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Susceptibility to heat spots: an analysis for the state of Ceará

Suscetibilidade a focos de calor: uma análise para o estado do Ceará

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Abstract: This study aims to identify the causes of fire activity in the state of Ceará and propose an Index of Susceptibility to Heat Spots, Fires, and Burnings through principal component factor analysis. The data used are of secondary nature and were obtained from various sources, covering agricultural, economic, and social aspects. The results suggest that indicators related to agricultural development, such as the number of rural properties, the area allocated to crops, pastures, and livestock herds, influence municipal susceptibility. The replacement of vegetative cover with tillage or pastures has a significant impact on fire activity. Out of the 184 municipalities analyzed, only three have high vulnerability, while 121 have medium-low risk, indicating moderate fragility to fire activity. The results can assist in planning strategies for the prevention, mitigation, and recovery of degraded areas, reducing risks for the most vulnerable populations.

Keywords: Factor analysis; Agricultural development; Fire.

Resumo: Este estudo tem como objetivo identificar as causas da atividade do fogo no estado do Ceará e propor o Índice de Suscetibilidade a Focos de Calor, Incêndios e Queimadas por meio da análise fatorial por componentes principais. Os dados utilizados são de natureza secundária e foram obtidos a partir de diversas fontes, abrangendo aspectos agropecuários, econômicos e sociais. Os resultados indicam que os indicadores ligados ao desenvolvimento agropecuário influenciam na suscetibilidade municipal, como o número de imóveis rurais, a área destinada às lavouras, pastagens e o rebanho da pecuária. A substituição da cobertura vegetal por lavouras ou pastagens tem impacto significativo na atividade do fogo. Dos 184 municípios analisados, apenas três possuem alta vulnerabilidade, enquanto 121 têm risco médio-baixo, indicando moderada fragilidade à atividade do fogo. Os resultados podem auxiliar no planejamento de estratégias de prevenção, mitigação e recuperação das áreas degradadas, reduzindo riscos para as populações mais vulneráveis.

Palavras-chave: Análise fatorial; Desenvolvimento agropecuário; Fogo.

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1. Introduction

Ceará, located in the Brazilian Northeast, is a state with a vast coastline and rich in ecosystems, including Caatinga, Cerrado, and Atlantic Forest. It is estimated that, in 2021, 5.57 million people resided in the 171 cities that make up the Semiarid Region (RSA), as proposed by the Superintendence for the Development of the Northeast (SUDENE, 2023).

Despite these particular characteristics, the region experiences occurrences of heat spots, fires, and burnings, due to both human and natural activity. According to the National Institute for Space Research (INPE, 2024a), from 1998 to 2023, the months of October and November averaged the highest number of heat spots in Ceará. In 2022, 4,136 heat spots were reported; whereas in 2023, 6,808 heat spots were reported, representing an increase of 64.60% compared to the previous year.

According to INPE (2024b), a higher incidence of heat spots is observed during the second half of the year. According to the Ceará State Health Department (SESA, 2022), this is due to the conditions of low air and soil humidity, dry vegetation, high temperatures, and intensive use of fires in agriculture. These events therefore pose a direct threat to the region's biodiversity and ecosystems, while also causing socio-economic problems.

According to SESA (2022), the impacts of biomass combustion are associated with the emission of atmospheric pollutants capable of penetrating the respiratory and circulatory systems. Additionally, Dittrich and McCallum (2020) describe that the costs associated with exposure to smoke from fires are exceedingly high, reaching millions or billions of US dollars, partly due to the significant mortality rate caused by this exposure.

In this context, Ceará maintains state and municipal programs¹ designed to combat heat spots and fires, aiming to mitigate damages and preserve its natural resources. However, the effectiveness of these initiatives depends on the ability to assess and predict susceptibility to these events. Therefore, it is important to understand the extent of this problem.

This study aims to investigate the agricultural and socioeconomic factors associated with fire activity in the state of Ceará. Specifically, the intention is to develop the Heat Spots, Fire, and Burning Susceptibility Index (ISFIQ) by municipality, using Principal Component Factor Analysis and geoprocessing to explore the results. The goal of this research is to contribute to the preservation of Ceará, providing evidence against the problems of heat spots, fires, and burnings, as well as to serve as a reference for other regions with similar challenges.

2. Theoretical Framework

The occurrence of fire is influenced by various factors. Among the social factors, the illiteracy rate was studied by Barati Jozan *et al.* (2023) to identify fire patterns in Mashhad, the second most populous city in Iran. Analyzing data from 2015 to 2019 and employing spatial econometrics applied to 29,889 fire events, the authors found that, among socioeconomic criteria, the illiteracy rate was one of the factors that contributed the most to fires in the area.

However, a high level of human capital can reduce heat spots and the area affected by burnings. This was observed by Michetti and Pinar (2019) in Italian regions from 2000 to 2011. The authors concluded that a higher percentage of the population aged 25 to 64 with higher education played a significant role in reducing fire damage. Therefore, high levels of education are a prominent factor in preventing these events.

The literature highlights another significant demographic aspect, poverty, which is linked to the incidence of heat spots, fires, and burnings, as revealed by De Torres Curth *et al.* (2012). In this study, factor analysis demonstrated a relationship between socioeconomic aspects and fires in the northern region of Argentine Patagonia, whereby areas of higher poverty rates showing a greater propensity for fire occurrence.

A study conducted by Edwards *et al.* (2020) evaluated the causes associated with forest fires in Indonesia, both at a district level as well as in 30,000 villages in the cities of Sumatra and Kalimantan. Poverty was found to be closely associated with fire activity suggesting that villages most likely to experience fires are those that are more remote, less developed, and that use fire in agriculture.

In the context of social aspects, it is important to consider population size. In Iran, Ghorbanzadeh *et al.* (2019) developed two indices, one for forest fire susceptibility and another for social and infrastructural vulnerability. The results showed that as the population increases, so does the proportion of heat spots in the northern region of Iran. De

¹ Program for Prevention, Monitoring, Control of Burnings, and Forest Fire Combat of the Environment and Climate Change Department (SEMA, 2023a), in collaboration with the Coordination of Civil Defense of Ceará State from the Public Security and Social Defense Department (SSPDS, 2023).

Torres Curth *et al.* (2012) concluded that a low frequency of fires was associated with low population density, while a higher frequency of fires was linked to intermediate population densities.

Furthermore, the Gross Domestic Product (GDP) is a recurring topic of discussion on the economic factors that affect the occurrence of heat spots. In this regard, Zhang *et al.* (2019) investigated, through regression analysis, the relationship between fire safety management performance and urbanization development. The results corroborated that, among the covariates explaining the urbanization process, GDP per capita is one of those that shows a positive relationship with the occurrence of fires.

Morello *et al.* (2020) observed that in the Brazilian Amazon, between 2008 and 2014, Gross Domestic Product (GDP) exhibited an inverse correlation with the incidence of heat spots across most of the models tested. The authors suggest that while there are indications of continued reliance on fire-based agriculture in the region, the observed inverse relationship can be attributed to the advancement of many Amazonian cities beyond the initial stages of development, where agriculture is based on fire use.

Regarding the labor market, there is a hypothesis that a higher employment rate is associated with a greater propensity to avoid fires. This assumption was addressed by Farinha, Cunha, and Dimuccio (2022), who conducted a factor analysis to investigate social vulnerability to forest fire risks in Portugal between 2010 and 2018. The results indicated a negative relationship between the variable representing families without unemployed members and fire risks in that locality, thus areas with employed individuals are less vulnerable to fire risks.

The relationship between agriculture and heat spots, fires, and burnings is investigated, suggesting that the size of rural properties may influence the incidence of fires. This hypothesis was verified by Martínez, Vega-Garcia, and Chuvieco (2009), when they identified the human factors related to fires in Spain. Among the covariates, they concluded that high density of agricultural properties increases fire risks, as conflicts and negligence become more likely.

Martínez, Vega-Garcia, and Chuvieco (2009) also highlighted agricultural machinery as another factor related to fire risks. Through logistic regression applied to 6,066 Spanish municipalities from 1988 to 2000, they concluded that the density of agricultural machinery (number of equipment per km²) is the most relevant variable in explaining forest fires, once again due to conflicts and negligence becoming more likely. Regarding agriculture, D'este *et al.* (2020) examined the causes that impact the occurrence of forest fire in the Mediterranean region of Spain and Italy between 2000 and 2012. Of the land cover categories, forest cover had a positive effect on fire occurrence, as did the extension of agricultural areas and the size of the fields.

Another contributing factor to heat spots, fires, and burnings is the area allocated for grazing. Cano-Crespo *et al.* (2015) investigated how the deforestation process and environmental degradation are related to forest fires in the Brazilian Amazon. The results indicate that a large portion of forest fires is not associated with deforestation, but rather with farming activities, which have significant implications for managing and monitoring these events.

However, it is also necessary to evaluate the role of livestock farming and its relationship with the fires. Martínez, Vega-Garcia, and Chuvieco (2009) observed that traditional livestock farming, which includes burning to maintain pastures, plays a critical role in high fire risks. Conversely, in large-scale properties in California, Siegel *et al.* (2020) suggest that cattle grazing can reduce the annual probability of forest fires, as the animals reduce available biomass.

In vegetal extraction, charcoal from wood carbonization plays a crucial role as an indicator of fires. While investigating the temporal relationship between fires and changes in vegetation diversity, Baboin *et al.* (2022), showed that charcoal is a key variable in fire regime composition. For the exploitation of timber resources, Morello *et al.* (2020) adopted the value of wood exports as a proxy for the extraction of this resource in the Brazilian Amazon, but found no relationship between this indicator and forest fires in the region.

3. Methodology

3.1 Contextualization and Characteristics of the Study Area

The study area comprises the state of Ceará, which covers 148,894 km² and includes 184 municipalities. It is noteworthy that 98% of the territory is included in the Semi-arid Region (RSA) (SUDENE, 2023), characterized by low rainfall. For the year 2021, according to data from the Brazilian Institute of Geography and Statistics (IBGE, 2023a), approximately 8.79 million people reside in the state of Ceará, of which 2.60 million live in the capital, Fortaleza.

3.2 Study Variables

The variables outlined to compose the ISFIQ were chosen according to the theoretical framework and data availability, organized thematically as presented in Table 1.

Table 1 – variables outlined to compose the ISFIQ.

Variable	Year	Description	Unity	Source	
Illiteracy	2010	Percentage of illiterate population	%	IBGE (2023b)	
Bolsa Família	2021	Families benefiting from the Bolsa Família Program	Count	Ministry of Development and Social Assistance, Family and Fight against Hunger (2023)	
Poverty	2010	Population in extreme poverty		IBGE (2023b)	
Population	2021	Resident population by municipality		IBGE (2023c)	
GDPpc	2020	Gross Domestic Product per capita	R\$ of 2020	IPECE (2023b) and IBGE (2023a)	
GVAagripic		Gross Value Added of Agriculture per capita			
EmpAgro	2021	Employment in the agricultural, forestry, hunting, fishing, and mineral extraction sectors	Count	Ministry of Labor and Employment (2023)	
Rural Properties	2017	Area of agricultural establishments	Ha	IBGE (2023d)	
Tractors		Quantity of tractors	Count		
Tillage	2021	Area allocated to tillage of temporary and permanent crops	Ha	IBGE (2023e)	
Pasture		Area allocated to pasture			
Charcoal		Charcoal production	Ton		
Firewood		Firewood production	m ³		
Timber		Timber production			
Cattle		Cattle stock	Count		IBGE (2023f)
Goats		Goats stock			
Sheep	Sheep stock				

Source: Authors (2024).

3.3 Principal Component Factor Analysis

Fávero and Belfiore (2017) highlight that Principal Component Analysis (PCA) is widely adopted extraction method while based on the analysis of correlations between explanatory variables, PCA differs from other approaches, which are based on measures of distance or similarity between evaluated units to form clusters or groups. Additionally, factor analysis identifies correlations among variables to create factors that represent linear combinations of the original variables, validating constructs established in the literature by assessing how variables are allocated in factors and further developing rankings using indicators based on these factors.

However, tests are necessary to assess the sample's suitability for PCA. The simplest test examines correlations in the data matrix. Hair Jr *et al.* (2009) suggest that if a visual inspection does not show correlations between variables above 0.30, factor analysis may not be viable. According to the author, partial correlations exceeding 0.70 are a solid indicator of the method's applicability.

There are other tests that assess the overall suitability of the sample for the factor extraction method. Bartlett's test of sphericity identifies correlations between variables, and it is significant if there is a correlation, indicating the viability of the analysis (Hair Jr *et al.*, 2009). An alternative to observe the overall adequacy of the sample is the Kaiser-Meyer-Olkin (KMO) statistic (Fávero & Belfiore, 2017), with values from 0.9 to 1.0 indicating high suitability. Between 0.8 and

0.9, adequacy is considered good, between 0.7 and 0.8, of moderate adequacy, and below 0.5, the data is considered inadequate for analysis.

The next step involves determining the number of factors to be extracted, which is related to the number of variables. In this study, with 17 variables under analysis, 17 factors will be extracted. The first factor represents a synthesis of the best linear combination of the variables. Conversely, the second factor corresponds to the second best linear combination, being orthogonal to the first. This process repeats until successive factors explain all the variance of the data (Hair Jr *et al.*, 2009).

Next, factors are selected based on criteria. According to Fávero and Belfiore (2017), a notable criterion, is that of eigenvalues or latent roots. This criterion determines that factors with eigenvalues below 1.0 are considered insignificant and discarded. Alternatively, enough factors are selected to achieve an explained variance equal to or greater than 60%.

After the selection, factor loadings are subjected to a rotation process. One of the most commonly used methods is the orthogonal rotation method, known as Varimax. Its objective is to reduce the number of variables with substantial loadings on a specific factor, redistributing the factor loadings and maximizing the shared variance in factors associated with lower eigenvalues (Fávero & Belfiore, 2017).

After the analysis is complete, factor loadings are evaluated to understand the role of each variable in contributing to the factorial structure. When acceptable factors are obtained, some significance is attributed to the pattern revealed by the relevant factor loadings. From the extracted rotated factors, the ranking of susceptibility to fire activity, the ISFIQ, is developed.

According to Fávero and Belfiore (2017), one of the methods consists on weighted summation and ordering. In this approach, the factors (those with eigenvalues exceeding 1.0) are summed for each municipality, weighted by their respective percentages of shared variance. Subsequently, the results are ordered to establish a hierarchy of information, and finally, the ISFIQ is standardized to a uniform scale, adjusting the values in the range from 0.0 to 1.0.

4. Results and discussion

4.1 Indicators of susceptibility to heat spots, fires, and burnings

Table 2 shows the extraction of five factors from the model with eigenvalues greater than 1.0, which explained 75.15% of the data variance. The factorial model presented a KMO value of 0.77, indicating that the adequacy of the factorial analysis is considered moderate. The result of the Bartlett's test statistic indicates that, for a significance level of 1% and 136 degrees of freedom, the Pearson correlation matrix is statistically different from the identity matrix with the same dimension, rejecting the null hypothesis of the test.

Table 2 – Main factors of fire activity in Ceará.

Factor	% of Variance	Dominant Variable	
Agricultural Development (5.18)	30.48%	Rural Properties	+0.94
		Pasture	+0.93
		Sheep	+0.92
		Tillage	+0.92
		Goats	+0.83
		Cattle	+0.77
Social and Economic Indicators (2.41)	14.21%	Poverty	+0.87
		Illiteracy	+0.85
		GDPpc	-0.73
Social Assistance and Demography (2.22)	13.08%	Population	+0.96
		Bolsa Família	+0.95
Vegetal Exploitation (1.55)	9.16%	Charcoal	+0.91
		Firewood	+0.77
Natural Resources and Economy (1.39)	8.22%	GVAagripc	+0.73
		Timber	+0.61

Source: Authors (2024).

Note: Values in parentheses represent the eigenvalues in each factor.

Among the factors, Agricultural Development encompasses the number of rural properties, the area allocated to tillage, pastures, and the livestock population of cattle, goats, and sheep. The Social and Economic Indicators factor consists of the illiteracy rate, poverty, and GDP per capita, while the Social Assistance and Demography factor incorporates the number of beneficiaries of the Bolsa Família and the population. The fourth factor, Vegetal Exploitation, aggregates the quantity of charcoal and firewood produced, while the fifth, Natural Resources and Economy, covers the quantity of timber produced and the Gross Value Added of agriculture per capita.

Given the composition of the factors, the first one, Agricultural Development, explains 30.48% of the total variance in the data. Therefore, according to the signs of the factorial loads, all significant variables showed a positive relationship with the vulnerability of Ceará municipalities to the occurrence of heat spots, fires, and burnings.

For Coutinho *et al.* (2013), livestock farming is more stable than agricultural activities, as many crops require regular rainfall, which can be challenging in Ceará, known for its semi-arid climate and variability in rainfall distribution throughout the year. It is worth noting that agricultural activity has been present in the state since colonial times (FARIAS, 2015), relating to the region's history as a means of subsistence during drought periods.

A challenge for the region would be the replacement of vegetation areas with new areas designated for tillage and pastures, which exacerbates the occurrence of heat spots. Possible means to that replacement could be the use of fire for the direct expansion of these areas and a probable increase in GVA of agriculture, which, according to the fifth factor, is related to the occurrence of these heat spots.

The second factor, Social and Economic Indicators, explains 14.21% of the total variance. While observing the signs of the factorial loads for the illiteracy and poverty variables, there is a direct relationship between these indicators and susceptibility to heat spots. However, the sign for the GDP per capita variable is negative, meaning that there is an inverse relationship with the factor in question. In other words, the low income of the population in Ceará cities may contribute to the occurrence of heat spots in these regions.

The Environmental Kuznets Curve (DINDA, 2004) explains that economic development initially associated with low GDP per capita intensifies agriculture and natural resource extraction, increasing environmental degradation indicators (heat spots). In advanced stages, industrialization, services, environmental awareness, and regulations mitigate this degradation. Nevertheless, Ceará municipalities with lower GDP per capita may have poor infrastructure, lower capacity to respond to natural disasters, or less investment in prevention and mitigation measures.

Although data on illiteracy and poverty are outdated, socioeconomically vulnerable populations may face greater challenges in adapting to and mitigating extreme weather events such as fires and heatwaves. Moreover, low literacy levels can lead to a lack of access to relevant information on how to protect and deal with extreme heat situations, increasing vulnerability.

For the third factor, Social Assistance and Demography, it is noted that the data explains about 13.08% of the total variance. Regarding the signs of the significant variables, it is observed that they have a direct relationship with the factor in question; thus, populous municipalities and those with a large number of beneficiaries of the Bolsa Família Program may contribute to the fragility of Ceará localities in the occurrence of heat spots, fires, and burnings.

Regarding the demographic aspect, more populous cities tend to present more heat spots since there is a higher probability due to the number of inhabitants. Analyzing the population census data for 2022, around 38.0% of Ceará municipalities experienced a population decline between 2010 and 2022 (IBGE, 2023g). However, despite this variation, there is no data available to indicate whether economic vulnerability increased during this period.

As for Bolsa Família beneficiaries, it is noteworthy that the socioeconomic conditions of these families can influence municipalities' susceptibility to heat spots. This may be related to domestic practices, such as the use of charcoal and firewood for cooking, and the burning of solid waste in regions with absent or low garbage collection.

The fourth factor, Vegetal Exploitation, is composed of charcoal production and municipal firewood exploitation and has a percentage of explained variance of 9.16%. When analyzing the signs of the variable, a direct relationship with the factor is perceived. However, it is important to emphasize that not all cities are significant producers of charcoal and firewood, as the extraction of these raw materials is restricted to 147 municipalities, according to data from the Municipal Agricultural Survey (IBGE, 2023e). It is worth mentioning that illegal production and sale of wood and charcoal may underreport the data, being likely to occur in rural areas or vulnerable regions where the population uses these resources for domestic activities.

The last factor addresses Natural Resources and the Economy, explaining 8.22% of the total data variance. In attention to the signs of the significant factorial loads, timber production and GVA of agriculture per capita are directly related to the factor. Thus, the five factors presented together explain more than 75% of the total data variance.

Despite the importance of the GVA of the agricultural sector, it is worth noting that, in only ten municipalities, the GVA of agriculture surpasses that of other economic activities (IBGE, 2023a; IPECE, 2023b), in such a way that the transition of the municipalities' production structure towards agricultural activities may be an important factor for establishing greater vulnerability regarding local hot spots and burnings.

Regarding the timber variable, only 85 cities are producers of this input (IBGE, 2023e). Although production is not significant in a municipal level, illegal deforestation may underestimate these values, as it may occur on a small scale. According to MapBiomás (2024), more than 23 thousand hectares were deforested in Ceará in 2023, demanding attention as deforestation is associated with heat spots, fires, and burnings.

4.2 Susceptibility Index to Hot Spots, Fires, and Burnings

As shown in Figure 1 below, the ISFIQ is categorized into four equally sized strata (from 0 to 0.25; from 0.25 to 0.50; from 0.50 to 0.75; and from 0.75 to 1). Darker shades denote areas with high susceptibility to heat spots, fires, and burnings. It is noted that the locations most prone to these events are situated in the interior of Ceará, specifically in the Planning Regions of Sertão dos Inhamuns and Sertão de Crateús².

The cities least susceptible to heat and fire outbreaks are located along the coast of the state of Ceará and in the planning regions of Greater Fortaleza and Baturité Massif. When analyzing the ISFIQ values in municipalities that are not part of the Semiarid Region (RSA), it can be observed that the 13 cities that make up this region had indices below 0.30. Fortaleza, on the other hand, has an index of 0.79, reflecting a high susceptibility of the state capital to fire activity.

In Fortaleza, one of the most affected areas is the Cocó State Park, the largest urban natural park in the North and Northeast regions and the fourth largest in Latin America (SEMA, 2023b). According to a technical note issued by the Public Security and Defense Department of the state of Ceará (SSPDS, 2021; 2022), in the years 2021 and 2022, the area has been affected by vegetation fires. As highlighted by Ferreira Filho and Araújo (2021), this problem has been recorded since 1999, with the fire season in the park occurring from August to December.

The cities of Tauá, Independência, Fortaleza, Morada Nova, and Boa Viagem are more susceptible to heat spots, fires, and burnings. Being located in Greater Fortaleza, the cities of Eusébio, São Gonçalo do Amarante, Maracanaú, Pacatuba, and Itaitinga show lower vulnerability to these events.

² Further details about the Planning Regions of the state of Ceará can be found in IPECE (2023c).

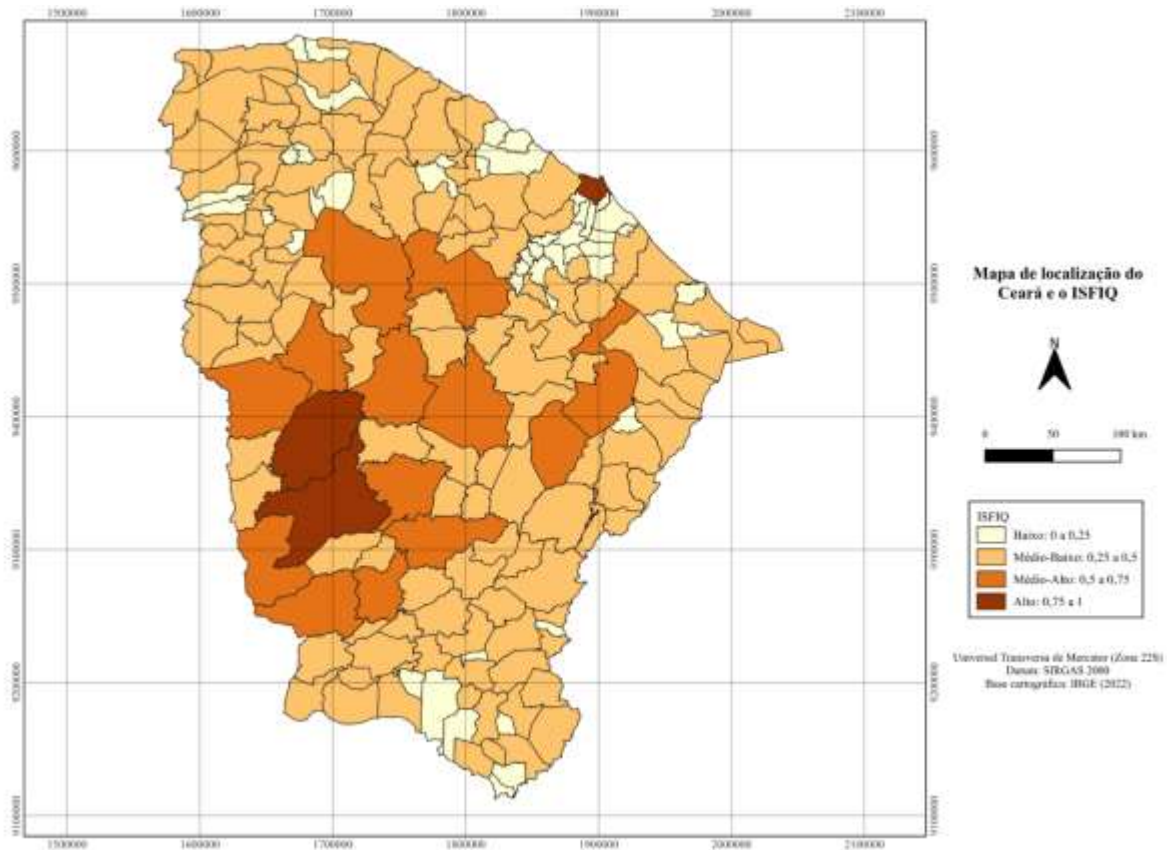


Figure 1 – Susceptibility Index to Heat Spots, Fires, and Burnings, Ceará.
Source: Authors (2024).

Another way to present the indices can be seen in Table 3, which includes the categorization of the ISFIQ, the number of cities per stratum, the percentage of the total population, and the percentage of the poor population. Thus, it is inferred that with susceptibility indices above 0.75, there are three municipalities (Tauá, Independência, Fortaleza), which account for 30.80% of the population and 10.08% of the population in poverty. On the other hand, in the second stratum, there are 15 municipalities that account for only 6.83% of the overall population and 13.08% of the poor population of the state.

Table 3 – Classification of ISFIQ by Municipalities and Population.

ISFIQ	Total Number of Municipalities	% of the population (2021)	% of the poor poulation ³
High: 0.75 to 1.00	3	30.80%	10.08%
Medium-high: 0.50 to 0.75	15	6.83%	13.08%
Medium-low: 0.25 to 0.50	121	45.79%	64.36%
Low: 0.00 to 0.25	45	16.58%	12.48%

Source: Authors (2024).

³ Data based on the 2010 population census (IBGE, 2023b).

In the last stratum, where the indices range from 0 to 0.25, there are 45 cities, with 16.58% of the total population and 12.48% of the poorest population. It is noted that the number of cities with a high propensity for heat spots and burnings is small (3), and that a large portion of these cities (121) presents medium-low risks of fire and concentrate a large percentage of the poor population.

5. Final Considerations

The results show that agricultural and socioeconomic factors are relevant to explain the vulnerability of municipalities in Ceará to the occurrence of heat spots, fires, and burnings. Notably, the area of tillage and pastures, livestock, illiteracy rate, population, poverty, beneficiaries of the PBF, GDP per capita, GVA of agriculture, and extraction of firewood and timber are highlighted as the main drivers of fire activity in Ceará.

The Agricultural Development covers 30.48% of the total variance of the data. This indicates that, given the importance of the factor, the replacement of vegetation cover by new areas of tillage or pastures can have a significant impact on the occurrence of heat spots in the region. In addition, concerning the ISFIQ, three cities have a high susceptibility to fire, namely Tauá, Independência, and Fortaleza. Among those with low susceptibility, there are Maracanaú, São Gonçalo do Amarante, and Eusébio, while Eusébio shows the best performance in the index. It is emphasized that a large part of the cities has medium-low risks to heat spots, fires, and burnings.

The research highlights the need to reinforce programs for combating and preventing heat spots and fires in more susceptible areas of Ceará. This requires dialogue with governmental authorities and the community to raise awareness about the inappropriate use of fire and to seek alternatives to practices such as burning, deforestation, and land clearing. These actions aim at environmental preservation and local economic development.

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