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Article

Corn in Brejo Paraibano: Productive Transformations and Agricultural Challenges from 2000 to 2023

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RESUMO

O Brasil é um dos maiores produtores e exportadores de milho do mundo. Na Paraíba, a microrregião do Brejo Paraibano constitui um importante polo agrícola, beneficiado por condições edafoclimáticas favoráveis à agricultura. No entanto, alguns fatores locais ainda representam entraves à produção. Nesse contexto, considerando a relevância da cultura do milho para a agricultura local, o presente estudo teve como objetivo analisar a dinâmica produtiva do milho na microrregião do Brejo Paraibano, no período de 2000 a 2023. Os dados utilizados nesta pesquisa foram obtidos junto ao banco de informações da Pesquisa Agrícola Municipal, do Instituto Brasileiro de Geografia e Estatística (IBGE), para a avaliação de seis variáveis relacionadas à produção de milho. Adicionalmente, empregaram-se uma Análise de Componentes Principais (ACP) e uma Análise de Agrupamento Hierárquico (HCA), esta última combinada com um mapa de calor (heatmap), a fim de compreender as inter-relações entre as variáveis ao longo do tempo. A produção de milho no Brejo Paraibano apresentou flutuações significativas ao longo do período analisado, com forte retração nas áreas plantada e colhida. No entanto, foram observados ganhos na produtividade. A ACP demonstrou que, para a região estudada, maiores quantidades produzidas de milho estão diretamente relacionadas à obtenção de maiores produtividades, e não à ampliação das áreas plantadas. Dada a importância econômica e cultural do milho para a microrregião, é necessário implementar esforços para melhorar o rendimento local dessa cultura, como, por exemplo, a tecnificação da produção.
Palavras-chave: análise de componentes principais; dinâmica produtiva; *Zea mays* L

ABSTRACT

Brazil is one of the largest corn producers and exporters in the world. In Paraíba, the Brejo Paraibano microregion is an important agricultural hub, benefiting from favorable soil and climate conditions for agriculture. However, some local factors still represent obstacles to production. In this context, considering the relevance of corn cultivation for local agriculture, the present study aimed to analyze the productive dynamics of corn in the Brejo Paraibano microregion, from 2000 to 2023. The data used in this research

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were obtained from the Municipal Agricultural Research database of the Brazilian Institute of Geography and Statistics (IBGE), to evaluate six variables related to corn production. Additionally, a Principal Component Analysis (PCA) and a Hierarchical Cluster Analysis (HCA) were used, the latter combined with a heatmap, in order to understand the interrelationships between the variables over time. Corn production in Brejo Paraibano showed significant fluctuations throughout the analyzed period, with a strong reduction in the planted and harvested areas. However, gains in productivity were observed. The PCA demonstrated that, for the studied region, larger quantities of corn produced are directly related to obtaining higher productivity, and not to the expansion of planted areas. Given the economic and cultural importance of corn for the microregion, it is necessary to implement efforts to improve the local yield of this crop, such as, for example, the technological development of production.
Keywords: principal component analysis; productive dynamics; *Zea mays* L.

Introduction

Corn (*Zea mays* L.) originates from Central America and stands out as one of the most important cereals due to its high nutritional value (Lopes et al. 2023). Since its domestication approximately 9,000 years ago, the crop has assumed an increasingly relevant and diversified role in global agrifood systems (Erenstein et al. 2022).

Its nutritional composition includes approximately 72% starch, 10% protein, approximately 5% oil, 6% to 8.5% fiber, and 3% sugar (Wani et al. 2021). In addition to vitamins such as A and B3, and approximately 2% ash, which highlights its nutritional value and productive potential, superior to that of other cereal crops (Suleman et al. 2022).

The growth in global corn production in recent decades is the result of a combination of factors: technological advances, increased productivity, expansion of cultivated areas, and rising global demand (Erenstein et al. 2022). Due to its remarkable adaptability, corn is widely cultivated in temperate, tropical, and subtropical zones, and is considered a fundamental cereal for food security and a relevant commodity in the international market (Santos et al. 2024a). It currently ranks third among the most produced cereals in the world, surpassed only by rice and wheat (Wani et al. 2021). Corn is an extremely versatile and multipurpose crop: in addition to its predominant use as animal feed, it plays an essential role in human nutrition in regions such as sub-Saharan Africa and Latin America, as well as in non-food applications (Erenstein et al. 2022). Industrially, it is a raw material for several products, such as corn oil, syrup, starch, flakes, dextrose, wax, cosmetics, alcohol and inputs for the leather industry (Suleman et al. 2022).

Brazil occupies a prominent position as a global food supplier, being the third largest producer of corn, responsible for approximately 12% of global production, behind only the United States (30%) and China (24%) (Bigolin & Talamini, 2024; Silva et al. 2024). Brazilian corn production occurs in two main harvests. The first accounts for 65% of the total, concentrated in the southern states — Rio Grande do Sul, Santa Catarina and Paraná — in addition to Minas Gerais. The second harvest stands out mainly in the states of Mato Grosso, Paraná and Mato Grosso do Sul (Lopes et al. 2023). In the Northeast, corn is the second most cultivated grain, and is of great importance in dryland agriculture (Matsunaga et al. 2023). In Brazil, corn cultivation is also essential for family and small-scale agriculture, characterized by the low use of technologies, such as machinery, improved seeds, correctives, fertilizers and other chemical inputs; generally carried out in small areas and with a small number of workers (Abreu et al. 2022).

Although Brazil has high productivity rates and a prominent position in global corn production, in the Brazilian Northeast (NEB), most of the mesoregions still adopt subsistence farming practices, with little or no mechanization and low technological level (Silva et al. 2024). In the state of Paraíba, the Brejo Paraibano microregion is an important agricultural hub, benefiting from edaphoclimatic conditions favorable to production (Sousa & Pereira, 2016).

In this context, considering the relevance of corn cultivation for local agriculture, this study aimed to analyze the productive dynamics of corn in the Brejo Paraibano microregion, from 2000 to 2023, aiming to understand the factors that influence this production chain, as well as the challenges to be faced.

Material and Methods

The Brejo Paraibano microregion (Figure 1), composed of the municipalities of Alagoa Grande, Alagoa Nova, Areia, Bananeiras, Borborema, Matinhas, Pilões and Serraria, covers a total area of 1,168.3 km² and a population of 113,307 inhabitants (IBGE, 2025). Located on the eastern escarpment of the Borborema Plateau, the region stands out for its favorable edaphoclimatic conditions, such as high rainfall and fertile soils. These characteristics make this region highly suitable for agriculture, favoring the development of dense vegetation and creating ideal conditions for the cultivation of temporary crops, such as corn (Arruda et al. 2022).

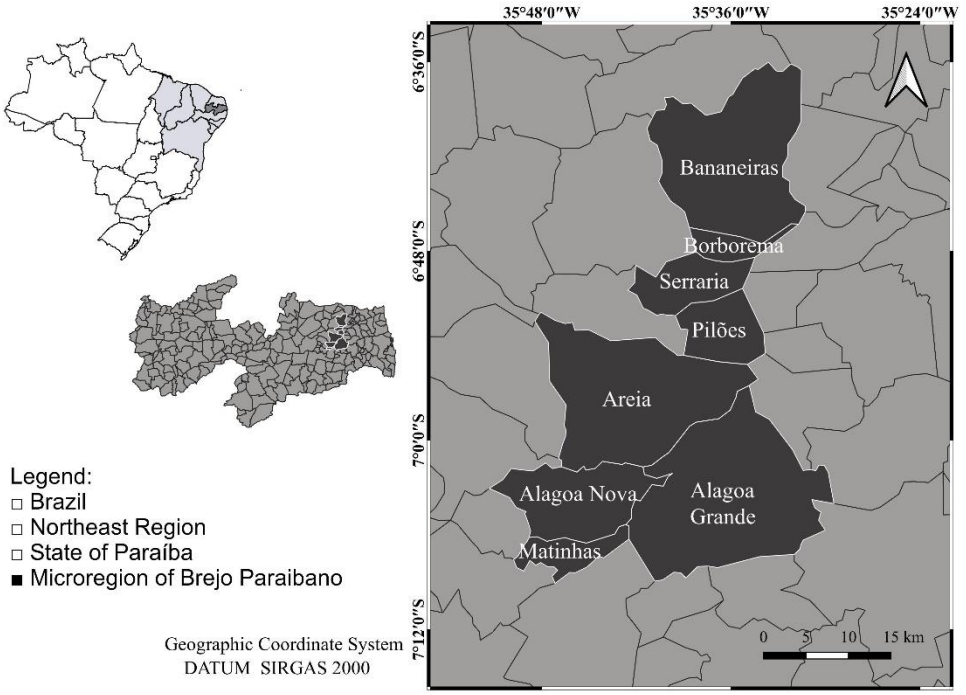

Figure 1. Location of the Brejo Paraibano microregion. Source. Prepared by the authors (2025).

For this study, corn production data were extracted from the Municipal Agricultural Research database, made available by the Brazilian Institute of Geography and Statistics (IBGE). Specifically, data from Table 1612 (Information on permanent crops) were used, from which information on corn production in Brejo Paraibano from 2000 to 2023 was obtained, using the Automatic Recovery System (SIDRA, 2025).

Six variables related to corn production were evaluated: (a) area intended for harvest in hectares (ha), which represents the total annual area cultivated with this crop in the microregion; (b) harvested area in hectares (ha), which corresponds to the total annual area actually harvested; (c) quantity produced in tons (t), which reflects the annual quantity of corn produced; (d) productivity in kilograms per hectare (kg/ha), calculated by the ratio between the quantity produced and the area harvested; (e) production value (in thousands of R$), calculated by the weighted average of the information on quantity and average price paid to the producer; (f) production value - percentage of the overall total, which indicates the participation of corn crops in the total value of production of temporary crops in Brejo Paraibano.

After extracting the data, they were organized into graphs and the data matrix was subjected to a Principal Component Analysis (PCA) to reduce the dimensionality of the variables and provide a clearer view of the data, without compromising the original information, ensuring its maximum preservation (Bhattacharya et al. 2020). Principal Component Analysis (PCA) has become popular as a tool to identify interannual patterns of agricultural production and has been successfully applied to assess the temporal dynamics of production in several agricultural crops, such as sugarcane (Pessoa et al. 2021), banana (Santos et al. 2024b), mango (Santos et al. 2024c), beans (Araújo et al. 2021; Santos et al. 2021) and corn (Silva et al. 2021; Araújo et al. 2025).

Additionally, a hierarchical cluster analysis (HCA) combined with a heat map (Heatmap) was used to group years with similar production characteristics. Both analyses were performed with the aid of R software, version 4.2.0 (R Core Team, 2025).

Results and Discussion

There was a strong fluctuation in the areas planted and harvested with corn in Brejo Paraibano (Figure 2), with a sharp temporal reduction in the areas destined for the production of this cereal.

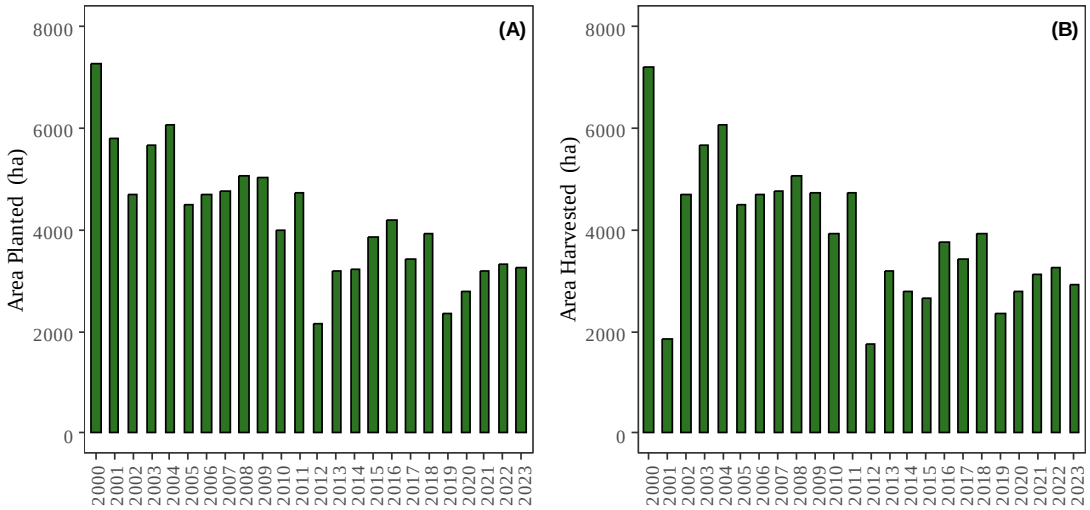

Figure 2. Area planted (A) and area harvested (B) with corn in Brejo Paraibano in the period 2000-2023. Source. Adapted from Sidra (2025).

The largest planted areas were observed at the beginning of the sampling period, especially in the year 2000, when 7,260 hectares were planted with corn in the aforementioned microregion. In contrast, in 2012, only 2,160 hectares were planted (Figure 2A). In 2012, one of the most severe droughts in the history of Northeast Brazil began, responsible for the drastic reduction in agricultural production in the region (Batista et al. 2018; Araújo et al. 2021). Even in areas with greater rainfall, such as Brejo Paraibano, production losses were recorded (Pessoa et al. 2021; Santos et al. 2024b).

Discrepancies between the planted area and the harvested area were observed in 11 of the 23 years sampled (2000, 2001, 2009, 2010, 2012, 2014, 2015, 2016, 2021, 2022 and 2023) (Figure 2B). Differences between these two variables, such as those observed in this study, are reported in several other studies on production dynamics in Northeast Brazil, both in temporary crops (Luna et al. 2021; Silva et al. 2021; Araújo et al. 2025) and in permanent crops (Santos et al. 2024c). These differences are mainly associated with variations in rainfall during the crop cycle, which compromises final productivity and, in extreme cases, makes harvesting economically unfeasible (Araújo et al. 2021; Santos et al. 2021).

As with the planted area, the largest harvested areas were also recorded in 2000, with 7,200 hectares, although, in that year, the harvested area was smaller than the planted area. The smallest harvested areas were recorded in 2012, when only 1,770 hectares of corn were harvested. A sharp reduction in the harvested area of corn was also recorded in that same year in other regions of Northeastern Brazil, such as in producing areas of Alagoas (Santana et al. 2023) and in other regions of Paraíba (Silva et al. 2021; Araújo et al. 2025).

The amount of corn produced in Brejo Paraibano ranged from 4,610 tons in 2000 to 383 tons in 2012 (Figure 3A). Relative stability was observed in this variable from 2003 to 2008, when local corn production was always above 2,800 tons. In contrast, after 2012, a downward trend was observed, with a slight recovery from 2016 onwards, but production of over 2,800 tons was only achieved in 2022. In recent years, public and private efforts have given new impetus to corn cultivation in several regions of the Northeast, especially with the introduction of more productive cultivars adapted to soil and climate conditions, which has generated higher production, even in smaller areas.

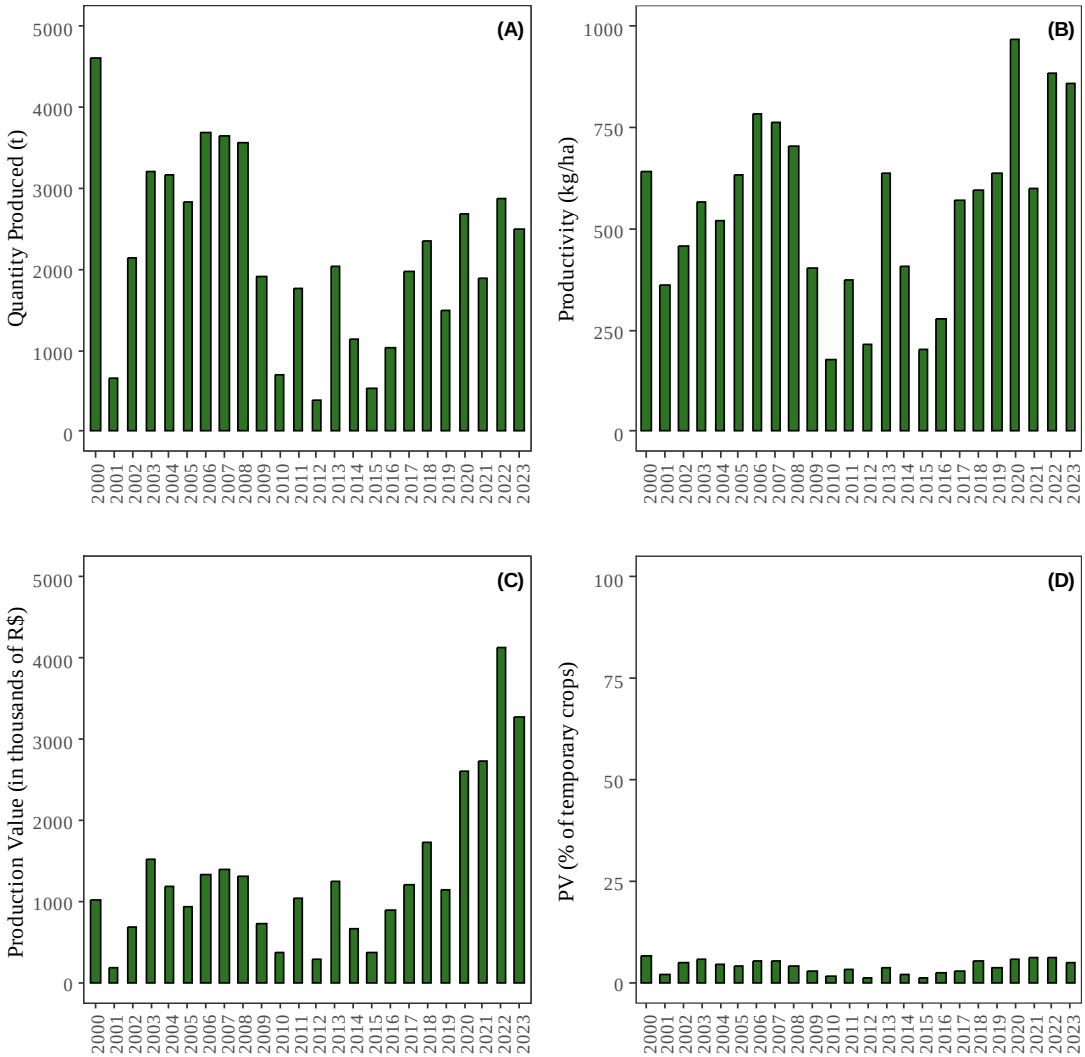

Figure 3. Quantity produced (A), productivity (B), production value (C) and production value (% of temporary crops) (D) of corn in Brejo Paraibano in the period 2000-2023. Source. Adapted from Sidra (2025).

Unlike what was observed for the variables reported previously, higher corn yields were recorded at the end of the sampling period, especially in 2020, 2022 and 2023, when yields of over 800 kg/ha were achieved (Figure 3B). These results demonstrate the impact of the use of new cultivars and appropriate agronomic management for this crop.

In 2020, which recorded a productivity of 968 kg/ha, the average yield of this crop locally was higher than the yield in Paraíba (794 kg/ha), but lower than the productivity of this cereal in the Northeast region (3,504 kg/ha) and in Brazil (5,695 kg/ha) for the same period (SIDRA, 2025). These results show that, even with the efforts already made, there is still a need for adjustments in this production chain, especially regarding the availability of technical assistance and the use of adequate inputs (Santana et al. 2021).

The value of corn production in the municipalities of the Brejo Paraibano microregion had minimum values of R$ 182,000 in 2001 and maximum values of R$ 4,119,000 in 2022 (Figure 1C). It is noteworthy that, as of 2020, production values have always been higher than R$ 2,500,000, which shows a trend of productive and economic improvement of this crop at the local level. Agriculture is one of the main economic activities in this region, and corn production, in addition to the economic aspect, has a high cultural appeal, with emphasis on food sovereignty. Corn cultivation had a low representation in the total value of production of temporary crops in the microregion, with a percentage share of less than 10% throughout the entire period analyzed (Figure 3D). The highest contribution percentages were recorded at the beginning of the historical series, in 2000 (6.45%), and more recently in 2021 and 2022 (6.33%), which indicates a possible new boost for this crop in Brejo Paraibano.

The municipality of Alagoa Grande stands out as the main corn producer in the microregion (Table 1). In 2023, the municipality presented the highest values for planted and harvested area, in addition to leading in quantity produced and production value. Regarding productivity, Alagoa Grande and Serraria recorded the best performances, with an average yield of 1,200 kg/ha. Despite this, these values remain significantly below the national average for the same period, which was 5,913 kg/ha (SIDRA, 2025).

Table 1. Planted area (AP), harvested area (AC), quantity produced (QP), productivity (PROD), production value (VP) and percentage production value of temporary crops (VPP) of corn in the municipalities of Brejo Paraibano in the year 2023.

Municipality	AP (ha)	AC (ha)	QP (t)	PROD (kg/ha)	VP (x R$ 1.000)	VPP (%)
Alagoa Grande	1100	1100	1320	1200	1848	6.78
Alagoa Nova	310	310	155	500	202	1.91
Areia	450	200	150	750	150	1.45
Bananeiras	450	360	144	400	187	3.94
Borborema	60	60	42	700	50	2.24
Matinhas	380	380	266	700	319	11.66
Pilões	350	350	245	700	294	8.41
Serraria	150	150	180	1200	216	5.07

Source. Adapted from Sidra (2025).

The largest share of corn in the total value of production from temporary crops was recorded in the municipality of Matinhas, where, unlike what occurs in most municipalities in the microregion, this crop accounted for more than 10% of the total. In contrast, the lowest percentage was observed in Areia, with only

1.45%. In this municipality, it is worth noting that the areas designated for temporary crops are used almost exclusively for the cultivation of sugarcane (Pessoa et al. 2021).

The principal component analysis (PCA) explained 90.8% of the original variance of the data in its first two axes (PC1 and PC2) (Figure 4). On axis 1, which grouped 57.4% of the data variance, a positive association was observed between Quantity Produced (QP) ($r = 0.95$; $p<0.01$), Percentage Production Value of Temporary Crops (VPP) ($r = 0.93$; $p<0.01$) and Productivity (PROD) ($r = 0.82$; $p<0.01$). These results demonstrate that, for the study region, larger quantities of corn produced are directly related to obtaining higher productivity, and not to larger planted areas, as observed in some other producing regions in the Northeast (Santana et al. 2021).

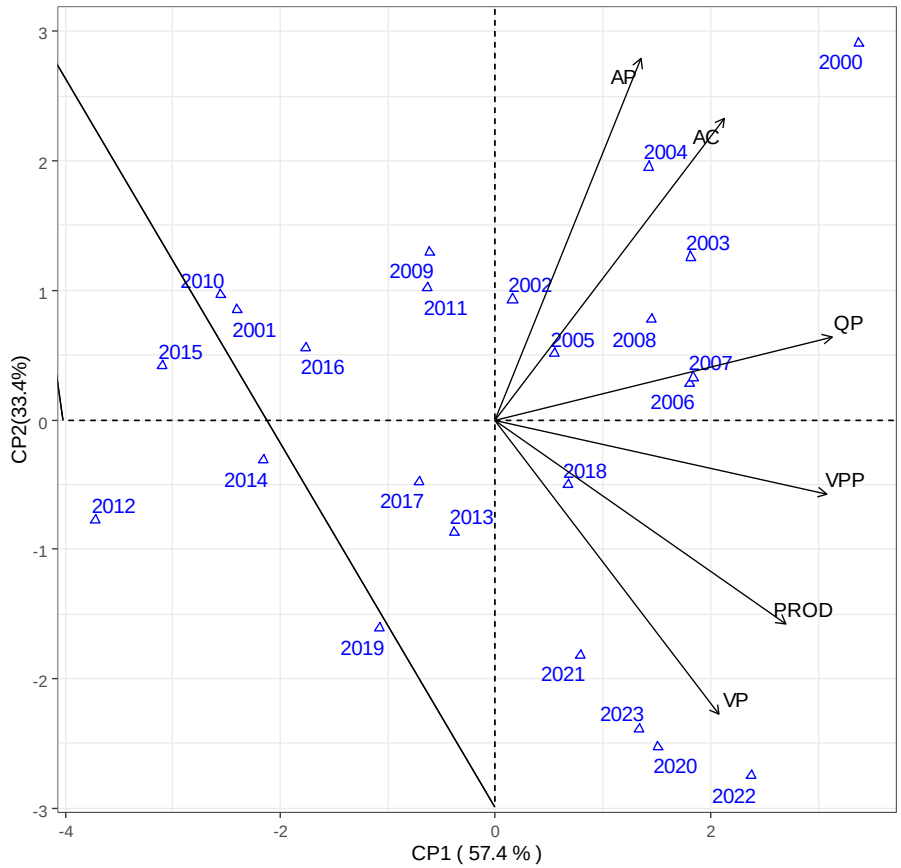

Figure 4. Biplot graphic dispersion of corn production in Brejo Paraibano, in the period 2000-2023, and based on scores of 6 productive traits, represented by the first two principal components: Planted area (AP), harvested area (AC), quantity produced (QP), productivity (PROD), production value (VP)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

On axis 2, which accounted for 33.4% of the variance, the association of Planted Area (AP) ($r = 0.84$; $p<0.01$) and Harvested Area (AC) ($r = 0.70$; $p<0.01$) was observed, which contrasted with the Production Value (VP) ($r = -0.69$; $p<0.01$). For this axis, the years 2000, 2003 and 2004 stand out, as they presented the largest planted and harvested areas, but with low production values.

From the hierarchical cluster analysis, 5 clusters were formed, grouping the years with similar production characteristics (Figure 5).

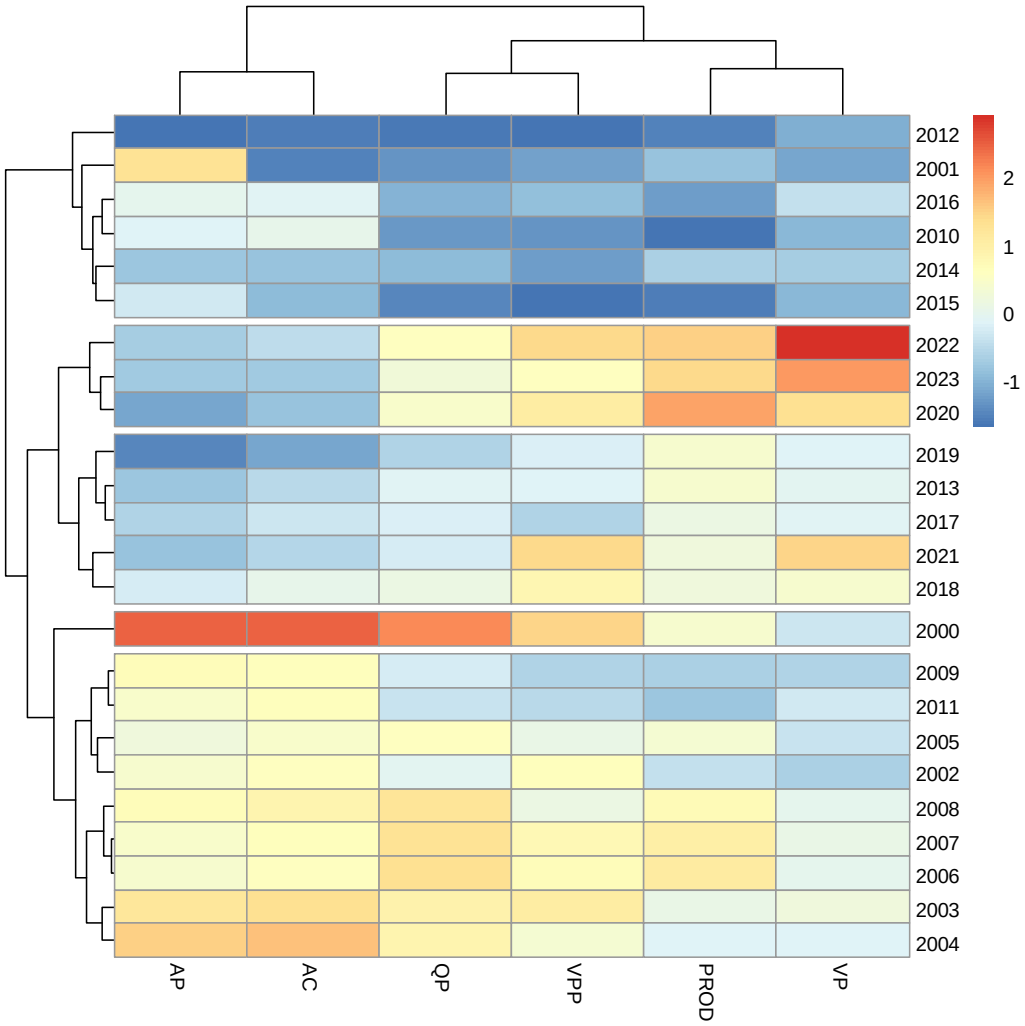

Figure 5. Hierarchical cluster analysis and heat map based on the years evaluated and productive traits. The colors red and blue represent the importance, from highest to lowest, respectively. Planted area (AP), harvested area (AC), quantity produced (QP), productivity (PROD), production value (VP) and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

The years 2020, 2022 and 2023 were grouped together, sharing the best productive metrics, especially the highest productivity and production value values (Figure 5). Regarding the planted area, harvested area and quantity produced, the year 2000 was grouped together in isolation, presenting the highest values of these variables. The years 2001, 2010, 2012 and the period from 2014 to 2016 were grouped together, sharing the worst productive performance of the sample series.

Considering the results obtained, it can be seen that, although there was a temporary reduction in the planted area and harvested area, gains were observed in productivity. This shows that, for Brejo Paraibano, there is a high potential for increasing the amount of corn produced, without, however, needing to expand the areas destined for the cultivation of this cereal. However, strategies to make local productivity competitive need to be implemented, such as the use of new cultivars, especially those developed for local soil and climate conditions, in addition to correct nutritional and phytosanitary management and the provision of technical assistance.

Conclusions

Corn production in Brejo Paraibano has shown significant interannual variability, with a sharp decline in the planted and harvested area. However, in recent years, there has been an increase in productivity, although the values still remain well below the national average.

Given the economic and cultural importance of corn for the microregion, efforts must be made to improve the local yield of this crop, such as the technological development of production. These actions are essential to ensure the sustainable growth of corn production and the economic strengthening of this production chain in Brejo Paraibano.

References

Abreu PADS, Costa BRS, Oldoni H, Silva WTL, Bassoi LH 2022. Corn crop responds positively to fertigation with black water from sewage treated by decentralized anaerobic system. *Ciência e Agrotecnologia* 46:e001222.

Araújo JRES, Batista MC, Sabino BTS, Almeida IVB, Abreu KG, Araújo EFB, Santos JPO 2021. Agricultura de sequeiro e variabilidade produtiva de uma cultura de subsistência em Gado Bravo, Semiárido da Paraíba. *Diversitas Journal* 6(3):2905-2918.

Araújo JRES, Silva JHB, Souza Júnior SL, Santos JPO 2025. Dinâmica Interanual da Produção de Milho em Aroeiras/PB, Brasil. *Vivências* 21(42):345-356.

Arruda LV, Rodrigues LPM, Silva IC, Souza RS 2022. Configuração geoambiental e dinâmica do espaço agrário atual do Brejo Paraibano (PB), Paraíba, Brasil. *Ciência Geográfica* 26(1):72-102.

Batista MC, Santos JPO, Silva Filho JA, Sousa JI, Silva Félix RJ, Silva JLC 2018. Influence of rainfall variability on bean production (*Phaseolus vulgaris* L.) in a municipality of Brazilian semiarid. *Journal of Environmental Analysis and Progress* 3(1):001-007.

Bhattacharya S, Maddikunta PKR, Kaluri R, Singh S, Gadekallu TR, Alazab M, Tariq UA 2020. A novel PCA-firefly based XGBoost classification model for intrusion detection in networks using GPU. *Electronics* 9(2):e219.

Bigolin T, Talamini E 2024. Impacts of climate change scenarios on the corn and soybean double-cropping system in Brazil. *Climate* 12(3):42.

Erenstein O, Jaleta M, Sonder K, Mottaleb K, Prasanna BM 2022. Global maize production, consumption and trade: trends and R&D implications. *Food security* 14(5):1295-1319.

IBGE *2025*. Cidades. Disponível em: https://cidades.ibge.gov.br/brasil. Acesso em: 10 de abril de 2025.

Lopes LS, Ramos GL, Alvarenga VO, Campagnollo FB, Oliveira SB, Freire L, Sant'Ana AS 2023. Quantitative risk assessment of the presence of fumonisin in corn produced in different regions of Brazil: Influence of climatic conditions. *Environmental research* 237:116907.

Luna IRG, Silva MR, Cartaxo PHA, Gonzaga KS, Santos JPO, Pereira DD 2021. Variabilidade pluviométrica e seus efeitos na produção de feijão-caupi em um município do semiárido paraibano. *Thema et Scientia* 11(1):255-265.

Matsunaga WK, Sales ESG, Assis Júnior GC, Silva MT, Lacerda FF, Lima EP, Santos CAC, Brito JIB 2024. Application of ERA5-Land reanalysis data in zoning of climate risk for corn in the state of Bahia—Brazil. *Theoretical and Applied Climatology* 155(2):945-963.

Pessoa GGFA, Alves AKS, Dantas ÉA, Almeida LJM, Silva JA, Araújo JRES, Silva DAM, Santos JPO 2021. Dinâmica temporal da produção de cana-de-açúcar em um município do Brejo Paraibano, Brasil (1995–2019). *Scientific Electronic Archives* 14(11):18-24.

R Core Team 2025. *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. Disponível em: https://www.R-project.org/. Acesso em: 10 de abril de 2025.

Santana WS, Pereira DD, Araújo JRES, Sousa VFO, Dias MS, Santos JPO 2023. Dinâmica Temporal da Produção de Milho em Pão de Açúcar, Alagoas, Brasil. *Revista Científica da Faculdade de Educação e Meio Ambiente* 14(2):158-169.

Santos JDA, Pedrotti A, Holanda FSR, Santos LDV, Andrade BMDS, Araújo Filho RN, Villwock APS, Gomes Filho RR, Conceição SF, Carvalho LDS 2024a. Impacts of the tillage systems on the production of green corn (*Zea mays* L.) in long-term plots in Northeastern Brazil. *Soil Use and Management* 40(2):e13061.

Santos JPO, Bulhões LEL, Cartaxo PHA, Gonzaga KS, Freitas ABTM, Ribeiro JKN, Pereira MCS, Dias MS, Xavier MA, Dantas EA 2021. Interannual variability of productive aspects of bean culture in a municipality in the Semi-arid region of Alagoas, Brazil. *Scientific Electronic Archives* 14(1):26-32.

Santos JPO, Bulhões LEL, Melo JAB, Lima DDS, Santos AS, Silva JHB, Silva LDR, Pereira DD, Sousa VFO, Nascimento IRS 2024c. Manga na Paraíba: Uma Análise Temporal (2002-2022) da Dinâmica da Produção. *Fronteira: Journal of Social, Technological and Environmental Science* 13(2):246-253.

Santos JP, Sousa VFO, Silva JHB, Santos GL, Silva AJ, Souza Júnior SL, Cruz JMFL, Diniz GL, Fátima RT 2024b. A bananicultura do Brejo Paraibano em transformação: um olhar temporal (2001-2021). *Revista Thema* 23(2):463-474.

Sidra 2025. *Produção Agrícola Municipal*. Disponível em: https://sidra.ibge.gov.br/pesquisa/pam/tabelas. Acesso em: 10 de abril de 2025.

Silva FDDS, Peixoto IC, Costa RL, Gomes HB, Gomes HB, Cabral Júnior JB, Araújo RM, Herdies DL 2024. Predictive Potential of Maize Yield in the Mesoregions of Northeast Brazil. *AgriEngineering* 6(2):881-907.

Silva MR, Luna IRG, Santos JPO, Pereira DD, Nascimento IRS, Silva DAM, Cartaxo PHA, Luna Neto EV, Alves AKS, Araújo JRES 2021. Variabilidade Pluviométrica e a Produção de Milho no Curimataú Ocidental da Paraíba. *Revista Gestão & Sustentabilidade Ambiental* 10(3):247-259.

Sousa DS, Pereira WE 2016. Atividade agrícola do brejo paraibano: declínio e tendências atuais. *Revista Brasileira de Agropecuária Sustentável* 6(3):11-20.

Suleman M, Ashraf M, Raza QUA, Bashir MA, Rahman SU, Aon M, Ali S, Shahzad M, Khalid MU, Raza MA, Raza HMA, Rehim A, Du Z 2022. Determining the cadmium accumulation in maize (*Zea mays* L.) and soil influenced by phosphoric fertilizers in two different textured soils. *Land* 11(8):1313.

Wani SH, Vijayan R, Choudhary M, Kumar A, Zaid A, Singh V, Kumar P, Yasin JK 2021. Nitrogen use efficiency (NUE): elucidated mechanisms, mapped genes and gene networks in maize (*Zea mays* L.). *Physiology and Molecular Biology of Plants* 27(12):2875-2891.