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SPATIAL-TEMPORAL OF FIRE FOCI IN THE STATE OF RIO DE JANEIRO, BRAZIL

ESPAÇO-TEMPORALIDADE DOS FOCOS DE CALOR NO ESTADO DO RIO DE JANEIRO, BRASIL

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ABSTRACT: This study evaluated the space-time variability of fire foci via environmental satellites for the State of Rio de Janeiro (SRJ) based on statistical procedures. The fire foci in the period of 2000 to 2015 were obtained from the BDQueimadas fire database. Descriptive, exploratory, and multivariate statistical analyses were performed in the software environment R i386 version 3.2.5. The north region had 6760 foci (21.11%), the south-central region had 3020 foci (9.43%), the Middle Paraíba had 6,352 foci (19.84%), the Metropolitan areas had 6671 foci (20.83%), and the Green Coast region had 292 foci (0.91%). The cluster analysis identified three homogeneous groups of fire foci (G_1, G_2, and G_3) but did not include the municipality of Campos dos Goytacazes (N_A). The G_1 group (6.21 ± 0.01 foci, 57.61%) included areas throughout the state and covered the coastal region and lowlands towards the north. The G_2 group (6.21 ± 0.01 foci, 34.81%) included the northern, south-central, and coastal shallows regions. The G_3 group (6.21 ± 0.01 foci, 9.78%) included the mountain ranges of the state. Environmental characteristics and socioeconomic are crucial in the dynamics of fire foci in Rio de Janeiro.

KEYWORDS: Wildfires. Burned. Environmental satellites. Statistical methods. Meteorological systems.

INTRODUCTION

In 1997, Brazil implemented an operational system called the Database of Fires (BDQueimadas), which was developed by the Center for Weather Forecasting and Climate Studies (CPTEC) of the National Institute for Space Research (INPE). The objective is monitoring the foci of fires and predicting the risk of fire in areas of vegetation (SETZER SISMANOGLU, 2006, CPTEC, 2016). BDQueimadas helps to prevent and minimize the environmental impacts caused by forest fires, especially in the Protected Areas in Brazil (CAÚLA et al. 2015; CLEMENTE; OLIVEIRA JÚNIOR; LOUZADA, 2017).

In the last decades, data from environmental [illegible] spots and to map burned areas (ROY; LEWIS; JUSTICE, 2002; CAÚLA et al., 2016). These data have been effective in monitoring, preventing, and combating fires (ROY et al., 2008; OLIVEIRA JÚNIOR et al., 2017). Based on the data, information and estimates of the location, period, and frequency of fires have been generated, which can provide evidence of their spatio-temporal dynamics (ANTUNES; RIBEIRO, 2000; SILVA; ROCHA; ANGELO, 2013). Systematic monitoring is essential for preventing and combating fires, especially in Protected Areas (FERNANDES et al., 2011; NUNES et al., 2015), as well as in planning, control, and efficient management (BATISTA, 2003; PIROMAL et al., 2008).

With the technological advancement of orbital sensors and geotechnologies, it has become possible to determine how anthropogenic actions interfere with the environment and to help managers in making decisions in relation to large forest fires (BAILING JÚNIOR; MEYER; WELLS, 1992, COCHRANE, 2003, COCHRANE; BARBER, 2009). The most advanced orbital sensors are the Advanced-Very-High-Resolution Radiometer (AVHRR) (SETZER; VERSTRAETE, 1994; GITAS; MITRI; VENTURA, 2004) and the Moderate Resolution Imaging Spectroradiometer (MODIS) (HUETE et al., 2002, CORREIA et al., 2006; [illegible] ODIS provides data on phenomena occurring on the Earth's surface, in the oceans, and in the atmosphere (PIROMAL et al., 2008; CAÚLA et al., 2016).

Remote sensing (RS) products are used as tools for the detection of fire fire foci to understand the patterns of the ecosystem response to fire events (KEELEY; ZEDLER, 2009; CLEMENTE; OLIVEIRA JÚNIOR; LOUZADA, 2017). Fires produce changes in several types of ecosystems (SETZER; SISMANOGLU, 2006), such as increases in surface albedo, changes in carbon stocks, and decreases

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in the availability of water resources due to soil impact, erosion, and deposition processes of sediments in riverbeds (ANDERSEN et al., 2009; BROCK and CARPENTER, 2010). Furthermore, the transport of combustion products by smoke can spread materials that are potentially dangerous for human health (SILVA et al., 2012; SETZER; SISMANOGLU, 2006; CAÚLA et al., 2015). Several studies show that there are direct relationships between climate and forest fires, so the trends and distributions must be observed and considered in the development of management policies (BAILING JÚNIOR; MEYER; WELLS, 1992; BATISTA, 2003; NUNES et al., 2015; CAÚLA et al., 2015; CLEMENTE; OLIVEIRA JÚNIOR; LOUZADA, 2017).

Understanding the variability of fire foci in the State of Rio de Janeiro (SRJ) constitutes a fundamental strategy in the definition of public policies, especially in areas with high risk of fires in the Atlantic Forest biome (COURA et al.; 2010; FERNANDES et al.; 2011; CLEMENTE; OLIVEIRA JÚNIOR; LOUZADA, 2017; CLEMENTE; OLIVEIRA JÚNIOR; LOUZADA, 2017). However, there are few studies on fire foci in SRJ with a methodological approach involving statistical tools, geoprocessing, and RS products (CAÚLA et al., 2016) in the search for relational patterns of heat sources on the spatial and temporal scale. Therefore, the objective of this study was to evaluate the spatial-temporal variability of the fire foci via environmental satellites through BDQueimadas for the SRJ based on statistical procedures.

MATERIAL AND METHODS

Study Area

SRJ is located in the southeast region of Brazil between latitudes of 20 ° 45 '54 and 23° 21' 57 "S and longitudes of 40° 57' 59" and 44°53' 18 "W. It has an area of 43,696,054 km² and borders Espírito Santo (ES) in the northeast (NE), Minas Gerais (MG) in the north and northwest (N-NW), São Paulo (SP) in the southwest, and the Atlantic Ocean to the south and east. It has an extensive coast that is approximately 635 km long. Currently, the Brazilian Institute of Geography and Statistics (IBGE) divides the geopolitical state into 92 municipalities (IBGE, 2018) and eight governmental regions (Metropolitan, Northern, Northwest, Coastal Flats, Mountainous, South-Central Fluminense, Middle Paraíba, and Green Coast), as shown in Figure 1.

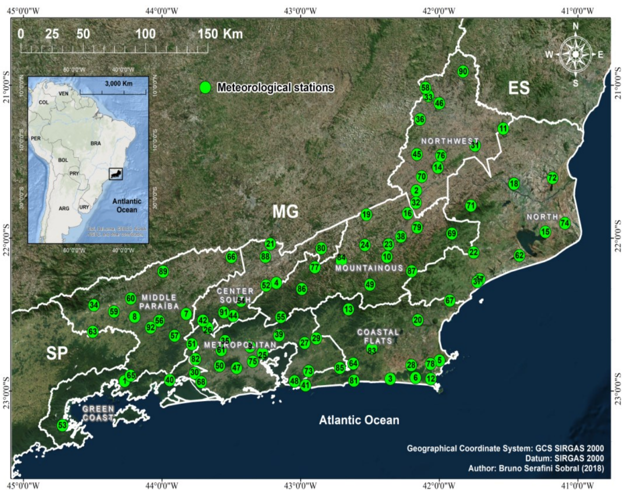

Figure 1. Location of meteorological stations in the State of Rio de Janeiro (Brazil) and subdivided in its eight regions of Government with 92 municipalities, respectively.

Time series of fire foci

Data on fire foci were obtained from BDQueimadas on the CPTEC website at the following address: http://pirandira.cptec.inpe.br/queimadas (CPTEC, 2016). Currently, CPTEC uses 31 environmental satellites with polar and geostationary orbits in its South American observation network. The environmental satellites include NOAA, GOES, AQUA (EOS PM-1), TERRA (EOS AM-1), METEOSAT, ATSR, and TRMM. These satellites perform orbital imaging in Brazil. The study period was from 2000 to 2015.

Statistical analysis

Analyses were done based on the following criteria: the application of descriptive statistics (DS) to describe and understand the series of fire foci in the SRJ; the measures of position (central tendency and separatrix) and dispersion (absolute and relative); and the annual accumulations of the fire foci subjected to an exploratory analysis (boxplot) with the purpose of identifying the major/minor occurrence periods of fire foci and outliers.

The annual cumulative time series of the fire foci obtained by the homogeneous groups from the cluster analysis (CA) were evaluated.

The CA technique was applied to the time series of fire foci in order to separate objects into groups based on the homogeneous characteristics that they have (EVERITT; DUNN, 1991; MONTGOMERY; RUNGER, 2007). The respective numbers of groups and a dendrogram of the 92 municipalities were determined based on the number of annual accumulated fire foci. The number of groups adopted and the stratification of fire foci were based on Ward's (1963) agglomerative hierarchical method by means of the measure of dissimilarity at the Euclidian distance (LYRA; OLIVEIRA-JÚNIOR; ZERI, 2014; BRITO et al., 2016). The Euclidean distance is given by equation 1:

$$d_E = \sqrt{\sum_{j=1}^{p}(x_{ij} - x_{kj})^2} \qquad \textbf{(1)}$$

Where d_E is the Euclidean distance, x_{ij} are quantitative variables j of individuals p, and x_{kj} are quantitative variables j of individuals.

In Ward's (1963) method, the distance between two clusters is the sum of the squares between the two clusters made for all variables. This method minimizes the dissimilarity or the total sum of squares within groups. That is, the data are grouped by homogeneity within each group and by heterogeneity outside each group (LYRA; OLIVEIRA-JÚNIOR; ZERI, 2014; BRITO et al., 2016).

$$W = \sum_{i=1}^{n} xi^2 - \frac{1}{n}\left(\sum xi\right)^2 \qquad \textbf{(2)}$$

W is the homogeneity and intragroup heterogeneity and is obtained by summing the square of the deviations, n is the number of analyzed values, and x_{ij} is the i_{-th} element of the cluster.

The standard deviation (SD) and the standard error (SE) of the annual fire foci were determined according to equations (3) and (4).

$$SE = \frac{DP}{\sqrt{n}} \qquad (3)$$

$$SD = \frac{\sqrt{\sum_{i=1}^{n}(x_n - \bar{x})^2}}{n-1} \qquad (4)$$

Where is the i_{th} observed fire focus, is the arithmetic mean of fire foci, and n is the sample size. All statistical procedures used in the study were calculated in the environment software R i386 version 3.4.2 R Core Team (2017).

RESULTS AND DISCUSSION

Descriptive and exploratory statistics applied to the series of fire foci in the government regions of Rio de Janeiro

The annual averages of fire foci increased significantly during the study period in SRJ. The highlight of 2015 is the average of 250 foci per government region. The North (6760 foci, 21.11%), Metropolitan (6671 foci, 20.84%), Middle Paraíba (6,352 foci, 19.84%), and south-Central (3020 foci, 9.43%) regions had the most fire foci. The high numbers in the respective regions are due to several factors, such as the quantity of factories, the complex relief (exposed granite), disorderly urban occupation, and the burning of waste and other associated human activities (mainly deforestation and agricultural activities) (CAÚLA et al., 2016; CLEMENTE; OLIVEIRA JÚNIOR; LOUZADA, 2017). There may also be temperatures above 47°C according to the orbital sensors of environmental satellites (SETZER; SISMANOGLU, 2006; CPTEC, 2016; CLEMENTE; OLIVEIRA JÚNIOR; LOUZADA, 2017).

There were 32,018 fire foci in SRJ, which had high temporal variability and the statistical parameters evaluated (Table 1). The Green Coast region had the lowest mean and SE (18 ± 3.16 foci) compared to the northwest (129 ± 4.86 foci) and Green Coast (127 ± 32.95 foci). However, similar results were obtained for the SD of the regions. The minimum values obtained by region were 0 foci (Green Coast), 1 focus (Coastal Flats), 4 foci (Metropolitan), and 8 foci (Central South). In the north, northwest, Mountainous, and Middle Paraíba regions, there were 62, 14, 27, and 25 foci, respectively.

The highest numbers were 41 foci in the Green Coast region, 486 foci in coastal shallows, 2,825 foci in Metropolitan areas, 939 foci in the south-Central region, 1,523 foci in the north region, 355 foci in the northwest region, 1,383 foci in Mountainous, and 1,345 foci in Middle Paraíba. The CV% was lower in the Green Coast, northwest, north, and Middle Paraíba, in contrast to the Mountainous, coastal shallows, southern, and Metropolitan regions.

The lower CV% values indicate low variability of the fire foci between the regions. The high CV% values represent significant changes in fire foci in SRJ during the study period (CLEMENTE; OLIVEIRA JÚNIOR; LOUZADA, 2017). The Ap coefficient characterizes how distant the data distribution is from a symmetric condition. The Ap coefficients for the eight SRJ regions showed a predominance of high asymmetric curves in the north (2.14), Mountainous (2.14), south-Central (2.20), and Metropolitan (2.47) regions, followed by (1.21), coastal shallows (1.59), and Middle Paraíba (1.18). However, the Green Coast region (0.22) presented a moderate positive asymmetry. In this case, the right tail is more elongated than the left tail for means greater than zero, which indicates the occurrence of high values with low frequency (VELÁSQUEZ et al., 2013, MACHIWAL; KUMAR; DAYAL, 2016). The K coefficients obtained for all regions of SRJ revealed leptokurtic distributions (K > 3, sharpest curve) of annual heat accumulated foci for the north, Mountainous, south-Central, and Metropolitan regions, unlike the northwest regions, Middle Paraíba, Green Coast, and coastal shallows, which had platykurtic distributions (K < 3, a more flattened curve) – (Table 1).

The North and Metropolitan regions had the highest annual amplitudes of 1,461 and 2,821 fire foci, respectively. The Mountainous and the Middle Paraíba regions had 1,356 and 1,345 foci, which were the lower and upper limits, respectively. The highest medians and SD occurred in the northern (334.00 ± 333.57 foci.years^{-1}), Metropolitan (171.00 ± 715.83 foci.years^{-1}), Mountainous (197.50 ± 329.04 foci.years^{-1}), and Middle Paraíba (273.00 ± 385.82 foci.years^{-1}).

Table 1. Results of the descriptive statistics applied to the time series of accumulated fire foci in the period of 2000-2015.

Governmental Regions	Amount of Fire Foci (Foci. Year^{-1}) Accumulated Annual	(%) Annual Accumulated Foci Fire	Average	Medium	Mode	Minimum Value	Maximum Value	Amplitude Total	Limit Bottom	Limit Higher
			(Focus. Year^{-1})							
Northern	6760	21.11	422.50	334.00	62.00	62	1523	1461	11.00	735.00
Northwest	2062	6.44	128.88	99.50	14.00	14	355	341	66.63	290.38
Mountainous	4827	15.08	301.69	197.50	27.00	27	1383	1356	252.75	739.25
South-Central	3020	9.43	188.75	133.00	8.00	8	939	931	235.63	529.38
Coastal Flats	2034	6.35	127.13	84.50	99.00	1	486	485	104.13	302.88
Metropolitan	6671	20.84	416.94	171.00	4.00	4	2825	2821	209.00	655.00
Middle Paraíba	6352	19.84	397.00	273.00	25.00	25	1345	1320	416.13	1016.88
Green Coast	292	0.91	18.25	17.00	17.00	0	41	41	17.25	50.75
Total	32018	100	2001.13	1309.50	256.00					

Governmental Regions	Coefficients					**Standard deviation (SD)**	**Standard error (SE)**	**Quartile**		**Interquartile Range (AIQ)**
	Sampling Variation (%) (CV)	Asymmetry (A_p)		Curtose (K)				Bottom (Q_1)	Higher (Q_3)	
						(Focus. Year^{-1})				
Northern	78.95	2.14	+	4.57	leptokurtic	333.57	83.39	268.75	455.25	186.50
Northwest	77.15	1.21	+	0.45	platykurtic	99.43	24.86	67.25	156.50	89.25
Mountainous	109.07	2.14	+	4.41	leptokurtic	329.04	82.26	119.25	367.25	248.00
South-Central	120.33	2.20	+	4.58	leptokurtic	227.13	56.78	51.25	242.50	191.25
Coastal Flats	103.66	1.59	+	1.47	platykurtic	131.78	32.95	48.50	150.25	101.75
Metropolitan	171.69	2.47	+	5.22	leptokurtic	715.83	178.96	115.00	331.00	216.00
Middle Paraíba	97.21	1.18	+	0.24	platykurtic	385.92	96.48	121.25	479.50	358.25
Green Coast	69.21	0.22	+	-1.18	platykurtic	12.63	3.16	8.25	25.25	17.00

This showed that the annual accumulated heat outlets in all SRJ regions had an asymmetric distribution. 25% of accumulated fire foci occurred below the median in the north, northwest, Mountainous, south-Central, coastal shallows, Metropolitan, and Middle Paraíba regions. The value of the first quartile (Q1) ranged from 48.50 to 268.75 foci.year^{-1} and was greater than 25% of the values of the third quartile (Q3), which ranged from 150.25 to 455.25 foci.year^{-1}. The interquartile range (AIQ) ranged from 89.15 to 358.25 foci.year^{-1} in the respective regions. The exception was the Green Coast region, which presented the lowest median, and 25% of the accumulated fire foci were lower than Q1 and or higher than Q3 (between 8.25 and 25.25 foci.year^{-1}). The AIQ was 17.00 foci.year^{-1}.

The analysis of the sample CV% for the SRJ government regions showed that the majority of the regions presented values above 70%. This indicated high temporal variability of annual heat accumulated in the SRJ. The higher SD and higher AIQs indicated a high degree of variability of annual accumulated fire foci around the average in the north, northwest, Mountainous, south-Central, coastal bays, Metropolitan, and Middle Paraíba regions (Table 1). The temporal variability in the detection of fire foci in SRJ can be explained by the anthropic actions along with the development of orbital sensors (AVHRR and MODIS) and algorithms, such as the Wild Fire-Automated Biomass Burning Algorithm (WF-ABBA) number (currently 31) and the types of satellites (polar or geostationary orbit), which are crucial factors in the increase in foci. INPE used the NOAA-12 reference satellite until August 2007 and then adopted the NOAA-15 satellite. Currently, it uses the AQUA-MT and TERRA-MT satellites (CPTEC, 2016).

According to Caúla et al. (2015), the AQUA-MT satellite has a polar orbit, and it is more successful in detecting fire foci per unit area in Brazil compared to geostationary satellites and in relation to others with the same orbit, such as the old reference satellites mentioned. The influence of meteorological systems on the time series of fire foci in SRJ, which in turn influence rainfall patterns and the distribution of temperature and humidity in the air, is also not ruled out. In this paper, we present the results of a study of forest fires and general fires (BATISTA, 2003; NUNES et al., 2015, OLIVEIRA JÚNIOR et al., 2017)..

Homogeneous regions of fire foci

The CA technique identified three homogeneous groups of fire foci (G_1, G_2, and G_3) and only the municipality of Campos dos Goytacazes did not cluster (N_A). Campos dos Goytacazes had more fire foci and was an outlier in the time series. The CA technique grouped all municipalities independently of the government region (Figure 2). The highest number of hot spots in Campos dos Goytacazes was due to the large areas of pasture, climatic conditions (high temperature and low rainfall) (BRITO et al., 2016, SOBRAL et al., 2018), and the production and harvest of sugarcane based on the practice and common use of fires (CAÚLA et al., 2016; CLEMENTE; OLIVEIRA JÚNIOR; LOUZADA, 2017). Furthermore, there is a greater number of industries in the region (IBGE, 2018). The results corroborate those from FERNANDES et al. (2011), who classified SRJ into regions of fire susceptibility. The North Fluminense was classified as a region of high susceptibility due to the factors mentioned and slopes with a high incidence of solar radiation.

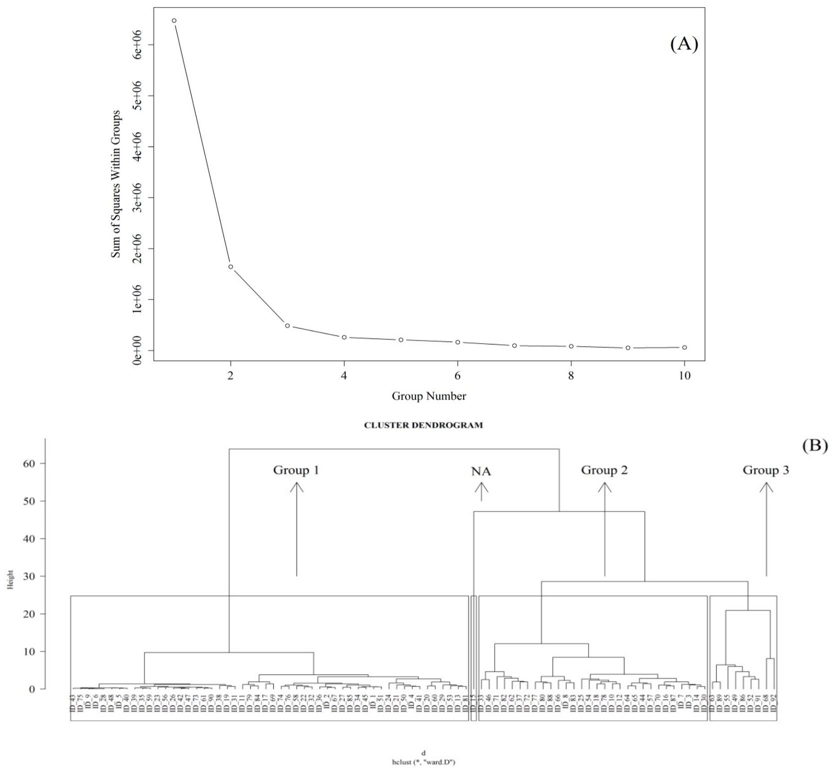

Figure 2. Group Number (**A**) and Dendrogram (**B**) obtained from the cluster analysis of the fire foci of the municipalities of the State of Rio de Janeiro, with their respective homogeneous groups (G_1, G_2, G_3 and N_A).

The exploratory analysis technique was applied for G_1, G_2 and G_3 via boxplot (Figure 3), using the mean values of the statistical parameters (mean, median, maximum, minimum and 1st and 3rd quartile) of the fire foci. The G_1 group was represented by Figure 3 (a), being the largest homogeneous group of fire foci, consisting of 53 municipalities in the state (57.61%). In group G_1, outliers were registered for all years of the dataset, the exceptions were 2003, 2005 and 2010. The highlights were 2014 and 2015, which registered most number of outliers, followed by average values (20.46 and 18.85 focus) greater than the median (14.00 and 12.50 focus). Similar to group G_1, outliers were also observed in group G_2, again there were exceptions for the years 2000, 2003 and 2007. Group G_2 was the second largest group consisting of 30 municipalities (34.81%), with an average ranging from 81.43 to 66.00 and the medians from 49.07 to 35.50, and an SD of 27.89 fire foci. In group G_3, there was a significant reduction of outliers. Group G_3 was the smallest homogeneous group consisting of nine municipalities (9.78%), ranging between 314.13 and 361.33 foci and with a median of 204.50 and 76.00 foci and the largest SD (196.75) compared to the other homogeneous groups. N_A did not show any outliers in the time series although 2015 registered 1000 fire focus.

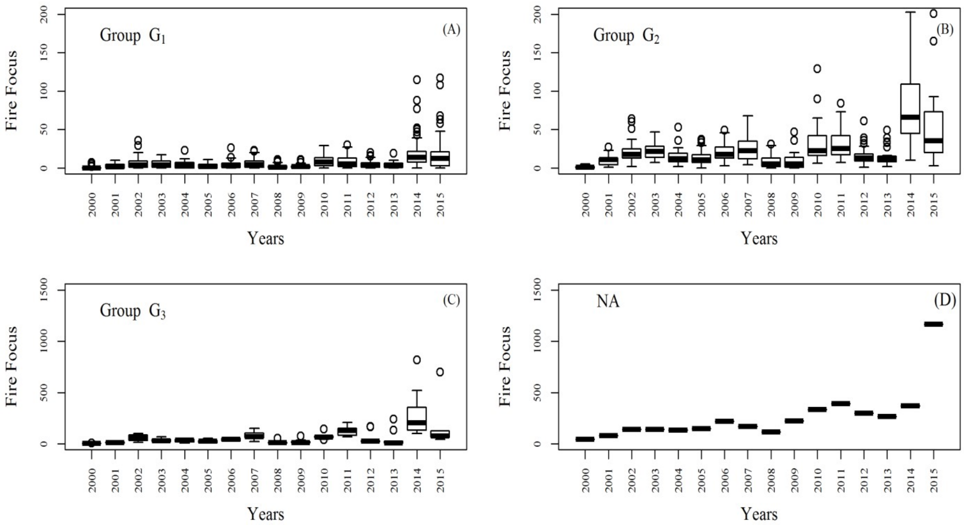

Figure 3. Boxplot of homogeneous groups G_1 (A), G_2 (B), G_3 (C) and NA (D) of hot flashes from 2000 to 2015 in the state of Rio de Janeiro.

The G_1 group covered the coast and the Coastal Flats region towards the northern part of the state. The southern part extends from the northeast to southwest. The G_2 group had a similar distribution to group G_1. The highest concentrations of municipalities were observed in the north (55.56%), Coastal Flats (45.45%), and Middle Paraíba (41.67%) with five municipalities each (Figure 4 ande Table 3).

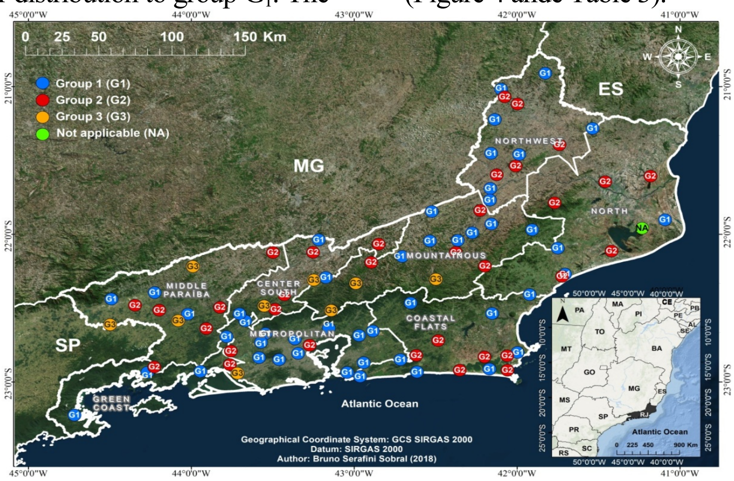

Figure 4. Spatial distribution of the homogeneous groups of fire foci G_1, G_2, G_3 and N_A in the State of Rio de Janeiro in the period 2000-2015.

Table 3. Percentage (%) of fire foci by government region and homogeneous groups (G_1, G_2, G_3 and N_A) in the period of 2000-2015 in the State of Rio de Janeiro.

Governmental Regions	G_1	(%) Governmental Regions	(%) Group	G_2	(%) Governmental Regions	(%) Group	G_3	(%) Governmental Regions	(%) Group
Northern	3	33.33	6%	5	55.56	17%	0	0.00	0%
Northwest	9	69.23	17%	4	30.77	13%	0	0.00	0%
Mountainous	8	53.33	15%	4	26.67	13%	3	20	33%
South-Central	4	44.44	8%	4	44.44	13%	1	11.11	11%
Coastal Flats	6	60	12%	4	40.00	13%	0	0	0%
Metropolitan	15	75	29%	4	20.00	13%	1	5	11%
Middle Paraíba	4	30.77	8%	5	38.46	17%	4	30.77	44%
Green Coast	3	100	6%	0	0.00	0%	0	0	0%
TOTAL	52			30			9		

The G_3 group had a smaller number of municipalities in the Middle Paraíba (30.77%) and the Mountainous region (20.00%). The entire G_3 group was concentrated along the mountain ranges of SRJ from Serra do Mar, which is part of Serra dos Órgãos in the Mountainous region, up to the Serra da Mantiqueira. The southewest border is shared with the States of São Paulo and Minas Gerais, where the rest of the Atlantic Forest is located. The differences in the numbers of fire foci are mainly due to local characteristics, such as vegetation, proximity to the coastal environment, complex topography, and multiscale meteorological systems that affect the region's climate (CAÚLA et al. 2016, FERNANDES et al., 2011; NUNES et al., 2015). Human activities also contribute to the variation (FERNANDES et al., 2011).

CONCLUSIONS

The statistical analysis has shown that the north, south-Central, Middle Paraíba, and Metropolitan regions stand out in relation to the temporal variability of fire foci in SRJ, but not the Green Coast region. The applied statistics clearly show that there is a considerable increase of fire foci in Rio de Janeiro throughout the time series, with emphasis on the high spatial-temporal variability in the government regions. The number of foci significantly increased in the analysis period due to the anthropic actions of each government region, the development of orbital sensors, and the increase of the numbers and types of environmental satellites.

Three homogeneous groups of fire foci were identified based on cluster analysis (G_1, G_2 and G_3), together with the municipality of Campos dos Goytacazes (N_A). This was achieved using Ward's method with the Euclidian distance as a dissimilarity measure. Spatially, the G_1 group was the largest in terms of the number of municipalities, which were spread throughout SRJ and covered the coastal and lowland regions towards the north. The G_2 group had a similar distribution to G_1 but with predominance in the north, south-central, and coastal shallows regions. The G_3 group was concentrated along the mountain ranges of the state. The local characteristics, proximity to the coast, complex topography, and multiscale meteorological systems contribute to the fire risk and are crucial factors in the spatio-temporal variability of fire foci in the state.

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RESUMO: Este estudo avaliou a variabilidade espaço-temporal de focos de calor via satélites ambientais para o Estado do Rio de Janeiro (SRJ) com base em procedimentos estatísticos. Os focos de calor no período de 2000 a 2015 foram obtidos a partir do banco de dados de focos do BDQueimadas. Análises estatísticas descritivas, exploratórias e multivariadas foram realizadas no ambiente de software R i386 versão 3.2.5. A região Norte tinha 6760 focos (21,11%), a região Centro-Sul tinha 3020 focos (9,43%), o Médio Paraíba tinha 6,352 focos (19,84%), as áreas metropolitanas tinham 6671 focos (20,83%) e a Costa Verde região teve 292 focos (0,91%). A análise de agrupamento identificou três grupos homogêneos de focos de calor (G_1, G_2 e G_3), mas não incluiu o município de Campos dos Goytacazes (N_A). Em que se observa no grupo G_1 uma forte presença de outliers com valores atípicos, em todos os anos da série temporal, sendo destaque para os anos de 2014 e 2015 que apresentam os maiores números de outliers seguidos dos valores das médias (20.46 e 18.85 focos) acima das medianas (14.00 e 12.50 focos). Comportamentos semelhantes foram observados nos grupos G_2 e G_3, sendo o grupo G_2 com média (81.43 mm e 66.00 focos) e medianas (49.07 e 35.50 focos) com um DP de 27.89 focos de fogo. O grupo G_3 com média (314.13 e 361.33 mm) e mediana (204.50 e 76.00 focos) e o maior DP (196,75 focos) em comparação aos demais grupos. Características ambientais e socioeconômicas são cruciais na dinâmica dos focos de calor no Rio de Janeiro.

PALAVRAS-CHAVE: Incêndios florestais. Queimadas. Satélites ambientais. Métodos estatísticos. Sistemas meteorológicos.

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