were obtained through questionnaires with 112 farmers (beneficiaries and non-beneficiaries of the program). For this purpose, the Agricultural Sustainability Index (ISA) (in the environmental and economic dimensions) and the Propensity Score Matching (PSM) were used. The results showed that the Rural Agent Program contributed to the adoption of environmentally sustainable technologies and the promotion of employment and income generation for beneficiary families.

Keywords: Rural Agent Program, avaluation, family farming, Ceará.

Resumo: A extensão rural desempenha papel relevante no desenvolvimento rural, atuando como instrumento de alavancagem econômica, social e ambiental. Ciente dessa importância, o Ceará reestrutura seus serviços de extensão com a implementação, em 2012, do Programa Agente Rural. Neste sentido, este estudo objetiva avaliar o impacto dessa política sobre a sustentabilidade agrícola e a geração de emprego e renda dos agricultores familiares no município de Crato, Ceará, em 2021. Os dados usados foram obtidos mediante aplicação de questionários com 112 agricultores (beneficiários e não beneficiários do programa). Para tanto, utilizou-se o Índice de Sustentabilidade Agrícola (ISA) (nas dimensões ambiental e econômica) e o *Propensity Score Matching* (PSM). Os resultados demonstraram que o Programa Agente Rural contribuiu na adoção de tecnologias ambientalmente sustentáveis e na promoção da geração de emprego e renda para as famílias beneficiárias.

Palavras-chave: Programa Agente Rural, avaliação, agricultura familiar, Ceará.

1. Introduction

The phenomenon of the green revolution of the 1950s and 1960s and agricultural modernization in Brazil in the 1960s, through the insertion of new technologies (machines and equipment, fertilizers, chemical pesticides, and improved seeds, among others), caused an increase in productivity of agricultural soils and expansion of previously unproductive areas. This promoted a surprising increase in the sector's growth rate. (Castro & Pereira, 2020).

However, it is important to highlight that the diffusion of technologies occurred in a heterogeneous way throughout the entire rural area. Large producers, having greater capital input, had better conditions of access to financing and rural extension services. This allowed them greater adherence to modernizing technologies, thus intensifying inequality in the countryside. Small rural producers, who received less attention from the government via public policies, were left on the margins of this development model (Castro, 2015).

Access to the technological package excludes family farmers due to restrictions on access to services offered by the State, such as rural technical assistance and credit that were offered to rural producers, depending on the size of the assets (given as a guarantee) and quantity produced (Hoffmann & Kageyama, 1985). In this innovative diffusionist model of rural extension, the technician informed the farmer which technologies should be adopted. This model was systematized by the North American researcher Everett Rogers (Gonçalves et al., 2016).

Given this exclusionary context for small producers, in the 1990s, protests emerged demanding rights for family producers, which culminated in the redirection of state action in the family segment through the implementation of public policies with emphasis on the expansion of technical assistance and rural extension (ATER), given its relevant role in rural development, primarily in developing countries, acting as an instrument of economic and social leverage (Faria & Duenhas, 2019; Castro & Pereira, 2020).

The rural extension services offered by ATER institutions are important mechanisms for improving agricultural production, as, according to the literature, offering only lines of credit alone does not guarantee improvements in productivity, employment, and income levels for family farmers (Cruz et al., 2021).

To meet the need for coordinating extension services, Peixoto (2008) highlights that, through Law No. 6,126 of 1974, the Brazilian Technical Assistance and Rural Extension Company (EMBRATER) was established. From then on, state organizations began to be called the State Technical Assistance and Rural Extension Company (EMATER) (Pereira & Castro, 2020).

The fiscal crisis of the 1980s, however, as emphasized by Caporal (2008) and Castro & Pereira (2017), affected the government at both federal and state levels. This imposed a review of the size of the State in the economy from the perspective of rationalizing public spending. This process culminated in 1989 with the extinction of EMBRATER, along with other state-owned companies, through Decree No. 97,455, of January 15, 1989.

During this period, state ATER institutions had up to 80% of their budget supported by federal resources, leading to the scrapping of some of these institutions, particularly those located in the North and Northeast states (Caporal, 2008). Therefore, after the closure of EMBRATER, the resources for the operation of EMATERS in each state became the responsibility of the respective state government. The operations of these companies may vary according to the fiscal capacity of each state (Castro, 2015).

The slow adaptation of state extension services to their financial structure forced the reduction or suppression of many services. Once again, family farmers were the most harmed, due to the difficulty in accessing these services, caused by the restriction of financial resources. Due to the lack of extension agents, rural extension services were carried out collectively.

In the state of Ceará, to expand ATER services to more producers and improve service quality, the State government restructured the rural extension and technical assistance services of the Ceará Technical Assistance and Rural Extension Company (EMATERCE). This was done by officially establishing the Rural Agent Program through Law No. 15,170 of June 18, 2012. According to Art. 1, the State, through EMATERCE, may grant technical assistance and rural extension to family farmers to improve agricultural productivity indicators, increase income, and enhance rural employment in Ceará (Fortaleza, 2012).

Despite these efforts to restructure extension and technical assistance services in the State of Ceará, little is known about the Rural Agent Program.

According to data from the Agricultural Census (Instituto Brasileiro de Geografia e Estatística, 2017), the state of Ceará had 394,330 agricultural establishments this year, of which 75.54% are family businesses. Concerning the receipt of technical assistance, only 10.78% claim to have received it. Regarding origin, 88.96% of beneficiaries of technical guidance attest to receipt through the State.

Given the above, it is necessary to evaluate the Rural Agent Program, since this policy represents an important instrument of rural development, as it is based on improving sustainable production rates, generating employment and income, and reducing the vulnerabilities of small farmers in terms of the poor. Therefore, the hypothesis considered in this paper is that the Rural Agent Program influences the adoption of sustainable agricultural practices and the generation of employment and income for beneficiary family producers.

This investigation allows us to identify whether the objectives proposed by the program were achieved in the region during the analysis period. Otherwise, it makes it possible to detect potential weaknesses and restrictions on the efficiency of resource allocation and public policy in the region. In view of these considerations, this article is based on the following question: Has the Rural Agent Program in Ceará influenced agricultural sustainability and the generation of employment and income for beneficiary family farmers?

In addition to this introduction, the present study comprises four more sections: theoretical foundation, methodology, results and discussion, and final considerations.

2. Theoretical Foundation

2.1 Rural extension: concept

For researchers on the topic, defining rural extension is not an easy task, as explained by Anaeto et al. (2012), any attempt to define it correctly involves a long explanation of several principles and philosophies, or, as Zwane (2012) highlights, due to its dynamic character, it is not possible to accept a single concept.

The Food and Agriculture Organization of the United Nations (FAO), in its publications, defines extension as a service or system that helps people on the farm, through educational procedures, improving agricultural methods and techniques, increasing efficiency and income from production, improving their living standards and raising the social level and educational standards of rural life (Swanson, 1984).

The new rural extension, or agroecological rural extension, consists of a planned intervention effort to establish sustainable rural development strategies, with an emphasis on popular participation in family farming and the principles of agroecology as a guide to promoting socio-environmental and economically sustainable agriculture (Caporal & Costabeber, 2000; Caporal, 2009).

For Zwane (2012), extension has three dimensions. The first dimension considers extension in terms of agricultural performance, focusing on improving farmers' production and profitability. The second dimension views extension as a contribution to the advancement of rural communities, including the enhancement of their agricultural development tasks. The third dimension equates extension with non-formal community education in a comprehensive manner.

According to Peixoto (2020), rural extension services are responsible for an educational process aimed at the technical and social training of rural producers, their families, and their organizations, while technical assistance services refer to the communication process of information for solving problems of a technical or managerial nature in economic activity.

2.2 Rural extension: empirical evidence

In specialized scientific literature, studies on the effectiveness of rural extension are limited, the emphasis is on studies by Bressan et al. (2009), Ferreira et al. (2010), Santos (2010), Ferreira et al. (2011), Freitas (2017) Rocha Júnior et al. (2020), Assunção et al. (2021) and Delgrossi et al. (2024).

Regarding the studies mentioned, Freitas (2017) verified the influence of rural extension on the agricultural sector in Brazil using data from the 2006 Agricultural Census. Rocha Júnior et al. (2020) investigated the influence of technical assistance on the monthly income of family farmers, using data from the National Household Sample Survey (PNAD) and impact assessment methods. Delgrossi et al. (2024) evaluated the impact of technical assistance and rural extension provided by the Dom Hélder Câmara Project in the Brazilian semi-arid region, considering ANATER records, records of family farmers from the PRONAF Declaration of Aptitude for a random sample of benefiting families, and data from the Single Registry for Social Programs for a sample of non-beneficiaries.

However, none of the authors mentioned analyzed agricultural sustainability and job creation in family farming. Therefore, this study considers these variables that were not the subject of debate in this specialized literature, in addition to working with a primary database, collected directly from family rural producers.

2.3 The Rural Agent Program

The first public technical assistance and rural extension services (Ater) were institutionalized in the United States at the end of the 19th century. In Brazil, Ater's services began in 1948, when Nelson Rockefeller and the governor of Minas Gerais established the first Rural Credit and Assistance Association (ACAR) in the state of Minas Gerais, to promote development in the countryside (Peixoto, 2008).

This institution was influenced by the North American developmental capitalist model, which connected farmers to the input, marketing, and credit sectors. Under this model, rural extension had the function of providing technical and financial assistance to farmers who adopted technologies coming from research institutions at the time (Castro, 2015).

Rural extension and technical assistance services in Ceará were initiated on February 16, 1954, with the creation of the Association of Credit and Rural Assistance of Ceará (ACAR-CE), later renamed the National Association of Credit and Rural Assistance (ANCAR-CE).

Subsequently, on July 6, 1976, the State Government, through Law No. 10,029, created the Technical Assistance and Rural Extension Company of Ceará (EMATER-CE), as a public body governed by private, non-profit law (Empresa de Assistência Técnica e Extensão Rural do Ceará, 2022).

Over the years, Ceará's Rural Extension service has established itself as an indispensable service for state agriculture, as it contributes to increased production, crop and livestock productivity, and the net income of farmers, especially family farmers, as well as the development of actions aimed at improving the quality of life and environmental agricultural sustainability.

EMATER-CE is responsible for developing, in partnership with public bodies, at the federal, state, and municipal levels, as well as private organizations, agricultural policies in the State of Ceará. The focus of extension actions is family farmers, the object of federal and state public policies. The company carries out, in addition to other programs and projects, the Rural Agent Program, created through Law No. 15,170, of 06/18/2012 (Fortaleza, 2012).

According to Law No. 15,170, dated 06/18/2012, the tasks of the rural agent are:

I - Educational development, aiming at the use of participatory methodologies in the construction of knowledge, observing the experiences of farmers and the knowledge of Rural Agents, to appropriate technologies by the Program's beneficiaries;
II - Development of the process of organizing family farmers, their families, and their representations, aiming at the collective purchase of inputs necessary for the production process;
III - in-service training of ATER Agents.
IV - Encourage and mobilize families in the community to participate and engage in activities developed within the scope of Programs and Projects developed by the Secretariat of Agrarian Development.

Therefore, the program, through EMATERCE, will be able to provide rural extension and technical assistance to small farmers, aiming to increase production in the agricultural sector in the state of Ceará. To this end, professionals participating in the Rural Agent Program apply sustainable production and cultivation techniques in a participatory manner, to stimulate human capital and the potential existing in family agricultural establishments, and thus increase income and employment in the localities. With this program, rural extension services began to be offered to farmers in a mixed form (individual and collective).

2.4 Agricultural sustainability, environmental and economic Sustainability

The concept of agricultural sustainability has grown from an initial focus on environmental aspects to include social, political, and economic dimensions (Pretty, 2008). In this sense, Merante et al. (2015) define sustainable agriculture as agriculture whose efficiency is correlated with compliance with environmental, economic, and social limits.

Environmental sustainability and economic sustainability comprise two of the three dimensions of agricultural sustainability and, as highlighted by Moldan et al. (2012), was developed by Goodland (1995), who defined it as one that aims to improve human well-being, protecting the sources of raw materials used for human needs.

In the view of Tilman et al. (2002), sustainable agriculture represents the adoption of practices that meet current and future social needs for food and fiber, ecosystem services, and healthy living, maximizing the net benefits of agriculture, when considering all the costs and benefits of these practices. In Häni's (2006) conception, sustainable agriculture requires the adoption of productive, competitive, and efficient practices, to protect and improve the environment and the global ecosystem.

Therefore, sustainable ownership (Merante et al., 2015) requires the best available practices, that is, technologies that can optimize your activities if they are being used sustainably.

Although sustainability is analyzed from other perspectives, the economic one is the most highlighted, due to the weight that human actions have, in terms of deteriorating the environment in the search for greater economic growth. As Lamas (2020) emphasizes, economic sustainability is important for the viability of all activities. Therefore, to be effective, activities need to provide an adequate financial return for maintaining the processes and remunerating the actors involved.

According to Wood & Hertwich (2012) apud Leão et al. (2016, p. 4), "economic sustainability arises from the balance of alignment between natural resources, human resources, ecosystem services and social harmony, necessary for the production of material goods."

Considering the theoretical support presented, the environmental agricultural sustainability conceived and adopted in this study comprises the adoption of agricultural practices capable of cultivating and producing food while preserving and ensuring the long-term availability of natural resources in the family farmer's production unit.

Regarding economic sustainability, despite encompassing all economic activities, both formal and informal, this research proposed to measure economic agricultural sustainability based on the quotient of the value of the annual agricultural income obtained by the interviewed farmers relative to their cultivated area (Passos, 2014).

3. Methodology

3.1 Source of data, study area, and sample

The data used in this research are of primary origin, resulting from the application of semi-structured questionnaires, to collect quantitative and qualitative information from family farmers who are beneficiaries and non-beneficiaries of the Rural Agent Program, in the municipality of Crato – CE, in 2021.

The municipality of Crato is located in the Metropolitan Region of Cariri (RMC), in the state of Ceará. It has an area of 1,138.15 km^2, corresponding to 0.77% of the state's area and around 24.68% of the total area of the RMC, constituting the largest municipality in territorial area in this location (Instituto Brasileiro de Geografia e Estatística, 2022).

Regarding the number of agricultural establishments, according to data from the Agricultural Census, in 2017, they corresponded to 2,649, of which 78.9% are family establishments and 21.1% are non-family establishments, and together they are equivalent to a total area of 19,662 hectares.

When compared to the eight municipalities of the RMC (Farias Brito, Caririaçu, Nova Olinda, Santana do Cariri, Juazeiro do Norte, Barbalha, Missão Velha, and Jardim), the municipality of Crato stands out with the largest territorial area, highest proportion of family establishments and a greater number of professionals participating in the EMATERCE Rural Agent Program.

Thus, due to the aforementioned characteristics, the municipality of Crato was chosen as the geographic area for analysis of the aforementioned public policy on technical assistance and rural extension.

As for the sample size of farmers, it was configured to meet the requirement of the propensity score model, which requires that the treatment and control groups be as similar as possible, to determine the "counterfactual". which can be obtained through two categories: experimental designs (random) and quasi-experimental designs (non-random).

For Fonseca & Martins (1996), the measurement of sample size in the case of a finite population of known size and less than 500,000 is given as follows:

$$n_0 = \frac{Z^2.p.q.N}{e^2\left(N-1\right)+Z^2.p.q} \tag{1}$$

where: n_0 = sample size; Z = standard normal abscissa (Z = 1.96); p = percentage with which the phenomenon occurs (p=0.5); q = complementary proportion of p (p = 0.5 assuming the hypothesis of a larger sample size, as the proportion of beneficiaries in relation to the total number of family farmers in the municipality is not known)); N = size of the beneficiary population (N=112) and, e = sample error n_0 (e =0.05), a value of 87 was found for the initial sample (n_0) of farmers benefiting from the program.

According to Pires (2006), when the resulting value is greater than 5% of the population size, it is necessary to carry out a procedure called correction factor. Therefore, the measurement of the definitive sample is expressed by:

$$n = \frac{n_0}{1 + \frac{n_0}{N}} \quad (2)$$

where, n_0 = the initial value of the sample calculated using the Fonseca & Martins (1996) formula. Carrying out the calculation, a minimum sample of 49 beneficiaries was obtained.

To determine the number of non-beneficiaries, this study used the same criteria adopted by Sobreira et al. (2018) who considered the control group superior to the treatment group by 20%. In this way, at least 59 farmers were not assisted by the program.

However, for this research, the sample was adjusted and 52 beneficiaries and 60 non-beneficiaries were interviewed, totaling 112 farmers interviewed in the municipality of Crato, Ceará.

3.2 Methods and Techniques

3.2.1 The Agricultural Sustainability Index (ISA)

The Agricultural Sustainability Index (ISA) is a composite index and corresponds to the arithmetic mean of the Environmental Agricultural Sustainability Index (ISAA) and the Economic Agricultural Sustainability Index (ISAE) (Passos & Khan, 2019), being calculated using the mathematical expression:

$$ISA = \frac{1}{m}\sum_{j=1}^{m}\left\{\frac{1}{2}\left(ISAA_j + ISAE_j\right)\right\} \quad (3)$$

where: ISA= Agricultural Sustainability Index (ISA); ISAA= Environmental Agricultural Sustainability Index; ISAE= Agricultural Economic Sustainability Index, and j = 1, 2...m (number of family farmers)

The ISA varies from zero to one, and the closer its value is to 1 (one), the better the farmer's position in the general ranking of agricultural sustainability. Conversely, the closer the ISA value is to zero (worst situation), the lower the agricultural sustainability of the family producer.

To assess the level of agricultural sustainability of beneficiaries and non-beneficiaries of the Rural Agent Program, the following limits were adopted, also considered by Passos & Khan (2019):

. Low level of agricultural sustainability $0.0 < ISA \leq 0.5$
. Medium level of agricultural sustainability $0.5 < ISA \leq 0.8$
. High level of agricultural sustainability $ISA > 0.8$

3.2.1.1 Environmental Agricultural Sustainability Index (ISAA)

The Environmental Agricultural Sustainability Index (ISAA), according to Passos & Khan (2019), can be calculated using the algebraic expression:

$$ISAA = \sum_{i=1}^{w} IS_c \quad (4)$$

where: ISAA = Environmental Agricultural Sustainability Index; ISc = Sustainability Index c, and c = 1, ...w (Indices).

The Sustainability Index "c" is calculated as follows:

$$IS_c = \frac{1}{d}\sum_{k=1}^{d} C_k \quad (5)$$

The participation of each indicator in the composition of the ISA is given by

$$C_k = \frac{1}{M}\sum_{j=1}^{m}\left[\frac{1}{n}\sum_{i=1}^{n}\left(\frac{E_{ij}}{E_{\max i}}\right)\right] \quad (6)$$

where: C_k = contribution of indicator "k" to IS_c; E_{ij} = score of the ith variable of indicator "k" obtained by the jth family farmer; Emaxi = maximum score of the ith variable of the "k" indicator; i = 1, ..., n (variables that make up the "k" indicator); j = 1, ..., m (family farmers), and k = 1, ..., d (indicators that make up the IS_c).

The same mathematical model was applied in the construction of the Agricultural Economic Sustainability Index (ISAE).

3.2.2. Definition of Agricultural Sustainability Indicators and Variables

In Chart 1, the indices and indicators and their constituent variables that were used to compose the Agricultural Sustainability Index are presented.

Chart 1 - Variables and indicators of the Agricultural Environmental and Economic Sustainability Index of beneficiaries and non-beneficiaries of the Rural Agent Program, in the municipality of Crato, Ceará.

Indices and indicators	Variables and their Operationalization
Environmental Sustainability Index	
Soil Preparation Practices Indicator	Does deforestation: Yes = 0; No = 1
	Burns: Yes = 0; No = 1
	Uses tractor: Yes = 1; No = 0
Planting and Fertilization Practices Indicator	Uses direct planting: Yes = 1; No = 0
	Rotates crops: Yes = 1; No = 0
	Uses manure: Yes = 1; No = 0
	Uses fertilizer: Yes = 0; No = 1
	Use compost/biofertilizer: Yes = 1; No = 0
Post-Planting Practices Indicator	Does manual weeding: Yes = 1; No = 0
	Uses herbicide: Yes = 0; No = 1
Pest Control Practices Indicator	Does biological control: Yes = 1; No = 0
	Uses chemical pesticides: Yes = 0; No = 1
Indicator of Environmental Resource Preservation Practices	Uses permanent vegetation cover: 1 = yes; 0 = no
	Fallow: 1 = yes, 0 = no
	Do reforestation: 1 = yes, 0 = no
	Makes rational use of water sources: Yes = 1, No = 0
Economic Sustainability Index	
Financial Efficiency Indicator	Agricultural Revenue (in R$) per hectare cultivated

Source: Adapted from Passos et al. (2018)

Although the topic of sustainability is approached from other perspectives, such as the research by Sousa et al. (2005), Damasceno et al. (2011), Passos et al. (2018) and Passos & Khan (2019) who analyzed sustainability from environmental, economic and social aspects, this research develops the sustainability index from environmental and economic perspectives, which are directly affected by the Rural Agent policy in the state of Ceará.

3.3 Measuring the Effect of the Rural Agent Program

The literature mentions various quantitative methods to evaluate public policies in diverse scenarios and with distinct objectives. Among these methods are Differences in Differences (DID), Synthetic Control (CS), and Propensity Score Matching (PSM). DID requires longitudinal data that demonstrate changes over time in the group of interest. CS seeks to create a comparable control group for a specific treatment unit, using data from several control units. This approach can be applied in different contexts, especially when there is no control group directly comparable to the treatment unit. On the other hand, PSM is more effective in correcting selection bias in observational studies and has flexibility in terms of variables to be included in the model. Furthermore, it is suitable for studies with cross-sectional data and a control group, as the case in this study (Heckman et al., 1997).

The estimation of the effect of the Rural Agent Program on agricultural sustainability and the generation of employment and income for beneficiary farmers was carried out using Propensity Score Matching (PSM).

To this end, initially, a logistic regression was estimated to obtain propensity scores, use observable variables. Then, individuals from the two groups analyzed were paired. Once this was done, the Average Treatment Effect on Those Treated (ATT) was estimated and concluded with sensitivity analysis to test whether the estimated results were robust.

The first step of PSM is the estimation of the Logit or Probit binary choice model. In both cases, the probability of occurrence of a given event varies from 0 to 1, therefore not exhibiting a linear trend in the response variable. However, the first is derived from a cumulative distribution function and the second from a normal distribution, which makes the latter's function numerically complicated (Gujarati & Porter, 2011). Thus, the frequency with which the Logit model is used at this stage is justified (Maia et al., 2013; Passos & Khan, 2019; Sobreira et al., 2018; Rodrigues et al., 2020).

Therefore, to identify the main observable characteristics that affect family farmers' access to the Rural Agent Program, a Logit model was estimated, with the variables described in Chart 2.

Chart 2 - Variables determining participation in the Rural Agent Program, in the municipality of Crato, Ceará, 2021.

Variables	Description	Classification
Participation in PAR	Dependent variable, referring to participation in the Rural Agent Program	Qualitative / 1 = beneficiaries; 0 = non-beneficiaries
Number of rooms	Number of rooms in the producer's residence	Quantitative
Cultivated area	Area cultivated in all crops (in hectares)	Quantitative
Do not use chemical fertilizer	Variable related to the non-use of chemical fertilizers on soil	Qualitative / 1 = No; 0 = Yes
Biological control	Regarding the adoption of biological control for pest control	Qualitative / 0 = No; 1 = Yes
Rational use of water	Related to the rational use of water sources	Qualitative / 0 = No; 1 = Yes
Credit	Associated with access to rural credit	Qualitative / 0 = No; 1 = Yes
Vegetables	Related to planting vegetables on the property	Qualitative / 0 = No; 1 = Yes
Family members involved in the production	Number of family members participating in agricultural production	Quantitative

Source: Own elaboration

The criteria used to verify the adjustment of the logit model were: likelihood function or Log Likelihood (LL), Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), pseudo R2 and percentage of correctly specified cases (Maia et al., 2013; Passos & Khan, 2019; Sobreira et al., 2018).

3.3.1 Propensity Score Matching (PSM)

To estimate the impact of the Rural Agent Policy on agricultural sustainability and the generation of employment and income for assisted farmers, the sample must comprise data from farmers at two moments. The first would be the moment when the farmer was a beneficiary of the extension policy (treated individual) and the second occasion would be when this farmer was not a beneficiary of the policy to identify what characteristics he would have if he did not enjoy the benefits of the public policy.

In this context, lies the main problem of causal inference between the public measure and its results or effects on the population. Therefore, the farmer can be a beneficiary or non-beneficiary of the program, making it impossible for him to present both characteristics (Barbosa et al., 2022).

Thus, given the absence of counterfactual data, the analyses of the present research were carried out with farmers assisted by the rural extension program (treated group), in relation to farmers not benefiting from the policy (control group). Thus, as a manner to prevent the estimation results from being biased, it is proposed that when establishing a causal inference between the assistance policy and the estimation results, the external elements that would be capable of influencing the observed results are isolated (Rodrigues et al., 2020).

To solve this problem, it is necessary to find the counterfactual group from the control group, so that it can be equated with the treated group so that the only difference between the groups is the policy intervention. To find the group with characteristics similar to the treatment group, the PSM model was applied. The PSM measures the probability of the farmer participating in the rural agent program based on observable characteristics, called a propensity score (Becker & Mendonça, 2021).

After determining the propensity scores for all units, the farmers who are part of the treatment group can be associated with those in the control group (Becker & Mendonça, 2021).

This mechanism aims to obtain the Average Treatment Effect on the Treated (EMTT). However, to estimate the ATT, it is first necessary to find family producers belonging to groups of beneficiaries and non-beneficiaries that can be associated, after adjusting the characteristics observed for each rural producer i related to a vector $X_i = [X_{ij,...}X_{jN}]$ where X_{ij} refers to characteristic j (Martins et al., 2020).

Therefore, it is necessary to pair individuals from the treated and control groups to make them comparable. According to Sobreira et al. (2018), there are several methods for this purpose, including: Matching by local linear regression, Matching by radius, Kernel Matching and Matching by nearest neighbor. To this end, in this research, matching was carried out using the nearest neighbor (Nearest Neighbor Matching = 1).

As Rodrigues (2016) points out, nearest-neighbor matching is one of the most used techniques in the literature. This method seeks to pair an observation in the treated group with its equivalent in the untreated group that contains a propensity score that is as similar as possible.

According to Maia et al. (2013), this procedure is measured by:

$$V(i) = Min_j \left\| p_i - p_j \right\|, i \in B \tag{7}$$

On what: $V(i)$ = set of observations from the untreated group to be associated with farmer *i* from the treated group; p_i and p_j = are the probabilities of accessing the program and B = group of beneficiaries of the Rural Agent Program.

However, for PSM matching to be valid, it is necessary to assume some assumptions. The first is called conditional independence and considers that the vector of observable characteristics X_i not affected by the treatment holds all the information regarding Y_i (0) and Y_i (1), which allows for a circumstance of independence between these results of interest (Martins et al., 2020).

Another hypothesis that needs to be assumed is the overlapping hypothesis, which states that, for each farmer in the untreated group (non-beneficiaries), there must be a corresponding farmer in the treatment group (beneficiaries). This ensures that the characteristics of individuals in the treatment group are mirrored in the control group (Becker & Mendonça, 2021).

Having assumed the hypotheses, the ATT is obtained by subtracting the means of $Y_i(1)$ and $Y_i(0)$. According to Rosenbaum & Rubin (1983), formally, ATT is defined as:

$$ATT = E\{E[Y_i|\,p(x_i),T_i = 1] - E[Y_i|p(x_i),T_i = 0]\} \tag{8}$$

where $p(x_i)$ is obtained through a binary variable model, in the case of the present research, logit was used.

The next step concerns the validation of the ATT estimates, which takes place through significance tests and the calculation of the standard errors of these estimates. However, as Caliendo & Kopeinig (2005) state, this is not a simple task. Therefore, the estimated variance of the ATT should include the variability related to the propensity scores, the determination of common support, and possibly the pairing order of the individuals in the treated group. Thus, there is a sample variation greater than normal, which means that standard errors are underestimated.

One way to solve this problem is by using bootstrapping. This technique is based on estimating the variance of a variable using several replications of subsamples of similar size, derived from the main sample. Concerning the number of replications, following the studies of Maia et al. (2013) and Passos (2014), 50 replications were considered for this research.

PSM makes it possible to eliminate selection bias derived from observable characteristics. However, the bias related to unobservable covariates cannot be controlled and cannot be measured directly, in the case of non-experimental research (Caliendo & Kopeinig., 2005). If the unobserved variables affect participation in the program and the response variable, there would be a violation of the assumption of conditional independence, which would cause a bias in the matching. Therefore, this work used the sensitivity analysis method, which allows estimating the impact of an unobserved variable on access to the program, in addition to allowing the robustness analysis of the results.

Formally, farmers i's participation in the program is estimated as:

$$P(x_i) = P(D_i = 1|x_i) = F(Bx_i + \gamma u_i) \tag{9}$$

where x_i is equivalent to the set of observable characteristics of the farmer; u_i refers to the unobserved variable; γ is the effect of the unobserved variable on policy participation.

When there is no selection bias ($\gamma = 0$), participation in the program depends only on the observed variables (Bx_i). However, faced with selection bias, family producers with similar observable characteristics will have different probabilities of participating in rural extension policy. Considering F as being from the logit model, farmers i and j will have, $\frac{p_i}{1-p_i}$ and $\frac{p_j}{1-p_j}$ chances of participating in the program, respectively.

The technique seeks to analyze whether the probability ratio limits are located between (Rosenbaum, 2002):

$$\frac{1}{e^{\gamma}} \leq \frac{p_i\left(1-p_j\right)}{p_j\left(1-p_i\right)} \leq e^{\gamma} \tag{10}$$

where, if e^{γ} =1, paired family farmers will have the same probability of accessing the program and, therefore, there will be no hidden bias derived from unobservable characteristics. However, if e^{γ} =2, paired producers with the same observable characteristics, then one of them has twice the chance of participating in the program. This is because they differ due to the presence of an unobserved variable.

4. Results and Discussion

4.1 Estimation of the Agent Rural Program on agricultural sustainability and the generation of employment and income for family farmers, in the municipality of Crato, Ceará, in 2021.

4.1.1 Descriptive statistics of the Logit model

This section addresses the socioeconomic characteristics of farmers who are beneficiaries and non-beneficiaries of the Rural Agent Program, in the municipality of Crato, Ceará.

Table 1 presents the main descriptive statistics of the determining variables (quantitative) of participation in the Rural Agent Program, in the municipality of Crato, Ceará, in 2021.

Following the criterion of high discrepancy in the data when the Coefficient of Variation (CV) is greater than 30% (Gomes, 1990), it is observed in Table 1 that all variables presented a CV greater than this value. The cultivated area is the variable with the greatest discrepancy around the average, due to having obtained a CV of 79.91%. This variable indicates that the smallest planted area among the interviewed farmers is 0.30 and the maximum is 6.91 hectares, well above the average cultivated area, which is 1.25 hectares.

Regarding the lowest variability around the average, there is the variable number of rooms, where the CV was 30.44%. In this variable, it was found that the minimum number of rooms in the interviewees' homes is 1 and the maximum is 9, with an average of 5.20 rooms.

Table 1 – Descriptive statistics of the variables determining participation in the Rural Agent Program, considered in the Logit model

Variables	Minimum	Average	Maximum	Standard deviation	*CV (%)
Number of rooms	1.00	5.20	9.00	1.58	30.44
Cultivated area	0.30	1.25	6.96	1.00	79.91
Family members involved in production	1.00	1.79	5.00	0.82	45.99

Note: * refers to the Coefficient of Variation. **Source**: Own preparation

The descriptive analysis of the qualitative variables used in the logit model by a group of beneficiaries and non-beneficiaries of the Rural Agent Program is presented in Table 2.

Therefore, the data in Table 2 shows that the majority of interviewees (90.18%) do not use chemical fertilizers on the soil. Of this total, 94.23% are beneficiaries and 86.67% are non-beneficiaries.

Table 2 – Absolute (fi) and relative (%) frequency of qualitative variables used in the Logit model by a group of beneficiary and non-beneficiary farmers, in Crato, Ceará, 2021.

Variables	Beneficiaries		Non-Beneficiaries		Total	
	fi	%	fi	%	fi	%
Do not use chemical fertilizer	49	94.23	52	86.67	101	90.18
Biological control	14	26.92	1	1.67	15	13.39
Rational use of water	45	86.54	48	80.00	93	83.04
Credit	9	17.31	9	15.00	18	16.07
Vegetables	25	48.08	10	16.67	35	31.25

Source: Own preparation

In terms of the adoption of biological control techniques, a minority uses this practice, especially beneficiaries (26.92%), compared to only 1.67% of non-beneficiaries.

Regarding the rational use of water sources, it is observed that 83.04% of family producers use water rationally. Of these, 86.54% are beneficiaries and 80% are non-beneficiaries. This predominance of beneficiary farmers to the non-use of chemical fertilizer and the use of biological control was also found in the study by Passos (2014).

Still, in Table 2, it can be seen that only 16.07% of producers in both groups have access to rural credit, where 17.31% are beneficiaries and 15% are non-beneficiaries. Concerning planting vegetables, 48.08% of beneficiaries carried out this type of cultivation, compared to 16.67% of non-beneficiaries.

4.1.2 Logit model estimation

The effects of the characteristics of family producers located in the municipality of Crato, Ceará, concerning the selection of the Rural Agent Program, are analyzed using the logit model.

The results of the logistic regression are presented in Table 3. By means of, it can be observed that, of the total of eight variables selected, six are significant. Of these, four are significant at the 5% level (cultivated area, non-use of chemical fertilizer, biological control, and family members involved in production) and two are significant at the 10% level (number of rooms and vegetables).

Table 3 shows that, except for the constant, the coefficients of the variables are positive, that is, they are directly related to participation in the Rural Agent Program. Thus, the family producer with the largest number of rooms in the residence, the largest cultivated area, the largest number of family members involved in the production, who plants vegetables, who adopts techniques to combat pests, and who does not use chemical fertilizers in the soil, has a greater propensity to become a beneficiary of the rural extension policy.

Additionally, Table 3 also presents the values of the estimated coefficients from the logit model in odds ratio values. Values greater than one suggest an increase in the chance of the family producer participating in the Rural Agent Program, and values less than one indicate a reduction in the farmer's chances of being assisted by the policy.

The information in Table 3 reveals that all variables have odds ratio values greater than unity, indicating that they all increase the chance of the rural producer being a beneficiary of the public policy. Of these, it is clear that the variables, biological control and non-use of chemical fertilizer are, in this order, responsible for the greatest increase in the producer's chances of benefiting from the policy. Therefore, using biological control techniques against pests on the plantation increases the chances of participating in the program by 1,035.04%. Not using chemical fertilizers on the soil increases the chances of being a beneficiary of the program by 710% compared to those who use this agricultural practice. These results may be related to the sustainable methodology used by rural agents, which influences rural producers who adopt this type of technique to participate in the program.

Table 3 – Result of the Logit model between beneficiaries and non-beneficiaries of the Rural Agent Program, in the municipality of Crato, Ceará, in 2021.

Variables	Coefficients	*Odss ratio*	P>|z|
Number of rooms	0.3002177	1.350153	0.063
Cultivated area	0.8436921	2.324789	0.02
Do not use chemical fertilizer	2.091869	8.100037	0.025
Biological control	2.42925	11.35037	0.045
Rational use of water	0.745992	2.108532	0.296
Credit	0.2244596	1.251646	0.733
Vegetables	1.149842	3.157694	0.056
Family members involved in the production	0.6614838	1.937665	0.032
Constant	-6.955039	0.000938	0.000
Criteria		**Coefficients**	
Log Likelihood – LL		-53.519347	
AIC criterion value		125.0387	
BIC criterion value		149.5052	
Pseudo R^2 value		0.3081	
Percentage of cases correctly classified		75.00	

Source: Own preparation using Stata software version 17.0.

Furthermore, Table 3 presents the criteria used to analyze the fit of the estimated logistic regression.

The LL, AIC, and BIC values presented the lowest values, and, therefore, the best adjustments when compared to the other estimated models.

As observed in the pseudo-R^2 value, it is possible to infer that around 30.81% of the variation in the dependent variable can be explained by the set of explanatory variables. Furthermore, the model was able to correctly classify 75% of the observations, which indicates quality in the model adjustment. Therefore, given the results presented, it is inferred that the logit model is adequate to explain the probability of family farmers participating in the Rural Agent Program.

4.1.3 Hypothesis Testing for ATT Estimates with the Bootstrapping Method

Table 4 presents the results of the ATT estimates corrected by the bootstrapping method, identifying the effectively significant impacts on the variables of interest.

Table 4 - Results of the Hypothesis Test for the ATT estimate, using Bootstrapping, for beneficiaries and non-beneficiaries of the Rural Agent Program, in the municipality of Crato, Ceará.

Variables	Observed coefficient	Standard “Bootstrapping” Error	Z	P >|z|
M.d.o familiar/ha	158.738	85.15597	1.86	0.062
M.d.o total/ha	142.0436	80.58006	1.76	0.078
Renda agrícola/ha	1,962.648	943.6722	2.08	0.038
ISA	0.05474	0.0193683	2.83	0.005
ISAA	0.0512613	0.0280116	1.83	0.067
ISAE	0.0582187	0.0279925	2.08	0.038

Source: Own preparation based on Stata software version 17.0.

The data in Table 4 show positive and significant program values for the variables family labor per hectare, total labor per hectare, and agricultural income per hectare, for ISA, ISAA, and ISAE. Considering the statistical significance of 1% for ISA, 5% for agricultural income per ha and for ISAE. Being family labor per hectare, total labor per hectare and ISAA, significant at the 10% level.

The results of the study conducted by Bressan et al. (2009) indicated a positive relationship between rural extension and producers' income in the state of Minas Gerais. Similar results were observed in studies by Ferreira et al. (2011); Rocha Júnior et al. (2020) and Delgrossi et al. (2024), respectively, for the state of Ceará, for Brazil, and the Brazilian semi-arid region.

4.1.4 Sensitivity Analysis

The results in Table 5 refer to the analysis using the Rosenbaum limits method (Rosenbaum, 2002). This type of analysis aims to verify the effect of unobservable variables in relation to the decision of non-beneficiaries to participate in the Rural Agent Program.

Through sensitivity analysis, the intensity of the influence of unobservable characteristics on the impact results for the variables of interest can be identified.

Values of Γ below 1.1 denote a greater effect of unobservable factors on the results obtained. In other words, the model's conclusions will be less robust in the presence of unobservable covariates (Araújo et al., 2010; Passos, 2014).

According to data in Table 5, all results are significant at the 1% level, presenting high robustness, due to the impact of the program maintaining statistical significance for Γ values greater than 1.1.

Table 5 - Sensitivity Analysis using the Rosenbaum Limits method, by response variable, gamma level, in the city of Crato, Ceará.

Variables	Γ			Variables	Γ		
	1.0	2.0	3.0		1.0	2.0	3.0
M.d.o family/per				ISA			
sig+	0	4.1 and -11	5.7 and -08	sig+	0	4.1 and -11	5.7 and -08
sig-	0	0	0	sig-	0	0	0
M.d.o total/per				ISAA			
sig+	0	4.1 and -11	5.7 and -08	sig+	0	4.1 and -11	5.7 and -08
sig-	0	0	0	sig-	0	0	0
Agricultural Income/per				ISAE			
sig+	0	4.1 and -11	5.7 and -08	sig+	0	3.2 and -14	5.7 and -08
sig-	0	0	0	sig-	0	0	0

Source: Own preparation based on Stata software version 17.0.

According to Rosenbaum & Rubin (2002), sensitivity analysis using Rosenbaum limits does not represent a formal test for the Conditional Independence Hypothesis (CIA), but it is relevant because it makes it possible to infer the intensity of the influence of unobserved factors on the estimated results from PSM.

5. Final Considerations

The present study carried out an impact assessment of the Rural Agent Program on agricultural sustainability (in the environmental and economic dimensions), and the generation of employment and income for family farmers, in the municipality of Crato-CE.

When evaluating the effect of personal and socioeconomic characteristics on participation in the Rural Agent Program, it was found that certain factors increase the likelihood of becoming a beneficiary. Family producers with the largest number of rooms in the residence, the largest cultivated area, and the largest number of family members involved in the production, who grow vegetables, adopt pest control techniques, and do not use chemical fertilizers on the soil are more likely to benefit from the rural extension policy.

Regarding the impacts of the program, the results of the study highlighted the significant importance of technical assistance services offered individually and collectively to program beneficiaries. These services positively influenced the adoption of sustainable agricultural practices and the generation of employment and income on the beneficiaries' properties.

Given the relevance of the program for rural development, it is suggested to increase investments in extension policy in the state of Ceará to expand access for a greater number of farmers. Although the municipality of Crato has the largest number of rural agents in the Metropolitan Region of Cariri, this contingent remains limited.

For future research, it is suggested that the Rural Agent Program be evaluated in other locations in the state of Ceará, to understand and compare the performance of this policy in different locations. Since limited information is available about the impact of this policy, rural families are assisted.

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