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Article

Rice Farming in Tocantins: A Temporal Analysis of Production in Lagoa da Confusão

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RESUMO

O Brasil se destaca como um dos líderes globais na produção de arroz, com uma produção anual superior a 11 milhões de toneladas, ocupando a terceira posição entre os grãos cultivados no país. O Tocantins é o terceiro maior produtor brasileiro de arroz, com o cultivo concentrado principalmente na região das várzeas tropicais, destacando-se o município de Lagoa da Confusão. Dada a importância econômica da rizicultura para essa localidade, é crucial compreender a dinâmica interanual da produção dessa cultura agrícola. Nesse sentido, este estudo objetivou analisar a dinâmica interanual da produção de arroz em Lagoa da Confusão, Tocantins, entre 2000 e 2023. Foram utilizados dados da Pesquisa Agrícola Municipal do IBGE (2000-2023) para analisar seis variáveis relacionadas à produção dessa cultura no município. Uma análise de componentes principais (ACP) também foi empregada para entender as inter-relações entre as variáveis ao longo do tempo. Os resultados mostraram que a área plantada com arroz em Lagoa da Confusão aumentou significativamente, com a produção variando de 53.820 toneladas em 2006 a 366.846 toneladas em 2017. A produtividade máxima atingiu 7.323 kg/ha em 2017. O valor da produção cresceu de R$ 10,9 milhões em 2000 para R$ 729,1 milhões em 2023. A ACP revelou que a produção está fortemente associada à expansão da área cultivada, enquanto a produtividade teve menor influência no volume produzido.
Palavras-chave: análise de componentes principais; *Oryza sativa L.*; variabilidade produtiva.

ABSTRACT

Brazil stands out as a global leader in rice production, with an annual output exceeding 11 million tons, ranking third among the grains cultivated in the country. Tocantins is the third-largest Brazilian rice producer, with cultivation concentrated primarily in the tropical floodplain region, particularly in the municipality of Lagoa da Confusão. Given the economic importance of rice farming for this region, understanding the interannual dynamics of rice production is crucial. Therefore, this study aimed to analyze the interannual dynamics of rice production in Lagoa da Confusão, Tocantins, between 2000 and 2023. Data from the IBGE Municipal Agricultural Survey (2000-2023) were used to analyze six variables related to rice production in the municipality. Principal component analysis (PCA) was also used to understand the interrelationships between the variables over time. The results showed that the area planted with rice in Lagoa da Confusão increased significantly, with production ranging from 53,820 tons in 2006 to 366,846 tons in 2017. Maximum productivity reached 7,323 kg/ha in 2017. The value of production increased from R$ 10.9 million in 2000 to R$ 729.1 million in 2023. The PCA revealed that production is strongly associated with the expansion of the cultivated area, while productivity had less influence on the volume produced.
Keywords: principal component analysis; *Oryza sativa L.*; productive variability.

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Introduction

Brazil is one of the world's leading rice producers, with an annual output of over 11 million tons (Silva et al. 2021a). Rice ranks third among the most widely cultivated cereals in the country, behind only soybeans and corn (NadaletI et al. 2023). In total, Brazil's rice fields cover over 1,500,000 hectares, distributed across various regions with tropical and subtropical climates. The main rice-producing states in Brazil are Rio Grande do Sul, Santa Catarina, and Tocantins (Fernandes Filho; Fonseca; Bendini, 2024).

Rice production in Brazil is divided between upland rice, grown with supplemental sprinkler irrigation or without irrigation, and lowland rice, which requires the presence of water during part of the growing cycle. It is noteworthy that lowland rice production accounts for 80% of the national total (Santos et al. 2021a). Lowland rice production is predominantly concentrated in southern Brazil (Heinemann et al. 2024) and is also practiced in some regions of the state of Tocantins (Santos et al. 2022). Upland rice cultivation in Brazil is primarily concentrated at latitudes below 20° South, especially in the central regions, encompassing four key states: Mato Grosso, Rondônia, Tocantins, and Goiás (Heinemann et al. 2024).

Tocantins has a predominantly flat landscape, fertile soils, a tropical climate, good water availability, and adequate road infrastructure, characteristics that favor agricultural production. The state stands out as a growing agricultural powerhouse, with an arable area that corresponds to half of the state's total area, totaling 13.8 million hectares (Volken et al. 2022). Although 80% of Brazil's rice production comes from the states of Santa Catarina and Rio Grande do Sul, rice production in the Tocantins lowlands is strategic for supplying the country, especially in the Central-West, North, and Northeast regions (Santos et al. 2022).

Tocantins stands out as a traditional producer of flood-irrigated rice, with cultivation concentrated in the floodplains of the Tocantins and Araguaia River valleys. These floodplains benefit from rising water tables, rainfall accumulation during the rainy season, and pumping of tributary water. The region's tropical floodplains offer ideal conditions for agriculture through irrigation during the rainy season, especially for rice (Fragoso et al. 2013).

In Tocantins, the municipality of Lagoa da Confusão stands out as one of the largest rice producers in the state, being the largest producer under the irrigated cultivation system. Furthermore, it houses a local agro industrial complex for processing and improving the grain (Santana & Sellito, 2020).

Given the economic importance of rice to the municipality of Lagoa da Confusão, understanding the interannual dynamics of this crop's production is crucial. Historically, rice farming has established itself as one of the pillars of the local and state economies, and analyzing its variations over time provides valuable insights for formulating strategies to improve the sector. In this context, this study aimed to analyze the interannual dynamics of rice production in Lagoa da Confusão, in the state of Tocantins, from 2000 to 2023. The aim was to identify the main factors influencing this production chain and understand fluctuations in production, with the aim of contributing to the development of initiatives that promote sustainability and improvement in the rice sector.

Material and Methods

The study was conducted in the municipality of Lagoa da Confusão (Figure 1), in Tocantins, which stands out as a significant agribusiness hub in the state and national context. The region is particularly recognized for its production of rice, soybean seeds, and watermelon, which contribute significantly to Tocantins' agricultural production.

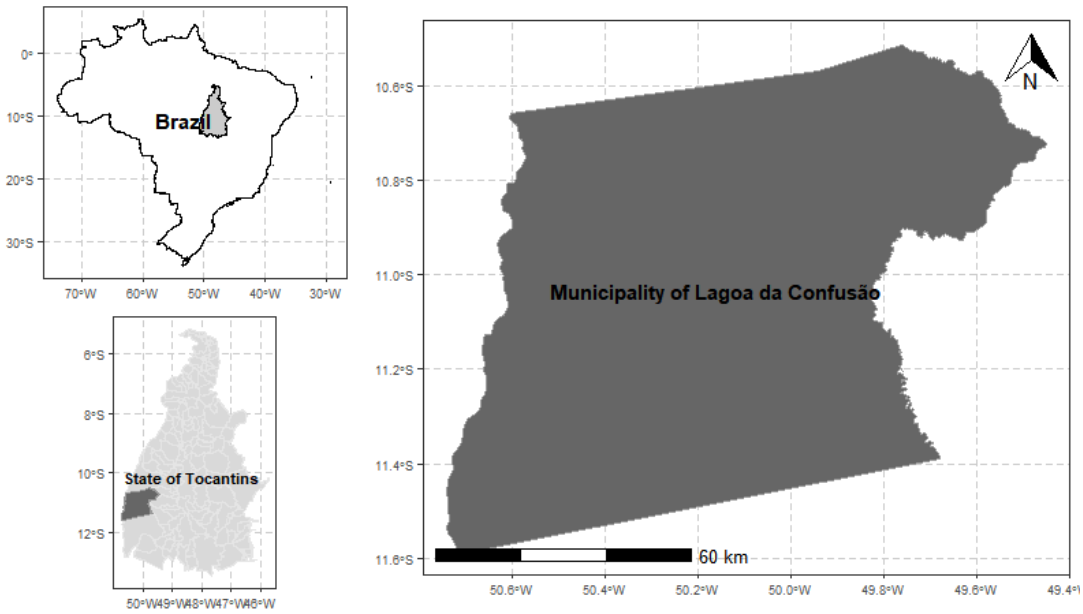

Figure 1. Location of the municipality of Lagoa da Confusão, Tocantins. Source: The authors (2025).

For this study, rice production data in Lagoa da Confusão from 2000 to 2023 were used. These data were obtained from the Municipal Agricultural Research database of the Brazilian Institute of Geography and Statistics (IBGE), specifically from table 1612 (Information on temporary crops), using the Automatic Recovery System (SIDRA, 2025).

Six variables related to rice production were considered: (a) planted area in hectares (ha), which represents the total annual area planted with this crop in the municipality; (b) harvested area in hectares (ha), which represents the total annual harvested area; (c) quantity produced (tons), corresponding to the annual quantity of rice produced; (d) productivity (kg/ha), calculated by the ratio between the quantity produced and the harvested area; (e) production value (x R$1000), calculated by the weighted average of the quantity information and the average current price paid to the producer; (f) production value - percentage of the general total, which represents the share of rice production in the total value of production of temporary crops in Lagoa da Confusão.

After extraction, the data were organized into figures and subjected to Principal Component Analysis (PCA). This technique aims to reduce data dimensionality by converting a set of variables into a smaller number of principal components. These components preserve most of the data's variance, maintaining essential information and ensuring independence between them. The process includes data standardization, constructing a correlation matrix, and using eigenvectors to generate new composite variables (Li, 2024).

This type of analysis has proven effective in assessing the temporal dynamics of the production of several temporary crops, such as beans (Santos et al. 2021b), corn (Silva et al. 2021b; Santana et al. 2023, Santos et al., 2025) and sugarcane (Dias et al. 2021), as well as in permanent crops, such as cashew (Souza Júnior et al. 2022), mango (Santos et al. 2024a), banana (Santos et al. 2024b) and sisal (Sabino et al. 2024).

Additionally, a hierarchical cluster analysis (HCA) combined with a heat map was used to group years with similar production characteristics. Both analyses were performed using R software, version 4.5.1 (R Core Team, 2025).

Results and Discussion

There was a strong fluctuation in the areas planted and harvested with rice in Lagoa da Confusão (Figure 2), with a sharp increase over time in the areas allocated to rice production. The smallest planted areas were observed in 2006, with an area of 13,800 hectares. In contrast, in 2020, 56,280 hectares were planted (Figure 2A), representing a 236% increase compared to 2000, the beginning of the sampling period.

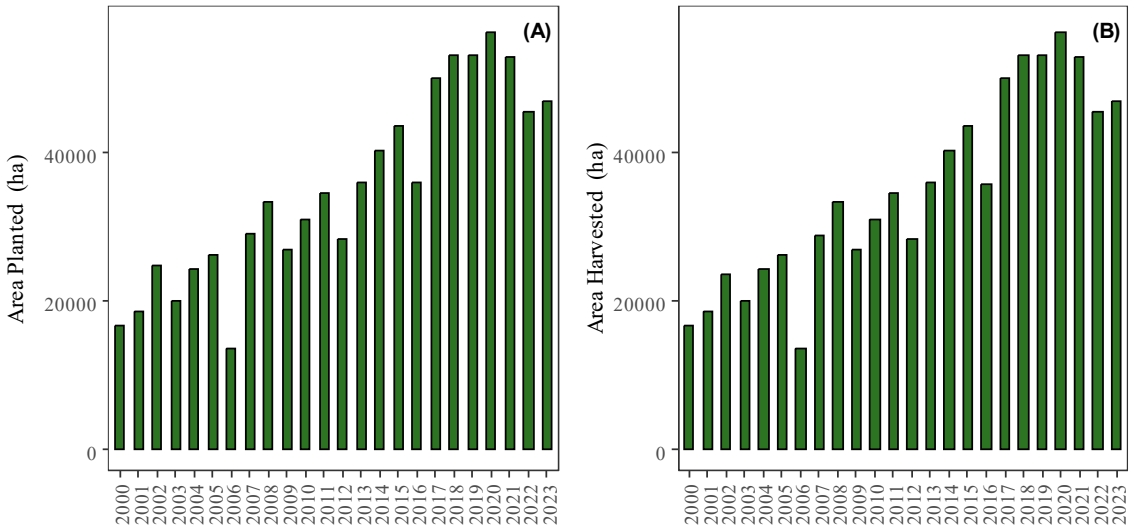

Figure 2. Area planted (A) and area harvested (B) with rice in Lagoa da Confusão – TO in the period 2000-2023. Source: Adapted from Sidra (2025).

As with the planted area, the largest and smallest harvested areas were also recorded in 2020 and 2006, with 56,280 hectares and 13,800 hectares, respectively (Figure 2B). Discrepancies between the planted area and the harvested area were observed in 3 of the 23 sampled years (2002, 2007, and 2016) (Figure 2B). Differences between these two variables, such as those observed in this study, are reported in several other studies on the productive dynamics of agricultural crops, both in temporary crops (Santos et al. 2021b; Araújo et al. 2025) and in permanent crops (Santos et al. 2024b). Among the main factors that can lead to the occurrence of these differences, the occurrence of pests and diseases during the crop cycle stands out (Kim et al. 2020), which compromises final productivity and, in extreme cases, makes the harvest economically unfeasible (Araújo et al. 2021; Santos et al. 2021b).

Rice production in Lagoa da Confusão ranged from 53,820 tons in 2006 to 366,846 tons in 2017 (Figure 3A). As with the planted and harvested area, there was a temporal upward trend in the quantity of this cereal produced. However, a downward trend began in 2018, which can be attributed to biotic and abiotic factors that impacted production in this crop.

Unlike the previously reported variables, although rice productivity in Lagoa da Confusão showed an upward trend over time, it was not as significant as that observed for the other variables (Figure 3B). These results are related to the fact that local rice production has always been guided by good agricultural practices, especially the appropriate use of inputs such as fertilizers and cultivars suited to local soil and climate conditions (Fragoso et al. 2013).

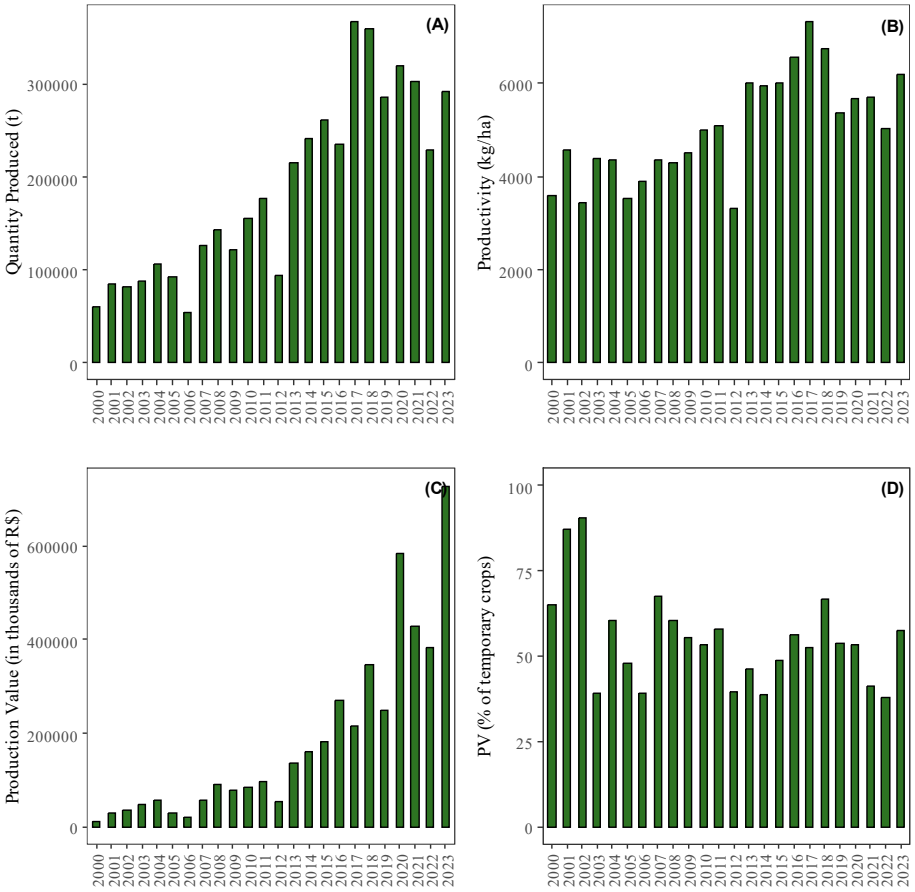

Figure 3. Quantity produced (A), productivity (B), production value (C) and production value (% of temporary crops) (D) of rice in Lagoa da Confusão – TO in the period 2000-2023. Source: Adapted from Sidra (2025).

The highest rice productivity was recorded in 2017, with a yield of 7,323 kg/ha (Figure 3B). In that year, the municipality's average productivity surpassed that of Tocantins (6,228 kg/ha), the North region (4,572 kg/ha), and Brazil (6,213 kg/ha) (SIDRA, 2025), highlighting Lagoa da Confusão's high potential for rice production.

Rice is a crop of great economic importance to the municipality, and its production value increased significantly over the sample period, rising from R$10.9 million in 2000 to R$729.1 million in 2023 (Figure 3C). Agriculture is Lagoa da Confusão's main economic activity, generating employment and income, and rice production also has significant cultural appeal, contributing to food sovereignty.

Despite the significant growth in rice-planted area, this crop's share of the municipality's total production value from temporary crops has been declining, falling from 90.53% in 2002 to 38% in 2022 (Figure 3D). This highlights the growing importance of other crops, such as soybeans and beans, although rice remains the mainstay of local agriculture.

Lagoa da Confusão is the only municipality outside Rio Grande do Sul to be among the 10 largest rice producers in the country in 2023 (Table 1), reinforcing the strength of municipal agribusiness and its high potential for rice production.

Table 1. Largest rice producers in Brazil in 2023.

Municipality	Quantity Produced (t)
Santa Vitória do Palmar (RS)	601163
Uruguaiana (RS)	562779
Alegrete (RS)	430315
Itaqui (RS)	407929
Dom Pedrito (RS)	317313
Lagoa da Confusão (TO)	291640
São Borja (RS)	259613
Arroio Grande (RS)	239475
Camaquã (RS)	237492
Mostardas (RS)	225700

Source: Adapted from Sidra (2025).

Principal component analysis (PCA) explained 89.3% of the original data variance in the first two axes (PC1 and PC2) (Figure 4). Axis 1, which concentrated 73.5% of the variance, revealed a strong positive association between Quantity Produced (QP) ($r = 0.98$; $p < 0.01$), Planted Area ($r = 0.97$; $p < 0.01$), and Harvested Area ($r = 0.97$; $p < 0.01$). These results indicate that, in the studied region, higher rice production volumes are directly related to the expansion of cultivated areas, suggesting that productivity plays a secondary role in this context. Similar results were observed for other cereals in different regions of the country, such as corn production in the semiarid region of Alagoas (Santana et al. 2023) and Paraíba (Araújo et al. 2025). The lower variability in productivity during the sampling period may explain this result, reducing its impact on the final quantity of rice production.

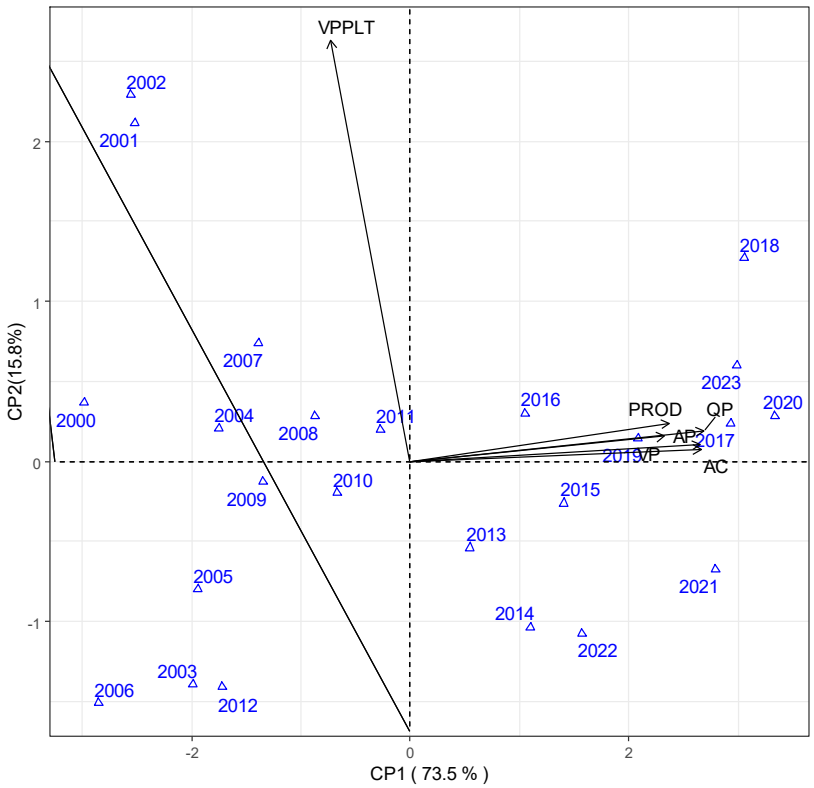

Figure 4. Biplot graphic dispersion of rice production in Lagoa da Confusão - TO, in the period 2000-2023, and based on scores of 6 productive traits, represented by the first two principal components. Planted area (AP), harvested area (AC), quantity produced (QP), productivity (PROD), production value (VP) and percentage production value of temporary crops (VPPLT). Source: The authors (2025).

On axis 2, which explained 15.8% of the variance, only the significant participation of the Percentage Production Value of Temporary Crops (VPPLT) was observed ($r = 0.96$; $p < 0.01$). This shows that this variable is not very dependent on the other variables analyzed, probably due to the fact that it derives from the general quantity of temporary agricultural crops produced in the municipality.

The hierarchical cluster analysis resulted in the formation of 6 clusters, which grouped the years with similar productive characteristics (Figure 5).

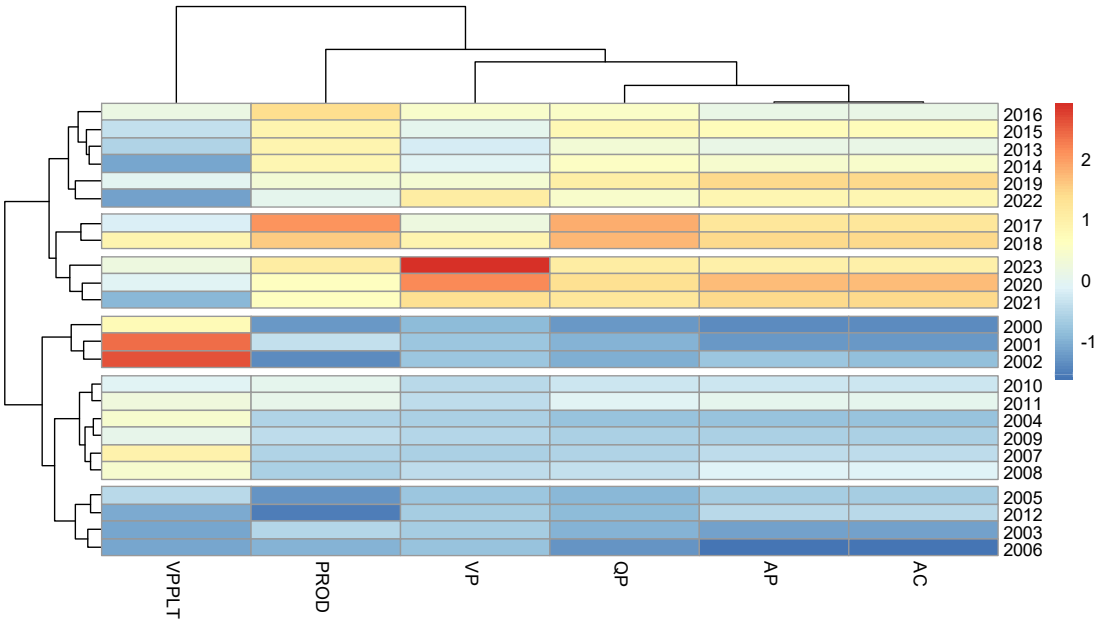

Figure 5. Hierarchical cluster analysis and heat map based on the years evaluated and productive traits. The colors red and blue represent importance, from highest to lowest, respectively. Planted area (AP), harvested area (AC), quantity produced (QP), productivity (PROD), production value (VP) and percentage production value of temporary crops (VPPLT). Source: The authors (2025).

The years 2020, 2021, and 2023 formed a group with the best production metrics, standing out for their highest production values (Figure 5). The years 2017 and 2018, on the other hand, were grouped together, sharing the best productivity and quantity produced. In contrast, the years 2003, 2005, 2006, and 2012 formed a group with the worst production performance in the sample series.

Conclusions

Rice production in Lagoa da Confusão showed significant interannual variability, with a considerable increase in planted and harvested area. Significant gains were also observed in the quantity produced and the value of production.

Although other agricultural crops have been increasing their share of the total quantity of temporary crops in the municipality, rice is still the main crop produced locally, reflecting Lagoa da Confusão's position among the largest national producers of this cereal.

The PCA revealed that production is strongly associated with the expansion of cultivated area, while productivity had less influence on production volume. Cluster analysis identified six distinct groups, highlighting the years 2020, 2021, and 2023, which presented the best production indicators. These analyses reinforce the importance of territorial planning and the efficient use of agricultural land to maintain the competitiveness of local rice production.

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