RBCTI
Revista Brasileira de Ciência, Tecnologia e Inovação
DOI: https://doi.org/10.18554/rbcti.v7i1.6395

Research Paper

# Space-time analysis of vegetation fire in vacant lots in Araxá City, Minas Gerais

## *Análise temporo-espacial dos incêndios em vegetação em lotes vagos de Araxá, Minas Gerais*

Anderson Passos de Souza*[1]; Ricardo Vicente Ferreira*[2]; Marcos Roberto Martines[3]

*Federal University of Triângulo Mineiro, Uberaba, Minas Gerais, Brazil.
[1] Orcid: https://orcid.org/0000-0002-6717-5900; E-mail: passos193@gmail.com;
[2] Orcid: https://orcid.org/0000-0001-9003-4834; ricardo.ferreira@uftm.edu.br;
[3] Federal University of São Carlos, Sorocaba, São Paulo, Brazil.
Orcid: https://orcid.org/0000-0002-7464-2431. E-mail: mmartines@ufscar.br

**ABSTRACT:** Fire in vacant lots is featured as hazardous type event related to human behavior. These events account for burning urban-zone vegetation, a fact that puts the local population in danger, leads to the emission of polluting gases, and even puts the patrimony at risk. The aim of the present study is to analyze the spatial distribution of wildfire in the vegetation of vacant lots in 2019 and 2020, in Araxá City, Minas Gerais State, Brazil. Data were collected from incident reports by Minas Gerais Military Fire Department. The study followed quantitative methods and Geographic Information Systems (GIS), based on space-time statistics, to detect occurrence clusters through a retrospective permutation method. Based on the results, fire cases in vacant lots happen more often between June and October, during the drought period. If one takes the whole year into account, those were the months accounting for the highest detection of clusters of fire events. In 2019, these events were recorded within shorter time intervals, and they were mainly observed in the city's Northern portion. On the other hand, in 2020, these events were more often recorded in the Southern part of the city. This finding may point out that the vegetation cover consumed by wildfire within 1-year period-of-time does not recover to the extent of suffering with the same effects of burnings in the following year; this process results in different incidence sites. The space-time analysis can highlight places for straight intervention by the public power, and help allocating resources and preventing the impacts of these events.

**Keywords:** Wildfire, SaTScan, Geographic Information Systems.

***RESUMO:*** *Incêndios em lotes vagos se caracterizam como um tipo de desastre relacionado ao comportamento humano. Nestes eventos há o incêndio de vegetações em áreas urbanas, resultando em perigo à população residente, emissões de gases poluentes, podendo incorrer em dano ao patrimônio. O objetivo deste estudo é analisar a distribuição espacial dos incêndios em vegetação de lotes vagos nos anos de 2019 e 2020 na cidade de Araxá, Minas Gerais. Os dados utilizados foram obtidos em boletins de ocorrência do Corpo de Bombeiros Militar de Minas Gerais. O estudo, que faz uso de métodos quantitativos e Sistemas de Informação Geográfica (SIG), utiliza uma análise estatística temporo-espacial, que detecta clusters de ocorrências por meio de um método retrospectivo por permutação. Os resultados mostram que os casos de incêndios em lotes vagos são mais recorrentes nos meses de junho a outubro, que corresponde ao período de estiagem. Considerando todo o ano, foi nestes meses a maior detecção de clusters. No ano de 2019 as ocorrências se deram em prazos mais curtos, concentrando-se na porção norte da cidade, ao passo que, no ano de 2020 essa constatação foi na porção sul. Isso pode indicar que a cobertura vegetal consumida pelos incêndios florestais de um ano não se regenera a ponto de sofrer os mesmos efeitos da queima no ano seguinte, resultando em áreas distintas de incidência. A análise temporo-espacial pode indicar os lugares para a intervenção direta da gestão pública, auxiliando a alocação de recursos e prevenção de impactos.*

***Palavras-chave****: Incêndios Florestais, SaTScan, Sistemas de Informação Geográfica.*

RBCTI
Revista Brasileira de Ciência, Tecnologia e Inovação

## INTRODUCTION

Wildfires in vegetation are seen as rural disturbances resulting from lightening. This phenomenon accounts for a significant fraction of the global emission of greenhouse gases, for changes in land use and for soil degradation (YEBRA; CHUVIECO; RIAÑO, 2008). However, more than 90 % of wildfire (or vegetation fire) causes in Brazil are not related to atmospheric discharges, but to human behavior (RAMOS, 1995).

Overall, three factors are needed to trigger wildfire events: fuel, oxygen and ignition source. The most flammable vegetation types are those presenting abundance of fine and dry fuel material concentrated close to soil surface and prone to ignition (NEPSTAD; MOREIRA; ALENCAR, 1999). Ignition source is, oftentimes, the anthropic origin of fire events, and it can be avoided. According to Medeiros e Fiedler (2004), the reinforcement of preventive actions can reduce the impacts from this category of events; moreover, environmental education is an essential part of this process. Environmental education and geo-processing can be the instruments to sensitize and raise the awareness of, and produce knowledge to, communities, in order to encourage them to prevent risks of fire.

Knowing the times of higher fire-events incidence is important to reduce their occurrence; therefore, the dry season is the riskiest time of the year (TORRES et al., 2010). The development of preventive actions and the combat to wildfire require statistical analyses to find when, where and why these events happen, since this is the way to likely identify risky sites (SOARES; SANTOS, 2002), as well as to set the legal instruments for public policies focused on coping with this issue, based on its several implications.

Vegetation wildfire in urban-zone vacant lots reflects the anthropic influence on its occurrences, because fire is often used to clean land plots (TORRES et al., 2010). Given the risks of aggravating the occurrence of this fire type, it is essential assessing it and detecting its occurrence in time and space in order to improve urban managements, when it comes to these aggravations.

Terrain analysis in Geographic Information Systems (SIG) is an important instrument to interpret the space dynamics of several phenomena presenting spatial expression (CÂMARA; DAVIS; MONTEIRO, 2001) fire cases can be analyzed from this perspective. United States International Strategy for Disasters Reduction (UN-ISDR, 2015) reinforces that adverse event-risk reduction, as well as losses and damage reduction, are linked to using information and to producing knowledge that include geographic information systems (SIG).

Using SIG and Remote Sensing to detect and analyze wildfire events is a strategy based on their ability to integrate different environmental variables in maps, such as vegetation, topography, climate and history of occurrence in different areas. This process allows mapping risky sites. (CHUVIECO et al., 1999). Wildfire events mapping based on orbital data has been possible since the 1970s, the time analysis can be carried out for 50 years, depending on the analyzed space scale. Analysis of risk and vulnerabilities, and planning strategies to reduce and combat risks, stand out among the several strategies for SIG application in wildfire studies (KAZMIERCZAK, 2015).

The first study on wildfire occurrences, based on the space-time scan statistics, was carried out by Tuia et al. (2008) It aimed at identifying places accounting for the highest occurrences of fire within the shortest periods-of-time in the Tuscany region (Italy). This study has shown that the statistic permutation method allows estimating the expected

RBCTI
Revista Brasileira de Ciência, Tecnologia e Inovação

number of cases for a given area by taking into consideration the frequency and location of cases that have happened in the past. Tonini et al. (2009) carried out a study in Florida State (USA) and applied the same methodology adopted by Tuia et al. (2008). They detected areas presenting the highest density of wildfire events in time and space, a fact that has enabled them to help managing prevention measures in the state.

Orozco et al. (2012) used the space-time permutation model in forest wildfire cases in Ticino Canton, Switzerland, based on a longer time cut, from 1969 to 2008. This process allowed them to conclude that the detection of forest wildfire in Ticino was related to areas showing the highest population densities. This finding points out that anthropic actions are the main causes of fire events.

Pereira et al. (2015) used the space-time permutation model in forest wildfire points in Portugal based on data provided by the Portuguese Rural Fire Database (PRFD) – a 27-year series. Their study used scanning windows at different space-time dimensions; these parameters stood out in model definition; consequently, they reflected the result interpretations.

Recently, Parente, Pereira and Tonini (2016) have analyzed space-time cluster cases of forest wildfire in Portugal, based on the 1990-2013 time-cut. They deepened their analysis by using climatic and fire management data. These authors took into account the association between climate and wildfire events taking place in the whole Portuguese territory; the detected clusters were interpreted in terms of atmospheric conditions. Two points stood out in their conclusions: (1) there are two fire regimes in the country, which are caused by different climate types in Northern and Southern Portugal; (2) the ability of the space-time scan statistics to properly identify clusters in comparison to their number, locations and to space-time size. The aim of the current study was to analyze the space distribution of vegetation fire events recorded by the Military Fire Department, in space and time, in Araxá's urban zone, Minas Gerais State, Brazil, in 2019 and 2020.

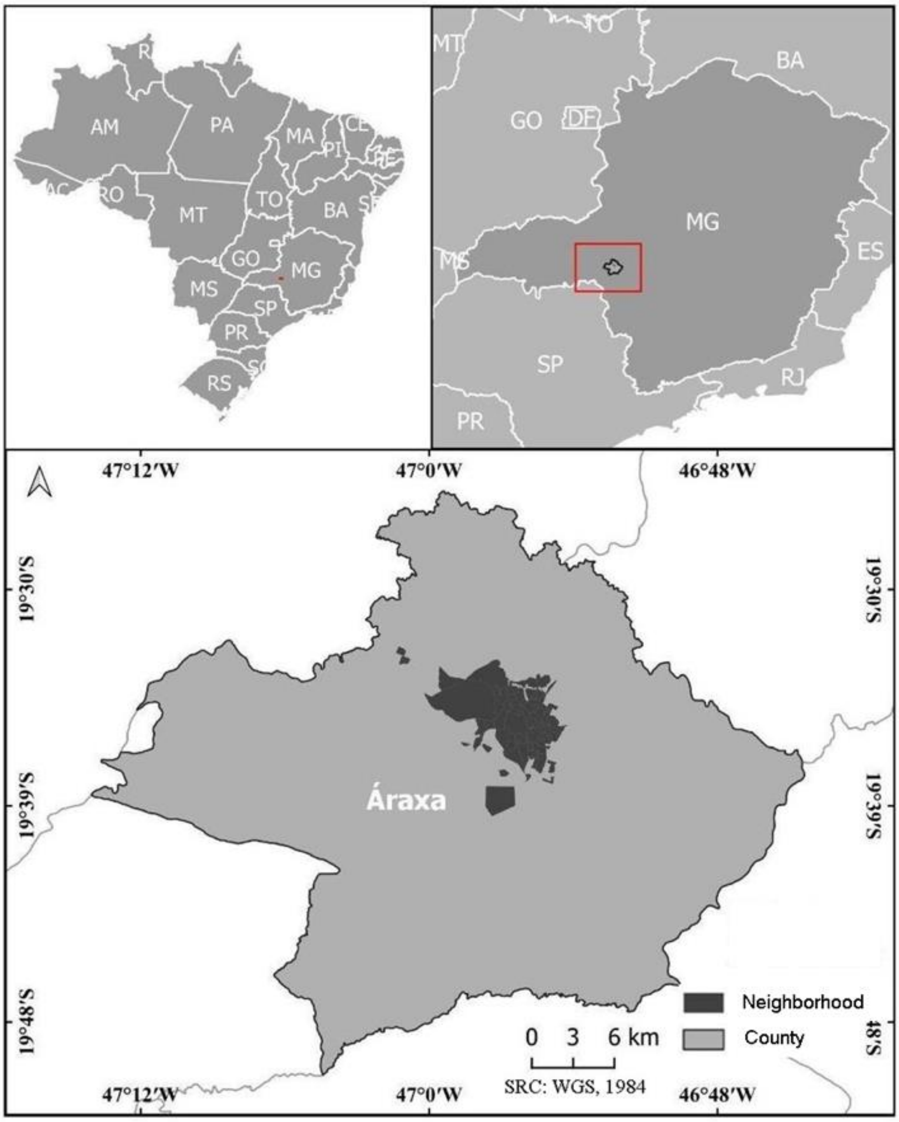
## METHODOLOGICAL PROCEDURES

The study followed the observational, descriptive, approach to make the space-time analysis of fire-events frequency in urban-zone vacant lots. Data were collected from Minas Gerais Military Fire Department incident reports (CBMMG), from Araxá County (MG), in 2019 and 2020.

Araxá County is located in Minas Gerais State, Triângulo Mineiro and Alto Paranaíba region. According to 2021 estimates, the county houses 108,403 inhabitants (IBGE, 2021) (**Figure 1**).

RBCTI
Revista Brasileira de Ciência, Tecnologia e Inovação

**Figure 1.** Araxá, MG county localization




The study adopted quantitative methods and Geographic Information Systems (SIG) to explain the relative risk and space distribution of urban wildfire occurrences recorded by CBMMG within the herein assessed area. Statistical analyses were carried out in SaTScan software (v.9.7) (KULLDORFF et al., 2005).

If one has in mind that the space-time pattern of vegetation fire is not random, seasonal climatic variations, fuel availability for burnings and the very presence of humans are factors related to fire events, which can be analyzed based on groups of cases in time and space.

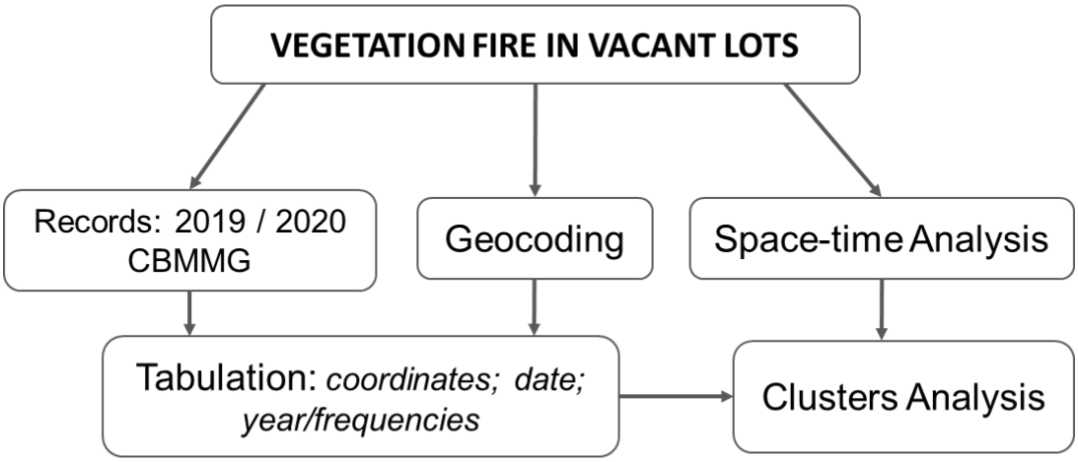
Accordingly, the analysis was made based on the space-time permutation model, which analyzes data of cases recorded at a given period-of-time and its locations, without the need of using control information. In other words, it uses a reference basis to estimate the relative risk of events within a given area (KULLDORFF, 2015).

Space-time permutation scan statistics uses several overlapped cylinders to find a

RBCTI
Revista Brasileira de Ciência, Tecnologia e Inovação

scanning window by setting a time limit to the analysis, so that it is possible finding the occurrences of a given phenomenon, in space (KULLDORFF 2005). The idea of the cylinder is merely illustrative, actually, the cartographic representation shows vector structures in circles (clusters) that present points detected during the analysis and a table of features with space-statistics information: detected clusters, analysis period of each cluster, number of observed events, number of expected events, cylinder radius (permutation model) and probability values (p-value). Accordingly, scan statistics detect clusters (cylinders) in space and time. The basis and height of a given cylinder represent the analyzed initial and final time, and cylinder width represents the space covered by the cluster (GAO, et al., 2013).
The study followed the tabulation and geocoding stages of fire events, described their occurrences per neighborhood and made their space-time analysis through space statistics (**Figure 2**).

**Figure 2**. Space-time analysis of vegetation fire in vacant lots methodology.




The points in the current study correspond to the locations of wildfire events reported in CBMMG's reports. Thus, the expected number of occurrences is estimated based on cases observed from the no space-time interaction hypothesis; it means that space-time locations of all events were independent from one another (OROZCO et al., 2012, KULLDORFF, 2005).

Input data were the points' geographic coordinates over the study time, the definition of number of Monte Carlo repetitions (up to 999 repetitions). clusters of fire events studies were carried out at two different periods: (1) wildfire event recorded between June 01, 2019 and October 31, 2019, with 50 records; (2) events recorded between June 01, 2020 and October 31, 2020, with 78 records.

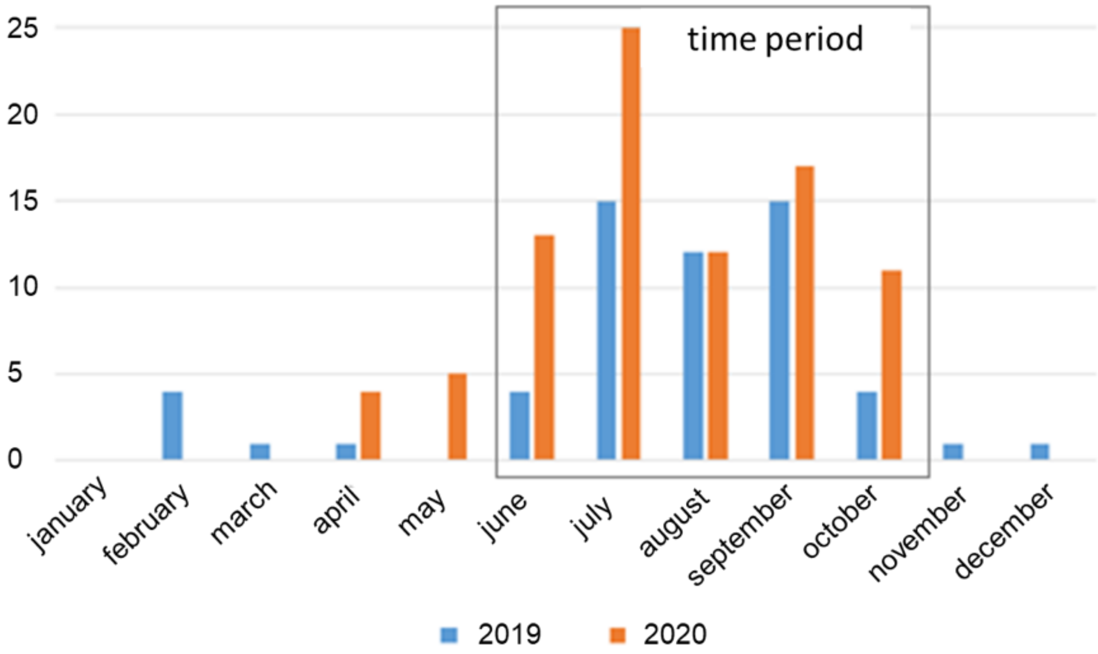
The following parameters were used in the analysis: (a) space-time retrospective analysis with aggregation time of 1 (one) day, and (b) detection of areas accounting for high rates between June 01, 2019 and October 31, 2019, and between June 01, 2020 and October 31, 2020. The space-time scanning window reached 50% within the assessed time interval, and 50% of the risky population. It means risk of occurrence based on the total annual reports per year.

RBCTI
Revista Brasileira de Ciência, Tecnologia e Inovação

## RESULTS AND DISCUSSION

The distribution of records in the two assessed years showed that fire event cases were more often observed between June and October, in the drought season (**Figure 3**). At this time of the year, reports can reach approximately 90% of forest wildfire cases or of fire events in vacant lots due to the environment favorable to them, since the vegetation is dry and relative humidity is low (TORRES et al., 2012).

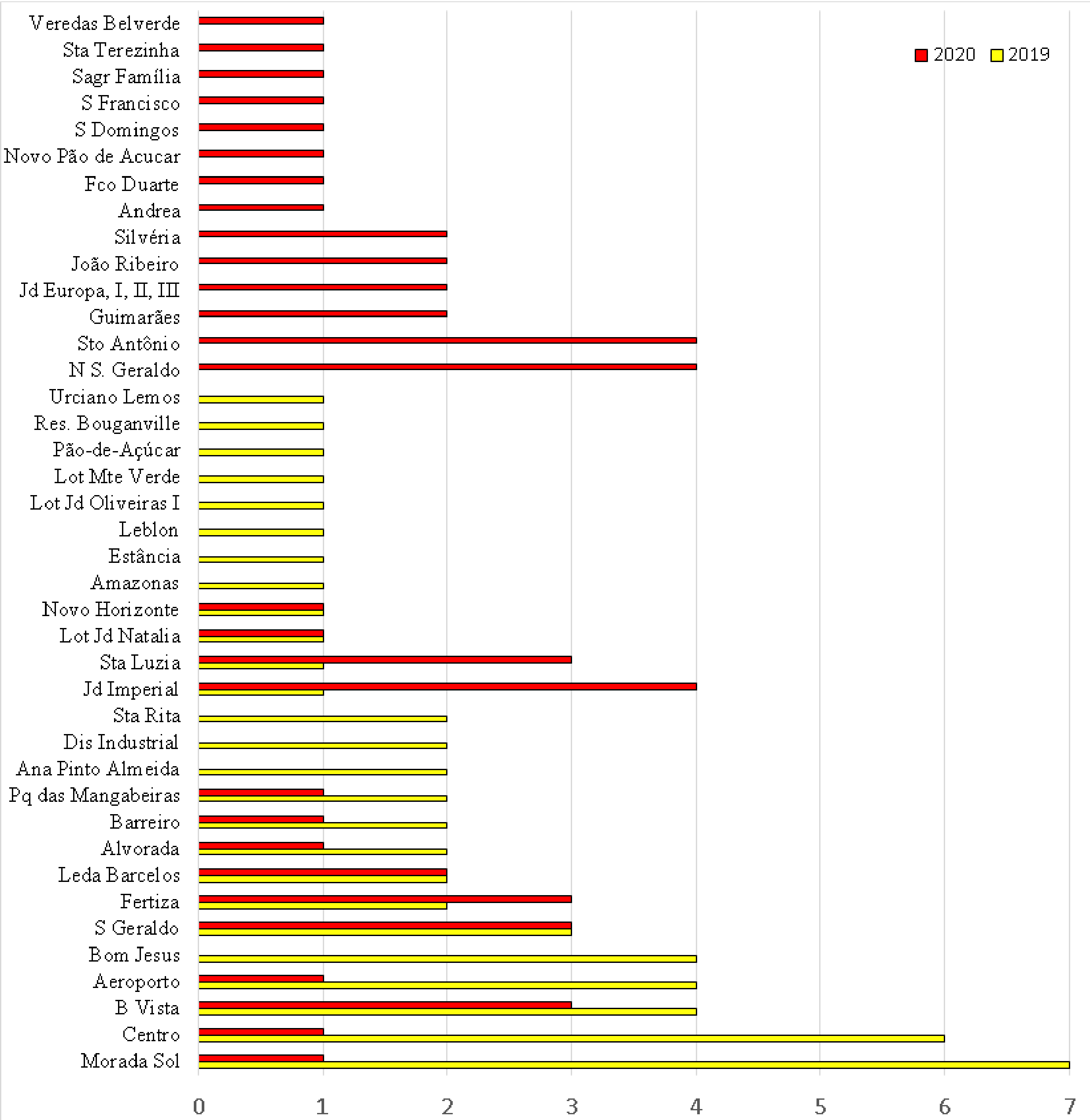
**Figure 3.** Records of occurrences of fires in vacant lots in the urban area of Araxá (MG) in 2019 and 2020, with emphasis on the months studied




In 2019, the most affected neighborhoods were Morada do Sol, Centro, Boa Vista, Aeroporto and Bom Jesus; and in 2020 one finds Jardim Imperial, Novo São Geraldo and Santo Antonio. The neighborhoods most affected by fire in vacant lots in the two consecutive years were Fertiza, São Geraldo, Leda Barcelos, Boa Vista, Centro and Morada do Sol (**Figure 4**).

RBCTI
Revista Brasileira de Ciência, Tecnologia e Inovação

**Figure 4.** Cases of fires in vacant lots in the years 2019 and 2020 in Araxá, MG




The space scan statistics analysis showed that fire reports in vacant lots in Araxá's urban zone followed a random pattern. With respect to the analyzed period-of-time, 2019 recorded shorter time occurrences that were concentrated in the city's Northern region, whereas it was observed in its Southern portion, in 2020 (**Figure 5**).

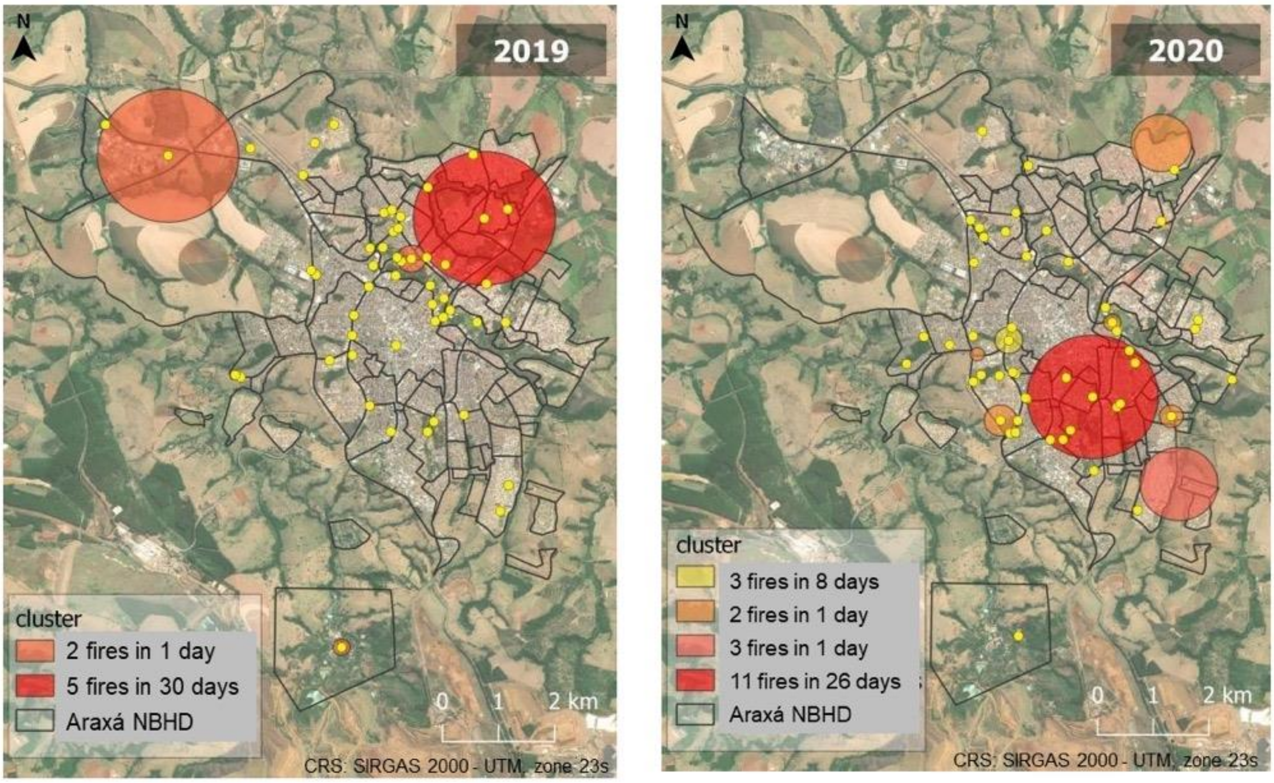
Wildfire in vacant lots tend to happen in sites where the herbaceous vegetation resembles field and pasture conditions; they are too susceptible to fire, since it is formed by final material and featured by an arrangement favorable to ignition and fire propagation (TORRES et al.,2012). In many cases, the reasons for these fire events are associated with different objects: waste burning, dry matter cleaning in land plots, among others. Oftentimes,

RBCTI
Revista Brasileira de Ciência, Tecnologia e Inovação

it aims security against the presence of poisonous animals, arachnids or insects (DE ASSIS; DA MATA LUCAS, 2018).

Based on research carried out in Santa Maria County, Rio Grande do Sul State, Brazil, fire records in urban zones were more frequent in neighborhoods accounting for the highest population densities and in those featured by low quality constructions and urban infrastructure in comparison to neighborhoods showing higher income rates and better urban infrastructure (WEBER; WOLLMAN, 2018). With respect to Araxá City, the higher frequency of fire event records in peripheral neighborhoods in comparison to the downtown area can also be related to demographic issues.

**Figure 5.** Space-time clusters in vacant lots in the neighborhoods (NBHD) of the urban area of Araxá (MG) in the years 2019 and 2020




The sense of randomness linked to cases in time and space is clear if one observes the results recorded for p (p-value), which were not significant in any cluster ($p<0.05$). This finding may be related to sample size; whenever there is a larger number of cases under observation, one can expect to find a reduced value. However, it is possible noticing clusters with two, or more, official fire-event records in the same day, during the drought season, as observed through the detection of eight clusters within the assessed period-of-time (**Table 1**). Similar to the research by De Assis & Da Mata Lucas (2018), who have reported that data recorded by the Fire Department tend to underestimate the real occurrences, since the recorded assistances often regard overall wildfire events – all calls end up issuing a report at the Fire Department, since it registers all reports in a database after the provided assistance.

RBCTI
Revista Brasileira de Ciência, Tecnologia e Inovação

Data shown in Figure 5 depict a slight change in the intensity of events in the city's neighborhoods between 2019 and 2020. It is possible inferring that the vegetation cover consumed by fire within one year does not recover to the extent of suffering with the same effects of fire in the following year. The geographic alternation of incidence can be associated with the same cause. Another hypothesis lies on the rainfall regime, which may have happened in different ways, in each site or period-of-time. Thus, it may have led to the production of different amounts of fuel available to be burned. The unbalanced rainfall regime may have influenced vegetation moisture or event ruled out eventual fires.

**Table 1.** Retrospective spatial clusters of fire events in vacant lots in Araxá, MG (2019 and 2020). Lower "p" values highlighted7

| Year | Cluster | Period | Fire cases observed | Fire cases expected | Radius (km) | p-value |
|---|---|---|---|---|---|---|
| 2019 | **1** | **09/30** | **2** | **0.078** | **0.1** | **0.301** |
| | 2 | 06/14 | 5 | 1.08 | 1.26 | 0.783 |
| | 3 | 07/09 | 2 | 1.7 | 1.26 | 0.958 |
| | 4 | 07/20 | 2 | 1.7 | 0.26 | 0.958 |
| 2020 | **1** | **08/04** | **2** | **0.052** | **0.1** | **0.388** |
| | 2 | 07/07 | 2 | 0.052 | 0.55 | 0.667 |
| | 3 | 08/27 | 2 | 0.052 | 0.13 | 0.667 |
| | 4 | 07/16 a 07/24 | 3 | 0.21 | 0.25 | 0.682 |
| | 5 | 09/03 a 09/08 | 3 | 0.26 | 0.70 | 0.891 |
| | 6 | 06/25 | 2 | 0.078 | 0.29 | 0.977 |
| | 7 | 08/11 a 08/15 | 2 | 0.078 | 0.21 | 0.977 |
| | 8 | 09/18 a 10/14 | 6 | 1.43 | 1.18 | 0.984 |

The present study reinforces the relevance of analyzing fire events from the space-time perspective. Its application in vacant lots' cases in urban zones can be broadened if the discrete Poisson model is applied by using vacant lots in urban zones as reference population. However, the application of this method requires a consistent geographic database, which can be elaborated with the help of remote sensing techniques and SIG.

## CONCLUSIONS

The space-time permutation scan statistics is a reliable methodology to detect clusters of fire events; it also has the advantage of analyzing the statistical significance of areas accounting for the highest frequency of events. Thus, it becomes an important strategy to analyze events that do not have a reference population (cases) per area. In other words, if part of the total space in an urban area has double the cases recorded for the whole area, there will be cluster formation in the smaller area.

This method's application must be understood as exploratory stage for the identification and interpretation of fire events' space and time dimensions. It works as instrument to feature the most susceptible periods-of-time and the sites most vulnerable to fire events.

RBCTI
Revista Brasileira de Ciência, Tecnologia e Inovação

The space-time scanning window used a standard parameter; it followed the references of already performed applications (PEREIRA et al., 2015; OROZCO et al., 2012). However, other windows can be defined and used, based on field observations or on some knowledge about the dynamics of wildfire events in a given space.

Fire events in vacant lots tend to have random occurrence within an urban spot. Areas that had their vegetation cover burned in a given year tend not to suffer with another fire event in the following year. This process is likely explained by insufficient time to produce fuel or, yet, there might have been fire, but it was not reported to the Fire Department.

The main limitation of the present study regards the 2-year time cut, which may have limited the process to feature fire event occurrences in the same vacant lot. In this case, it would be necessary having a longer time series, for instance: 6 or more years. In order to make the short time series more effective, one must design a larger sample, which, overall, is not possible to be set only based on official records; it can be broadened by tele-detection in combination to field inspection.

The space-time analysis can point out places for direct intervention by the public power to help resources allocation processes and the prevention of impacts from these events. The method's application is not limited to urban-fire events; it can be performed to detect space-time clusters of fire events in the countryside.

## ACKNOWLEDGMENT

This research was supported by the 5th Platoon of Military Firefighters – Araxá and Captain Augusto for providing data.

## REFERENCES

CÂMARA, G.; DAVIS, C.; MONTEIRO, A. M. V. **Introdução a Ciência da Geoinformação**. São Paulo: INPE, 2001. Available at: http://www.dpi.inpe.br/gilberto/livro/introd/cap1-introducao.pdf. Accessed on: 2021 Sep. 30.

CHUVIECO, E.; SALAS, F. J.; CARVACHO, L.; RODRIGUEZ-SILVA, F. Integrated fire risk mapping. Remote Sensing of Large Wildfires: In the **European Mediterranean Basin**, p. 61-100, 1999.

DE ASSIS, S. S.; DA MATA LUCAS, F. Queimadas urbanas em Ituiutaba (MG). **Revista Inova Ciência & Tecnologia/Innovative Science & Technology Journal**, p. 32-40, 2018. Available at: https://periodicos.iftm.edu.br/index.php/inova/article/view/226/265. Accessed on: 2023 Feb. 11.

GAO, P.; GUO, D.; LIAO, K.; WEBB, J. J.; CUTER, S. L. Early Detection of Terrorism Outbreaks Using Prospective Space–Time Scan Statistics. **The Professional Geographer,** v. 65, n. 4, p. 676-691, 2013. DOI: https://doi.org/10.1080/00330124.2012.724348

IBGE. Instituto Brasileiro de Geografia e Estatística. **IBGE Cidades: Brasil, Minas Gerais, Araxá, 2021**. Available at: https://cidades.ibge.gov.br/brasil/mg/araxa/panorama. Accessed on: 2021 Sep. 26.

RBCTI
Revista Brasileira de Ciência, Tecnologia e Inovação

KAZMIERCZAK, M. L. Sensoriamento remoto para incêndios florestais. In: SAUSEN, T.M. & LACRUZ, M. S. P. **Sensoriamento Remoto para Desastres**. São Paulo: Oficina de Textos, 2015.

KULLDORFF, M.; HEFFERNAN, R.; HARTMAN J.; ASSUNÇÃO, R.M.; MOSTASHARI, F. A space-time permutation scan statistic for the early detection of disease outbreaks. **PLoS Medicine**, v. 2, n. 3, p. e59, 2005. DOI: https://doi.org/10.1371/journal.pmed.0020059

KULLDORFF, M. **SatScan™ manual do usuário**. Tradução de Alessandra Cristina Guedes Pellini. 2015. p. 113. Available at: https://www.satscan.org/techdoc.html. Accessed on: 2021 Sep. 17.

MEDEIROS, M. B.; FIEDLER, N. C. Incêndios florestais no Parque Nacional Da Serra Da Canastra: desafios para a conservação da biodiversidade. **Ciência Florestal**, Santa Maria, v. 14, p. 157-168, 2004. DOI: https://doi.org/10.5902/198050981815

NEPSTAD, D. C.; MOREIRA, A. G.; ALENCAR, A. A. **A floresta em chamas: origens, impactos e prevenção de fogo na Amazônia**. Brasília: Ministério do Meio Ambiente. Programa Piloto para a Proteção das Florestas Tropicais no Brasil, 1999. 172p. Available at: https://www.terrabrasilis.org.br/ecotecadigital/pdf/floresta-em-chamas-origens-impactos-e-prevencao-do-fogo-na-amazonia.pdf. Accessed on: 2022 Aug. 10.

OROZCO, C. V.; TONINI, M.; CONEDERA. M.; KANVESKI, M. Cluster recognition in spatial-temporal sequences: the case of forest fires. **Geoinformatica**, v. 16, n. 4, p. 653-673, 2012. DOI: https://doi.org/10.1007/s10707-012-0161-z

PARENTE, J.; PEREIRA, M. G.; TONINI, M. Space-time clustering analysis of wildfires: The influence of dataset characteristics, fire prevention policy decisions, weather and climate. **Science of the Total Environment**. v. 559, p. 151-165, 2016. DOI: http://dx.doi.org/10.1016/j.scitotenv.2016.03.129

PEREIRA, A.; FRANÇA, H.; SANTOS, J.E. Método para avaliação da susceptibilidade da vegetação do Cerrado ao fogo em relação a indicadores antrópicos. *In:* **Anais XI SBSR**, INPE, p. 501-508, 2003. Available at: http://marte.sid.inpe.br/col/ltid.inpe.br/sbsr/2002/11.18.22.03/doc/04_427.pdf. Accessed on: 2019 Aug. 28.

PEREIRA, M. G.; CARAMELO, L.; OROZCO, C. V.; COSTA, R; TONINI, M. Space-time clustering analysis performance of an aggregated dataset: The case of wildfires in Portugal. **Environmental Modelling & Software**, v. 72, p. 239-249, 2015. DOI: https://doi.org/10.1016/j.envsoft.2015.05.016

RAMOS, P. C. M.; MENDES, A. Sistema nacional de prevenção e combate aos incêndios florestais. **Fórum Nacional Sobre Incêndios Florestais**, v. 1, p. 29-38, 1995.

SOARES, R. V.; SANTOS, J. F. Perfil dos incêndios florestais no Brasil de 1994 a 1997. **Floresta**, v. 32, n. 2, 2002. DOI: http://dx.doi.org/10.5380/rf.v32i2.2287

TONINI, M.; TUIA, D.; RATLE, F. Detection of clusters using space–time scan statistics. **International Journal of Wildland Fire**, v. 18, n. 7, p. 830-836, 2009. DOI: https://doi.org/10.1071/WF07167.

RBCTI
Revista Brasileira de Ciência, Tecnologia e Inovação

TORRES, T. P. T.; 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. DOI: https://doi.org/10.1590/S0100-67622010000200012.

TORRES, T. P. T.; RIBEIRO, G. A.; MARTINS, S. V.; LIMA, G. S. Perfil dos Incêndios em Vegetação nos Municípios de Juiz de Fora e Ubá, MG, de 2001 a 2007. **Floresta e Ambiente,** v. 17, n. 2, p. 83-89, 2012. DOI: http://dx.doi.org/10.4322/floram.2011.010.

TUIA, D.; RATLE, F.; LASAPONARA, R.; TELESCA, L.; KENEVSKI, M. Scan statistics analysis of forest fire clusters. **Communications in Nonlinear Science and Numerical Simulation**, v. 13, n. 8, p. 1689-1694, 2008. DOI: https://doi.org/10.1016/j.cnsns.2007.03.004

UN-ISDR – International Strategy for Disaster Reduction. 2015. **Sendai Framework for Disaster Risk Reduction 2015 – 2030**. Available at: https://www.preventionweb.net/drr-framework/sendai-framework. Accessed on: 2021 Sep. 27.

WEBER, A. A.; WOLLMANN, C. A. Mapeamento dos incêndios residências na área urbana de Santa Maria, RS, Brasil utilizando o estimador de densidade Kernel. **Investigaciones Geográficas**, n. 51, p. 49-60, 2016. DOI: https://doi.org/10.5354/0719-5370.2016.41748

YEBRA, M.; CHUVIECO, E.; RIAÑO, D. Estimation of live fuel moisture content from MODIS images for fire risk assessment. **Agricultural and Forest Meteorology**, v. 148, n. 4, p. 523-536, 2008. DOI: https://doi.org/10.1016/j.agrformet.2007.12.005

Received on: 2022/09/05
Approved on: 2023/01/13