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Expansion of soybean culture in the North Araguaia microregion: Temporal analysis in the municipality of Confresa - MT

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A B S T R A C T

Soybean (*Glycine max* L. Merrill) is one of the main global agricultural commodities, with Brazil standing out as the largest producer and exporter in the world. In the state of Mato Grosso, the Northern Araguaia microregion has been consolidating itself as a new agricultural frontier, with the municipality of Confresa being one of the main hubs of this expansion. In this context, this study aimed to analyze the soybean production dynamics in Confresa between 2003 and 2023. The data were obtained from the Municipal Agricultural Survey (*Pesquisa Agrícola Municipal* - PAM) of the Brazilian Institute of Geography and Statistics (*Instituto Brasileiro de Geografia e Estatística* - IBGE), covering six agricultural variables. To understand the relationships between these variables and the evolution of production, Principal Component Analysis (PCA) and Hierarchical Cluster Analysis (HCA) were used, the latter accompanied by heat maps. The results showed a significant expansion of soybean cultivation in the municipality, with an increase in the planted area from 810 ha (2010) to 55,370 ha (2023) and production from 2,430 tons to more than 200,000 tons, representing an increase of over 8,130%. The production value rose from R$ 1.38 million in 2010 to R$ 649 million in 2022. PCA indicated that this growth was strongly associated with the expansion of the cultivated area, while productivity had a secondary influence. HCA identified four distinct temporal groups, with the most recent years showing the best production indicators. Given soybeans' leading role in the local economy, the importance of planning and adopting strategies aimed at the sustainability of agricultural activity in the municipality is emphasized.

R E S U M O

A soja (*Glycine max* L. Merrill) é uma das principais commodities agrícolas globais, com destaque para o Brasil, maior produtor e exportador mundial. No estado de Mato Grosso, a microrregião do Norte Araguaia vem se consolidando como nova fronteira agrícola, tendo o município de Confresa como um dos principais polos dessa expansão. Nesse contexto, este estudo teve como objetivo analisar a dinâmica produtiva da soja em Confresa entre 2003 e 2023. Os dados foram obtidos junto à Pesquisa Agrícola Municipal (PAM), do Instituto Brasileiro de Geografia e Estatística (IBGE), abrangendo seis variáveis agrícolas. Para compreender as relações entre essas variáveis e a evolução da produção, foram utilizadas Análise de Componentes Principais (ACP) e Análise de Agrupamento Hierárquico (HCA), esta última acompanhada por mapas de calor. Os resultados evidenciaram uma expressiva expansão da sojicultura no município, com aumento da área plantada de 810 ha (2010) para 55.370 ha (2023) e da produção de 2.430 toneladas para mais de 200 mil toneladas, representando um crescimento superior a 8.130%. O valor da produção passou de R$ 1,38 milhão em 2010 para R$ 649 milhões em 2022. A ACP apontou que esse crescimento esteve fortemente associado à expansão da área cultivada, enquanto a produtividade teve influência secundária. A HCA identificou quatro grupos temporais distintos, com os anos mais recentes apresentando os melhores indicadores produtivos. Diante do protagonismo da soja na economia local, destaca-se a importância do planejamento e da adoção de estratégias voltadas à sustentabilidade da atividade agrícola no município.

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Introduction

Soybean (*Glycine max* L. Merrill) is one of the most relevant crops in the global agricultural scenario, representing about 30% of the world's oilseed production. Soybeans are highly nutritious, containing between 40% to 45% protein, 20% to 22% oil, and 20% to 26% carbohydrates (Rao *et al.*, 2023). In addition to being the main source of vegetable oil and high-quality vegetable protein, soybean is widely used as a raw material in animal feed, as well as in the food, pharmaceutical, and chemical industries. This versatility has driven the growing global demand for soybean derived products (Guo *et al.*, 2022).

Considered one of the main global commodities, soybean plays a central role in food and energy security, being used both in human nutrition and in animal feed and biofuel production. Brazil, the United States, and Argentina are the three largest global producers and exporters, accounting for more than 80% of global soybean exports (Reis; Aktas; Machado, 2025).

In the national context, soybean occupies a prominent position in Brazilian agribusiness, consolidating Brazil as the world's largest producer and exporter of the crop (Toloi *et al.*, 2024). Initially introduced in the southern states, especially in Rio Grande do Sul and Paraná, regions with a subtropical climate, soybean cultivation expanded significantly from the 1970s and 1980s. With the support of the Brazilian Agricultural Research Corporation (EMBRAPA), varieties adapted to the tropical climate were developed, which made it possible to expand into the Brazilian cerrado, especially to the states of Mato Grosso, Mato Grosso do Sul, and Goiás (Colussi *et al.*, 2024).

The state of Mato Grosso stands out as the country's leading producer of soybeans, in addition to leading the national production of cotton, corn, sunflower, and beef cattle (Toloi *et al.*, 2021a; Toloi *et al.*, 2024). The dynamism of soybean production in the state reflects its economic potential, related to the increasing demand for inputs, the expansion of planted area, and the rise in productivity. Thus, the soybean production chain broadly impacts all agents involved directly or indirectly in the activity (Toloi *et al.*, 2021b).

Soybean production in the Norte Araguaia microregion, in Mato Grosso, is part of a broader process of agricultural expansion in the state, but it presents specific dynamics that require localized analysis. Although Mato Grosso is the country's largest soybean producer, the diversity of biomes, soils, and geographic conditions imposes different rhythms of land occupation and use. In this context, between 2005 and 2015, Norte Araguaia began to consolidate as a new agricultural frontier, with several municipalities in the region becoming more effectively integrated into the Mato Grosso soybean cultivation map (Barrozo & Rosa, 2017).

In the North Araguaia microregion, the municipality of Confresa has stood out for its accelerated pace of economic growth, driven largely by the consolidation of soybean cultivation as a significant source of employment and income generation (Gawenda, 2014). In this context,

it becomes essential to understand the year-to-year dynamics of soybean production in the municipality, identifying the factors that influence its expansion, the variations over time, and the associated socioeconomic impacts.

Despite the vertiginous growth of soybean cultivation in North Araguaia, quantitative studies that assess the interannual dynamics of production at the municipal level are still scarce, especially through the use of multivariate techniques. It should be noted that the municipality of Confresa concentrates a significant number of Agrarian Reform settlers and is undergoing a pronounced transition from small-scale agriculture to large-scale commodity production.

Thus, the present study aims to analyze the behavior of soybean production in Confresa, in the period from 2003 to 2023, in order to provide subsidies that contribute to territorial planning, the sustainability of the activity, and the strengthening of the production chain.

Methodology

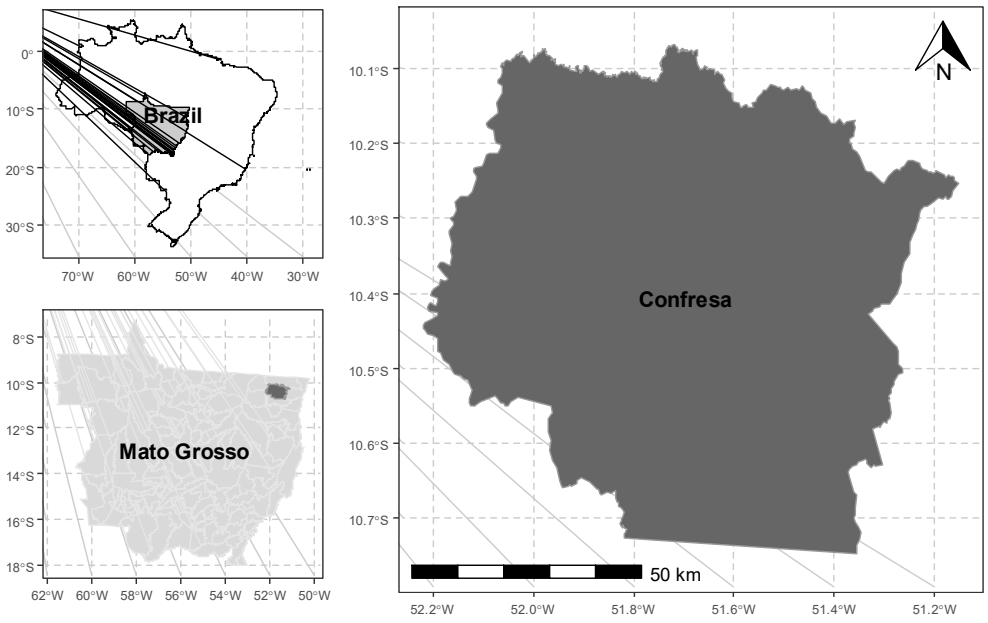
The municipality of Confresa (Figure 1) is located in the Northeast region of Mato Grosso, within the Araguaia-Xingu region and in the North Araguaia microregion, with coordinates 10°38'38" S and 51°34'08" W, and an approximate altitude of 237 meters. It has a tropical rainforest climate, with two well-defined seasons: rainy summer and dry winter. The dry period generally occurs between June and August, and may extend until September. The average annual precipitation is about 1,900 mm, mainly concentrated in January, February, and March. The average annual temperature is 28°C, ranging from 15°C to 41°C (Silva *et al.*, 2022).

The municipality has shown consistent growth, progressively standing out in the agropastoral and agroindustrial scenario of the State of Mato Grosso. The expansion of the agricultural frontier has favored the implementation of large-scale soybean crops, driving the attraction of companies linked to agribusiness, which have established themselves in the region to meet the growing demand. Moreover, the municipality has an operating slaughterhouse, which reinforces its relevance in the beef cattle production chain (Gawenda, 2014).

For the realization of this study, data regarding soybean production in the municipality of Confresa (MT) were used, for the period from 2003 to 2023. The information was extracted from the database of the Municipal Agricultural Survey (*Pesquisa Agrícola Municipal* - PAM), provided by the Brazilian Institute of Geography and Statistics (*Instituto Brasileiro de Geografia e Estatística* - IBGE), through the Automatic Recovery System (SIDRA, 2025), specifically from Table 1612, which deals with temporary crops.

Figure 1.

Location of the municipality of Confresa, Mato Grosso.



Source: The authors (2025).

Six agricultural variables were analyzed: (a) planted area (ha), corresponding to the total area cultivated with soybeans each year; (b) harvested area (ha), representing the area actually harvested annually; (c) quantity produced (t), which expresses the total volume of annual production; (d) productivity (kg/ha), obtained by the ratio between production and harvested area; (e) production value (in thousands of reais), calculated based on the weighted average of production and the average prices paid to producers; and (f) percentage of the production value in relation to the total of temporary crops, indicating the economic participation of soybeans in the municipal agricultural context.

The data were organized into figures and subsequently submitted to Principal Component Analysis (PCA). For performing the PCA, the data were previously standardized (Z-score). The significance of the association between the original variables and the principal components was verified using Student's t-test ($p < 0.05$) through the dimdesc function of the FactoMineR package (Lê *et al.*, 2008). The number of axes retained for interpretation followed Kaiser's criterion (eigenvalues > 1) and the proportion of explained variance.

PCA is a multivariate statistical technique used for reducing the dimensionality of high complexity data sets, with the aim of retaining the largest possible proportion of the total variance present in the original variables. This method performs a linear transformation of the correlated variables into a new set of orthogonal variables, called principal components, which are uncorrelated with each other and ordered according to the amount of variance explained (Jewsbury & Johnson, 2025).

Principal Component Analysis (PCA) has established itself as an efficient statistical tool for investigating the temporal dynamics of agricultural production. Its application has been frequent in studies involving seasonal crops such as rice (Blaszczyk *et al.*, 2025), beans (Araújo *et al.*, 2021; Santos *et al.*, 2021), tomatoes (Silva *et al.*, 2025), corn (Santana *et al.*, 2023; Araújo *et al.*, 2025; Santos *et al.*, 2025), and sugarcane (Bulhões *et al.*, 2025). In addition to these, PCA has also been used to evaluate the productive dynamics of fruit species, such as cashew (Souza Júnior *et al.*, 2022), mango (Santos *et al.*, 2024a), and banana (Santos *et al.*, 2024b), as well as fiber crops such as sisal (Sabino *et al.*, 2024).

Additionally, a Hierarchical Cluster Analysis (HCA) was performed using Ward's method and Euclidean distance, with the number of clusters optimized by the Silhouette index. The results were integrated into a heatmap with ordering by importance and dendrogram clustering. All analyses were conducted in the R statistical software, version 4.5.1 (R Core Team, 2025).

Results and Discussion

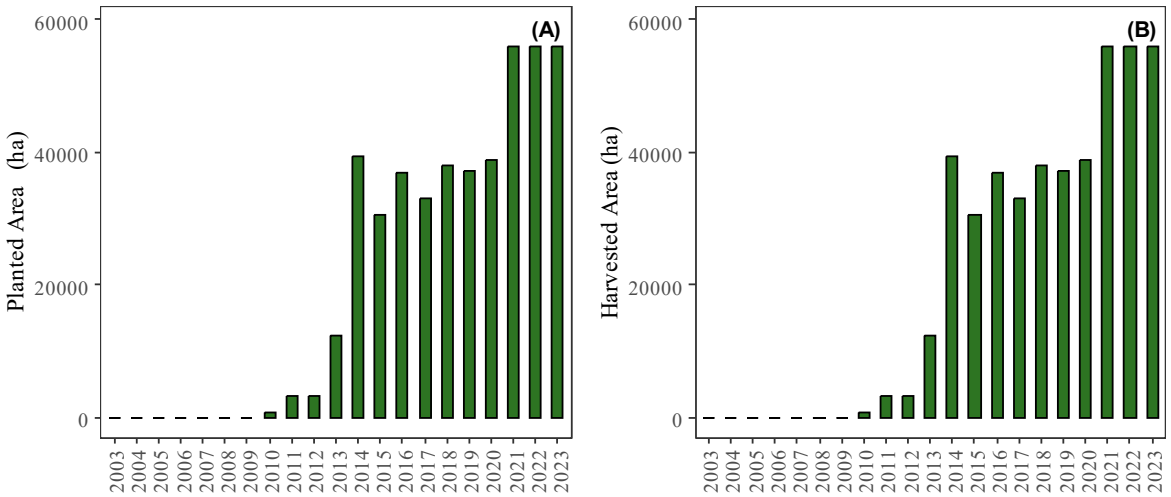
The first official records of commercial soybean planting in Confresa date back to 2010, when 810 hectares of this crop were cultivated in the municipality (Figure 2A). A significant increase in this area was observed until 2014, reaching 39,411 hectares. Subsequently, a downward trend was noted, followed by a period of stability, until a new sharp growth occurred in the last three years of the analyzed period, when the planted area exceeded 55 thousand hectares.

It is important to emphasize that this research set the year 2003 as the starting point to highlight the arrival and expansion of this culture in the region. Historically, the colonization of Confresa aimed at opening land for sugarcane cultivation, intended for a local distillery. With the closure of this plant's activities in 2009, the arable lands were redirected to other crops, with soybeans taking a leading role (Gawenda, 2014).

In all the years evaluated, the harvested area consistently followed the planted area (Figure 2B). These results demonstrate that, in Confresa, soybean cultivation has been conducted under proper agronomic management and favorable edaphoclimatic conditions. Discrepancies between the planted and actually harvested area are frequently reported in other studies with seasonal crops, such as corn (Santana *et al.*, 2023; Araújo *et al.*, 2025), and are generally attributed to factors such as adverse climatic events, pest attacks, and pathogen incidence (Santos *et al.*, 2021).

Figure 2.

Planted area (A) and harvested area (B) of soybeans in Confresa - MT in the period 2003-2023.



Source: Adapted from Sidra (2025).

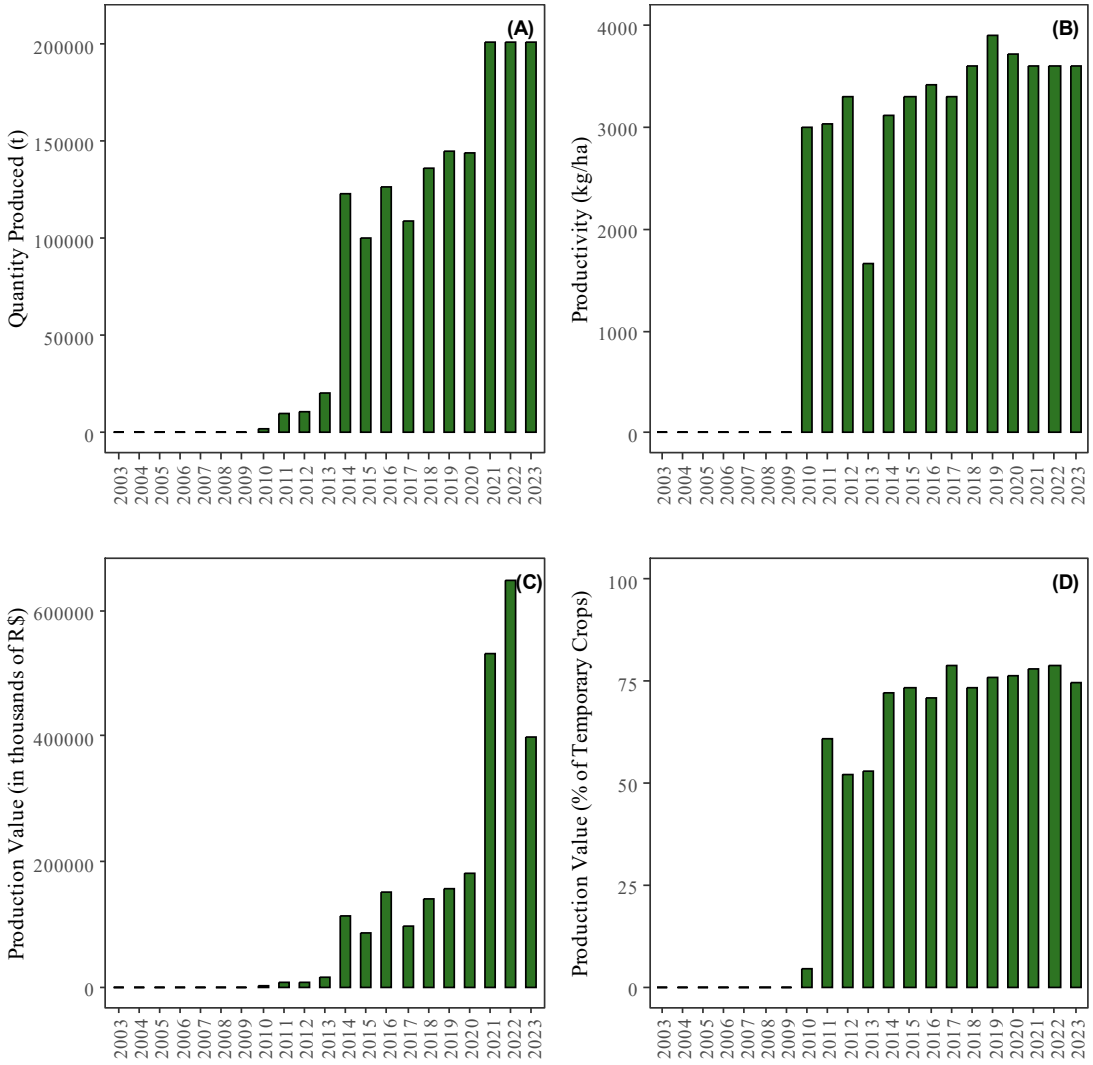
The amount produced of this oilseed in the municipality increased from 2,430 tons in 2010 to more than 200,000 tons in the last three years of the analyzed period, representing an increase of more than 8,130% (Figure 3A).

This significant growth highlights the strong expansion of soybean farming in the region. The Araguaia Valley region, of which Confresa is a part, has been called, for several years, “the new agricultural frontier” of the state, due to the favorable soil and climate conditions for agricultural production. With a clear vocation for agriculture, northeastern Mato Grosso has been receiving several investments in infrastructure. The remarkable development of soybean cultivation in the region has occurred progressively, driven mainly by these investments (Demambro *et al.*, 2021).

Soybean productivity in Confresa fluctuated between 1,668 kg/ha in 2013 and 3,900 kg/ha in 2019 (Figure 3B). In 2023, at the end of the monitored period, the average yield was 3,600 kg/ha. It is noteworthy that, in 2019, local productivity exceeded the averages recorded for the state of Mato Grosso (3,316 kg/ha), for the Central-West region (3,251 kg/ha), and for Brazil (3,185 kg/ha), according to SIDRA data (2025). In 2023, although Confresa’s productivity remained above the national average (3,425 kg/ha), it was below the values recorded for Mato Grosso (3,708 kg/ha) and for the Central-West region (3,721 kg/ha) (SIDRA, 2025).

Figure 3.

Quantity produced (A), productivity (B), production value (C), and production value (% of temporary crops) (D) of soybeans in Confresa - MT in the period 2003-2023.



Source: Adapted from Sidra (2025).

The value of soybean production in Confresa increased from R$ 1,385,000 in 2010 to R$ 649,348,000 in 2022, representing an increase of over 46,000% (Figure 3C). These results reinforce the significant expansion of soybean farming in the municipality and its high economic impact on local agriculture. This prominence is evidenced by the share of soybean in the total value of temporary crops grown in Confresa, which went from 4.28% in 2010 to more than 70% in all years from 2014 onwards (Figure 3D).

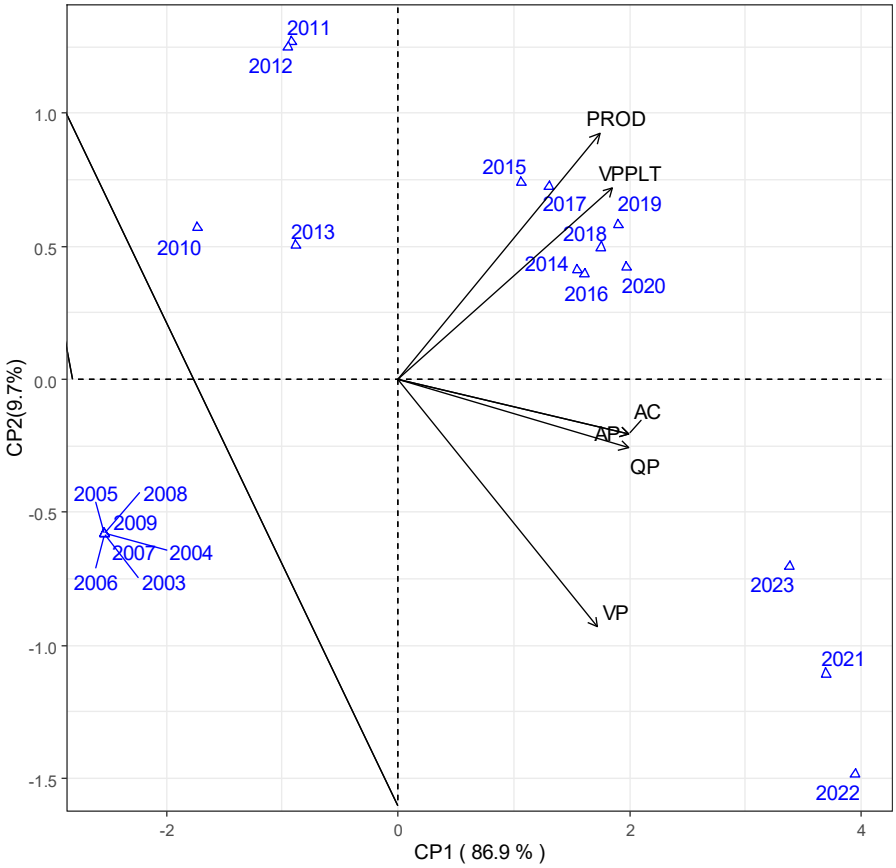
According to Cunha, Espíndola, and Farias (2024), in 2022, the Northeast mesoregion of Mato Grosso, in which the municipality of Confresa is located, produced 7.5 million tons of soybeans, registering an accumulated growth of 581% compared to 2003, reflecting the strong expansion of the activity in the region. The average productivity was 3,578 kg/ha, with an increase of 26.5% over the period. The Gross Value Added (GVA) generated reached R$ 20.9

billion, which corresponds to 19.8% of the state total, the second-largest contribution among the mesoregions. With an average annual growth rate of 13.3% over the past decades, the Northeast of the state stands out for the rapid spread of production and growing agricultural specialization.

Principal Component Analysis (PCA) explained 96.6% of the total variance of the data in the first two principal axes (PC1 and PC2) (Figure 4). The first axis (PC1) concentrated 86.9% of the variance and revealed a strong positive association between Produced Quantity (QP) ($r = 0.98$; $p < 0.01$), Planted Area (AP) ($r = 0.98$; $p < 0.01$), and Harvested Area (AC) ($r = 0.98$; $p < 0.01$). These results indicate that, in the analyzed region, the increase in soybean production is strongly related to the expansion of cultivated areas, which indicates that productivity plays a secondary role in this scenario. Similar results are reported for other crops, such as maize production in the interior of Alagoas (Santana *et al.*, 2023).

Figure 4.

Biplot graphic dispersion of soybean production in Confresa - MT from 2003-2023, based on scores of 6 productive characters, 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).

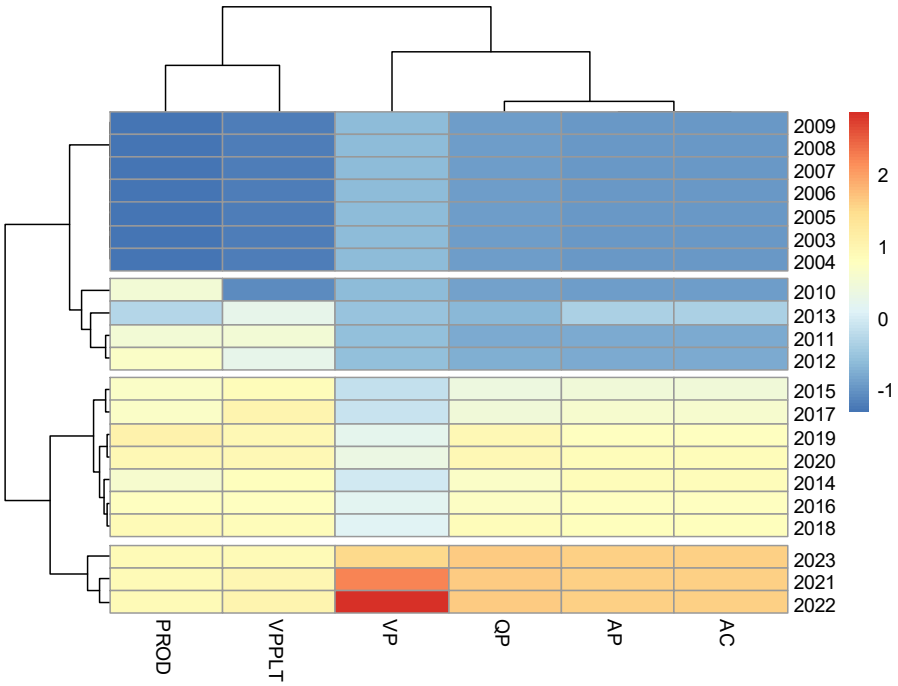
Source: The authors (2025).

In the second axis (CP2), which explained 9.7% of the variance in the data, a negative association was observed between Productivity (PROD) ($r = 0.45$; $p < 0.05$) and Production Value (VP) ($r = -0.45$; $p < 0.05$). These results indicate that higher production values are not necessarily associated with higher productivity levels, reinforcing the evidence observed in CP1 that the increase in generated value is more related to the expansion of the cultivated area than to yield per hectare.

The hierarchical cluster analysis resulted in the formation of 4 clusters, which group the years with similar productive characteristics (Figure 5). A cophenetic correlation coefficient of $r = 0.86$ was obtained, indicating a high degree of reliability in the clustering.

Figure 5.

Hierarchical cluster analysis and heat map based on the evaluated years 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 from 2003 to 2009 were grouped together due to the absence of soybean production during this period in Confresa. On the other hand, the years 2021, 2022, and 2023 formed a group characterized by the best productive metrics, standing out for the highest production values (Figure 5). The period from 2014 to 2020 was grouped for presenting an intermediate productive performance.

The combined results highlight the temporal expansion of soybean cultivation in Confresa, with significant gains in planted area, production volume, and production value.

These advances are not limited to the municipality, also extending to the microregion of Norte Araguaia, which has been standing out in the Mato Grosso agricultural sector not only for soybean production but also for the cultivation of other crops, such as corn, in addition to livestock farming (Barrozo & Rosa, 2017).

Final Considerations

Soybean production in the municipality of Confresa showed significant interannual variability, driven mainly by the expansion of the cultivated area. Productivity, although variable, played a secondary role in the dynamics of production, as evidenced by the Principal Component Analysis, which highlighted the positive correlation between planted area, harvested area, and quantity produced.

The hierarchical cluster analysis identified distinct temporal clusters, with the most recent years showing the best productivity indicators.

The results obtained confirm the consolidation of soybeans as the dominant crop in the municipality and point to the need for territorial planning and sustainable management strategies to ensure the continuity and efficiency of agricultural activity in the region.

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