PERIODS OF HIGHEST OCCURRENCE OF FOREST FIRES IN BRAZIL

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Resumo

Períodos de maior ocorrência de incêndios florestais no Brasil. Os incêndios florestais afetam os ecossistemas e causam danos que podem ser minimizados pelos programas de prevenção de incêndios. O objetivo foi determinar os períodos com maior probabilidade de ocorrência de incêndios em vegetação no Brasil. Registros de focos de calor detectados por satélites entre 1999 e 2014 e a frequência de ocorrências de incêndios e tamanho de áreas queimadas de 2006 a 2014, foram avaliados. Uma análise estatística do agrupamento de médias permitiu separar os meses com o maior número de fontes de calor em grupos homogêneos, sendo possível validá-los com os meses com o maior registro de incêndios nas UCs, definindo a estação normal de incêndio. O número de focos de calor registrados no Brasil foi maior no inverno e na primavera, com estação normal do fogo de agosto a novembro. A ocorrência de incêndios foi maior entre agosto e outubro, e a maior área queimada em setembro. Os períodos de maior ocorrência de incêndios no Brasil variaram entre as regiões de acordo com as características climáticas e, portanto, estratégias de prevenção e controle de incêndios na vegetação devem ser intensificadas durante a estação normal de incêndio. O período de agosto a novembro precisa de maior atenção do poder público na implementação de programas de prevenção e controle de incêndios. Os meses de setembro e outubro compõem a estação normal do fogo de todas as regiões do Brasil.
Palavras-chave: Estação do fogo; combate a incêndios; áreas protegidas; gestão de incêndio.

Abstract

Forest fires affect ecosystems and cause damage that can be minimized by fire prevention programs. The objective was to determine the periods with the highest probability of occurrence of forest fires in Brazil. Heat source records detected by satellites between 1999 and 2014, and the frequency of occurrences of fire and burnt area sizes from 2006 to 2014, were evaluated. A statistical analysis of averages grouping allowed to separate the months with the highest number of heat sources into homogeneous groups, being possible to validate them with the months with the highest record of fires in the Conservation Units, thus defining the normal fire season. The number of heat sources records in Brazil was higher in winter and spring, dry seasons with lower rainfall and higher temperatures, with normal fire season from August to November. The fire occurrences were higher between August and October, with the higher burnt area in September. The periods of highest fire occurrence in Brazil varied between regions according to the climatological characteristics, and therefore strategies for fire prevention and control in vegetation must be intensified during the normal fire season. The period from August to November needs the greatest attention from the public authorities regarding the implementation of prevention and control fire programs. The months September and October make up the normal fire season from all regions of the Brazil.
Keywords: Season fire; firefighting; protected areas; fire management.

INTRODUCTION

Forest fires interfere in the ecosystem dynamics and can cause ecological disturbances, economic losses and increase of CO_2 emissions comparable to those of burning fossil fuels, affecting the carbon cycle and contributing to global warming (HUIJNEN *et al.*, 2016).

Climate change is increasing the extreme fire danger levels, and South America is one of the regions most vulnerable to these changes (BEDIA *et al.*, 2015). As the daily maximum temperature increases, areas of savanna vegetation such as the Cerrado and Caatinga biomes in Brazil, are threatened (SILVA *et al.*, 2016).

Climatological variables and plant species characteristics are determinants of propagation rate, impact and fire control difficulty (BEDIA et al., 2015). These variables, when used in modeling programs, help to predict spatial patterns of long-term fire events and guide fire management strategies in different parts of the world (HUIJNEN et al., 2016; SILVA et al., 2016). The annual periods during which climatological factors, mainly low precipitation and relative humidity, favor the occurrence of a large number of fires in vegetation are classified as the normal fire season (TORRES *et al.*, 2010).

The definition of the normal fire season helps guide public fire prevention and fighting policies (SILVA *et al.*, 2016), but studies that determine this period for Brazil are still incipient. Firefighting actions in Brazil are carried out in a single calendar of actions and measures without following specific guidance that considers the

most fire-prone periods for each state or region. The huge climatic and vegetational heterogeneity and other factors that influence the fire occurrences are disregarded when adopting a single prevention and combat calendar (PEZZATTI *et al.*, 2013).

An alternative to define the normal fire season is the heat sources data use. These heat sources are geographic points captured by space sensors on the earth's surface when a temperature above 47 °C are detected. There is some degree of detection systems uncertainty and inaccuracy of these sensors, and field validation through fire records is required for refinement (LAZZARINI *et al.*, 2016).

Data from heat sources in Brazil are available for consultation through the National Institute for Space Research, being the official source of data for fire behavior studies. Another data source is the National Fire Information System (SISFOGO), of the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA), which allows to consult a database with records fire occurrences in protected areas, entitled Conservation Units (CUs) in accordance with Law Nº 9,985 de 2000 that establishes the National System of Nature Conservation Units. In SISFOGO the user can access data such as date, location, area burned, source and cause of fires, being the only free source of access to this type of information.

Given the lack of methodology for determining the normal fire season, proposals are needed to establish this period. An available and applicable method is the statistical analysis of averages grouping that allows to separate months with the highest number of heat sources into homogeneous groups, being possible to validate them with the months with the highest record of fires in the CUs, thus defining the normal season of fire (TORRES *et al.*, 2010).

Brazil is one of the areas most affected by fires globally, with changes in land use and cover, such as deforestation and fire use to convert forests into agricultural and pasture areas, being important sources of ignition for fire episodes in the country (MATAVELI *et al.*, 2018). These changes interfere with the fire-climate relationship, modify the fire regime and are one of the main sources of greenhouse gas emissions (HUIJNEN *et al.*, 2016).

Regions, even those near to each other, present specific fire behavior contexts, and therefore, local fire statistics studies are fundamental when creating fire prediction programs that guide the adoption of specific and more efficient measures (PEZZATTI *et al.*, 2013). These programs contribute to the prevention, combat and reduction of fire damages, indicating danger situations and assisting in management decisions (SILVA *et al.*, 2016). Preventive measures such as the regulation of the fire management, the establishment of high-risk stations and the adoption of educational and participatory measures in relation to safe fire management and fire risks also contribute to occurrences reduction (FÉLIX *et al.*, 2018).

Brazil is a country with continental territorial extension, with climatic and vegetation variation among its five regions, causing different susceptibility conditions to forest fires. The objective was to determine the periods with the highest probability of forest fires occurrence in Brazil, based on the hypothesis that each Brazilian region has a different normal fire season. This type of study contributes to more efficient fire prevention initiative orientations, according to each region singularities.

MATERIAL AND METHODS

Temporal distribution of heat sources

The records of heat sources between 1999 and 2014 in Brazil were obtained from the National Institute for Space Research/Weather Prevision Center and Climate Studies (INPE/CPTEC). Heat sources were detected by the polar orbiting satellites NOAA-12 (1999 to 2007) and AQUA_M-T (2007 to 2014). For these satellites, field validation indicates that each focus corresponds to an area of fire about 30 m long by 1 m wide or larger. For more details see www.inpe.br/queimadas/bdqueimadas.

Fire occurrences in Brazil

Data on fire occurrences between 2006 and 2012 were obtained from the Fire Occurrence Records (FORs) of the Conservation Units (CUs) of Brazil. There were 1,873 FORs throughout the period analyzed. The months of occurrence and burnt area (ha) were obtained from these records. FORs without this information were excluded.

The distribution of CUs and FORs between the regions was respectively: Northeast: 17 and 693, North: 12 and 85, Midwest 12 and 287, Southeast: 25 and 662 and South: 9 and 146.

Data analysis

The data were organized in Excel and the monthly averages of heat sources, fire occurrence and burnt area (ha) analyzed nationally and for the five macroeconomic regions of Brazil: North, Northeast, Midwest, Southeast and South (Figure 1). Averages were compared using the Scott Knott (SK) test at 5% probability in the software R. This test was chosen because it is the most suitable for averages grouping, since there is no overlap between the results of the groups. The months group with the highest averages of heat source records were

indicated as the normal fire season. The normal fire season was validated witch the highest averages of fire occurrences and burnt area (ha). The SigmaPlot version 10 was used to create the graphics.

RESULTS

The heat sources between 1999 and 2014 in Brazil were 2,754,275, with higher numbers in the winter (June to September) and spring (September to December). The normal fire season was from August to November, with the highest number of heat sources in September. The total number of fire occurrences and burnt area in CUs of Brazil from 2006 to 2012 was 1873 and 853,230.61 ha, respectively. August to October and August to September were the periods with the highest number of occurrences (61.34%) and largest burnt area (72.03%) with peak in August and September, respectively. The average burnt area in CUs of Brazil was 455.54 ha (Figure 1).

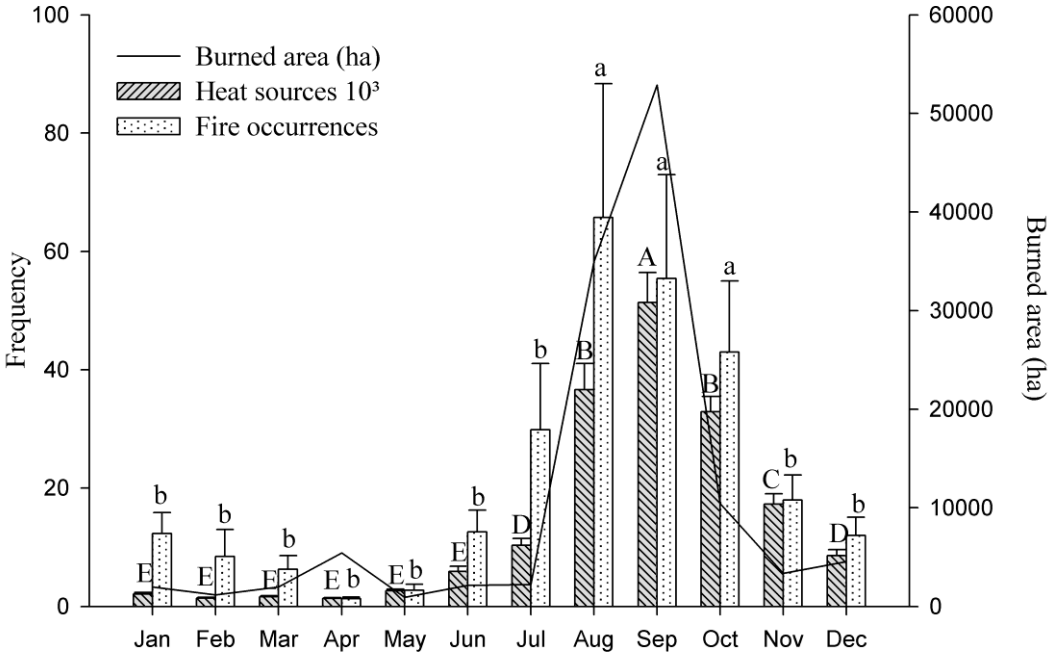

Figure 1. Average frequency of heat sources (x10³) per month between 1999 and 2014 in Brazil and average frequency occurrences of fires and burned area (ha) in Conservation Units of Brazil between 2006 and 2012. Jan = January, Feb = February, Mar = March, Apr = April, Jun = June, Jul = July, Aug = August, Sep = September, Oct = October, Nov = November, Dec = December. Similar average scores are similar by the Scott Knott test (P <0.05). Vertical bars are ± standard average error average (n = 16) (n = 7).

Figura 1. Frequência média dos focos de calor (x10³) por mês entre 1999 e 2014 no Brasil e frequência média de ocorrências de incêndios e área queimada (ha) em Unidades de Conservação do Brasil entre 2006 e 2012. Jan = janeiro, Fev= fevereiro, Mar = março, Apr = abril, Jun = junho, Jul = julho, Aug = agosto, Sep = setembro, Oct = outubro, Nov = novembro, Dec = dezembro. Valores médios semelhantes de acordo com o teste de Scott Knott (P <0,05). As barras verticais são ± erro padrão da média (n = 16) (n = 7).

The heat source records in the North and Northeast regions were the largest with 35.0; 28.3% of the total, respectively. The normal fire season in these regions was from August to November and September to November, respectively. However, an abnormality with a high burned area in the month of June for the northeast region was observed. The fire records in the Midwest corresponded to 27.9% of the total and the normal fire season was from August to October (Figure 2).

The fire occurrence was highest between 2006 and 2012 in the Northeast, Midwest and North regions of Brazil were 693, 287 and 85, respectively. The highest occurrence was from August to December (85.3%), July to September (64.80%) and August to October (76.47%) to these regions. The burnt areas were the largest in the country and corresponded to 17.22; 21.23 and 38.28%, respectively. September was the month with the largest

average burnt area in the Northeast region. The largest burned areas were recorded in the months of the normal fire season, however the averages did not differ between months by SK test in each region.

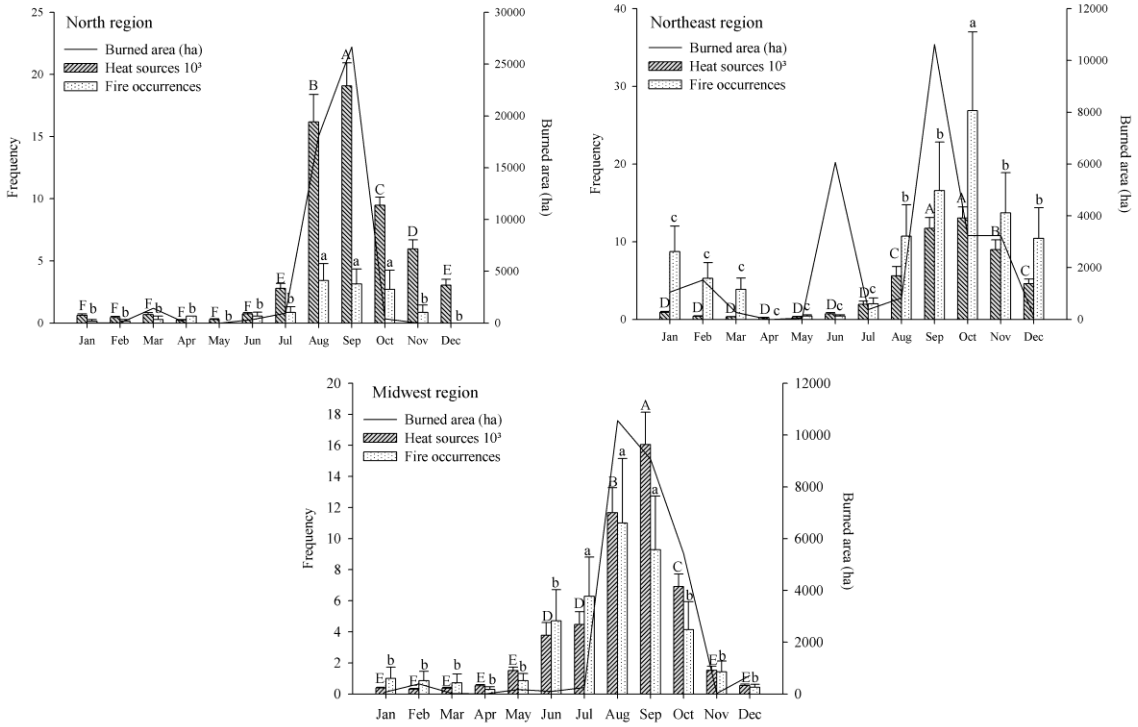

Figure 2. Average frequency of heat sources (x10³) per month between 1999 and 2014, and average frequency occurrences of fires and burned area (ha) in Conservation Units between 2006 and 2012 in the North, Northeast and Central West regions of Brazil. Jan = January, Feb = February, Mar = March, Apr = April, Jun = June, Jul = July, Aug = August, Sep = September, Oct = October, Nov = November, Dec = December. Similar average scores are similar by the Scott Knott test (P <0.05). Vertical bars are ± standard average error (n = 16) (n = 7).

Figura 2. Frequência média dos focos de calor (x10³) por mês entre 1999 e 2014 e frequência média de ocorrências de incêndios e área queimada (ha) em nas Unidades de Conservação entre 2006 e 2012 das regiões Norte, Nordeste e Centro-Oeste do Brasil. Jan = janeiro, Fev= fevereiro, Mar = março, Apr = abril, Jun = junho, Jul = julho, Aug = agosto, Sep = setembro, Oct = outubro, Nov = novembro, Dec = dezembro. Valores médios semelhantes de acordo com o teste de Scott Knott (P <0,05). As barras verticais são ± erro padrão da média (n = 16) (n = 7).

The fire records in the Southeast and South regions were the lowest and corresponded to 7.02 and 2.16% of the total, respectively. The normal fire season was from August to October and August to September, respectively (Figure 3).

The fire occurrences, between 2006 and 2012, in CU's of the Southeast and South regions were 662 and 147, with highest occurrence from July to September (80.36%) and August to September (47.94%), respectively. The burnt areas were the lowest with 10.53% and 10.97%, respectively. The burnt area average values did not differ between the months by the SK test to these regions. A high burned area was observed in April, outside the normal fire season, in the South region (Figure 3).

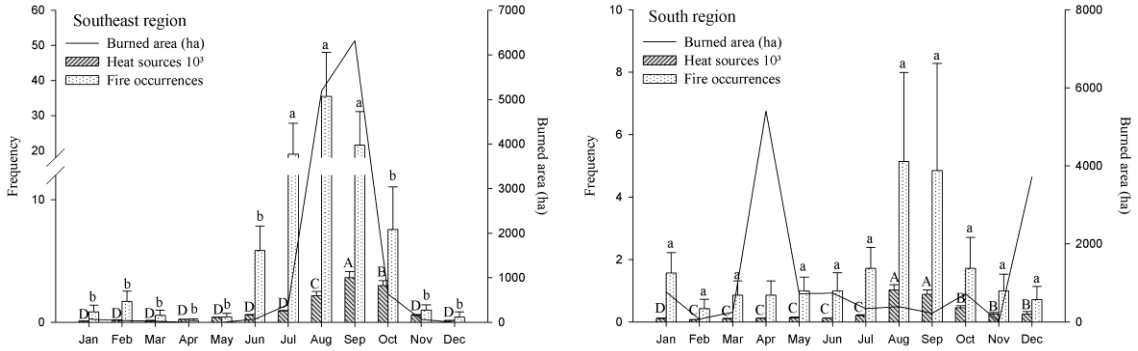

Figure 3. Average frequency of heat sources (x10³) per month between 1999 and 2014, and average frequency occurrences of fires and burned area (ha) in Conservation Units between 2006 and 2012 in the Southeast and South regions of Brazil. Jan = January, Feb = February, Mar = March, Apr = April, Jun = June, Jul = July, Aug = August, Sep = September, Oct = October, Nov = November, Dec = December. Similar average scores are similar by the Scott Knott test (P <0.05). Vertical bars are ± standard average error (n = 16) (n = 7).

Figura 3. Frequência média dos focos de calor (x10³) por mês entre 1999 e 2014 e frequência média de ocorrências de incêndios e área queimada (ha) em nas Unidades de Conservação entre 2006 e 2012 das regiões Sudeste e Sul do Brasil. Jan = janeiro, Fev= fevereiro, Mar = março, Apr = abril, Jun = junho, Jul = julho, Aug = agosto, Sep = setembro, Oct = outubro, Nov = novembro, Dec = dezembro. Valores médios semelhantes de acordo com o teste de Scott Knott (P <0,05). As barras verticais são ± erro padrão da média (n = 16) (n = 7).

DISCUSSION

The highest number of heat sources in winter and spring in Brazil is due to the drier climate influence in most of the country in this period (SOARES *et al.*, 2006) as reported for the fire occurrences in South America (BEDIA *et al.*, 2015). Equatorial of the South Atlantic (EAMs) and Tropical (TAMs) air masses produce low precipitation on the coast and mainland of Brazil, with few clouds, high or low sunshine, and significant thermal amplitude during the winter days (TORRES; MACHADO, 2011). The TAMs predominate in spring and the Tropical Continental air masses (TCAMs) at the end of this season, heating the continent and giving rise to a hot, unstable mass with low humidity (TORRES; MACHADO, 2011). The normal fire season is influenced by climatological characteristics, since it occurs in periods with high pressure systems associated with dry conditions, with low rainfall and air humidity , and high insolation, increasing evapotranspiration and transforming the vegetation material into fuel (HUIJNEN *et al.*, 2016).

The highest occurrence of fires in CUs, from August to October, winter and spring, was similar to the normal fire season indicated for Brazil, with a difference in the occurrences peak in August. The differences can be related to the number of FORs not representing the total number of fires in Brazil, since of the 959 CUs, the FORs observed only accounted for 75 with there being no records in the states of Acre, Amazonas and Rio Grande do Norte. FORs are scarce and often incomplete, due to the urgency and the physical and emotional exhaustion associated with firefighting in CUs (BONTEMPO *et al.*, 2011). July to November and July to October were the months of highest fire occurrences in studies between 1893 and 1987, 1994 and 1997, and 1998 and 2002, respectively (SOARES *et al.*, 2006). The average burnt area in these studies was lower than that found (455.54 ha), being 76, 135 and 4.42 ha, respectively, with the lower value in the latter is attributed to the higher fire occurrences recorded influencing the data amplitude. The differences found, in these studies, are related to the data use from companies and forest enterprises concentrated mostly in the Southeast region, that use fire protection systems and plantations of few species (SOARES *et al.*, 2006). This implies a period of fire occurrence similar to that of the Southeast region with the highest number of records and the greater control of fires, not allowing them to reach large areas as registered in the CUs.

The normal fire season in the North region, during August to November, was the only one equal to the national one, and its expressive fire registers between the others influenced the overall record for Brazil. The records during this period may be related to the increase in dry days frequency in winter and spring in some states of the region (ALENCAR *et al.*, 2006), variation in precipitation due to changes in sea surface temperature (BUFACCHI *et al.*, 2016), and significant deforestation that changes the hydrological cycle and causes more light and wind to enter into forests during the dry season, transforming them into flammable material (ALVES *et al.*, 2017). Vegetation moisture, apparent density and surface area to volume ratio are defining parameters in fire

occurrences in the region (BUFACCHI *et al.*, 2016). Extreme drought events under the influence of climatic events such as El Niño and La Niña are common and increase the duration of the dry season, further accentuating fire occurrences, similar to records in Southeast Asia (HUIJNEN *et al.*, 2016).

The normal fire season in the Northeast, the region with the second highest number of heat sources, was from September to November and may be related to the concentration of the drought period in the second half of the year, with the fewest rainy days average in the months of normal fire season under the Intertropical Convergence Zone (IZC) and East Undulatory Disorders (EUD) influences (SILVA *et al.*, 2011). Continentality accentuates drought in the states farthest from the coast with the number of months with low rainfall increasing from one to eight from the coast to the interior (TORRES; MACHADO, 2011).

The abnormality of burned area in the month of June for the northeast region can be explained by the registration of a fire with an extension of 6,052.6 ha in the Nascentes do Rio Parnaíba National Park, in 2007. This park is the second largest conservation unit in the region, with Cerrado biome vegetation predominant. The high fire occurrences in this CU, and the burning of large areas are a recurring problem. Between 1998 and 2011 it was the CU with the highest fire occurrences outbreaks in the Northeast region, which, according to Vallejo (2012), is directly associated with the territorial conflicts derived from the large agribusiness expansion projects in the region. Land regularization problems within the Park area also contribute to the fire occurrences, since there are still private properties that are not expropriated, in which the owners use fire to manage native pasture in "veredas" areas and to clean areas after deforestation (IBAMA, 2007).

The normal fire season of the Midwest region, from August to October, may be related to the reduction of accumulated precipitation in winter and autumn and to the annual precipitation concentration between October and April in the Cerrado (BORGES *et al.*, 2014). Changes in land use and land cover associated with deforestation and fire use in the management of agricultural areas are common in the Amazon, Caatinga and Cerrado biomes, which are distributed in greater numbers in the North, Northeast and Midwest regions respectively (SPERA *et al.*, 2016). These practices generate sources of ignition for fire occurrence and contribute to the threat of extinction of the last two biomes (ALVES *et al.*, 2017; MATAVELI *et al.*, 2018). Fires over large areas were recorded within the normal fire season in the North (ALENCAR *et al.*, 2006) and Midwest (MATAVELI *et al.*, 2018).

The highest fires occurrence periods in CUs in the North, Midwest and Northeast regions coincided with the normal fire season, except in the Northeast, but in subsequent months, which may be related to the drought period in this region (TORRES; MACHADO, 2011). The number of fires occurrence in the regions was not related to the burnt area size. The northern region, even with the lowest occurrences number, had the largest burnt area in CUs (38.28%) in Brazil. The variation in burnt area between the regions may be related to the fire-fighting efficiency, the predominant vegetation type (SILVA *et al.*, 2016), the difficulty degree to access the areas and the insufficient number of employees and firefighters, hindering combat efforts in the CUs (FÉLIX *et al.*, 2018).

The normal fire season in the Southeast from August to September may be related to the higher incidence and solar radiation time in almost the entire region between September and March, resulting in longer days and higher temperatures (COELHO *et al.*, 2016). The rainfall period is influenced by the frontal systems (FS) decrease, which causes a reduction in the precipitation volume during this period (COELHO *et al.*, 2016). The climatic transition of the Southeast region is close to the tropical climates and the rainy and dry seasons are well defined (RAO *et al.*, 2016). The less frequent records of fire outbreaks for the region may be related to the fact that this region it is does not among the regions those ones presenting greatest agricultural expansion in Brazil (SPERA *et al.*, 2016), where fire ignition sources are higher due to changes in land use and occupation (MATAVELI *et al.*, 2018). The normal fire season of the Southern region, from August to September, occurs under through the influence of the Atlantic Polar air mass (APAM) associated with anticyclones formed in the sub-Antarctic region (Weddel Sea) in which they blow on the region Northeast winds from the South Atlantic Anticyclone, bringing stable climate with abrupt heating, forming pre-frontal heating (TORRES; MACHADO, 2011).

The highest fires occurrences in the Southern region, from August to September, and the Southeast, from July to September, coincide with the normal fire season indicated for the regions. The smaller burnt areas of the country for these two regions and the similarity of fires occurrences in all the months in the South region can be explained because they comprise portions of the coastal area where hot and humid air currents from the Atlantic Ocean cause distributed orographic rains throughout the year and this precipitation increases humidity and reduces the possibilities of fire spreading (RAO *et al.*, 2016). The highest number of occurrences in August (80.36%) in the Southeast region is explained by favorable meteorological conditions, with low relative humidity and dry vegetation, which favors the fires occurrence (MEDEIROS; FIEDLER, 2004). In both regions, in the period of greatest fire occurrence, rural producers use fire to prepare the soil for the agricultural crop, which increases the incidence of outbreaks and the fires occurrence (TETTO *et al.*, 2012).

The highest burned area in April, out of the normal fire season, in the South can be explained by fires records in this month in the Ilha Grande National Park, in the 2006 and 2009 years, with 35,000 and 2,753 hectares, respectively. The 2009 records were intensified due to the rainfall decrease as an effect of the La Niña phenomenon

(PARANÁ, 2020). The causes of fires in this park are due to the flammability characteristics of the vegetation, but mainly of human activities, such as hunting, fishing and pastures burning, which are sources of ignition. In addition, the Fire Prevention and Fighting Plans inefficiency, mainly related to the combat personnel lack, may explain the fires occurrence during the normal fire season as well as during less probability periods (KOPROSKI, 2004).

CONCLUSIONS

- The period with the highest probability of vegetation fires occurrence in Brazil is from August to November. This is the period that needs the greatest attention from the public authorities regarding the implementation of fire prevention and control programs.
- Records of forest fires with a high area burned outside the normal fire season were related to the use of fire in the expansion of agricultural borders and point to the need for combat teams also in periods of low probability of fires.
- The normal fire season varied on a regional scale, and the months September and October make up the normal fire season from all regions of the Brazil.
- The regions with the highest records of fire outbreaks were, in descending order, North, Northeast, Midwest, Southeast and South. The burnt area was larger, in descending order, in the North, Center-West, Northeast, South and Southeast regions.
- Climatic characteristics and anthropogenic interventions may affect the seasonality and periods duration of greatest fire occurrence in Brazil, with the highest records during winter and spring, with September being the most critical month.

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REFERENCES

ALENCAR, A.; NEPSTAD, D.; DIAZ, M. C. V. Forest Understory Fire in the Brazilian Amazon in ENSO and Non-ENSO Years: Area Burned and Committed Carbon Emissions. **Earth Interactions**, v. 10, n. 6, p. 1–17, 2006.

ALVES, L.M., MARENGO, J.A., Fu, R. and BOMBARDI, R.J. Sensitivity of Amazon Regional Climate to Deforestation. **American Journal of Climate Change**, v. 06, n. 01, p. 75–98, 2017.

BEDIA, J.; GOLDING, N.; CASANUEVA, A.; ITURBIDE, M.; BUONTEMPO, C.; GUTIÉRREZ, J.M.. Global patterns in the sensitivity of burned area to fire-weather: Implications for climate change. **Agricultural and Forest Meteorology**, v. 214–215, p. 369–379, 2015.

BONTEMPO, G. C.; LIMA, G.S.; RIBEIRO, G.A.; DOULA, S.M.; SILVA, E.; JACOVINE, L.A.G. Registro de Ocorrência de Incêndio (ROI): evolução, desafios e recomendações. **Biodiversidade Brasileira**, v. 1, n. 2, p. 247–263, 2011.

BORGES, P. DE A.; FRANKE, J.; DO SANTOS SILVA, F.D.; WEISS, H.; BERNHOFER, C. Differences between two climatological periods (2001–2010 vs. 1971–2000) and trend analysis of temperature and precipitation in Central Brazil. **Theoretical and Applied Climatology**, v. 116, n. 1–2, p. 191–202, 2014.

BUFACCHI, P.; KRIEGER, G.C.; MELL, W.; ALVARADO, E.; SANTOS, J.C.; CARVALHO, J.A. Numerical simulation of surface forest fire in Brazilian Amazon. **Fire Safety Journal**, v. 79, p. 44–56, 2016.

COELHO, C. A. S.; DE OLIVEIRA, C.P.; AMBRIZZI, T.; REBOITA, M.S.; CARPENEDO, C.B.; Campos, J.L.P.S.; TOMAZIELLO, A.C.N.; PAMPUCH, L.A.; CUSTÓDIO, M. de S.; DUTRA, L.M.M.; The 2014 southeast Brazil austral summer drought: regional scale mechanisms and teleconnections. **Climate Dynamics**, v. 46, n. 11–12, p. 3737–3752, 2016.

FÉLIX, G. D. A.; LIMA, G.S.; TORRES, F.T.P.; COSTA, A.D.G.; DA SILVA JÚNIOR, M.R. Avaliação da Eficiência de combate aos incêndios florestais em Unidades de Conservação brasileiras. **FLORESTA**, v. 48, n. 1, p. 113, 2018.

HUIJNEN, V.; WOOSTER, M.J.; KAISER, J.W.; GAVEAU, D.L.A.; FLEMMING, J.; PARRINGTON, M.; INNESS, A.; MURDIYARSO, D.; MAIN, B.; VAN WEELE, M. Fire carbon emissions over maritime southeast Asia in 2015 largest since 1997. **Scientific Reports**, v. 6, n. 1, p. 26886, 2016.

IBAMA - Instituto Brasileiro do Meio Ambiente e Recursos Naturais Renováveis. Centro Nacional de Prevenção e Combate aos Incêndios Florestais – Prevfogo. Parque Nacional das Nascentes do Rio Parnaíba. Plano operativo de prevenção e combate aos incêndios florestais do Parque Nacional das Nascentes do Rio Parnaíba. Corrente-PI: IBAMA - 2007. 17p.

KOPROSKI, L. P.; BATISTA, A. C.; SOARES, R. V. Ocorrências de incêndios florestais no Parque Nacional de Ilha Grande-Brasil. **Floresta**, v. 34, n. 2, 2004.

LAZZARINI, G. M. J.; FERREIRA, L.C.C.; FELICÍSSIMO, M.F.G.; OLIVEIRA, L.N. de; GIONGO, M. Análise da detecção e ocorrência de queimadas em áreas urbanizadas e entorno. **Ciência e Natura**, v. 38, n. 3, p. 1265, 2016.

MATAVELI, G. A. V.; SILVA, M.E.S.; PEREIRA, G.; DA SILVA CARDOZO, F.; KAWAKUBO, F.S.; BERTANI, G.; COSTA, J.C.; DE CÁSSIA RAMOS, R.; DA SILVA, V.V.. Satellite observations for describing fire patterns and climate-related fire drivers in the Brazilian savannas. **Natural Hazards and Earth System Sciences**, v. 18, n. 1, p. 125–144, 2018.

MEDEIROS, M. B. DE; FIEDLER, N. C. Incêndios florestais no parque nacional da Serra da Canastra: desafios para a conservação da biodiversidade. **Ciência Florestal**, v. 14, n. 2, p. 157–168, 2004.

PARANÁ. COORDENADORIA ESTADUAL DA DEFESA CIVIL. **Com a estiagem incêndios florestais aumentam no Paraná**. Disponível em: <http://www.defesacivil.pr.gov.br/Noticia/Com-estiagem-incendios-florestais-aumentam-no-Parana> Acesso em: 12/07/2020.

PEZZATTI, G. B.; ZUMBRUNNEN, T.; BÜRGI, M.; AMBROSETTI, P.; CONEDERA, M. Fire regime shifts as a consequence of fire policy and socio-economic development: An analysis based on the change point approach. **Forest Policy and Economics**, v. 29, p. 7–18, 2013.

RAO, V. B.; FRANCHITO, S.H.; SANTO, C.M.E.; GAN, M.A. An update on the rainfall characteristics of Brazil: seasonal variations and trends in 1979–2011. **International Journal of Climatology**, v. 36, n. 1, p. 291–302, 2016.

SILVA, V. P. R.; PEREIRA, E.R.R.; AZEVEDO, P.V. de; SOUSA, F. de A.S. de; SOUSA, I.F Análise da pluviometria e dias chuvosos na região Nordeste do Brasil. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 15, n. 2, p. 131–138, 2011.

SILVA, P.; BASTOS, A.; DACAMARA, C.C.; LIBONATI, R. Future Projections of Fire Occurrence in Brazil Using EC-Earth Climate Model. **Revista Brasileira de Meteorologia**, v. 31, n. 3, p. 288–297, 2016.

SOARES, R. V.; BATISTA, A. C.; SANTOS, J. F. Evolução do perfil dos incêndios florestais em áreas protegidas no Brasil, de 1983 a 2002. **Floresta**, v. 36, p. 93–100, 2006.

SPERA, S. A.; GALFORD, G.L.; COE, M.T.; MACEDO, M.N.; MUSTARD, J.F. Land-use change affects water recycling in Brazil's last agricultural frontier. **Global Change Biology**, v. 22, n. 10, p. 3405–3413, 2016.

TETTO, A. F.; BATISTA, A. C.; SOARES, R. V. Ocorrência de incêndios florestais no estado do Paraná, no período de 2005 a 2010. **Floresta**, v. 42, n. 2, p. 391–398, 2012.

TORRES, F. T. P.; RIBEIRO, G.A.; MARTINS, S.V.; LIMA, G.S Determinação do período mais propício às ocorrências de incêndios em vegetação na área urbana de Juiz de Fora, MG. **Revista Árvore**, v. 34, n. 2, p. 297–303, 2010.

TORRES, F. T. P.; MACHADO, P. J. DE O. **Introdução à climatologia**. São Paulo: Cengage Learning, 2011.

VALLEJO, L. R. Uma avaliação sobre os focos de calor e os conflitos territoriais em áreas protegidas do Nordeste brasileiro (1998-2011). **Cadernos do Logepa**. v.7, n.1, p. 3–24, 2012.