RCMOS – Revista Científica Multidisciplinar O Saber. ISSN: 2675-9128. São Paulo-SP.

Ano VII, v.1 2026 | submissão: 08/11/2026 | aceito: 15/11/2026 | publicação: 20/11/2026

Correspondence analysis of tambaqui farmers according to PRONAF types, regions, and water surface area classes in Brazil

Análise de correspondência dos proprietários de cultivos de tambaqui segundo tipos de PRONAF, regiões e classes de espelhos de água no Brasil

Análisis de correspondencia de los propietarios de cultivos de cachama según tipos de PRONAF, regiones y clases de superficie de espejo de agua en Brasil

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Abstract

Data from the IBGE (2017) regarding the number of tambaqui farmers participating in PRONAF programs were evaluated by comparing the PRONAF B and PRONAF V programs separately first by region and then by water surface area class. The objective of this study was to conduct an exploratory and descriptive analysis of the primary association trends between the aforementioned development programs, the North and Northeast regions of Brazil, and six water surface area classes (in hectares). Pearson's chi-square test was first applied to assess the dependency between PRONAF program types and regions, and subsequently between program types and water surface area classes; simple correspondence analysis was then used to identify the strongest association trends. Our results indicated a stronger tendency for an association between the number of PRONAF B tambaqui farmers and the Northeast region, and between PRONAF V farmers and the North region. Furthermore, a stronger association was observed between PRONAF B and the 5–10 hectares water surface area class, and between PRONAF V and the 50–100 hectares class. Thus, overall, we observed that the North region is associated with the PRONAF V program and larger water surface area classes, while the Northeast region is associated with PRONAF B and smaller water surface area classes.

Keywords: Correspondence analysis; tambaqui farmers; North and Northeast; water surface area in hectares.

Resumo

As informações do IBGE de 2017 sobre o quantitativo de proprietários de cultivo de tambaqui conforme os programas PRONAF'S foram avaliadas comparando-se os programas PRONAF B e PRONAF V separadamente segundo as regiões e depois segundo as classes de espelhos de água. O objetivo deste estudo foi verificar de forma exploratória e descritiva as maiores tendências de associações entre os tipos de programas de Fomento supracitados segundo as regiões Norte e Nordeste do Brasil e seis classes de espelhos de água em hectares. Primeiramente foi aplicado o teste do Qui-quadrado de Pearson para verificar dependência entre os tipos de PRONAF'S versus as regiões e depois entre estes tipos de PRONAF'S versus as classes de espelhos de água, e posteriormente análises de correspondência simples para constatar as maiores tendências de associações. Nossos resultados indicaram que no Brasil há maior tendência de associação entre o quantitativo de proprietários de cultivo de tambaqui do PRONAF B com a região Nordeste e do PRONAF V com a região Norte. Havendo maior tendência de associação do PRONAF B com a classe de espelho de água entre 5 até 10 hectares e do PRONAF V com a classe entre 50 e 100 hectares. Assim, de uma forma geral, observamos

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que a região Norte se associa com o programa PRONAF V e com maiores classes de espelhos de água, e a região Nordeste com o PRONAF B e com as menores classes de espelhos de água.

Palavras-chave: Análise de correspondência; proprietários de cultivo de tambaqui; Norte e Nordeste; espelhos de água em hectares.

Resumen
Se evaluó la información del IBGE de 2017 sobre el número de propietarios dedicados al cultivo de cachama en el marco de los programas PRONAF, comparando los programas PRONAF B y PRONAF V por separado según las regiones y, posteriormente, según las clases de superficie de espejo de agua. El objetivo de este estudio fue verificar, de manera exploratoria y descriptiva, las principales tendencias de asociación entre los tipos de programas de fomento mencionados, las regiones Norte y Nordeste de Brasil y seis clases de superficie de espejo de agua (en hectáreas). En primer lugar, se aplicó la prueba de chi-cuadrado de Pearson para verificar la dependencia entre los tipos de programas PRONAF y las regiones, y posteriormente entre dichos programas y las clases de superficie de espejo de agua; a continuación, se realizaron análisis de correspondencia simple para identificar las principales tendencias de asociación. Los resultados indicaron que, en Brasil, existe una mayor tendencia de asociación entre el número de propietarios de cultivos de cachama del programa PRONAF B y la región Nordeste, y entre los del PRONAF V y la región Norte. Asimismo, se observó una mayor tendencia de asociación del PRONAF B con la clase de superficie de espejo de agua de entre 5 y 10 hectáreas, y del PRONAF V con la clase de entre 50 y 100 hectáreas. En términos generales, se constató que la región Norte se asocia con el programa PRONAF V y con las clases de mayor superficie de espejo de agua, mientras que la región Nordeste se asocia con el PRONAF B y con las clases de menor superficie.

Palabras clave: Análisis de correspondencia; propietarios de cultivos de cachama; Norte y Nordeste; superficie de espejo de agua en hectáreas.

1 Introduction

Family farming plays an important role in the occupation of Brazilian territory; initially, however, it received no government support to develop adequately (Mattei, 2014). The same author notes that, until the early 1990s, no nationwide public policy addressed the specific needs of family farmers. In recent decades, public policies have become established, and since the creation of the National Program for Strengthening Family Farming (PRONAF), it has become the main agricultural policy for family farming, reaching many beneficiaries nationwide and involving substantial funding (Grisa & Schneider, 2015).

PRONAF was created in 1996 and, according to Mattei (2014), responded to a longstanding demand by rural workers' organizations for specific rural development policies. Its creation was structured around financing rural research and extension, production funding for operating costs, investment and infrastructure, and procurement of municipal services to train and professionalize family farmers (Mattei, 2015).

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Family farmers represent an important source of food production because, according to Schneider (2003), family farming is a regional development strategy that uses family members' labor in its activities, creating working relationships connected with the surrounding economic and social environment, whether rural or urban. These producers are also key to achieving sustainable development goals and are essential to ending hunger, particularly among the most vulnerable populations (Silva et al., 2022).

Considering that family farming is associated with small, low-productivity holdings, it contributes significantly to sustainable rural economic development (Gomes et al., 2012). According to Inoue et al. (2022), it adopts varied production systems with a wide diversity of crops, including fish, with fish farming considered an integrating activity for family farming.

Rural fish farming offers an alternative for supplementing farm income and providing protein to underserved communities (Santos et al., 2014). These authors noted that existing figures on Brazilian fish farming indicate its economic viability. PRONAF enables increased rural income through fish farming and contributes to better quality of life for participating producers (Gomes et al., 2012). Thus, the overall objective of this study was to comparatively assess the number of tambaqui farm owners under PRONAF B and V in relation to Brazil's North and Northeast regions and water surface areas.

2 Materials and methods

This study used a secondary database obtained from the Brazilian Institute of Geography and Statistics (IBGE) platform, known as the IBGE Automatic Retrieval System (SIDRA/IBGE), for 2017 (IBGE, 2017). This observational and exploratory study initially used Pearson's chi-square test to determine whether the analyzed categories were associated. The contingency tables were then subjected to simple correspondence analysis (CA) to graphically represent the structure of these associations.

Statistical analyses were performed in R (R Core Team, 2025). Descriptive statistics followed Britto et al. (2021) and Britto et al. (2025), while simple correspondence analysis (CA) followed Hair et al. (2009), Manly & Alberto (2019), and Greenacre (2017). Two CA analyses were conducted. The first compared observed frequencies of tambaqui farm owners in two PRONAF categories (PRONAF B and PRONAF V) across two Brazilian regions (North and Northeast). The second compared observed frequencies for PRONAF B and V across six water surface area classes expressed in hectares (ha): 4 to less than 5; 5 to less than 10; 10 to less than 20; 20 to less than 50; 50 to less than 100; and 100 to less than 200 hectares.

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Categorical variables were PRONAF program categories, geographic regions, and water surface area classes. Observed frequencies in each contingency table cell corresponded to the number of tambaqui farm owners recorded for each combination of categories. The analytical unit was the observed frequency of owners in each contingency table cell. Simple correspondence analyses (CA) were performed in R (R Core Team, 2025) using FactoMineR (Lê et al., 2008). Data were imported from Excel spreadsheets using the readxl package (Wickham & Bryan, 2025).

3 Results and discussion

3.1 Correspondence analysis results for PRONAF program type versus Brazil's North and Northeast regions

Two correspondence analyses (CA) were performed: one comparing the number of tambaqui farm owners by PRONAF B and PRONAF V against Brazil's North and Northeast regions, and another comparing owner numbers by PRONAF B and PRONAF V against water surface area classes: 4 to less than 5; 5 to less than 10; 10 to less than 20; 20 to less than 50; 50 to less than 100; and 100 to less than 200 hectares. Correspondence analysis results for owner numbers by PRONAF type versus region are shown in Tables 1, 2, and 3 and Figure 1. Table 1 presents the number of tambaqui farm owners by PRONAF type and North and Northeast regions. Table 2 shows the percentage of total inertia in Dimension 1, which was 100%. Table 3 presents category contributions and representation quality. Figure 1 provides the biplot showing PRONAF types versus Brazilian regions.

Table 1. Number of tambaqui farm owners by PRONAF type and Brazilian region in 2017.

PRONAF type	North	Northeast	Total
B	133	309	442
V	152	179	331
Total	285	488	773

Source: the authors (2026).

As shown in Table 1, descriptive analysis indicated that PRONAF B predominated over PRONAF V, with both predominating in the Northeast. The chi-square test showed an association between PRONAF types and the two Brazilian regions (X-squared = 19.704, df =

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1, p-value = 9.04e-06). Thus, significant chi-square results justified applying correspondence analysis (CA) to investigate the structure of the associations examined.

Table 2. Total inertia percentages in Dimension 1.

Dimension	Total inertia (%)
Dimension 1	100

Source: the authors (2026).

Table 2 indicates that Dimension 1 had 100% inertia.

Table 3. Categories, contributions, and quality of representation in the plane.

Category	Dimension 1 (%)	Cos2
PRONAF B	42.82	1.00
PRONAF V	57.18	1.00
North	63.13	1.00
Northeast	36.87	1.00

Source: the authors (2026).

Table 3 indicates that PRONAF V contributed the most (57.18%), followed by PRONAF B (42.82%); among regions, the North contributed the most (63.13%). All variables in Table 3 had a representation quality of $Cos^2 = 1.00$.

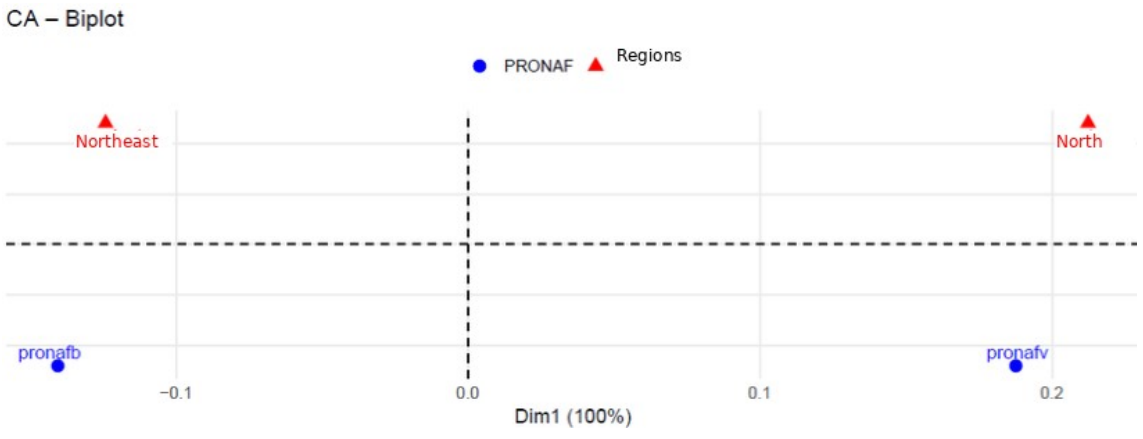


Figure 1. Comparative biplot of PRONAF types among tambaqui farm owners versus Brazil's North and Northeast regions in 2017.

The correspondence analysis between PRONAF types, based on the number of tambaqui farm owners, and the two regions indicated that Dimension 1 explained 100% of total

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inertia. Thus, the high concentration of inertia in Dimension 1 indicated that virtually the entire association structure was represented by a single axis. For PRONAF categories in Dimension 1, PRONAF V contributed 57.18% and PRONAF B 42.82%; among regions, the North contributed 63.13%. These had greater contributions and high representation quality in the plane ($Cos^2 = 1.00$). The biplot in Figure 1 indicated a stronger tendency for association between PRONAF B tambaqui farm owners and the Northeast, and between PRONAF V owners and the North.

3.2 Correspondence analysis results for PRONAF program types versus water surface area classes

Analysis results for PRONAF B and PRONAF V versus water surface areas are presented in Tables 4, 5, and 6 and Figure 2.

Table 4. Number of tambaqui farm owners by water surface area class in Brazil in 2017.

PRONAF type	4–5 ha	5–10 ha	10–20 ha	20–50 ha	50–100 ha	100–200 ha	Total
B	39	94	87	129	60	33	442
V	21	51	56	92	67	44	331
Total	60	145	143	221	127	77	773

Source: the authors (2026).

The descriptive statistical analysis of Table 4 revealed more tambaqui farm owners under PRONAF B. This difference indicated a significant association with water surface area classes according to Pearson's chi-square test (X-squared = 17.444, df = 5, p-value = 0.00373). Thus, significant chi-square results justified applying correspondence analysis (CA) to investigate the structure of the observed associations.

Table 5. Total inertia percentages in Dimension 1.

Dimension	Total inertia (%)
Dimension 1	100

Source: the authors (2026).

Table 5 indicates that Dimension 1 had 100% inertia.

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Table 6. Categories, contributions, and quality of representation in the plane.

Category	Dimension 1 (%)	Cos2
PRONAF B	42.82	1.00
PRONAF V	57.18	1.00
4–5 ha	8.59	1.00
5–10 ha	19.86	1.00
10–20 ha	4.48	1.00
20–50 ha	0.73	1.00
50–100 ha	29.35	1.00
100–200 ha	36.98	1.00

Source: the authors (2026).

Correspondence analysis between PRONAF program types, based on the number of tambaqui farm owners, and water surface area classes indicated that Dimension 1 explained 100% of total inertia. Thus, the high concentration of inertia in Dimension 1 indicated that virtually the entire association structure was represented by a single axis. For PRONAF categories in Dimension 1, PRONAF V contributed the most (57.18%), followed by PRONAF B (42.82%); among water surface area classes, the 100 to less than 200 hectare class contributed 36.98%. These had greater contributions and high representation quality in the plane (Cos^2 = 1.00). The biplot indicated a stronger tendency for association between PRONAF B tambaqui farm owners and the 5 to less than 10 hectare class, and between PRONAF V owners and the 50 to less than 100 hectare class.

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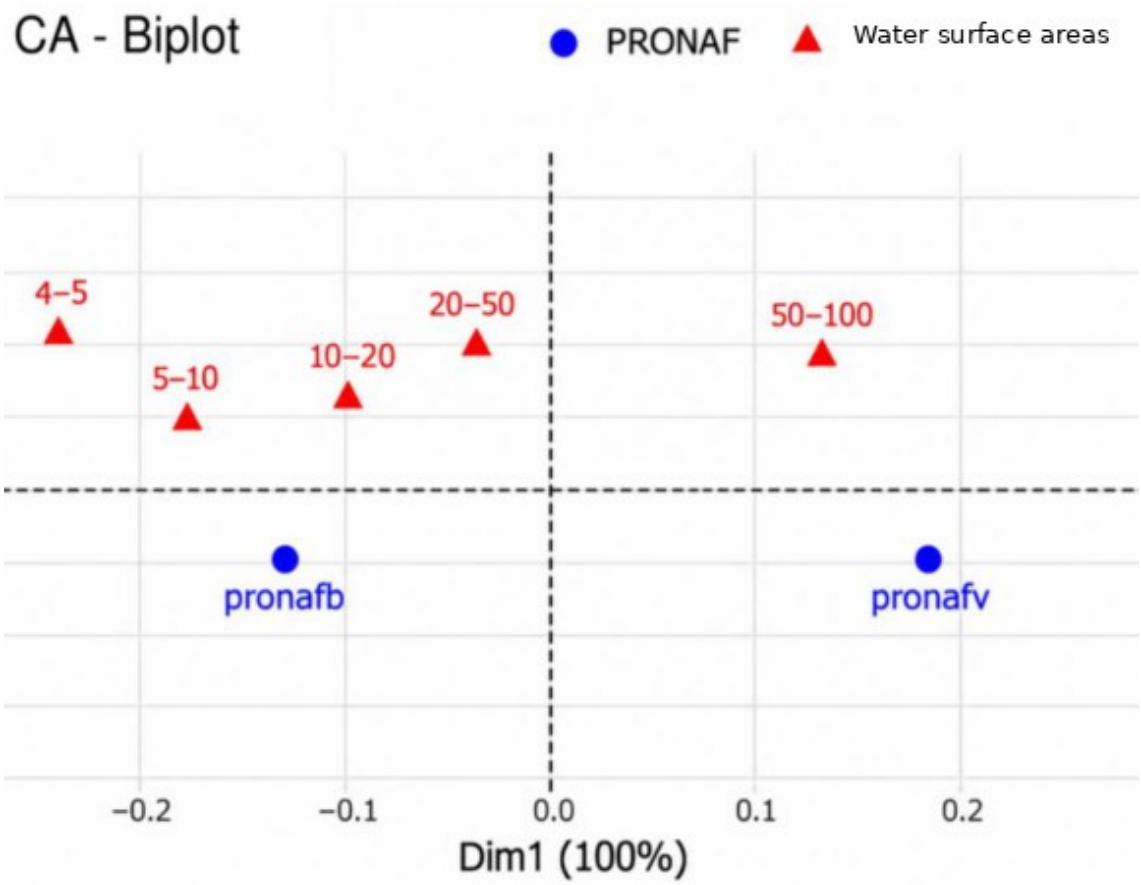


Figure 2. Comparative biplot of PRONAF types among tambaqui farm owners versus water surface area classes in Brazil in 2017.

The term "aquaculture" in IBGE 2017 and the IBGE Agricultural Census of 2019

Based on the collected data on PRONAF types versus regions and water surface areas in Tables 1 and 4, and our methodology using the number of tambaqui farm owners, we emphasize that, regarding the 2017 Agricultural Census, according to IBGE (2019), "aquaculture" refers to records previously counted in the 2006 Agricultural Census and retained in the 2017 census. Furthermore, according to IBGE (2019), in the 2017 census, "aquaculture" comprises a single census questionnaire item encompassing a set of characteristics simultaneously accounting for the distribution of the holding and its use.

These terms within the "aquaculture" item include recording pond areas, public aquaculture water areas, lakes; paths; buildings; improvements, including those for animal husbandry in a broad sense; degraded land, including eroded, sanitized, desertified, and "other

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undefined" land; and land unsuitable for agriculture, such as swamps, quarries, sandy areas, and "other undefined" land (IBGE, 2019).

Distinction between family aquaculture producers or family farmers and nonfamily aquaculture producers or nonfamily farmers

According to Article 3 of Law 11,326 of July 24, 2006, the concept of family farmer is cited together with that of rural family entrepreneur. Under this law, these entities meet the same requirements (BRASIL, 2006).

Thus, according to Brasil (2006), both have the characteristics described in the clauses of Article 3: clause I requires an area no larger than four fiscal modules; clause II requires labor from family members in the holding or enterprise; clause III requires family income to come from economic activities carried out in the holding or enterprise; and clause IV requires the holding or enterprise to be managed solely by the family.

Under paragraph 2, clause II of the same law, a family aquaculture producer is a farmer or rural family entrepreneur operating water reservoirs with water surface areas of up to 2 hectares, or occupying up to 500 m³ of water when using net cages.

The law contains only the concept of family aquaculture producer or family farmer. Thus, Aquino et al. (2014) stated that, by exclusion, those not expressly meeting the concepts in Article 3 of Law 11,326 of July 24, 2006, paragraph 2, clause II, cited by BRASIL (2006), are nonfamily aquaculture producers or nonfamily farmers.

Thus, according to those authors, nonfamily aquaculture producers are entities operating water surface areas starting at 2 hectares, or occupying at least 500 m³ of water when using net cages.

Our collected data covered only water surface areas exceeding 2 hectares; therefore, our study focused on nonfamily aquaculture producers receiving support from PRONAF B and V.

PRONAF B and V versus the North and Northeast regions

Our results collected from IBGE's SIDRA system (2017) on PRONAF B and V, shown in Table 1, indicated a larger number of tambaqui farm owners in the Northeast using both PRONAF B and PRONAF V, with these PRONAF categories predominating in that region.

Regarding PRONAF and regions, our correspondence analysis (CA) results indicated a stronger tendency for association of PRONAF B with the Northeast and PRONAF V with the North, as shown in Figure 1.

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These findings agree with Santana et al. (2019), who reported that PRONAF overall, regardless of type, was most prominent in the South, with 43% of use, followed by the Northeast with 27% and the North with 5%, when comparing Brazil's five major regions: North, Northeast, Southeast, South, and Central-West.

Regarding PRONAF B and V classification, PRONAF B is described as microcredit for family farmers (BRASIL, 2026). For PRONAF V, Aquino & Schneider (2015) reported a nomenclature change around mid-2008, when other PRONAF groups C, D, and E, aimed at more capitalized family farmers, were incorporated into the Variable Group or Group V.

Thus, because our data were obtained between 2006 and 2016 according to IBGE (2017), at the time of the 2017 Agricultural Census, we infer that PRONAF V information in our IBGE SIDRA database (2017) retained these characteristics as Group V, corresponding to the target population previously cited by Aquino & Schneider (2015).

We emphasize that our classification of family and nonfamily aquaculture producers followed Law 11,326 cited by Brasil (2006) and Aquino et al. (2014), respectively, relating to water surface area classes in hectares, unlike the classification used by Aquino & Schneider (2015).

Regarding PRONAF types and participants, Machado et al. (2024) reported three types of family farmers: PRONAF B farmers with lower productive capacity; PRONAF V farmers with more structured operations; and “non-PRONAF participants”, who qualify as family farmers but lack the characteristics required for acceptance into PRONAF.

Considering the distinction between family and nonfamily aquaculture producers under Law 11,326 cited by Brasil (2006) and Aquino et al. (2014), respectively, our results probably agree with Machado et al. (2024). Simple correspondence analysis indicated a stronger association of PRONAF B tambaqui farm owners with smaller water surface areas, between 5 and 10 hectares, and of PRONAF V owners with larger areas, between 50 and 100 hectares.

However, we emphasize that our collected data concern only tambaqui farm owners with access to PRONAF B and V. Comparing family and nonfamily farmer concepts according to Brasil (2026) and Santana et al. (2019), respectively, our data correspond to the target population of “nonfamily aquaculture producers”. We also note that the IBGE SIDRA database (2017) shows both PRONAF types applying to family and nonfamily aquaculture producers.

Machado et al. (2024) also indicated that, because PRONAF V farmers have more structured operations, they may have greater access potential and obtain larger financing amounts. These findings probably corroborate ours, since we found a stronger tendency for

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association of PRONAF V tambaqui farm owners with larger water surface areas, between 50 and 100 hectares. We reiterate that our data were restricted to nonfamily tambaqui aquaculture producers.

PRONAF B and V versus water surface areas

Regarding PRONAF type and water surface areas, our collected data considered PRONAF B and V use for the areas in Table 4: 4–5; 5–10; 10–20; 20–50; 50–100; and 100–200 hectares. The data collected in this article on those programs cover tambaqui farm owners considered nonfamily aquaculture producers by inference from the concept cited by Aquino et al. (2014).

These data on water surface area classes in hectares in the IBGE Automatic Retrieval System (SIDRA) (IBGE, 2017) were obtained through the 2017 Agricultural Census (IBGE, 2019). This information was also available as contracts by holding related to water surface areas in the Rural Credit Data Matrix (MDCR) database of the Central Bank of Brazil (BCB) (Santana et al., 2019). Our information agrees with Santana et al. (2019), who stated that aquaculture business data are obtained through census activity and the Central Bank database.

We emphasize that the full IBGE SIDRA 2017 database from which we obtained our data covered these programs for aquaculture producers with areas from 0–0.1 hectare, through 1–2 hectares, up to 10,000 hectares or more. Thus, the full IBGE (2017) database contained 18 water surface area categories including family and nonfamily aquaculture producers, predominantly nonfamily producers with 72.22% (13), compared with 27.78% (5) for family producers.

We also emphasize that this study did not use the entire database because our methodology required selecting only the water surface area classes in Table 4. Low observed frequencies for classes below 4 hectares and above 200 hectares in the full original IBGE (2017) database would have prevented chi-square tests and simple correspondence analysis (CA). Thus, we worked with the data in Table 4 and exclusively with nonfamily aquaculture producers, according to the exclusion-based concept of Aquino et al. (2014).

4 Conclusion

Our simple correspondence analysis results for nonfamily aquaculture producers indicate that PRONAF B has a stronger tendency for association with the Northeast and the water surface area class from 5 to less than 10 hectares. For the same producer category,

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PRONAF V has a stronger tendency for association with the North and the class from 50 to less than 100 hectares.

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Ano VII, v.1 2026 | submissão: 08/11/2026 | aceito: 15/11/2026 | publicação: 20/11/2026

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Ano VII, v.1 2026 | submissão: 08/11/2026 | aceito: 15/11/2026 | publicação: 20/11/2026

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