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# Sesame: A viable economic alternative for off-season double cropping systems in Mato Grosso, Brazil

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ABSTRACT

This study investigates the economic feasibility of sesame (*Sesamum indicum L*) cultivation as an alternative to off-season double cropping systems in Mato Grosso, Brazil, focusing on the period from 2016 to 2023. By employing a combination of qualitative and quantitative methodologies, it scrutinizes production costs, profitability, and climatic risks associated with both crops. The findings reveal that sesame cultivation entails consistently lower production costs, yielding superior margins, and exhibiting remarkable resilience against economic and climatic adversities compared to off-season maize. Despite minor fluctuations, sesame demonstrates stability in profitability, mitigating the impact of climatic risks on farmers' financial outcomes. Through its comprehensive analysis, this research not only underscores the economic advantages of sesame cultivation but also emphasizes the importance of considering climatic risks in agricultural decision-making. By offering invaluable insights into the economic viability of sesame cultivation amidst climatic challenges, this study contributes to informed policy formulation and agricultural practice refinement in Brazil.



## Introduction

Brazil holds a prominent position in global agricultural production, serving as a crucial contributor to global food security. Its vast land area and diverse climatic conditions provide optimal conditions for cultivating a wide range of crops. Brazilian agriculture not only meets domestic demands but also plays a pivotal role in the global market, reinforcing global food security (Martinelli et al., 2010; USDA, 2023).

The ability to conduct two crop seasons annually in Brazil is a notable advantage, facilitating efficient production optimization and solidifying the nation's position as a leading agricultural producer (Nóia Júnior & Sentelhas, 2019a). This off-season cropping, which refers to crops that are sown after the summer crop has been harvested (also referred to as the 'safrinha' or 'segunda safra' in Portuguese), is particularly significant given the prominence of crops such as maize and sorghum (Battisti et al., 2020; Pires et al., 2016; Souza et al., 2018). From here on, we will adopt the term off-season cropping. Presently, over 80% of Brazil's maize output originates from the off-season cropping, typically following soybean harvest. However, off-season cropping cultivation entails heightened climatic risks, resulting in notable interannual yield fluctuations (Bigolin & Talamini, 2024; Nóia Júnior & Sentelhas, 2019b). Consequently, amidst these challenges and the volatility of maize prices, there arises an urgent need to explore alternatives that not only complement but also optimize yields during this period (CEPEA, 2023).

In times of volatility in maize production and pricing, identifying opportunities in alternative crops becomes imperative to ensure the economic viability of Brazilian farmers (Battisti et al., 2020; Peri, 2017; Nóia Júnior & Sentelhas, 2019a). Sesame (*Sesamum indicum L*), with its favorable growth attributes and versatility - including short cropping cycles, ease of management, low production costs, adaptability, income-generating potential, and increasing demand emerges as a promising alternative deserving further scrutiny (Arriel et al., 2007; Dossa et al., 2023; Zhang et al., 2021). Brazil has recently experienced notable growth in sesame exports, particularly to markets like India, following the opening of trade ways to that nation (Ibrafe, 2022; MAPA, 2022). The escalating international demand for sesame has positively affected prices, making it a more attractive option for Brazilian producers (Apex, 2022a). The sesame cropping area surged from 53 thousand hectares in the 2018/2019 season to 175 thousand hectares in the 2019/2020 season, with sesame grain exports reaching approximately US$ 70.3 million in 2020, representing a 2.2% share of the global market (Apex, 2022a; Embrapa, 2021). This underscores both the economic significance of sesame and Brazil's strategic positioning in global agricultural markets, notwithstanding outdated and infrequently updated sowed area statistics.

This study aims to contribute to understanding the diversification of Brazil's off-season cropping, focusing on sesame's potential as a viable alternative amidst economic challenges and market uncertainties in agriculture. By evaluating its feasibility, the study endeavors to bolster farmers' resilience and elevate Brazil's stature as a frontrunner in innovation and sustainable agricultural adaptation on the global stage. It is anticipated that sesame cultivation will offer advantages in terms of profitability, adaptability, and environmental sustainability compared to other crops conventionally grown during the off-season. Thus, this paper seeks to assess this viability, furnishing pertinent insights for the diversification and optimization of agricultural practices during off-season, after the summer crop has been harvested.

## Material and Methods

The current study employed a combination of qualitative and quantitative methods to assess the feasibility of sesame cultivation as an alternative for off-season cropping, cultivated after the harvest of summer crops, in Brazil. Spanning from 2016 to 2023, the research focused on gathering data related to production costs, profitability, and margins. Our study, while having implications for the entire Brazilian territory, focused on the state of Mato Grosso as a case study example.

### Data Collection

Production cost data were gathered through consultations with agricultural experts and consultants in Mato Grosso, the primary sesame-producing region. Prices for various inputs were sourced from CONAB databases and local retailers. Official data from the Mato Grosso Institute of Agricultural Economics (IMEA) provided maize prices, while sesame prices were obtained from industry specialists.

The state of Mato Grosso is classified into two climate zones according to Koppen (Alvares et al., 2013): Monsoon climate, characterized by significant rainfall throughout the year and one dry month (Am), and savanna climate, characterized by significant rainfall throughout the year and a dry winter (Aw). Within the state, we selected eight municipalities equally spaced geographically (Table 1). For these municipalities, we downloaded data on maximum and minimum air temperature (°C), global solar radiation (MJ $m^{-2}$ $d^{-1}$), rainfall (mm), wind speed ($m^{-2}$ s) and relative humidity (%), all on a daily scale, from the NASA Power Prediction of Worldwide Energy Resources (NASA Power) system. We conducted a climatic risk analysis for sesame compared to off-season maize for these eight municipalities.

### Cost Analysis

The analysis considered all relevant factors, including fertilizers, pesticides, labor, seeds, post-harvest expenses, financial costs, taxes, and depreciation. Lease costs were excluded, as they are specific to the summer crop (soybean).

### Profitability and Margin Analysis

Profitability was calculated by comparing selling prices with production costs for both crops. Margins were then assessed to provide additional insights into economic performance.

**Table 1.** Municipalities from where the weather stations (WS) were selected, their associated geographical coordinates.

| Municipalities | Latitude | Longitude |
|---|---|---|
| Alto Garças | -53.58 | -16.88 |
| Bom Jesus do Araguaia | -51.74 | -12.22 |
| Ipiranga do Norte | -56.06 | -12.01 |
| Juruena | -58.59 | -10.36 |
| Marcelândia | -54.05 | -10.89 |
| Poconé | -56.94 | -16.78 |
| Santa Rita do Trivelato | -55.29 | -13.83 |
| Tangará da Serra | -58.32 | -14.42 |

### Climatic Risks analysis

We considered the number of days with maximum air temperature above 35 °C as the number heat, maximum air temperature above 30 °C as moderate heat, ratio between actual and potential evapotranspiration (ETa/ETp) below 0.6 as moderate drought and ETa/ETp below 0.3 as drought. The ratio between actual and potential evapotranspiration (ETa/ETp) is essential for assessing plant water availability. It indicates the level of water stress, helping to determine whether the crop is receiving sufficient water to reach its full productive potential. In order to consider the impact of compounded climatic events, which occur when two extreme weather events happen simultaneously, we constructed the variable compound of heat and drought, which is the number of days when heat (Max air Temp > 35 °C) and drought (ETa/ETp < 0.6) occur simultaneously. The choice of thresholds was intended to reflect environmental conditions to which most of the crops generally exhibited sensitivity. The potential evapotranspiration (ETp) was calculated using the Penman-Monteith method, on a daily scale. Actual evapotranspiration (ETa) was derived from the daily soil water balance based on the Thornthwaite and Mather method, with a maximum soil water holding capacity of 100 mm.

### Statistical Analysis

Standard deviation and other statistical metrics were utilized to analyze margin variability over the study period. The statistical analyses were carried out using the software Excel and R (R Core Team, 2017). To more clearly comparing sesame and off-season maize in terms of exposure to extreme weather events, we conducted a PCA (Principal Component Analysis). Although both sesame and maize can be cultivated within the same cropping season (as they can serve either as a summer crop or an off-season crop), with distinct sowing periods, maize remains the predominant off-season crop following the summer harvest in the state of Mato Grosso. Thus, we consider maize the most appropriate reference for any comparison involving alternative off-season cropping systems.

PCA is a statistical technique used to reduce the dimensionality of large datasets while preserving as much variability as possible. It identifies the principal components—new variables that capture the most significant variation in the data—allowing us to visualize patterns and relationships between the variables, such as exposure to extreme weather events.

The PCA was carried out by using the differences of the following five variables: heat (number of days with Max Temp > 35 °C), moderate heat (Max air Temp > 30 °C), drought (ETa/ETp < 0.3), moderate drought (ETa/ETp < 0.6), and the compound of heat and drought climatic factor (when heat and drought occur simultaneously on the same day). The PCA method reduces the dimensionality of data with a large number of measured variables by transforming these to a new, considerably smaller set of variables called Principal Components (PCs). Both crops (sesame and off-season maize) were submitted to a PCA, in two different sowing dates, 1st February and 1st March. The data were standardized by dividing the difference between each data point and the arithmetic mean of the variable of interest by the standard deviation of the variable, so that the results were not influenced by the magnitude of the variable units. Two PCs were selected considering all variables, following the criterion indicated by Kaiser (1974), which is based on the presence of PCs with eigenvalues >1. Further information about principal component analysis can be found in Demšar et al. (2013) and Yeater et al. (2015).

This methodological approach enabled a thorough and well-grounded examination, yielding valuable insights into the economic viability of sesame cultivation as an alternative to off-season crop in Brazil.

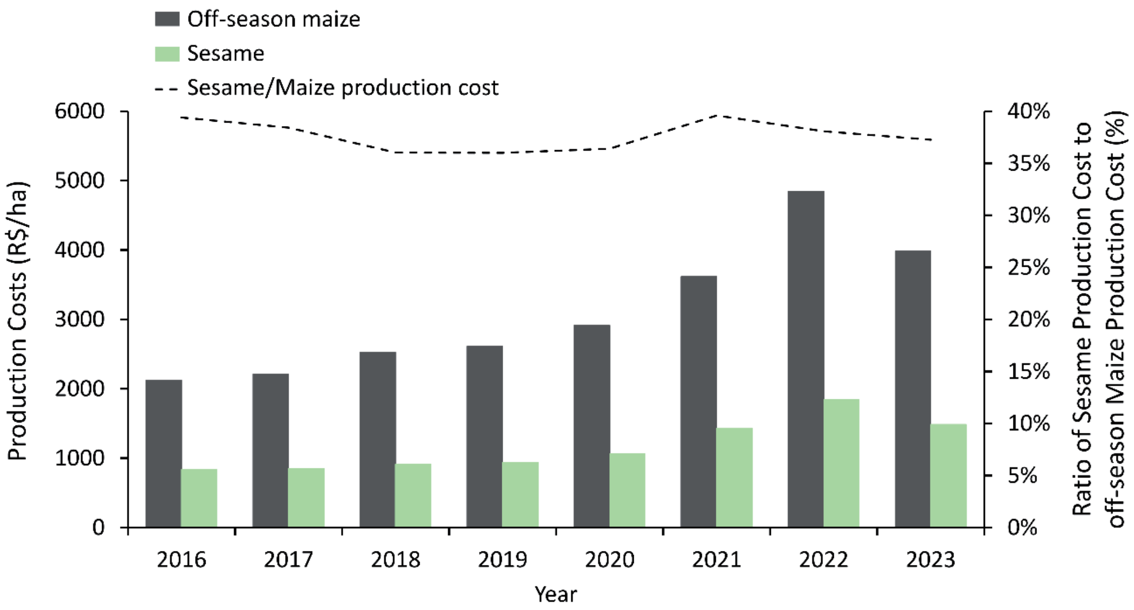
## Results and discussion

### Production Costs and Profitability

The results reveal a significant disparity in production costs between sesame and off-season maize during the off-season cropping period. Particularly, the cost associated with sesame crop proved to be substantially lower, representing less than 40% of the cost of off-season maize over the analyzed period (Figure 1). This finding is crucial for assessing the economic viability of sesame as an agricultural alternative, especially considering the significant impact of production costs on farmers' decisions.

The substantial difference in production costs directly reflects in the profitability achieved by farmers, indicating that sesame crop emerges as a more financially viable option (Figure 2). This aspect is of utmost importance, considering that sesame not only requires lower initial investment but also entails lower financial risk for

**Figure 1.** Production Costs (R$/ha) and Sesame Production Cost/Off-season Maize Production Cost Ratio.




producers. The reduction in production costs is attributed to the lesser-input demand for sesame compared to off-season maize, owing to its high productivity. Indeed, the costs associated with off-season maize cultivation are, on average, 2.2 times higher for fertilizers, 1.8 times higher for pesticides, 2.2 times higher for operations, 3.3 times higher for seeds, 5.3 times higher for post-harvest, 3.3 times higher for financial costs, and 1.3 times higher for depreciation compared to sesame.

The preference for lower-cost crops like sesame not only alleviates financial pressure on farmers but also provides an effective strategy to mitigate risks associated with price fluctuations in agricultural commodity markets. In an economic uncertainty context, opting for sesame cultivation emerges as a strategic decision that can contribute to farmers' economic stability, thus promoting long-term sustainability.

Profitability analysis between sesame and off-season maize from 2016 to 2023 reveals interesting patterns and offers valuable insights into the economic dynamics of these crops.

The observation that sesame profit exceeded that of off-season maize in the years 2016, 2017, 2018, 2019, and 2023 underscores sesame's consistent ability to provide attractive financial returns for farmers for most of the analyzed period option (Figure 3). This suggests that, under normal market conditions, sesame cultivation has proven to be an economically advantageous option compared to off-season maize.

The shift in profit patterns in 2020, 2021, and 2022, where profits from off-season maize were substantially higher, is closely linked to maize price fluctuations during that period. The significant increase in maize prices during these years resulted in higher profitability for farmers engaged in maize cultivation (Figure 3). However, the observation that sesame profitability regained the upper hand in 2023 suggests a potential normalization of maize prices, making sesame once again a competitive option in terms of profitability.

It is relevant to highlight those variations in sesame profitability over the period are notably lower compared to those of off-season maize. The lower standard deviation of sesame (R$ 193) indicates relative stability in returns over time, suggesting that sesame may offer more consistent financial predictability for farmers. In contrast, the higher standard deviation of off-season maize (R$ 1,496) reflects greater volatility in returns, indicating significant sensitivity to changes in maize prices.

This lower volatility in sesame profitability can be attributed to the steady demand growth for this product, as well as its lower sensitivity to market factors compared to maize. A report by Mordor IntelligenceTM (2023) indicates that the sesame grain market will grow from USD 7.4 billion in 2023 to USD 8.5 billion in 2028. The financial predictability offered by sesame may be an additional factor contributing to its attractiveness as an off-season crop.

Margin analysis between sesame and off-season maize over the investigated period highlights distinct trends, providing valuable insights into the relative profitability of these crops.

In general terms, the observation that sesame margins consistently exceed those of off-season maize in most years suggests an intrinsic economic advantage to sesame cultivation. This consistency in positive margins indicates sesame's overall ability to provide higher net returns for

**Figure 2.** Off-season Maize and Sesame Profit Over the Years.

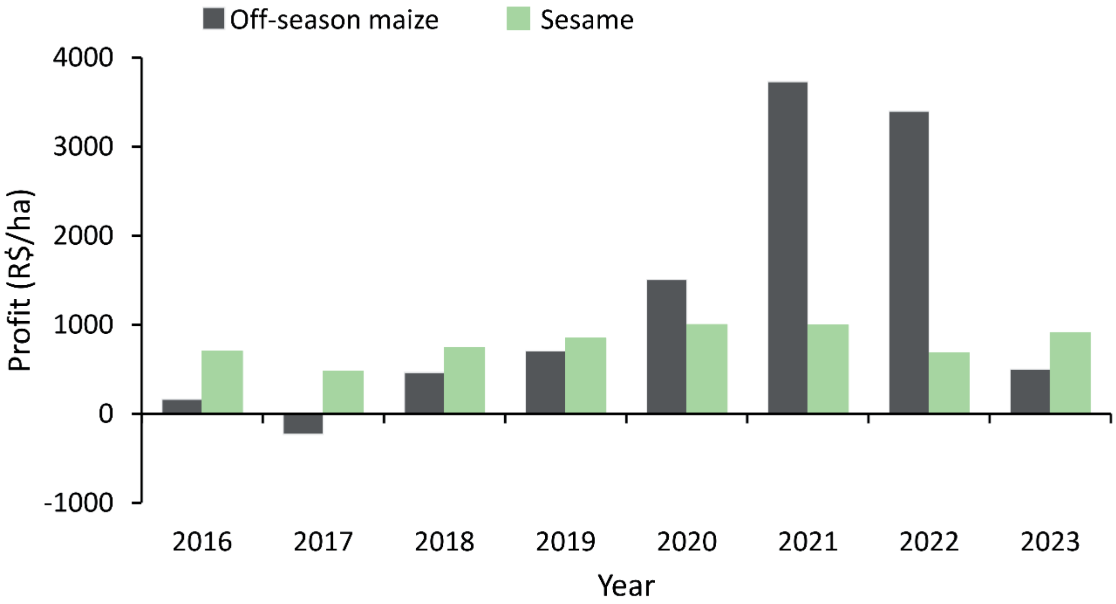
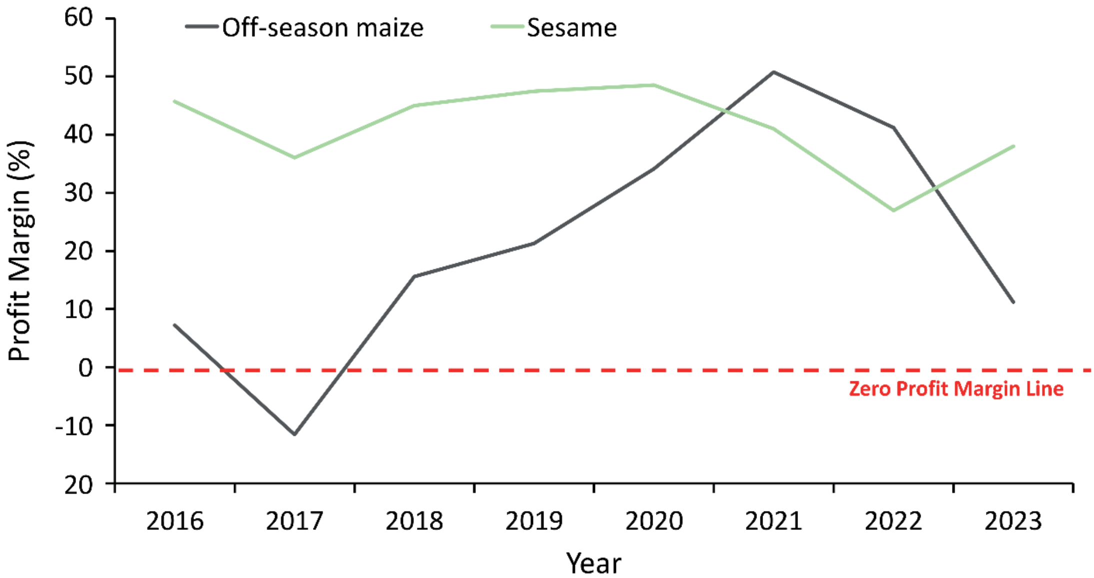



**Figure 3.** Off-season Maize and Sesame Margins Over the Years. The red dashed line indicates the Zero Profit line, highlighting where the profit margin equals zero.




farmers, regardless of market fluctuations.

However, the exceptions in the years 2021 and 2022, where sesame margins were lower than those of off-season maize, highlight the sensitivity of these margins to changes in production costs and market prices. The significant increase in sesame production costs, particularly related to pesticides and fertilizers, without a corresponding increase in sesame prices, contributed to this reversal in margins. This phenomenon underscores the importance of considering not only selling prices but also production costs when assessing the economic viability of a crop.

The years 2021 and 2022 presented a particularly challenging scenario, as international maize prices were heavily influenced by instability resulting from the war between Ukraine and Russia, as well as the global disruptions caused by the COVID-19 pandemic (Carriquiry et al., 2022). This geopolitical context had a significant impact on off-season maize margins, making them superior to those of sesame. This observation highlights the influence of external factors and unexpected events on the global agricultural commodity market, emphasizing the complexity and volatility of this sector.

However, even with these variations in the mentioned years, the overall margin analysis indicates that sesame remains a more profitable and stable option compared to off-season maize. The lower variability in sesame margins, indicated by the lower standard deviation (24%), suggests greater consistency in net returns over time, reducing financial risk for farmers. In contrast, the higher standard deviation (37%) in off-season maize margins reflects greater volatility, highlighting this crop's sensitivity to external factors and changes in market conditions.

In summary, the results underscore that sesame not only presents higher margins in most cases but also exhibits greater resilience to market shocks, making it an attractive alternative for the Brazilian off-season. The lower variability in margins, coupled with lower outlays and reduced risk, reinforces sesame's position as a promising choice for farmers seeking to optimize profitability and effectively manage economic challenges in agricultural production.

**Climatic Risks**

For climatic risk analysis, we consider five variables: heat (number of days with Max air Temp > 35 °C), moderate heat (Max air Temp > 30 °C), drought (ETa/ETp < 0.3), moderate drought (ETa/ETp < 0.6), and the compound of heat and drought climatic factor (when heat and drought occur simultaneously on the same day). Initially, our focus will be on heat, drought, and the compound of drought and heat. Subsequently, we will utilize all five variables in a PCA analysis to better characterize the climatic risks of sesame compared to off-season maize.

We consider that off-season maize has an average cycle of 140 days, while sesame has an average cycle of 110 days. Our analyses were conducted for eight representative municipalities and producers within the state of Mato Grosso, Brazil. Due to the shorter cycle of sesame, there is less exposure to extreme climatic events that may occur when the crops are in the field. For example, if planted in February, off-season maize would have an average exposure to drought ranging from 11 to 28 days depending on the location, while sesame would have 1 to 10 days of exposure (Table 2). Similarly, off-season maize would have exposure of 0 to 21 days to heat and 0 to 9 days to the compound of heat and drought, whereas sesame would have an average exposure of 0 to 17 days to heat and 0 to 5 days to the compound of heat and drought (varying according to the locality).

If there is a delay in sowing, and both off-season maize and sesame are cultivated at the beginning of March, more extreme weather events are expected for both crops (Table 3). This occurs due to the approach of the end of the rainy season in April in the region and the onset of the dry season in May (Nóia Júnior & Sentelhas, 2019a). Consequently, maize sown in March will have exposure varying by location, from 33 to 55 days with drought, 0 to 25 days with heat, and 0 to 15 days with the compound of heat and drought. On the other hand, Sesame has its exposure to drought reduced by more than half for all studied regions, ranging from 10 to 25 days of exposure to drought. Additionally, sesame will have a variation of 0 to 17.9 days with heat and 0 to 8 days with the compound of heat and drought, representing at least a 50% reduction in exposure compared to off-season maize.

After analyzing the spatial variation in the distribution of extreme weather events across the state of Mato Grosso, our findings indicate that drought is the predominant challenge faced in the region (Figure 4). Furthermore, it is observed that regions located further south such as Poconé (MT) and westward like Bom Jesus do Araguaia (MT) are those with the highest likelihood of being exposed to extreme weather events. Poconé is where there may be a higher frequency of heat and the compound of heat

**Table 2.** Average number of extreme climatic events during the maize and sesame-growing season when sown in February.

| Location | Number of extreme climatic events(*) | | | | | |
|---|---|---|---|---|---|---|
| | Drought | | Heat | | Compound | |
| | Crop | | | | | |
| | Maize | Sesame | Maize | Sesame | Maize | Sesame |
| Alto Garças | 20.1 | 4.9 | 0.0 | 0.0 | 0.0 | 0.0 |
| Bom Jesus do Araguaia | 27.8 | 5.3 | 3.3 | 0.6 | 2.9 | 0.3 |
| Ipiranga do Norte | 22.2 | 2.8 | 0.5 | 0.2 | 0.4 | 0.1 |
| Juruena | 11.9 | 1.7 | 0.5 | 0.2 | 0.5 | 0.2 |
| Marcelândia | 19.7 | 1.5 | 0.2 | 0.1 | 0.1 | 0.0 |
| Poconé | 25.6 | 10.1 | 21.8 | 17.7 | 8.8 | 5.3 |
| Santa Rita do Trivelato | 21.8 | 3.5 | 1.0 | 0.7 | 0.6 | 0.4 |
| Tangará da Serra | 11.7 | 1.3 | 0.0 | 0.0 | 0.0 | 0.0 |

(*)Number of days with heat (>35 °C), drought (ETa/ETp < 0.3), and the compound of heat and drought climatic factor (when heat and drought occur simultaneously on the same day) during off-season maize and sesame for sowing on the 1st of February.

**Table 3.** Average number of extreme climatic events during the maize and sesame growing season when sown in March.

| Location | Number of extreme climatic events(*) | | | | | |
|---|---|---|---|---|---|---|
| | Drought | | Heat | | Compound | |
| | Crop | | | | | |
| | Maize | Sesame | Maize | Sesame | Maize | Sesame |
| Alto Garças | 43.2 | 17.8 | 0.0 | 0.0 | 0.0 | 0.0 |
| Bom Jesus do Araguaia | 55.1 | 24.9 | 8.8 | 2.7 | 8.5 | 2.4 |
| Ipiranga do Norte | 48.5 | 19.5 | 2.3 | 0.4 | 2.3 | 0.4 |
| Juruena | 36.0 | 10.0 | 1.6 | 0.4 | 1.6 | 0.4 |
| Marcelândia | 46.6 | 16.8 | 1.5 | 0.0 | 1.5 | 0.0 |
| Poconé | 45.8 | 22.9 | 25.8 | 17.9 | 15.4 | 7.8 |
| Santa Rita do Trivelato | 47.4 | 19.1 | 1.5 | 0.8 | 1.3 | 0.6 |
| Tangará da Serra | 33.9 | 9.8 | 0.2 | 0.0 | 0.2 | 0.0 |

(*)Number of days with heat (>35 °C), drought (ETa/ETp < 0.3), and the compound of heat and drought climatic factor (when heat and drought occur simultaneously on the same day) during off-season maize and sesame for sowing on the 1st of March.

and drought among the studied regions, while all other regions are less exposed to heat and more exposed to the occurrence of drought. In this analysis, it is also noted how the choice of cultivating sesame compared to off-season maize can significantly reduce the average number of days during the cycle with exposure to at least one of the extreme weather events. The total number of days with exposure to one of these three events can vary to nearly 90 days in Poconé (MT) and Bom Jesus do Araguaia (MT) if off-season maize is sown in March, compared to 30 days if sesame is chosen for sowed in the same period and location.

To more clearly comparing sesame and off-season maize in terms of exposure to extreme weather events, we conducted a PCA analysis (Figure 5). From this analysis, it is noted that the points represented by off-season maize in dark gray are primarily distributed in the lower quadrants, where there are more occurrences of moderate heat, moderate drought, and drought if sown in February and more drought and moderate drought if sown in March. It is also observed that the variables heat, and the compound of heat and drought are strongly correlated, primarily pointing to Poconé (MT) (represented by the downward-pointing triangle) and Bom Jesus do Araguaia (MT) (represented by the upward-pointing triangle). The points in green, representing sesame, are mainly located in the first quadrant (upper left for those looking at Figure 5), moving in the opposite direction to any type of drought and heat.

In our study, we considered the number of extreme climatic events occurring during the off-season maize and sesame cropping period for the climate risk analysis, with the only difference between the crops being the length of the growing cycle—140 days for off-season maize and 110 days for sesame. However, it is important to highlight that the impact of extreme climatic events varies depending on the timing of their occurrence in relation to the crop's phenology. For instance, impacts during the flowering stage can be more pronounced than during the mid-vegetative stages (Nóia Júnior & Sentelhas, 2019b). Additionally, these crops may exhibit different sensitivities to specific extreme climatic events, which should also be considered. Our analysis simplified this by assuming that a higher or lower number of extreme climatic events during the growing cycle directly indicates higher or lower climate risk, respectively, without accounting for these other factors. We recommend that future studies incorporate these aspects for a more comprehensive risk assessment.

Another limitation of this study is the lack of analysis regarding the impacts of sesame cultivation on soil chemistry, physics, and biology, which are critical for assessing the sustainability of the cropping system, particularly when grown in succession to soybean. Without addressing soil health and protection, the long-term environmental consequences of widespread sesame cultivation remain uncertain. Future studies should incorporate these factors to provide a more comprehensive evaluation of the sustainability of this agricultural practice.

### Future Challenges and Opportunities for Sesame Cultivation in Brazil

Sesame faces significant challenges in production and commercialization in Brazil. Aspects such as nutritional management, agricultural mechanization - especially in harvesting - and seed and grain quality have been the focus of investigations conducted by academic institutions and private companies.

Sesame is known for its dehiscence, a process in which the plant's capsules spontaneously open during maturation, resulting in significant productivity losses. Additionally, sesame exhibits an indeterminate growth

**Figure 4.** Spatio-temporal variation of grain cropping climatic risks in Mato Grosso. Spatial and temporal variation of the number of days with heat (>35 °C), moderate heat (Max Temp > 30 °C), drought (ETa/ETp < 0.3), moderate drought (ETa/ETp < 0.6), and the compound of heat and drought climatic factor (when heat and drought occur simultaneously on the same day) during off-season maize and sesame for two different sowing dates, 1st February and 1st of March.

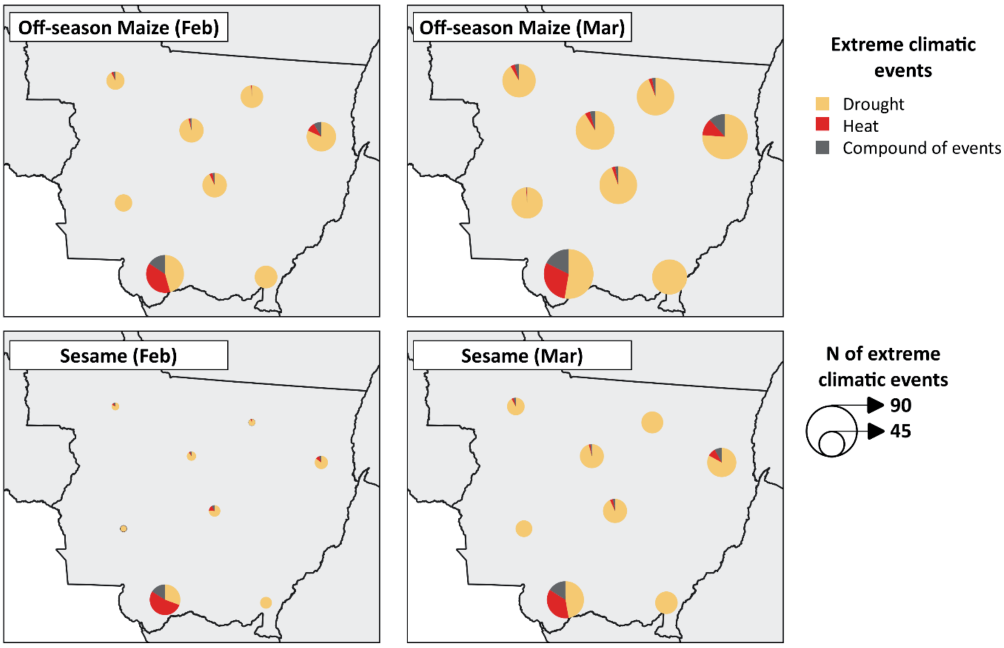
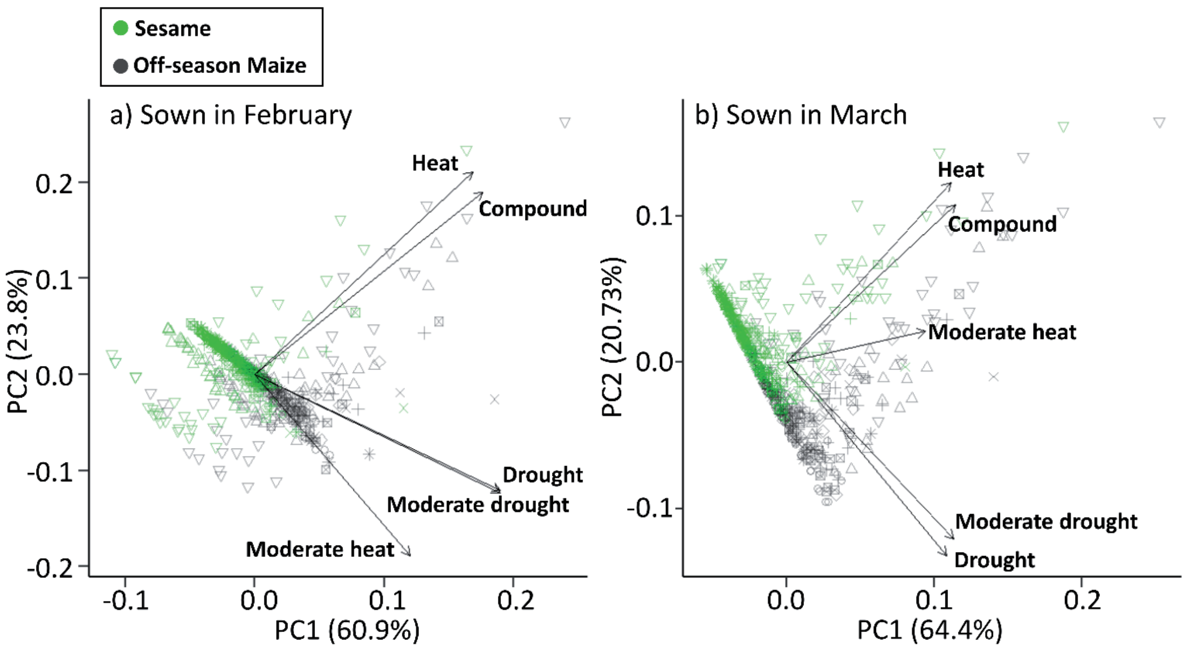



**Figure 5.** Biplot of the loadings of the original variables in the first two canonical variables for sesame and off-season maize in different sowing dates, with (a) sown in February and (b) in March. The percentage of total variance explained by each canonical variable is indicated in parentheses. Different symbols refer to the eight distinct locations in Mato Grosso, Brazil, as indicated in Table 1.




pattern, leading to uneven capsule maturation and consequently grain heterogeneity during harvesting. In Brazil, all currently cultivated varieties share these characteristics (Fiorese et al., 2023).

Despite the yield potential of varieties like BRS Seda and BRS Anahí, which can reach 2,200 kg/ha, mechanical harvesting of these varieties results in losses of over 50% (Arriel et al., 2007; Fiorese et al., 2020). On the other hand, the K3 variety, with lower yield potential, has become the most produced due to its lower harvest loss, around 10-20%. Despite the yield potential, average yields in Brazil range between 350 and 500 kg/ha (CONAB, 2024).

The selection of sesame varieties with determinate growth and placental adhesion is crucial for modernizing production. However, there is a significant gap in the availability of cultivars adapted to these needs in Brazil. Additionally, research on sesame characterization and genetic improvement in the country is in its early stages, highlighting the need for targeted research efforts.

In addition to the economic benefit associated with the sale of the final product, sesame offers advantages to the agricultural system, such as breaking pest and disease cycles, increasing soil organic matter, and reducing nematode populations. Compared to maize, sesame leaves less straw, but demonstrates benefits in the following season, even with less straw. Studies show that soybeans grown after sesame performed better in terms of root dry mass, plant height, and productivity compared to soybeans grown after maize.

### Consumer Market Dynamics and Global Trade Agreements

The global sesame trade is robust, with a total volume of 2.4 million tons traded in 2020, representing a value of 3.2 trillion dollars. This increase in trade is driven by growing consumption, motivated by the high nutritional value of sesame, which includes vitamins (A and E), minerals, fibers, beneficial fatty acids, carbohydrates (approximately 13.5%), and proteins (around 24%) (Wei et al., 2022).

About 65% of sesame seeds produced worldwide are processed for edible oil, while the remaining 35% are used as whole seeds or processed for tahini production (Wei et al., 2022). One of the main challenges internationally for expanding Brazilian sesame exports is access to target markets. Recently, markets such as India and Mexico have been opened, representing promising opportunities for Brazilian exporters.

In 2020, Brazilian sesame exports to Turkey experienced significant growth, totaling US$ 8.8 million. However, Turkey still imports most of its sesame seeds from African countries, despite an increase in domestic production. India, the fourth-largest global importer of sesame, opened its market to Brazil in 2020, resulting in a significant increase in trade relations between the two countries. Brazilian exports to India reached US$ 14.4 million in 2020, making Brazil the third-largest supplier to the country. Saudi Arabia, although the 11th largest global importer of sesame has become a significant destination for Brazilian exports, with Brazil holding an 8.7% market share in the Saudi market (APEX, 2022a).

The Chinese market, the world's largest, is in the process of opening up to Brazilian sesame, representing a future opportunity for Brazilian producers. Europe has also emerged as a relevant market due to growing health concerns and changes in consumer dietary patterns. Brazilian sesame exports to Europe have grown significantly, reflecting the potential of this market for Brazilian sesame. These data underscore the importance of international sesame trade and the opportunities and challenges faced by Brazilian producers in this sector (APEX, 2022a, 2022b).

## Conclusion

In conclusion, sesame crop emerges as a promising alternative to off-season crop in Mato Grosso state, Brazil, offering economic viability, stability, and resilience against climatic risks. With lower production costs, superior margins, and reduced exposure to extreme weather events, sesame crop is an opportunity for agricultural diversification and sustainable practices. The findings advocate for policymakers and practitioners to consider sesame as a strategic crop, capable of enhancing food security and elevating Brazil's position in the global agricultural landscape. However, addressing challenges related to seed quality, mechanization, and market access remains crucial to fully unlock the transformative potential of sesame cultivation. In essence, this study not only provides valuable insights for agricultural policy formulation but also underscores the imperative of embracing innovative solutions to navigate the complexities of modern agriculture and ensure long-term sustainability.

## Author Contributions

B. F. CHRISTO was responsible for the conception of the work, data acquisition and analysis, and drafting of the manuscript. R. M. LORENZONI, E. M. JUNIOR, and L. O. PAGOTTO contributed to the conception of the work and manuscript revision. R. S. NÓIA JÚNIOR assisted with the climate risk analysis, as well as in the revision of the manuscript.

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# Gergelim: Uma alternativa econômica viável para a segunda safra em sistemas de cultivo em sucessão no Mato Grosso, Brasil

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RESUMO

Este estudo investiga a viabilidade econômica do cultivo de gergelim (Sesamum indicum L) como uma alternativa para a segunda safra em sistemas de cultivo em sucessão no Mato Grosso, Brasil, com foco no período de 2016 a 2023. Utilizando uma combinação de metodologias qualitativas e quantitativas, são analisados os custos de produção, a rentabilidade e os riscos climáticos associados às culturas. Os resultados indicam que o cultivo de gergelim apresenta custos de produção consistentemente mais baixos, gerando margens superiores e demonstrando notável resiliência diante de adversidades econômicas e climáticas, em comparação ao milho safrinha. Apesar de pequenas variações, o gergelim demonstra estabilidade na lucratividade, mitigando os impactos dos riscos climáticos sobre os resultados financeiros dos agricultores. Através de uma análise abrangente, esta pesquisa não apenas evidencia as vantagens econômicas do cultivo de gergelim, mas também ressalta a importância de considerar os riscos climáticos na tomada de decisões agrícolas. O estudo avalia a viabilidade econômica do gergelim frente aos desafios climáticos, apoiando o aprimoramento das práticas agrícolas no Brasil.



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