Gestão & Regionalidade

Tipo de artigo:
Artigo Original

Recebido em: 21/03/2024
Aceito em: 11/12/2025

Family farming in Rio Grande do Sul and related sustainable practices: a taxonomy of the activity

Agricultura familiar no Rio Grande do Sul e práticas sustentáveis relacionadas: uma taxonomia da atividade

Frederico Pereira Tenchini[1i], Orcid: https://orcid.org/0000-0001-8942-7147; **Jorge Ferreira da Silva**[2ii], Orcid: https://orcid.org/0000-0002-0021-8398; **Marcos Cohen**[3iii], Orcid: https://orcid.org/0000-0003-3248-7776

1. Pontifícia Universidade Católica do Rio de Janeiro – PUC-Rio de Janeiro – Brasil. E-mail: fredtenchini@yahoo.com.br
2. Pontifícia Universidade Católica do Rio de Janeiro, Programa de Doutorado em Administração, Instituto de Administração e Gerência - IAG, Rio de Janeiro, RJ, Brasil. E-mail: shopshop@iag.puc-rio.br
3. Pontifícia Universidade Católica do Rio de Janeiro, Programa de Doutorado em Administração, Instituto de Administração e Gerência - IAG, Rio de Janeiro, RJ, Brasil. E-mail: mcohen@iag.puc-rio.br

ABSTRACT
Family farming is essential for food security and sustainable development but faces challenges related to credit access, technical assistance, and the adoption of efficient production practices. This study classifies family farming in Rio Grande do Sul through a taxonomy based on productive performance and sustainability. Using a quantitative approach and data from the 2017 Agricultural Census (IBGE), factor analysis and clustering techniques were applied to identify production patterns. The results reveal four distinct municipality profiles: *Incipients* (low productivity and limited access to technology), *Takers* (high credit usage but low adoption of sustainable practices), *Champions* (high economic performance but efficiency challenges), and *Preservers* (balance between production and sustainability). The findings indicate the need for tailored public policies for each profile, promoting technical assistance and sustainable practices. This study contributes to the discussion on rural development and policy formulation for family farming.
Keywords: family farming; sustainability; rural development; taxonomy; public policies.

RESUMO
A agricultura familiar é essencial para a segurança alimentar e o desenvolvimento sustentável, mas enfrenta desafios relacionados ao crédito, assistência técnica e adoção de práticas produtivas eficientes. Este estudo classifica a agricultura familiar no Rio Grande do Sul por meio de uma taxonomia baseada em desempenho produtivo e sustentabilidade. Utilizando uma abordagem quantitativa e dados do Censo Agropecuário de 2017 (IBGE), aplicou-se análise fatorial e técnicas de *cluster* para identificar padrões produtivos. Os resultados revelam quatro perfis distintos de municípios: *Incipientes* (baixa produtividade e acesso restrito a tecnologias), *Tomadores* (alto uso de crédito, mas baixa adoção de práticas sustentáveis), *Campeões* (alta performance econômica com desafios na eficiência produtiva) e *Preservadores* (equilíbrio entre produção e sustentabilidade). Os achados indicam a necessidade de políticas públicas específicas para cada perfil, promovendo assistência técnica e práticas sustentáveis. O estudo contribui para o debate sobre desenvolvimento rural e formulação de políticas direcionadas à agricultura familiar.
Palavras-chave: agricultura familiar; sustentabilidade; desenvolvimento rural; taxonomia; políticas públicas.

Citation: Tenchini, F. P., Silva, J. F. da, Cohen, M. (2026). Family farming in Rio Grande do Sul and related sustainable practices: a taxonomy of the activity. *Gestão & Regionalidade*, v. 42, e20269501. DOI https//doi.org/10.13037/gr.vol42.e20269501

Copyright: © 2026, os autores. Licenciado sob os termos e condições da licença Creative Commons Atribuição-NãoComercial-SemDerivações 4.0 Internacional (CC BY-NC-ND 4.0) (https://creativecommons.org/licenses/by-nc-nd/4.0/).

1. INTRODUCTION

Brazilian large scale agricultural production has reached successive record levels. Yet hunger and food insecurity still affect a substantial share of the population. This contradiction points to the need to better understand the productive dynamics and public policies that shape the agricultural sector, particularly within family farming, which plays a major role in food security and in the country's socioeconomic development. Family farming accounts for about 76% of agricultural establishments and produces roughly 50% of the foods that make up the basic food basket in Brazil (IBGE, 2017). It is also an important source of income and employment, especially in small municipalities, where it helps curb rural out migration (Abramovay, 1999; Bacelar & Favareto, 2020; Bustamante, Leite, & de Fátima Barbosa, 2021).

Part of the output generated by this segment comes from crops cultivated under sustainable practices that respect local environmental conditions and seek to operate in a sustainable manner. According to Schwab, Calle Collado, and Muñoz (2020), family farming is highly relevant to social and sustainable development. Even so, a considerable share of producers still adopts unsustainable practices, including the use of pesticides. This issue highlights the urgency of advancing sustainable practices in support of food sovereignty, given the sector's capacity to meet society's food demand.

Even so, the sector faces a range of constraints, including limited access to credit, appropriate technologies, and technical assistance, as well as barriers to the adoption of sustainable practices (Cruz, Jesus, Bacha, & Costa, 2020; de Souza, Rebello, & dos Santos, 2021). Many farmers still depend on practices that degrade the environment, such as the intensive use of pesticides, which undermines both the sustainability of agricultural production and the health of consumers and producers themselves (Tenchini & Freitas, 2024). In addition, the weak alignment between public policies and regional specificities constrains the implementation of effective solutions (Concha Amim, Waquil, & Schneider, 2013; Fossá, Matte, Mattei, & Schneider, 2020; Noskoski, Costa, Oliveira, Dalcin, & Mabetana, 2024).

Current environmental conditions also make the impact of conventional and extensive production on the environment increasingly evident. Recent studies, such as Balsalobre Lorente, Driha, Bekun et al. (2019) and Tan, Adedoyin, Alvarado et al. (2022), identify a direct relationship between agricultural production in Europe and the BRICS countries and environmental degradation, which underscores the urgency of adopting sustainable practices under the risk of systemic breakdown. In the Brazilian case, studies such as De Sartre, Oszwald, et al. (2016) and De Paula, Sais, et al. (2019) document the expansion of rural communities alongside varying levels of environmental degradation in areas of native vegetation. These regions face persistent challenges, including difficulties in income generation, food insecurity, and resource scarcity.

The literature points to important gaps in this field. Studies such as Kageyama (2004) and Correa, Silva, and Neder (2008) show that increases in production are not necessarily associated with advances in the social and environmental dimensions. More recent work, such as Tenchini and Freitas (2024), indicates that credit directed to the sector may have a negative effect on sustainability when it is not accompanied by measures that encourage production diversification and the adoption of sustainable practices. These gaps suggest the need for

Copyright: © 2026, os autores. Licenciado sob os termos e condições da licença Creative Commons Atribuição-NãoComercial-SemDerivações 4.0 Internacional (CC BY-NC-ND 4.0) (https://creativecommons.org/licenses/by-nc-nd/4.0/).

research that integrates productive, social, and environmental dimensions in order to understand the interactions among these factors and propose more effective responses.

Family farming in Rio Grande do Sul stands out not only because of its economic relevance, but also because of the diversity of its production systems, its strong cooperative tradition, and its long standing adoption of innovative practices (Concha Amim, Waquil, & Schneider, 2013; Silva, Pedrozo, & Silva, 2023). According to the most recent Agricultural Census, the state ranks first nationally in gross value of production generated by family farming (IBGE, 2017), which makes it a strategic setting for research on productive performance, sustainability, and food security. This combination of features turns Rio Grande do Sul into a natural laboratory for investigations aimed at understanding the dynamics of family farming and its effects on rural development.

The state's geographical diversity, which includes the Pampas, the Atlantic Forest, and the Araucaria Forest, directly shapes production systems and the challenges faced by farmers. While some regions have adopted highly technified practices, others still rely on more traditional and sustainable methods. This heterogeneity creates a suitable empirical setting for examining different production models and their relationship with economic and environmental viability.

The choice of Rio Grande do Sul as the study area is justified not only by its economic weight, but also by the complexity and diversity of its agricultural systems. Understanding these patterns may provide useful inputs for the design of strategies aimed at strengthening family farming in Brazil and promoting more balanced and sustainable rural development. Even so, despite the state's relevance in this context, there are still few studies examining how these specificities affect sustainable development and food security, which points to the need for further theoretical and practical contributions (Noskoski, Costa, Oliveira, Dalcin, & Mabetana, 2024).

Against this background, this study seeks to address these gaps by developing a taxonomy that categorizes the different productive configurations of family farming in Rio Grande do Sul. The study is guided by the following research question. Which patterns of productive performance and sustainability can be identified in family farming in Rio Grande do Sul, and how can these patterns inform the formulation of more effective public policies? To answer this question, the study uses data from the 2017 Agricultural Census (IBGE, 2017) and robust quantitative methods, including factor analysis and clustering techniques.

The main objective is to provide an integrated analysis that helps explain the factors associated with the sustainable performance of family farming across economic, social, and environmental dimensions. The expectation is that the results will contribute not only to theoretical advancement, but also to the development of practical inputs for policies aligned with the 2030 Agenda, particularly Sustainable Development Goals 2 on ending hunger, 10 on reducing inequalities, and 13 on climate action (United Nations, 2015).

The proposed methodological approach also seeks to generate a model that can be replicated in other regions, thereby extending its relevance and applicability. By integrating economic, social, and environmental variables, this study aims to contribute to the promotion of a more resilient and inclusive food system that is consistent with the principles of sustainability. In this way, the study seeks to support the formulation of strategies that position

Copyright: © 2026, os autores. Licenciado sob os termos e condições da licença Creative Commons Atribuição-NãoComercial-SemDerivações 4.0 Internacional (CC BY-NC-ND 4.0) (https://creativecommons.org/licenses/by-nc-nd/4.0/).

family farming as a driver of socioeconomic development and environmentally responsible production, reinforcing its role in the construction of a more equitable and sustainable future.

2. THEORETICAL BACKGROUND

The literature on strategic management and business frequently draws on taxonomic and typological approaches (Olteanu & Fichter, 2022; Rashidi-Sabet, Madhavaram, & Parvatiyar, 2022; Mendini, Peter, & Gibbert, 2018). These approaches involve the careful selection of variables to group units of analysis into clusters or types, thereby revealing their similarities and differences. They also require the selection of profiling variables to describe the identified types and the examination of the performance implications associated with the strategies found.

2.1. Family Farming and Sustainable Development

According to the World Commission on Environment and Development, the concept of sustainable development involves meeting present needs without compromising the ability of future generations to meet their own needs (WORLD COMMISSION ON ENVIRONMENT AND DEVELOPMENT, 1988). Because multiple perspectives coexist on this subject, definitions may vary, and sustainability remains partly subjective, depending on the standpoint, environmental beliefs, and dimensions emphasized by each actor involved (LAFER, 1996).

Sachs (2002) argues that sustainable development is one in which economic activities are economically viable, socially just, and environmentally sound. The author also maintains that cultural, ecological, territorial, and political dimensions should be taken into account when defining the concept.

According to Schmidheiny (2002), development inevitably affects the environment, yet appropriate management can reduce these effects. Naime (2005), in turn, views sustainable development as an alternative to absolute economic growth, which focuses exclusively on the quantitative expansion of the economy, although this does not imply that the two concepts are mutually exclusive.

Law No. 11,326 (BRAZIL, 2006), which establishes guidelines for the formulation of the National Policy on Family Farming and Rural Family Enterprises, defines family farmers as individuals who meet the following conditions. They hold a property of up to four fiscal modules. They rely predominantly on family labor. Their family income derives mainly from economic activities linked to the property. They jointly manage the establishment or business with their family. The law also recognizes as family farmers those foresters, aquaculture producers, extractivists, and fishers who meet the same legal principles described above.

Silva and Mendes (2009) define family farming as an activity that integrates land, labor, and family, characterized by the direct management of the means of production by the family itself, which assumes primary responsibility for labor activities and may rely, when necessary, on support from third parties, provided that the maximum area limits established regionally are respected. Despite its regional and local particularities, which ensure adaptation and continuity in contemporary society, this segment has faced economic, social, and territorial challenges since the modernization of agricultural activity in the 1970s (Grisa & Schneider, 2015).

In these productive organizations, ownership of the means of production and labor are closely tied to the family. Inácio et al. (2013) note that the emerging paradigm of sustainable

Copyright: © 2026, os autores. Licenciado sob os termos e condições da licença Creative Commons Atribuição-NãoComercial-SemDerivações 4.0 Internacional (CC BY-NC-ND 4.0) (https://creativecommons.org/licenses/by-nc-nd/4.0/).

development has broadened both the scope and the debate surrounding this field in the twenty first century, highlighting its relevance and feasibility. According to these authors, Sustainable Regional Development arises from the interaction between regional development, which considers local resources, community interests, and collaborative governance, and sustainable development, which encompasses principles of environmental, economic, and social sustainability.

The concept of sustainability in agriculture represents an evolution of the original idea and, likewise, remains open to different interpretations. Frater and Franks (2013) argue that the existence of multiple understandings of agricultural sustainability reflects a limited understanding of agriculture's impacts on ecosystems in both the short and long term. Even so, the authors note that this conceptual adaptability may be beneficial because it allows for a broader perspective.

Balsalobre-Lorente, Driha, Bekun et al. (2019), as well as Tan, Adedoyin, Alvarado et al. (2022), also emphasize that agricultural activity is directly associated with environmental degradation, to the extent that this phenomenon may collapse the entire production chain if sustainable practices are not implemented. In this regard, these authors underscore the urgency of public policies and private initiatives that promote clean technologies and cultivation methods capable of reducing environmental impacts.

The coexistence of these different concepts highlights the relevance of conducting research focused on sustainability and using multicriteria approaches, since such tools are useful for addressing complex, subjective decisions marked by considerable uncertainty (Wang, 2010; Ershadi & Ashtiyani, 2019). For this reason, in addition to these methods, it is necessary to adopt criteria for categorizing sustainability.

Dias et al. (2021) argue that farmers and institutions have shown growing interest in the adoption of biodiversity and sustainability practices. Actions such as increasing carbon sequestration in production, adopting renewable energy sources, and expanding organic farming position this group as a leading actor in the transition toward a sustainable production model.

Beginning in 2015, the United Nations General Assembly (UN, 2015) adopted the 2030 Agenda for Sustainable Development with the purpose of establishing a lasting relationship of harmony and progress between humanity and the environment (UNITED NATIONS, 2015). The premise of this agreement is that all UN member states should achieve the Sustainable Development Goals, which constitute a joint declaration of global needs aimed at reconciling economic, social, and environmental development (Fonseca & Carvalho, 2019).

The Sustainable Development Goals are used as indicators to assess progress toward sustainable development in a given activity or locality (Barbier & Burgess, 2017). Based on this principle, the present study seeks to establish variables capable of grouping family farming activity according to environmental, economic, and social dimensions, as well as its alignment with the SDGs.

Figure 1. Sustainable Development Goals

Copyright: © 2026, os autores. Licenciado sob os termos e condições da licença Creative Commons Atribuição-NãoComercial-SemDerivações 4.0 Internacional (CC BY-NC-ND 4.0) (https://creativecommons.org/licenses/by-nc-nd/4.0/).



Source. Sustainable Development Goals of the 2030 Agenda (UN, 2015)

2.2. Variables Related to Sustainable Development

The selection of variables that can reliably and reproducibly describe family farming activity remains a recurring concern when assessing the fit of such variables to analytical models. Studies conducted by Kageyama (2004), Damasceno, Khan, and Lima (2011), Serafim et al. (2018), and Ferreira et al. (2022) indicate that this choice requires attention to the dimensions of sustainability.

These authors include in their studies variables such as income, water and energy use, access to rural technical assistance, planted area, wages, employment, credit, clean production techniques, forest and water preservation, among others. Following this line of work, the present study selected variables consistent with those already found in the literature on sustainability and family farming. At the same time, the literature lacks variables that exactly match those available in the official Brazilian government database, the Agricultural Census of the IBGE (2017). Even so, the variables found in the literature share characteristics similar to those in the official database, which justifies their use in this study.

The literature presents the following types of variables as relevant to family farming. Farm size (De Paula, Sais, Oliveira, & Olival, 2019), number of family members involved (Kageyama, Bergamasco, & de Oliveira, 2013), family farm income (Avelar & Stamm, 2019), productivity (Buainain, Garcia, & Vieira Filho, 2018), crop characteristics, use of technology, access to agricultural credit (Freitas, Silva, & Braga, 2017), use of inputs, and adoption of sustainable practices (Tenchini & Freitas, 2024).

2.3. Strategic Taxonomies and Typologies

Hambrick (1980) argues that a viable way to study strategy is to identify patterns that symbolize different combinations of strategic variables. This set of models, whether conceived theoretically as a typology or derived empirically as a taxonomy, is intended to reduce the broad diversity of possible combinations to a manageable set. According to Hambrick (1983), these categories are gestalts that define holistic packages of attributes. As described by Venkatraman and Prescott (1990), such models represent wholes that capture the simultaneous and joint interactions of the phenomenon and therefore reflect its complexity.

Copyright: © 2026, os autores. Licenciado sob os termos e condições da licença Creative Commons Atribuição-NãoComercial-SemDerivações 4.0 Internacional (CC BY-NC-ND 4.0) (https://creativecommons.org/licenses/by-nc-nd/4.0/).

The categorization of strategies into typologies, found in the strategic management literature in works such as Chrisman et al. (1988), Miles and Snow (1978), Mintzberg (1988), and Porter (1980), has influenced most subsequent research related to taxonomy. Whereas the Miles and Snow (1978) typology focuses on the firm's general strategic orientation, other classifications consider dimensions such as target market scope, broad versus narrow, competitive strategies, low cost versus differentiation, and segment differentiation, that is, whether the same competitive strategies are used across markets or different ones are adopted in different markets.

Research on the agricultural sector, particularly in family farming, which is the focus of this study, contains relatively limited use of activity classification schemes based on the clustering of empirical data. In this study, some of these references are presented briefly and in chronological order.

Kageyama (2004), by combining distinct sources of information, develops an indicator designed to assess rural development in the state of São Paulo. In this index, the researcher classifies variables according to demographic, economic, social, and environmental aspects of production.

Conterato, Schneider, and Waquil (2010) created a framework composed of nineteen variables to characterize family farming styles and their grouping into factors in order to highlight their heterogeneity. Using cluster analysis, the state of Rio Grande do Sul was classified into five distinct groups intended to clarify agricultural activity in the state and the different production types found there.

Concha-Amin, Waquil, and Schneider (2013) present a classification of municipalities in the state of Rio Grande do Sul using information from the Agricultural Census (IBGE, Agricultural Census 2006, 2006) and the Demographic Census (IBGE, 2010). Based on these data, simple indicators were computed and municipalities were grouped into distinct agricultural and demographic clusters, thereby highlighting the diversity of groups within the state.

Kageyama, Bergamasco, and de Oliveira (2013) establish a typology of Brazilian agricultural establishments based on the 2006 Census (IBGE, 2006). In their study, the authors classify activities according to characteristics such as area, value of production, productivity, and sources of income. They also analyze agriculture through the lens of existing inequalities in the sector and identify where such inequalities occur.

In her study, Souza (2019) conducts a multidimensional analysis to explain and categorize rural development in the state of Rio de Janeiro. Her findings indicate that, after classification through cluster analysis, the state displays a heterogeneous reality, with some regions showing high development, whereas others, mainly associated with the legacy of coffee and sugarcane cycles, exhibit the opposite condition. These conclusions support, in a different context, the results of the study conducted by Conterato, Schneider, and Waquil (2010), which found that regions associated with the legacies of commodity cycles tend to display weaker rural performance.

3. RESEARCH METHODOLOGY

This study adopts an exploratory quantitative approach (Creswell, 2010), using the municipalities of the state of Rio Grande do Sul as the unit of analysis. The independent variables were selected to cover the three pillars of sustainable development, namely the

Copyright: © 2026, os autores. Licenciado sob os termos e condições da licença Creative Commons Atribuição-NãoComercial-SemDerivações 4.0 Internacional (CC BY-NC-ND 4.0) (https://creativecommons.org/licenses/by-nc-nd/4.0/).

environmental, social, and economic dimensions (Sachs, 2002). The dependent variables were designed to assess the concepts of market share (Porter, 1980), employment (Jones, 1995), income (Barney, 1991; Teece, 2018), productivity (Teece, Pisano, & Shuen, 1997), and sustainability (Hart, 1995; Porter & Van der Linde, 1995).

The database was processed using IBM SPSS® software, after which algorithms were applied for the multivariate analyses conducted in this study. Cluster formation followed a hybrid approach. First, a hierarchical method was applied to determine the optimal number of groups. Next, the k means method was used to refine the segmentation of municipalities. This strategy increases statistical robustness and allows for a clearer interpretation of the results.

3.1. Population, Sample, and Data Source

The data used in this study were drawn from the 2017 Agricultural Census (IBGE, 2017), publicly released by the Brazilian Institute of Geography and Statistics through the IBGE Automatic Retrieval System (IBGE, 2023). This database provides a detailed overview of the socioeconomic characteristics, agricultural practices, resource use, productivity, and environmental conditions of rural properties across the national territory.

Because of its breadth and depth, this source is widely recognized and frequently used in research on agricultural development and public policy design (IBGE, 2017; Moura & Campos, 2022). The Agricultural Census is the main official reference for the population of active family farmers in Brazil and provides a reliable basis for empirical analysis and policy making.

Family farming in the state of Rio Grande do Sul was examined on the basis of data from the 2017 Agricultural Census (IBGE, 2017), which made it possible to identify specific characteristics of the sector within the state. This analysis included economic, social, and environmental aspects, allowing for a better understanding of local and regional dynamics. The richness of the data provides a detailed picture of family farming practices and conditions, which helps assess its role in the state's socioeconomic and environmental development.

Family farming is defined according to the criteria established by Law No. 11,326 (BRAZIL, 2006), which specifies dimensions related to farm size, characteristics of the enterprise, and the social profile of producers. This definition was adopted because it is the same one used by IBGE in the Agricultural Census, which ensures conceptual and methodological consistency.

The initial sample comprised the 497 municipalities of the state of Rio Grande do Sul, each containing representative information on family farming production according to the variables examined in this study. This scope allowed for a broad and detailed analysis, contributing to the identification of regional patterns and to a better understanding of the dynamics affecting the sector.

According to the technical documentation of the cited report, the database contains a particular coding rule in which the symbol "X" represents confidential information, since the value was based on responses from fewer than three respondents, whereas the symbol "-" indicates values below 1 and approximating zero. These symbols were recoded as zero in order to avoid treating them as missing values.

Copyright: © 2026, os autores. Licenciado sob os termos e condições da licença Creative Commons Atribuição-NãoComercial-SemDerivações 4.0 Internacional (CC BY-NC-ND 4.0) (https://creativecommons.org/licenses/by-nc-nd/4.0/).

Even though the state has 497 municipalities, which would in principle define the number of cases to be analyzed, the municipality of Canguçu displayed values on several variables that were substantially higher than those observed for the remaining municipalities, making it an outlier capable of distorting the model. It was therefore removed from the analysis. The municipalities of Balneário Pinhal, Cachoeirinha, Capão da Canoa, Esteio, Imbé, and Xangri-lá showed either no Gross Value of Production or a value below 1% of the state average for Gross Value of Production and were also removed.

3.2. Study Variables

Table 1 presents the variables used in this study, together with their operational definitions and the sustainability pillar to which they belong. These variables were selected on the basis of their theoretical and practical relevance in representing the economic, social, and environmental dimensions of family farming.

Table 1. Clustering and performance variables

Clustering variables		
Variable	**Description**	**Pillar**
Ater_ne	Number of establishments that used Rural Technical Assistance services	Social and Environmental
Aduborg_ne	Number of establishments that used organic fertilization	Environmental
Nagrot_ne	Number of establishments that did not use pesticides	Environmental
Ncorret_ne	Number of establishments that did not use soil amendments	Environmental
Medic_ne	Number of establishments that used veterinary medicines	Environmental and Economic
Energ_ne	Number of establishments that used electricity	Economic and Social
Comb_ne	Number of establishments that used fuels	Economic
Salario_ne	Number of establishments that paid wages	Economic and Social
Adub_ne	Number of establishments that used fertilization	Environmental
Agrot_ne	Number of establishments that used pesticides	Environmental
Nascp_ne	Number of establishments with preserved springs	Environmental
Riachp_ne	Number of establishments with preserved streams	Environmental
Cistern_ne	Number of establishments with cisterns	Environmental, Economic, and Social
Armaz_ne	Number of establishments with storage units	Economic
Orgn_ne	Number of establishments engaged in organic farming	Economic and Environmental
Plant_niv	Number of establishments using contour planting	Environmental
Rot_cult	Number of establishments practicing crop rotation	Environmental and Economic
Pousio	Number of establishments practicing fallowing with straw cover	Environmental

Copyright: © 2026, os autores. Licenciado sob os termos e condições da licença Creative Commons Atribuição-NãoComercial-SemDerivações 4.0 Internacional (CC BY-NC-ND 4.0) (https://creativecommons.org/licenses/by-nc-nd/4.0/).

Prot_enc	Number of establishments practicing slope protection	Environmental and Social
Rec_mat_cil	Number of establishments engaged in riparian forest restoration	Environmental
Reflor_nasc	Number of establishments carrying out reforestation to protect springs	Environmental and Social
Man_flor	Number of establishments engaged in forest management	Environmental and Economic
Esc_sup_ne	Number of establishments in which the farmer has higher education	Social
Reside_ne	Number of establishments in which the producer resides on the property	Social
Nprop_ne	Number of establishments in which the producer does not own the land	Social and Economic
Prop_ne	Number of establishments in which the producer owns the land	Social and Economic
Mulheres_ne	Number of establishments managed by women	Social
Irrig	Number of establishments using irrigation	Environmental and Economic
Mat_flor_perm	Number of establishments with preserved forests	Environmental
Mat_flor_nat	Number of establishments with native forests	Environmental
Mat_flor_plant	Number of establishments with planted forests	Environmental
Lam_dagua	Number of establishments with water surface areas	Environmental
Veic_Impl	Number of establishments with vehicles and implements (Freitas, Silva, & Braga, 2017)	Economic
pronaf_vl	Amount of PRONAF credit contracted in the municipality (Tenchini & Freitas, 2024; Freitas, Silva, & Braga, 2017)	Economic

Performance variables

Variable	Description	Pillar
Area_fam	Area cultivated by family farming in the municipality, in hectares (De Paula, Sais, Oliveira, & Olival, 2019)	Economic and Social
PO_tot_fam	Labor employed in family farming activity in the municipality (Kageyama, Bergamasco, & de Oliveira, 2013)	Economic and Social
vbp_fam	Gross Value of Production, that is, revenue obtained (Avelar & Stamm, 2019)	Economic and Social
Part_prod	Share of production relative to extensive agriculture in the municipality (Buainain, Garcia, & Vieira Filho, 2018)	Economic and Social
IDRSR	Rural Sustainable Regional Development Index (Tenchini & Freitas, 2024)	Environmental, Economic, and Social

Source. Prepared by the authors.

The set of variables described above reflects the complexity and breadth of family farming by covering different dimensions of sustainability, including economic, social, and environmental aspects. These variables facilitate the understanding of the practices and conditions of rural establishments and make it possible to identify relevant patterns that may

Copyright: © 2026, os autores. Licenciado sob os termos e condições da licença Creative Commons Atribuição-NãoComercial-SemDerivações 4.0 Internacional (CC BY-NC-ND 4.0) (https://creativecommons.org/licenses/by-nc-nd/4.0/).

inform the design of public policies and targeted intervention strategies aimed at strengthening family farming and promoting sustainable regional development.

3.3. Statistical Method

This study followed five methodological stages to achieve its results, using IBM SPSS® software, as illustrated in Figure 2. In the first stage, the clustering and performance variables were selected, with appropriate treatment of missing values and outliers. Six municipalities with negligible production were excluded because they behaved as negative outliers, while Canguçu, recognized as the national capital of family farming due to its exceptional performance, was also removed from the analysis. This initial stage was necessary to ensure data consistency and reliability and to prevent distortions that could compromise subsequent analyses.

The second stage involved reducing the clustering and performance spaces through factor analysis and principal components analysis. These procedures made it possible to extract new factors using summated scales and rotation techniques. The purpose was to simplify the dimensionality of the data, facilitate interpretation, and improve the identification of meaningful patterns.

The third stage involved identifying the optimal cluster configuration from the reduced spaces. First, hierarchical cluster analysis was applied to determine the most appropriate number of groups. Next, nonhierarchical cluster analysis, using the k means method, was employed to assign municipalities to the defined clusters. To validate cluster consistency and assess centroid equality, statistical tests based on multivariate analysis of variance were performed.

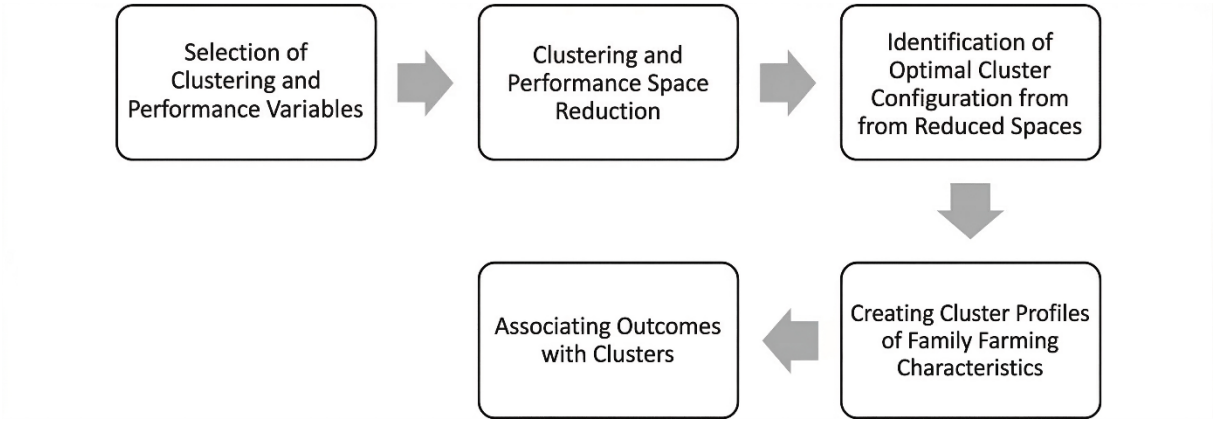
The joint use of hierarchical and nonhierarchical cluster analysis is widely supported in the literature because these methods offer complementary advantages (Jain, 2010; Hair Jr., Black, Babin, & Anderson, 2019). Hierarchical clustering is effective in the initial stage because it helps identify the optimal number of groups and provides a structured view of the data through dendrograms. Nonhierarchical clustering, such as k means, then improves the allocation of cases to the predefined clusters by reducing within cluster variance. Combining the two methods increases precision and robustness by bringing together the strengths of each approach and by handling data complexity in a way that produces interpretable and reliable results.

In the fourth stage, cluster profiles were developed on the basis of family farming characteristics. The variables extracted from the clustering procedure were used to explore similarities and differences in the Final Cluster Centers matrix. This step was necessary to identify and interpret the specific characteristics of each cluster in the context of family farming.

In the fifth and final stage, the results were associated with the clusters by comparing performance vectors across the different identified types. Additional statistical tests, including MANOVA and post hoc procedures such as Bonferroni and Tukey tests, were used to assess equality across clusters and establish a final ranking. This stage allowed for a more detailed analysis of the relationships between clusters and their specific performance patterns, generating findings that may support future applications and research.

Figure 2. Workflow of the methodological procedures used in this study

Copyright: © 2026, os autores. Licenciado sob os termos e condições da licença Creative Commons Atribuição-NãoComercial-SemDerivações 4.0 Internacional (CC BY-NC-ND 4.0) (https://creativecommons.org/licenses/by-nc-nd/4.0/).



Source. Prepared by the authors.

4. RESULTS

4.1. Reduction of the clustering and performance spaces

A total of 34 clustering variables were submitted to Factor Analysis using the Principal Components Method with Varimax rotation to extract orthogonal factors. The KMO and Bartlett's sphericity tests were adequate. The cut off criteria were five components and loadings greater than 0.70, accounting for 50% of the variance (Hair Jr., Black, Babin, & Anderson, 2019). The analysis generated four orthogonal factors (Table 1), which explained 75.90% of the total variance.

Table 1. Final results of the factor analysis

	Rotated component matrixa				
	Component				
	1	2	3	4	5
Ater_ne	.895				
Nagrot_ne		.929			
Ncorret_ne	.733				
Medic_ne	.807				
Energ_ne	.841				
Comb_ne	.873				
Salario_ne	.727				
Adub_ne	.907				
Agrot_ne	.940				
Nascp_ne	.772				
Riachp_ne	.846				
Rot_cult	.856				
Recup_mat_cil				.881	
Reflor_nasc				.851	
Esc_sup_ne		.730			
Prop_ne	.829				
Nprop_ne					
Reside_ne	.858				
Irrig			.715		
Mat_flor_perm	.877				
Mat_flor_plant	.856				
Lam_dagua	.847				
Mulheres		.764			

Copyright: © 2026, os autores. Licenciado sob os termos e condições da licença Creative Commons Atribuição-NãoComercial-SemDerivações 4.0 Internacional (CC BY-NC-ND 4.0) (https://creativecommons.org/licenses/by-nc-nd/4.0/).

Veic_impl	.761	
Pronaf_vl		.731

Extraction Method. Principal Component Analysis. Rotation Method. Varimax with Kaiser Normalization.
a. Rotation converged in 10 iterations.
b. Variables that did not reach the minimum factor loading of 0.70 and were suppressed were Aduborg_ne, Cistern_ne, Armaz_ne, Orgn_ne, Plant_niv, Prot_enc, Pousio, Man_flor, Nprop_ne, and Mat_flor_nat.

The extracted clustering factors were grouped into four summated scales based on the mean of the summed factor loadings for each component. These were then transformed into variables indicating family farming production profiles, labeled Traditional (TRADIC), Professionalized (PROF), Irrigators (IRRIG), Forest Based (FLOR), and PRONAF Credit (CREDIT), respectively, according to the clustering variables involved.

The performance metrics cover several aspects of the construct, especially indicators of effectiveness, IDRSR and market share, and variables of an economic nature, Gross Value of Production, Labor Employed, and Planted Area. Through Factor Analysis using the Principal Components Method with Varimax rotation to extract orthogonal factors, the KMO and Bartlett's sphericity tests were also satisfactory. Two factors were extracted, with eigenvalues greater than 1, and showed loadings above 0.70, accounting for 50% of the variance. Table 2 shows the distribution of the performance variables across the extracted factors, which explained 78.98% of the total variance.

Table 2. Results of the factor analysis of the performance variables

	Rotated component matrix	
	Component	
	1	2
VBP_fam	.774	
Part_Prod		.877
IDRSR		.829
PO_Tot_fam	.922	
Area_fam	.907	

Extraction Method. Principal Component Analysis. Rotation Method. Varimax with Kaiser Normalization.
a. Rotation converged in 3 iterations.
Source. Prepared by the authors.

The variables used in the study were grouped according to the extracted factors into summated scales. Accordingly, the performance variables were transformed into the variables ECON and EFIC, where the variables included in Component 1 characterize economic performance, while those included in Component 2 are more closely related to production efficiency, such as market share and production sustainability.

4.2. Cluster formation

Based on the reduced clustering space, five main categories were identified, Traditional (TRADIC), Professionalized (PROF), Irrigators (IRRIG), Forest Based (FLOR), and PRONAF Credit (CREDIT). The optimal cluster configuration was first determined through the hierarchical method, which suggested the ideal number of groupings. The nonhierarchical method, k means, was then applied to assign municipalities to each cluster, complemented by statistical tests such as multivariate analysis of variance, MANOVA, to verify centroid equality and validate the results.

Copyright: © 2026, os autores. Licenciado sob os termos e condições da licença Creative Commons Atribuição-NãoComercial-SemDerivações 4.0 Internacional (CC BY-NC-ND 4.0) (https://creativecommons.org/licenses/by-nc-nd/4.0/).

The results of the Final Cluster Centers Matrix, presented in Table 3, provide a detailed overview of the average profiles of each cluster, represented by standardized scores for the reduced variables. These values clarify the predominant characteristics of each group and help identify similarities and differences across clusters. This analysis deepens the understanding of the role and relevance of each cluster in the context of family farming and contributes to discussions on public policies and sector specific strategies within the state.

Table 3. Final Cluster Centers Matrix

	Cluster			
	1	2	3	4
Z score(TRADIC)	-.29016	.24416	2.09940	.80875
Z score(PROF)	-.19967	-.20116	2.30460	.00923
Z score(IRRIGA)	-.19796	.01189	2.11546	.00835
Z score(FLOR)	-.28217	.06755	.38586	2.53064
Z score(CREDIT)	-.25311	3.01116	.15282	.14540

Source. Prepared by the authors.

Composed of 388 municipalities, Cluster 1 includes about 78% of the state's cities. Despite its territorial reach, it accounts for only 60% of the cultivated area, which indicates lower land use intensity. This pattern reflects the concentration of the population in small family farms, a distinctive characteristic of the region. Even so, average results are negative, revealing structural constraints such as limited access to technologies and low economic efficiency. The limited use of rural technical assistance services, ATER, further aggravates this condition by restricting productive potential. This group therefore reflects family farming under vulnerable conditions, in line with the observations of Concha-Amim, Waquil, and Schneider (2013).

Municipalities classified in Cluster 2, labeled Borrowers, stand out because of their high degree of financial leverage, especially through PRONAF credit. This availability of resources favors investment in agricultural technologies and results in high productivity levels. Yet the adoption of sustainable practices, such as ecological management and environmental conservation, remains low, which explains the weak sustainability performance measured by the Rural Sustainable Regional Development Index, IDRSR. Despite good economic performance, the lack of integration with sustainable practices suggests that there is still a long way to go before productive efficiency and environmental responsibility are aligned.

Cluster 3, composed of 36 municipalities, contains the economic champions of family farming in the state. These municipalities stand out because of their high Gross Value of Production, VBP, with 10 of them ranking among the 20 largest in the state. Their financial success is strongly associated with the intensive use of rural technical assistance services and advanced agricultural management techniques. Yet environmental and social efficiency still pose challenges. Despite exceptional economic results, low scores on the IDRSR indicate the need to incorporate more sustainable practices in order to balance financial growth and sustainability.

Cluster 4 includes 37 municipalities that combine efficient productive practices with a strong commitment to sustainability. These municipalities stand out because of initiatives such as reforestation to protect springs and sustainable forest management, which contribute to high IDRSR scores, hence the label Preservers. The combination of positive economic results and environmental conservation also shows that sustainable practices can coexist with productive

Copyright: © 2026, os autores. Licenciado sob os termos e condições da licença Creative Commons Atribuição-NãoComercial-SemDerivações 4.0 Internacional (CC BY-NC-ND 4.0) (https://creativecommons.org/licenses/by-nc-nd/4.0/).

efficiency, challenging the view that sustainability and productivity are incompatible. This group serves as an example of how economic progress can be combined with environmental responsibility.

The analysis of the four clusters, characterized by different productive configurations and by the two categorizations of performance variables, revealed significant differences among the groups that might previously have gone unnoticed. The MANOVA procedure confirmed that at least two clusters were statistically distinct. The ANOVA and post hoc tests, including Bonferroni and Tukey, also showed that the dimensions related to traditional and professionalized practices were the main drivers of these differences, which indicates the influence of these variables on cluster structure and performance.

Charts 1 through 5 compare the clustering variables across the four clusters and highlight the differences among groups. Cluster 3, labeled Champions, brings together municipalities that combine traditional practices, TRADIC, professionalized practices, PROF, and efficient use of irrigation, IRRIGA, which results in high economic performance. Cluster 4, identified as Preservers, is characterized by a strong emphasis on sustainable practices such as reforestation and spring protection, demonstrating a balance between productivity and sustainability.

Cluster 2, known as Borrowers, stands out because of high access to credit, especially through PRONAF, yet lacks sustainable practices and shows dependence on more traditional production methods. Cluster 1, labeled Incipients, represents the municipalities with the lowest economic and productive performance and faces major constraints such as low technological adoption and limited access to technical assistance, which restrict sustainable development.

Chart 1. Univariate ANOVA Z TRADIC

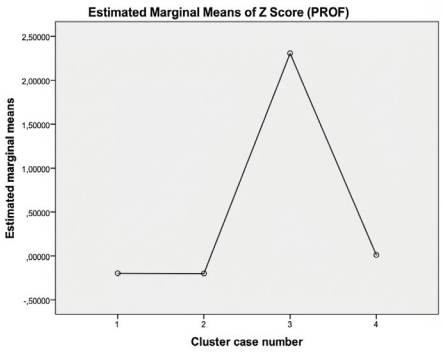


Gráfico 2. Chart 2. Univariate ANOVA Z PROF

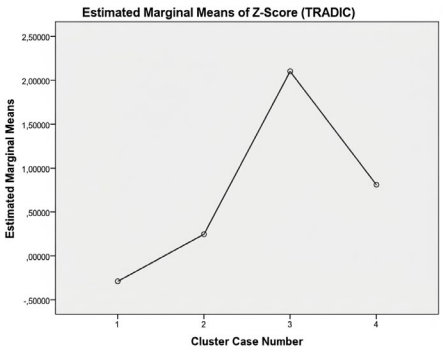
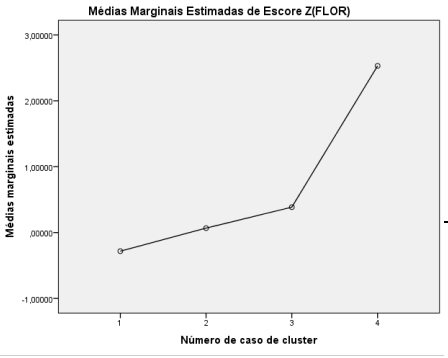


Chart 3. Univariate ANOVA Z IRRIGA

Chart 4. Univariate ANOVA Z FLOR



Copyright: © 2026, os autores. Licenciado sob os termos e cond
NãoComercial-SemDerivações 4.0 Internacional (CC BY-NC-NI

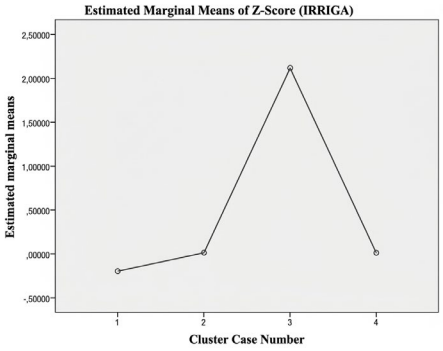
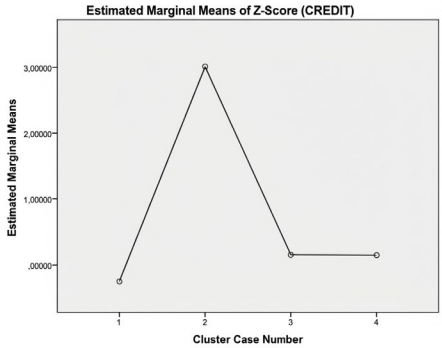


Chart 5. Univariate ANOVA Z CREDIT



4.3. Cluster performance analysis

The MANOVA analysis showed statistically significant differences between at least two clusters with respect to the performance variables, while the ANOVA and post hoc tests provided a more detailed understanding of the behavior of each group, as illustrated in Charts 6 and 7. Cluster 3, labeled Champions, stands out for its high economic performance, reflected in the variable ECON. This group includes municipalities with high productivity resulting from intensive practices and substantial use of technical resources. Yet it shows the worst results for the variable EFIC, efficiency, indicating that although profitable, this cluster faces difficulties in aligning economic gains with sustainable practices and therefore exhibits low effectiveness in the rational use of resources.

Cluster 4, known as Preservers, combines high productive efficiency with environmental responsibility. This group shows the best performance in EFIC and the second highest in ECON, indicating that productivity and sustainability can be reconciled. Many municipalities in this cluster are among the largest VBP producers in the state, reinforcing the view that practices such as reforestation and spring preservation can coexist with solid economic results, which consolidates this cluster as a model of balanced production.

Cluster 2, labeled Borrowers, shows intermediate performance in both ECON and EFIC. This group benefits from a high volume of PRONAF credit but does not translate this advantage into greater efficiency or sustainability. Although access to credit facilitates investment, the results suggest that the allocation of these resources is not sufficient to promote structural changes that integrate more modern and environmentally responsible productive practices, as also highlighted by Tenchini and Freitas (2024).

Cluster 1, the Incipients, is the group with the lowest performance across all analyzed variables. With low technological adoption and limited access to technical assistance, this cluster reflects family farming that still depends on traditional methods and has little capacity

Copyright: © 2026, os autores. Licenciado sob os termos e condições da licença Creative Commons Atribuição-NãoComercial-SemDerivações 4.0 Internacional (CC BY-NC-ND 4.0) (https://creativecommons.org/licenses/by-nc-nd/4.0/).

for modernization or sustainability. Its contribution to overall performance is limited, although it represents the largest share of municipalities.

Chart 6. Efficiency

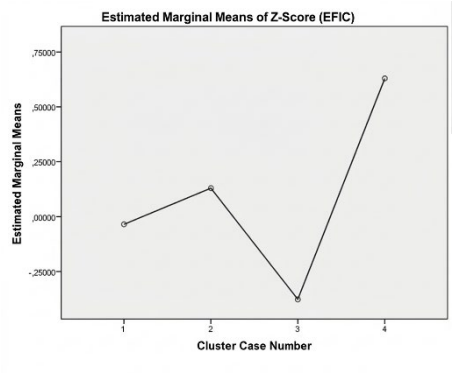
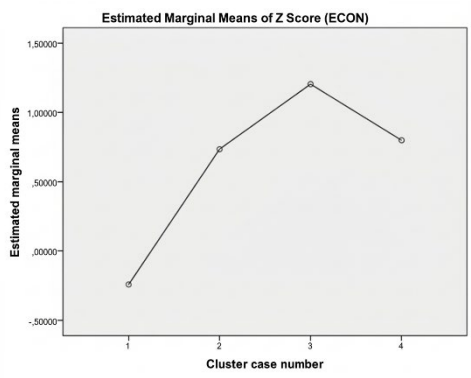


Chart 7. Economic Performance



Source. Prepared by the authors

These results show that a strategic orientation toward sustainable development has a direct effect on productive efficiency, whereas clusters with a technicist orientation, TRADIC + PROF + IRRIG, achieve the strongest economic results. This analysis points to the need for public policies and investments that balance economic growth with sustainable practices, maximize the potential of the most efficient groups, and promote progress in the more vulnerable clusters.

5. DISCUSSION

This section provides a detailed analysis of the main characteristics of the clusters, whose labels were assigned according to their respective strategic orientations. Table 4 complements this discussion by highlighting the average differences in performance variables across clusters in relation to the state average.

Table 4. Means of cluster performance variables in relation to state averages

	Employment	Productivity (thousand BRL)	GVP (million BRL)	Market Share	IDRSR	Area (ha)	Technical Assistance
State of Rio Grande do Sul	1,427	4.53	40.76	0.54	0.50	10,935	295
Cluster 1, Incipients	1,077	4.57	32.30	0.53	0.49	8,298	225
Cluster 2, Borrowers	2,070	5.85	66.38	0.57	0.51	12,600	419
Cluster 3, Champions	3,831	2.81	82.72	0.43	0.48	33,692	717
Cluster 4, Preservers	2,249	4.74	68.62	0.69	0.55	15,137	504

Source. Prepared by the authors.

5.1. Cluster 1, Incipients (78.07%)

Copyright: © 2026, os autores. Licenciado sob os termos e condições da licença Creative Commons Atribuição-NãoComercial-SemDerivações 4.0 Internacional (CC BY-NC-ND 4.0) (https://creativecommons.org/licenses/by-nc-nd/4.0/).

Cluster 1 comprises most of the municipalities in the state, accounting for 78.07% of the total. Despite this broad representation, these municipalities show the lowest performance across both clustering and performance variables. With the lowest average employment level, 1,077 workers, and the lowest income levels, their average Gross Value of Production, BRL 32.30 million, is well below that observed in the other clusters and negatively affects the state average of BRL 40.76 million. Productivity, BRL 4.57 thousand per hectare, and market share, 0.53, are close to the state average, which suggests a modest and constrained use of available resources.

One of the main limitations of this group is the low number of cases served by rural technical assistance services, with an average of only 225 cases, far below the state average of 295. This shortage reflects the lack of technical support, which limits the modernization of agricultural practices and constrains competitiveness. These municipalities remain strongly dependent on traditional cultivation methods and display limited technological integration. The profile of the Incipients reveals a vulnerable segment with low capacity to absorb public policies and technological advances, which in turn perpetuates regional inequality in the agricultural sector.

5.2. Cluster 2, Borrowers (5.9%)

Comprising only 29 municipalities, Cluster 2 accounts for 5.9% of the state total and includes cities such as Passo Fundo, Garibaldi, Erechim, and Bento Gonçalves. These municipalities display the highest access to credit, especially through PRONAF, which enables investment in technology and produces a substantial increase in productivity. With an average productivity level of BRL 5.85 thousand per hectare, this cluster clearly outperforms the others and exceeds the state average of BRL 4.53 thousand per hectare, which makes it the productivity leader.

Municipalities in Cluster 2 have an average GVP of BRL 66.38 million, well above the state average, and lead in market share, 0.57, which indicates the economic relevance of their production relative to extensive agriculture. Even so, the Rural Sustainable Regional Development Index, with an average of 0.51, shows that these economic outcomes are not accompanied by stronger sustainable practices. This pattern points to a production model that is highly dependent on credit and on conventional practices, with limited environmental concern. Although the cluster has the capacity to generate strong economic returns, it shows clear limitations in sustainability, which weakens its alignment with longer term rural development strategies.

5.3. Cluster 3, Champions (7.3%)

Composed of 36 municipalities, including Santa Maria, São Gabriel, Caxias do Sul, and Venâncio Aires, Cluster 3 is the group with the strongest economic indicators in the state. These municipalities record an average of 3,831 jobs, more than twice the state average of 1,427, and an average GVP of BRL 82.72 million, also more than double the state average. This strong economic performance is sustained by the combination of traditional practices, TRADIC, professionalized practices, PROF, and irrigation, IRRIG, which together drive financial outcomes.

Despite this economic success, the cluster faces serious efficiency and sustainability challenges. Average productivity is only BRL 2.81 thousand per hectare, equivalent to 62% of the state average, and the IDRSR of 0.48 is the lowest among all groups. These figures reveal an imbalance in resource use, where the emphasis on economic intensification does not translate into efficiency or environmental responsibility. The Champions show that, although the

Copyright: © 2026, os autores. Licenciado sob os termos e condições da licença Creative Commons Atribuição-NãoComercial-SemDerivações 4.0 Internacional (CC BY-NC-ND 4.0) (https://creativecommons.org/licenses/by-nc-nd/4.0/).

intensification of productive practices may be profitable, it may also come at the expense of sustainability and rational resource use, which limits the group's long term resilience.

5.4. Cluster 4, Preservers (7.55%)

Composed of 37 small municipalities, including Santa Rosa, Chapada, Santo Ângelo, São Jerônimo, and Erval Seco, Cluster 4 stands out as the most balanced group in terms of economic outcomes and sustainability. With the highest Rural Sustainable Regional Development Index, 0.55, and an average productivity of BRL 4.74 thousand per hectare, these municipalities show that sustainable practices can be combined with productive efficiency.

These municipalities have an average GVP of BRL 68.62 million, the second highest among the clusters, and are aligned with environmental preservation strategies such as reforestation, spring protection, and the recovery of degraded areas. Although productivity is only 4.6% above the state average, the efficient use of natural resources shows that conservation oriented practices do not undermine economic outcomes. This balance suggests that, with stronger financial and technical support, the Preservers could further expand their contribution to sustainable development and consolidate themselves as an ideal model of family farm production.

5.5. Comparative synthesis

The analysis of the four clusters reveals the diversity of family farming in the state and highlights challenges and opportunities that require differentiated responses. The Incipients, which account for 78.07% of the municipalities, face severe structural constraints such as low productivity, weaker job creation, and restricted access to rural technical assistance. These municipalities, marked by traditional practices and limited modernization, require public policies that expand technical assistance coverage, promote technical training, and facilitate access to credit for the modernization of agricultural practices. Incentives for collective organization, such as cooperatives, may also strengthen market access and improve competitiveness.

The Borrowers, which account for only 5.9% of the municipalities, stand out because of high productivity driven by access to credit, especially through PRONAF. Even so, this dependence on financing is not accompanied by sustainable practices, which results in only moderate performance on the Rural Sustainable Regional Development Index. Public policies may condition access to credit on the adoption of environmentally responsible practices while also encouraging integrated technologies that combine productivity with environmental conservation. Programs that support sustainable product certification and the creation of green markets may also help align sustainability with economic performance.

Cluster 3, the Champions, includes 7.3% of the municipalities and stands out because of strong economic results, leading in Gross Value of Production and job creation. Even so, this group displays a clear imbalance, with low productive efficiency and the weakest IDRSR performance. The prioritization of financial outcomes over sustainability calls for policies that encourage the adoption of technologies such as precision irrigation and integrated management, as well as environmental education programs that promote awareness of the efficient use of natural resources. Incentives for sustainable practices may help reconcile strong financial returns with environmental efficiency.

The Preservers, which account for 7.55% of the municipalities, are the most balanced group, combining productivity and sustainability. With the best IDRSR and the second highest average GVP, these municipalities show that conservation oriented practices such as

Copyright: © 2026, os autores. Licenciado sob os termos e condições da licença Creative Commons Atribuição-NãoComercial-SemDerivações 4.0 Internacional (CC BY-NC-ND 4.0) (https://creativecommons.org/licenses/by-nc-nd/4.0/).

reforestation and spring recovery can be integrated with strong economic outcomes. Even so, public policies may strengthen this profile further by offering targeted financial incentives, environmental certification, and technical support aimed at increasing productivity without compromising the sustainability already achieved.

These profiles reinforce the need for public policies tailored to the specific needs of each cluster. An integrated policy design should include expanded technical assistance, stronger sustainable credit, the promotion of modern technologies, and greater recognition of conservation oriented practices. Continuous monitoring systems are also needed to assess the effects of the policies implemented and to adjust strategies when necessary. Such actions may contribute to a more balanced development trajectory for family farming in the state, align it more closely with the Sustainable Development Goals, and support a more resilient and sustainable future for the sector.

6. CONCLUSIONS

This study sought to identify patterns of productive performance and sustainability in family farming in Rio Grande do Sul by classifying municipalities into four clusters, Incipients, Borrowers, Champions, and Preservers. The results show that conservation oriented practices and access to rural credit, when combined with technical knowledge and professionalization, can generate substantial gains in productivity and sustainability. At the same time, cluster performance highlights relevant challenges, such as the low efficiency of Cluster 3 and the structural vulnerability of the Incipients, which account for most municipalities.

The Incipients display the weakest economic results, reflecting the lack of technical and financial support. The Borrowers, although highly productive, face difficulties in integrating sustainable practices. Cluster 3, despite leading in economic indicators such as Gross Value of Production and job creation, lacks productive efficiency and sustainability. This pattern contrasts with the Preservers, which show that conservation oriented practices can be aligned with strong economic outcomes.

Among the study's limitations, one should note its restriction to the context of Rio Grande do Sul, which may limit the generalizability of the findings to other regions. In addition, the selection of variables based on available data may not have captured all relevant dimensions of family farming. Even so, the study contributes to the literature by highlighting the relationship between credit, sustainable practices, and agricultural performance, while also providing inputs for public policy design.

The findings suggest that public policies aimed at family farming should balance productive and environmental incentives. The implementation of conditionalities in agricultural credit, linked to the adoption of sustainable practices, may be an effective strategy for aligning productivity with environmental preservation. Expanded rural technical assistance services may also help municipalities in Cluster 1 overcome structural constraints and improve productive performance.

The results further suggest differentiated policy directions across clusters. Incipients should receive broader access to rural technical assistance and incentives for cooperative formation. Borrowers could benefit from credit conditionalities designed to encourage sustainable practices. For the Champions, it is necessary to promote technologies that improve resource efficiency, such as precision irrigation. For the Preservers, financial incentives and certification mechanisms may amplify both their productive and environmental contributions.

Copyright: © 2026, os autores. Licenciado sob os termos e condições da licença Creative Commons Atribuição-NãoComercial-SemDerivações 4.0 Internacional (CC BY-NC-ND 4.0) (https://creativecommons.org/licenses/by-nc-nd/4.0/).

Future research may deepen this analysis by examining how different financing models affect the sustainability of family farming in other regions of Brazil. It may also explore how PRONAF can promote sustainable practices more evenly across the state, or conduct benchmarking across states in order to validate the cluster classification. This study provides a solid basis for the development of effective public policies and for further theoretical and practical advances, showing that sustainable practices not only promote environmental conservation but also improve productive efficiency, thereby contributing to the reduction of food insecurity through sustainable means.

7. REFERENCES

Abramovay, R. (Agosto de 1999). Agricultura Familiar e Desenvolvimento Territorial. *Reforma Agrária – Revista da Associação Brasileira de Reforma Agrária, 28-29*.

Avelar, F., & Stamm, C. (2019). AGRICULTURA FAMILIAR: EFEITOS DO PRONAF NA REGIÃO OESTE DO PARANÁ. *Geosul, 34*(72), pp. 359-394.

Bacelar, T., & Favareto, A. (2020). O PAPEL DA AGRICULTURA FAMILIAR PARA UM NOVO DESENVOLVIMENTO REGIONAL NO NORDESTE – UMA HOMENAGEM A CELSO FURTADO. *Revista Econômica do Nordeste, 51 (Suplemento Especial)*, pp. 9-29. doi:https://doi.org/10.61673/ren.2020.1261

Balsalobre-Lorente, D., Driha, O., Bekun, F., & Osundina, O. (29 de 06 de 2019). Do agricultural activities induce carbon emissions? The BRICS experience. *Environmental Science and Pollution Research*.

BRASIL. (2006). *Lei nº 11326 - Estabelece as diretrizes para a formulação da Política Nacional da Agricultura Familiar e Empreendimentos Familiares Rurais.* Acesso em 06 de 06 de 2019, disponível em Planalto.gov: http://www.planalto.gov.br/ccivil_03/_Ato2004-2006/2006/Lei/L11326.htm

Buainain, A., Garcia, J., & Vieira Filho, J. (2018). A economia agropecuária do Matopiba. *Estudos Sociedade e Agricultura, 26*(2), 376 - 401.

Bustamante, P., Leite, M., & de Fátima Barbosa, F. (2021). A IMPORTÂNCIA DA AGRICULTURA FAMILIAR NO ÂMBITO DO AGRONEGÓCIO BRASILEIRO. *Confluências | Revista Interdisciplinar De Sociologia E Direito, 23*(3), pp. 113-139.

COMISSÃO MUNDIAL SOBRE MEIO AMBIENTE E DESENVOLVIMENTO - CMMAD. (1988). *Nosso Futuro Comum.* Fundação Getúlio Vargas, Rio de Janeiro.

Concha-Amim, M., Waquil, P., & Schneider, S. (2013). Tipologia dos municípios gaúchos com base nos dados dos censos Agropecuário de 2006 e Demográfico de 2010. *Ensaios FEE, 34*.

Corrêa, V. P., Silva, F. F., & Neder, H. D. (Julho de 2008). CONSTRUÇÃO DE UM ÍNDICE DE DESENVOLVIMENTO RURAL – RESULTADOS PARA AS REGIÕES NORDESTE E SUL DO BRASIL. *Anais do Congresso da Sociedade Brasileira de Economia, Administração e Sociologia Rural*.

Cruz, N., Jesus, J., Bacha, C., & Costa, E. (2020). Acesso da agricultura familiar ao crédito e à assistência técnica no Brasil. *Revista de Economia e Sociologia Rural, 59*, p. e226850. doi:https://doi.org/10.1590/1806-9479.2021.226850

Copyright: © 2026, os autores. Licenciado sob os termos e condições da licença Creative Commons Atribuição-NãoComercial-SemDerivações 4.0 Internacional (CC BY-NC-ND 4.0) (https://creativecommons.org/licenses/by-nc-nd/4.0/).

De Paula, R. P., Sais, A. C., Oliveira, R. E., & Olival, A. A. (Dez de 2019). Agroforestry systems in the rural landscape in Terra Nova do Norte-MT: space metrics in aiding environmental conservation policies in family production areas. *Desenvolvimento e Meio Ambiente*.

De Sartre, X. A., Oszwald, J., Veiga, I., Castro, M., DE Assis, W. S., Michelloti, F., . . . Lavelle, P. (Dez de 2016). Sustainable development policies and the spread of land-sharing practices – A statistical assessment in a frontier region of the Brazilian Amazon. *Journal of Rural Studies*, pp. 65-76.

de Souza, C., Rebello, F., & dos Santos, M. (2021). Impactos econômicos, sociais e ambientais do PRONAF no Brasil: uma revisão sistemática da literatura . *Geosul, 36*(80), pp. 292-314. doi:https://doi.org/10.5007/2177-5230.2021.e77416

Ershadi, M., & Ashtiyani, F. (2019). Analyzing the factors affecting environmental risks of projects using a hybrid approach of DEMATEL-ANP, artificial neural network: A case study. *Environmental Quality Management, 29*(1), 77-88.

Fossá, J., Matte, A., Mattei, L., & Schneider, S. (2020). Acesso e Distribuição do Pronaf entre Agricultores Familiares. *Desenvolvimento em Questão, 18*(53), pp. 222-244. doi:http://dx.doi.org/10.21527/2237-6453.2020.53.222-244

FRATER, P., & FRANKS, J. (2013). Measuring agricultural sustainability at the farm-level: A pragmatic approach. *International Journal of Agricultural Management, 2*(4), 207-225.

Freitas, C., Silva, F., & Braga, M. (2017). Extensão Rural e Eficiência Técnica na Agropecuária Brasileira: Uma análise a partir dos microdados do Censo Agropecuário. *Anais do 45º Encontro Nacional de Economia*.

Grisa, C., & Schneider, S. (2015). Três gerações de políticas públicas para a agricultura familiar e formas de interação entre sociedade e estado no Brasil. *Revista de economia e sociologia rural, 52*, 125-146.

Hair Jr., J., Black, W., Babin, B., & Anderson, R. (2019). *Multivariate Data Analisis* (8th ed.). Hampshire: Cengage Learning.

IBGE. (2017). *Censo Agropecuário.* Instituto Brasileiro de Geografia e Estatística, Brasília.

IBGE. (2023). *Sistema IBGE de Recuperação Automática*. Fonte: SIDRA: https://sidra.ibge.gov.br/home/pimpfbr/brasil

Inácio, R., Rodrigues, M., & Minussi, T. (04 de 11 de 2013). Desenvolvimento Regional Sustentável - abordagens para um novo paradigma. *Desenvolvimento em questão*, pp. 6-40.

Jain, A. (2010). Data clustering: 50 years beyond K-means. *Pattern Recognition Letters, 31*(8), pp. 651-666. doi:https://doi.org/10.1016/j.patrec.2009.09.011

KAGEYAMA, A. (Set-Dez de 2004). Desenvolvimento Rural: Conceito e Medida. *Cadernos de Ciência & Tecnologia*, pp. 379-408.

Kageyama, A., Bergamasco, S., & de Oliveira, J. (2013). Uma tipologia dos estabelecimentos agropecuários do Brasil a partir do censo de 2006. *Revista de Economia e Sociologia Rural (SOBER), 51*(1), pp. 105-122.

Copyright: © 2026, os autores. Licenciado sob os termos e condições da licença Creative Commons Atribuição-NãoComercial-SemDerivações 4.0 Internacional (CC BY-NC-ND 4.0) (https://creativecommons.org/licenses/by-nc-nd/4.0/).

LAFER, C. (1996). O projeto CIEDS. Definindo uma agenda de pesquisa sobre desenvolvimento sustentável. Abertura de Seminário - Rio de Janeiro, 28-29 Novembro de 1994: Brasília.

Moura, J., & Campos, K. (2022). Competitividade da agricultura familiar no sul brasileiro. *DRd - Desenvolvimento Regional Em Debate, 12 (ed.esp.Dossie)*, pp. 191-216. doi:https://doi.org/10.24302/drd.v12ied.esp.Dossie.3820

Naime, R. (2005). *Gestão de Resíduos Solidos: Uma abordagem prática.* . Novo Hamburgo: Feevale.

Noskoski, L., Costa, N., Oliveira, G., Dalcin, M., & Mabetana, K. (2024). O PRONAF no estado do Rio Grande do Sul: uma revisão sistemática da literatura. *Revista de Gestão e Secretariado, 15*(5), pp. e-3836. doi:https://doi.org/10.7769/gesec.v15i5.3836

Sachs, I. (2002). *Caminhos para o Desenvolvimento Sustentável* (3 ed.). Rio de Janeiro: Garamond.

Schmidheiny, S., Holliday, C., & Watts, P. (2002). *Cumprindo o prometido: caso de sucesso de desenvolvimento sustentável.* Rio de Janeiro: Campos.

Schwab, F., Calle-Collado, A., & Muñoz, R. (2020). Economía social y solidaria y agroecología en cooperativas de agricultura familiar en Brasil como forma de desarrollo de una agricultura sostenible. *CIRIEC-España, Revista de Economía Pública, Social y Cooperativa*(98), 189-211.

Silva, E., Pedrozo, E., & Silva, T. (2023). National School Feeding Program (PNAE): A Public Policy That Promotes a Learning Framework and a More Sustainable Food System in Rio Grande do Sul, Brazil. *Foods, 12*(19), p. 3622. doi:10.3390/foods12193622

Silva, J., & Mendes, E. (2009). Agricultura familiar no Brasil: características e estratégias da comunidade de Cruzeiro dos Martírios - Município de Catalão (GO). *Anais do XIX Encontro Nacional de Geografia Agrária*, (pp. 1-28). São Paulo.

Tan, D., Adedoyin, F., Alvarado, R., Ramzan, M., Kayesh, S., & Shah, M. (06 de 2022). The effects of environmental degradation on agriculture: Evidence from European countries. *Gondwana Research*, pp. 92-104.

Tenchini, F., & Freitas, C. (2024). Agricultura Familiar no Estado do Rio de Janeiro: Desenvolvimento Regional Sustentável e sua Relação com o Crédito via PRONAF. *Revista de Economia e Sociologia Rural, 62*(2), p. e26675.

Wang, W. (2010). A fuzzy linguistic computing approach to supplier evaluation. *Applied Mathematical Modelling, 34*(10), 3130-3141.

Copyright: © 2026, os autores. Licenciado sob os termos e condições da licença Creative Commons Atribuição-NãoComercial-SemDerivações 4.0 Internacional (CC BY-NC-ND 4.0) (https://creativecommons.org/licenses/by-nc-nd/4.0/).

[i] Mestrado em Administração, área de gestão e estratégia, pela Universidade Federal Rural do Rio de Janeiro (2022). Doutorando em Administração de Empresas, área de estratégia, pela Pontifícia Universidade Católica do Rio de Janeiro.

[ii] Mestre em Administração de Empresas (1983) e Doutor em Engenharia de Produção pela Pontifícia Universidade Católica do Rio de Janeiro (1997).

[iii] Mestre (1998) e Doutor (2007) em Administração de Empresas pela Pontifícia Universidade Católica do Rio de Janeiro (PUC-Rio).

Copyright: © 2026, os autores. Licenciado sob os termos e condições da licença Creative Commons Atribuição-NãoComercial-SemDerivações 4.0 Internacional (CC BY-NC-ND 4.0) (https://creativecommons.org/licenses/by-nc-nd/4.0/).