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Fire regime in Goiás - Brazil and Mozambique between 2010 and 2019: frequency, recurrence, and most affected cover classes

Regime de queima em Goiás, Brasil, e em Moçambique entre 2010 e 2019: frequência, recorrência e classes de cobertura mais afetadas

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ABSTRACT

Over the last few years, the world has experienced extreme events related to the occurrence of fire, which has caused a great deal of damage to people and ecosystems. In 2020 fires raged in Australia, Brazil, the United States, and other nations. Thus, the forest fire issue becomes a matter of global relevance and urgency and requires a better understanding and monitoring of these events. This study sought to identify similarities and differences between the fire regime, specifically the frequency and recurrence, in Mozambique and the state of Goiás, Brazil, between 2010 and 2019. Both focuses are located in the same bioclimatic zone, where savannas are present. Savannas, considered the most fire-resilient ecosystems, are not immune to the consequences of intense and frequent fires. Therefore, monitoring such events in these ecosystems is important, especially to identify characteristics that can guide decision-making. The methodological steps for developing this study involved database organization and using cloud-based geospatial processing platforms, which resulted in fire event characterization products. In both of the studied focuses, fire occurs annually in significant extensions, especially in Mozambique, where the burnt area percentage is higher than in Goiás. Such dynamics may be related to each region's specificities. These results allow for a better understanding of how fires and burning occur in different savannas. and may motivate further research aimed at further clarification.

Keywords: fire; recurrence; savannas; land use and cover; biomass burning.

RESUMO

Nos últimos anos, o mundo tem experienciado eventos extremos relacionados à ocorrência do fogo, que vêm causando uma série de danos às populações e ecossistemas. Em 2020 incêndios assolaram Austrália, Brasil, Estados Unidos, entre outras nações. Isso dá à temática dos incêndios florestais relevância e urgência globais e torna necessários a maior compreensão e o monitoramento desses eventos. O presente trabalho buscou identificar semelhanças e diferenças no regime de fogo, mais especificamente na frequência e recorrência, entre Moçambique e no Estado de Goiás, Brasil, entre 2010 e 2019. Ambos os recortes estão localizados na mesma zona bioclimática, onde estão presentes as savanas. Estas, consideradas ecossistemas com maior resiliência ao fogo, não estão imunes às consequências de incêndios intensos e frequentes. Logo, monitorar tais eventos nesses ecossistemas é importante, principalmente para identificar características que possam nortear a tomada de decisões. As etapas metodológicas para o desenvolvimento da presente pesquisa envolveram organização de base de dados e uso de plataformas de processamento geoespacial baseado em nuvem, o que resultou em produtos de caracterização dos eventos de queima. Em ambos os recortes estudados, o fogo ocorre anualmente em extensões consideráveis, principalmente no caso de Moçambique, cujo percentual de área queimada anualmente é maior que o de Goiás. Tal dinâmica pode estar relacionada a especificidades de cada região. Os presentes resultados possibilitam melhor compreensão de como se dá a ocorrência de incêndios e queimadas em diferentes savanas e podem motivar outras pesquisas a respeito, com vistas a maiores esclarecimentos.

Palavras-chave: fogo; recorrência; savanas; uso e cobertura da terra; queima de biomassa.

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Introduction

Every year fire affects large dimensions of the earth's surface, causing a variety of impacts, such as carbon emissions into the atmosphere (Bowman et al., 2009). In 2020, about 27% of the world's second-largest floodplain, the Pantanal, was affected by fires that caused severe damage to flora and fauna and contributed to the generation of smoke clouds that affected a considerable area in the country (Stevanim, 2020). In 2021, parts of southern Europe recorded temperatures at levels not seen since the 1980s, with record numbers in Greece and Turkey and severe fires of unusual proportions (NASA, 2021).

According to data from the *Canadian Wildland Fire Information System* (CWFIS, 2021), the forest fire season in Canada in 2021 was also intense compared to previous years. The burnt area was 4.18 million hectares, equivalent to double the average of the past ten years. The *Intergovernmental Panel on Climate Change* (IPCC, 2021) has warned that forest fires will increase in frequency, in regions such as South America, Europe, and North America, with the coming of climate change.

More intense and frequent fire events particularly affect the most fire-sensitive ecosystems, such as tropical forests, which are poorly adapted and more vulnerable (Pivello et al., 2021). On the other hand, studies indicate that fire plays a role in maintaining biodiversity in some environments, given that different fire regimes create unique habitats at local and regional scales (Kelly and Brotons, 2017), influence biological evolution, chemical cycles, and promote ecological services and biological diversity maintenance (Bowman et al., 2011). Certain plants and animals have even developed adaptation and synergistic mechanisms with fire (Pivello et al., 2021). In these so-called fire-dependent or fire-influenced environments, fire exclusion can lead to combustible material accumulation and provide for more severe and destructive fire events (Hardesty et al., 2005), in addition to impacting the maintenance of vegetation physiognomies (Pinheiro and Durigan, 2009).

Savannas are ecosystems characterized by the presence of a continuous layer of grasses, regardless of the presence of trees (Lehmann et al., 2011), with tree and shrub canopy discontinuity. There is no consensus on the major determinants of savanna formation, and there are even vast areas of these environments occurring under climatic conditions that could sustain forests (Bond, 2008). Accumulated moisture, rainfall, and burnt area are common environmental factors that shape savannas, but the interaction between each of these components plays out differently across continents, reflecting differences such as vegetation type and amount of accumulated fuel (Lehmann et al., 2014). Lehmann et al. (2011) demonstrated that while in Brazil and Venezuela the association between low soil fertility and high rainfall provided the occurrence of savannas, in Africa and Australia the savannas emerged due to high soil fertility associated with low rainfall.

Savanna areas are among the most affected by fire occurrence (Randerson et al., 2012; Andela et al., 2019; Ramo et al., 2021) and are considered fire-dependent or fire-influenced environments since, unlike fire-sensitive environments, they are more resilient to burning. In these places, fire is responsible for maintaining some of their structural, compositional, and landscape characteristics (Hardesty et al., 2005).

Even in savannas, where fire plays an important role and has been occurring for thousands of years, not all fire is desired. There is a complex relationship between fire and vegetation, which is influenced by the fire season and environmental characteristics (França et al., 2007). Components such as climate, land use and cover, and anthropic actions have interfered with fire dynamics in many regions (Werf et al., 2017). Over the past few decades, savannas have been the biomes most affected by native vegetation suppression, which is an anthropogenic factor that can affect their climate system (Hofmann et al., 2021) and the characteristics of fire events.

It is necessary to consider the influence that anthropic action has on the burning process, which makes current fire regimes differ from those of the pre-industrial period (Bowman et al., 2011). Jolly et al. (2015) noted that, on a global scale, most biomes showed a considerable increment in their fire seasons, especially in savannas, where an average increase of 33 days in fire season length was verified over the past 35 years.

In agropastoral practices around the world, using fire dates back to pre-historical times (Alves and Modesto Junior, 2011). It is generally used to clear areas for planting and to renew pastures (Embrapa, 2000). However, when not managed properly, this type of practice can cause a series of deleterious consequences and impacts (Miranda, 2001; Sá et al., 2007), including fires. In the state of Mato do Grosso, Brazil, cattle ranching has been identified as one of the burning vectors in the state, with the probable use of fire to manage pasture (Venturieiri et al., 2013). Grass areas, such as pastures, are more conducive to burning since they have less combustible material and more higher-combustion material. On the other hand, agricultural areas have more biomass and higher humidity and consequently need more time to reach burning-conducive conditions (Sodré et al., 2018).

Climate change also interferes with the characteristics of fire events, as it provides conditions for a more severe burning (Pivello et al., 2021). Local characteristics of each area and climate, such as drought frequency, physical aspects, and available fuel, among others, are also responsible for determining whether or not fire occurrence is appropriate and what will be its effect on the resident population (Moritz et al., 2014).

For Bowman et al. (2020), it is critical to obtain information regarding the different vegetation types affected by fire to make a concrete and reliable assessment of the environmental impacts of fire. Thus, high-quality monitoring of the fire regime is important for decision-making and the proper management of this phenomenon (Whelan, 2009). Chuvieco et al. (2019) highlight the need for the mapping of burnt areas to generate information that favors the monitoring of the global effects of forest fires. Also, according to these authors, the emergence of new global satellites is responsible for significant successes in fire-related studies since the burnt area products incorporate different variables that assist users in their analyses. Bowman (2018) points out that, despite their limitations, satellite imagery has been responsible for a revolution in understanding the fire regime.

Currently, remote sensing information is used for mapping and identifying fire behavior and regime, which enables the identification of aspects such as frequency, intensity, seasonality, recurrence, extent, and burnt area (Probert et al., 2019; Nieman et al., 2021; Silva et al., 2021), with products that enable mapping at global (Dwyer et al., 2000; Padilla et al., 2014; Chuvieco et al., 2019), regional (Sodré et al., 2018; Rodrigues et al., 2019), and local scales.

Monitoring the frequency of fire events is important to understand how this process occurs and for decision-making. Therefore, this study aimed to evaluate the occurrence and recurrence of fire events in the last ten years in the state of Goiás, Brazil, and Mozambique. Furthermore, it analyzes the spatial distribution of fire activity in association with the land use and land cover classes of the study areas. This is an exploratory study, aimed at helping to understand the fire regime in these two savannas that have similarities and differences, and also raising other questions to motivate further studies.

These two spatial focuses were chosen because, although located on different continents, they share some common characteristics, such as the presence of savannas, the Miombo in Mozambique and the Cerrado in Goiás, the location in the same bioclimatic zone, Portuguese colonization and Portuguese as the official language, as well as the fire action history.

Methods

Study areas

Savannas have different nomenclatures according to their region of occurrence. In Brazil we have the Cerrado, in Venezuela the Llanos, in Australia the savannah, and the Miombo in the African continent (Cole, 1986). The Brazilian Cerrado covers an area of approximately two million km², which corresponds to about 20% of the national territory. While the African Miombo occupies a total area of approximately 2.8 million km², and is present in 9 countries (Oliveira, 2020), the State of Goiás, located in the central portion of Brazil (Figure 1), has about 340 thousand km² of land area, and is the only state in Brazil with almost all of its extension occupied by the Cerrado, one of the facts that motivated its selection for this study. Mozambique, with about 801 thousand km², has a considerable proportion of its territory covered by the Miombo, and is similar to Brazil in some aspects, such as their history of Portuguese colonization and their official language.

Data

The organized database comprised cartographic products related to burnt area, hotspots, land use, and land cover, obtained using public platforms and databases (Table 1).

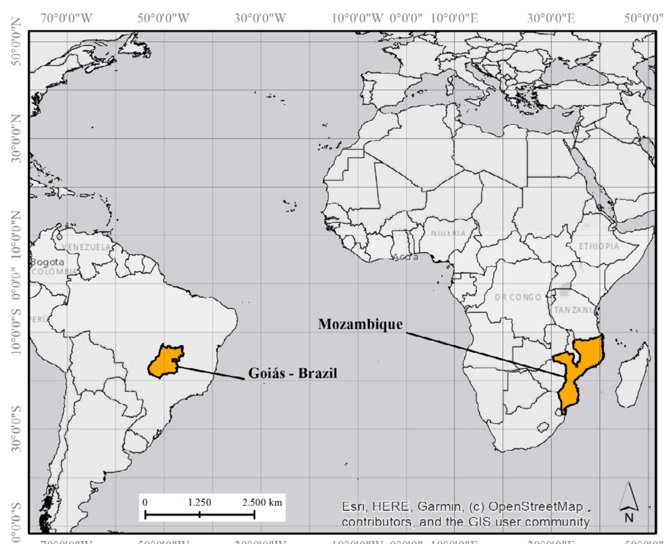


Figure 1 – Location of the State of Goiás and Mozambique.

Table 1 – Collected data description.

Data	Spatial resolution	Time resolution	Selected period	Source	Reference
Burnt area - FireCCI51	250 m	Monthly	2010 - 2019	European Space Agency (ESA) Climate Change Initiative (CCI) Programme, Fire ECV	(Chuvieco et al., 2018b)
Hotspots	-	Daily	2010-2019	INPE	INPE (2020)
Copernicus Global Land Cover Layers (CGLS-LC100)	100 m	-	2019	Copernicus	(Buchhorn et al., 2020a)

Burnt area

Over the past few years, a number of techniques for mapping burnt areas using satellite imagery have been proposed, and currently there are four global burnt area products standing out (Pinto et al., 2020): FireCCI51 (250 m approximate resolution); MCD64A1C6 (500 m resolution); *Global Fire Emission Database*; and FireCCILT10. According to the same author, the algorithms for generating the MCD64A1C6 and FireCCI51 products involve creating temporal composites for identifying persistent changes in the images, filtering out the low quality pixels and combining the information obtained with active fire data. This study used the FireCCI51 product because of its better resolution, scope, and temporal scale, which are relevant to the proposed objectives.

The FireCCI51 is a monthly global data, derived from the MODIS sensor bands aboard the Terra satellite, and has a coverage period ranging from 2001 to 2019 (Pettinari et al., 2020). FireCCI51 was developed by the *European Space Agency* (ESA) *Climate Change Initiative* (CCI) program, and is also part of the *Copernicus Climate Change Service* (C3S).

Hotspots

The data on hotspots were collected in the database of the National Institute for Space Research (INPE), INPE's Burning Program Website. The hotspots made available by INPE come from the processing of images from a total of ten satellites, with optical sensors operating in the thermal-medium range of 4*one*. The INPE system detects the hotspot, but it does not evaluate the burnt area dimensions since the burning front that can be detected varies according to the type of satellite. In the case of polar orbit satellites (NOAAs at 800 km above the surface, and TERRA and AQUA at 710 km), the detected fire front can have a dimension close to 30m long by 1m wide, while with satellites like NPP-SUOMI and NOAA-2º the detected area can reach a few m² (INPE, 2020). The fire detection work at INPE began in mid-1985, and daily hotspot data have been available since the late 1990s.

This website provided the hotspot data from reference satellites, for the period between 2010 and 2019, for the State of Goiás-Brazil and Mozambique.

Land use and cover

In order to assess land use and cover characteristics, this study used the *Copernicus Global Land Cover Layers* (CGLS) collection 3 product, with a spatial resolution of 100 m and land use and cover maps from 2015 to 2019 (Buchhorn et al., 2020b). The maps derived from the PROBA-V 100 m time series.

Among its 23 land use and cover classes, grasslands and savannas are not distinct. According to Buchhorn et al. (2020b), mapping the grassland classes would require adjustments to the mapping methodology used and developing new training and validation data sets. For savannas, even though the product includes classes such as open forest, which is a mixture of trees, shrubs, and pastures, this may only partly correspond to savannas since a 100 m² pixel may include fewer trees, but can still be considered savannas.

The fact that pastures and savannas are not distinct among the product classes represents a limitation, since these are generally the classes most affected by fire events. Nevertheless, this study used this data due to its relevant spatial resolution because it has the same most recent year of burnt area data mapping, and for covering both study areas.

Processing

Data processing relied on computer programs for geographic data processing and cloud-based geospatial processing platforms, in this case the *Google Earth Engine*. After processing, the products were handled in Geographic Information Systems (GIS) and tabulated in spreadsheet editors. Geographic Information System tools, such as mapping software, have greatly improved in recent years and have significant potential applications in the geotechnology field. Using such tools made it possible, within the scope of this study, to generate maps, graphs, and tables characterizing the burning and fire events between 2010 and 2019. The time frame at issue was defined considering an analysis of the 10-year period of fire events, with a definition of the final year due to the temporal resolution of the burnt area data, which at the time of access was until 2019.

Pre-processing

Burnt area (FireCCI51) and use and cover (CGLS-LC100) data were accessed, selected for the study areas, and pre-processed in the cloud-based geospatial processing platform *Google Earth Engine*. Pre-processing was conducted by making and adapting *scripts* from the *Earth Engine* for the study area and data used, and involved the steps of selecting the temporal (annual burnt area data between 2010 and 2019) and spatial (Goiás-Brazil and Mozambique) focuses, converting the raster format to *Shapefile* and *download*.

The *Google Earth Engine* is a geospatial processing platform based on cloud computing technology, which facilitates access to high performance computing resources for processing large data sets (Gorelick et al., 2017). The *Google Earth Engine* has a catalog of several petabytes of public data, including a series of more than 30 years of imagery taken by sensors deployed aboard several satellites (Google Earth Engine, 2019).

Fire regime

According to França et al. (2007), a fire regime comprises the historical characteristics of burning, based on a time series, including aspects such as the intensity of the fire event, time of occurrence, frequency, and recurrence. However, as pointed out by Whelan (2009), burning frequency is an important element of the fire regime, which varies from region to region.

Data on frequency, recurrence, and occurrence of burnt areas can be obtained by overlaying burnt area data, the burning scars. This study considers recurrence as the number of times a certain area burned during the selected period, how many times the fire occurred in the same area. In other words, how many times fire events recurred in the same place in a certain period of time.

After obtaining and pre-processing the annual burnt area data in a digital platform, they were overlaid in a GIS environment, which made it possible to obtain the fire events recurrence map. This map expresses how many times each area was burned in the last ten years, with frequency ranging from 0 (areas that have not burned even once in the last ten years) to 10 (areas that have burned every year in the selected time frame). Thus, it is possible to identify where the most frequent burning events are located and concentrated, the occurrence of fire events. The hotspot data were also handled in GIS, and resulted in maps of cumulative hotspot density and concentration between 2010 and 2019.

The annual burning frequency was obtained by counting the total burnt area and the number of hotspots per year in each of the spatial focuses. Then, illustration graphics were prepared in spreadsheet editors.

In order to perform a preliminary analysis of which land use and land cover class have been most frequently affected by fire events, the burnt area and recurrence data were intersected with the CGLS-LC100 land use and cover data using tools available in a GIS environment. The results were tabulated and illustrated in spreadsheets that allowed a better information analysis.

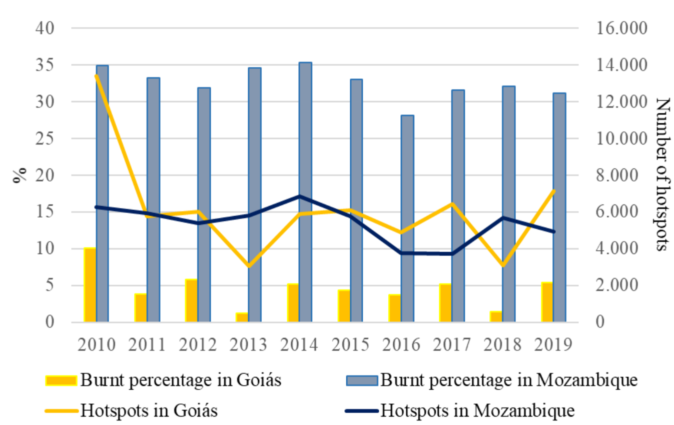
Results and Discussion

Over the past ten years, the most significant burnt area peaks occurred in the state of Goiás in 2010, and the most pronounced, in 2012 and 2019, which were also accompanied by an increase in the number of hotspots. The highest hotspot peaks occurred in 2010, 2015, 2017, and 2019, hence these do not necessarily follow the peaks in the burnt area. There were expressive drops in burnt area and number of hotspots in 2013 and 2018. Over the last ten years evaluated, we found that years of high burnt area are followed by years of low burnt area. Such data allow us to infer that the fire events in Goiás tend to be cyclical, alternating between higher and lower intensity periods (Figure 2).

The burnt percentage did not exceed 10% of the state's total area, a figure that was reached only in 2010. In the following years, the fire percentage remained in the range between 1 and 5%. Even though there are no indications of any direct relationship between intense drought events and fire occurrence in the central portion of Brazil (Cunha et al., 2019), the burnt area and the hotspot peaks in 2010, as well as those in 2015 and 2017, coincided with extreme drought events that occurred in the region (Ribeiro et al., 2018; Cunha et al., 2019). For example, in the Eastern Amazon Sodré et al. (2018) identified some relationship between less rainy periods and an increase in hotspots, and most of the hotspots were in anthropized areas. Projections indicate that with increasing temperatures as a result of climate change, fire events in the Cerrado may increase later this century (Silva et al., 2019). Ribeiro et al. (2018) highlight that the combination of extreme droughts and inappropriate fire use can influence the vulnerability of biomes such as the Cerrado.

We have identified burnt area peaks in Mozambique in 2010, 2014, and 2018, which were also followed by a higher number of hotspots. The smallest burnt area was in 2016, and its percentage was close to 28% of the country, with a reduction in the total number of fires as well. The annual percentages of burnt area observed in Mozambique were higher than in Goiás, between 30% and 35% of the country's territorial area burnt annually. During the evaluated period we also observed an alternation between the periods of higher and lower burning in Mozambique, a cyclical regime, but with slightly longer intervals, with variations every 2 years approximately.

In global terms, the African continent is one of the most affected by fire events, with rates higher than those in South America, which also has considerable fire records (Giglio et al., 2006; Giglio et al., 2018; Andela et al., 2019). Mozambique is among the most fire-affected countries in the southern portion of the African continent (Chuvieco et al., 2018a). Using fire for pasture management is one of the factors responsible for the high record of burning in the sub-Saharan African region (Erb et al., 2009). In Brazil the fire regime is influenced by a number of factors, among which: land use and land cover type, climatic conditions, farming techniques, and recreation practices (Pivello et al., 2021).



Data source: European Space Agency (ESA) Climate Change Initiative (CCI) Programme, Fire ECV; INPE; Copernicus.

Figure 2 – Fire frequency and number of hotspots per year in the state of Goiás and in Mozambique.

In Goiás, more than 75% of the state had no presence of fire in the analyzed period, about 13% showed areas that burned only once, and 5% areas that burned twice. Only 6% of the state burned more than twice between 2010 and 2019, and there were no significant areas with a recurrence of more than 4 times. Fire events were most recurrent in the northern and northeastern portions of the state and in some southwestern portions. In the other parts of the territory, areas that have not experienced any fire events in the last 10 years, or have only burned once, predominate (Figure 3).

There is a greater recurrence of fire events in the southeastern part of the state, and also a concentration of hotspots. When comparing with the use and cover mapping of the state of Goiás, prepared by the Mapbiomas (2021) project, we noted that this area of higher burning concentration coincides with the location of sugarcane cultivation areas, whose controlled burning can be carried out in the state upon request for authorization to the Department of Environment and Sustainable Development (SEMAD) (GOIÁS 2020; 2021).

In Mozambique, the burnt area percentages were higher than in Goiás, less than 30% of the total area of the country did not suffer from fire in the last 10 years. We can observe a certain regularity in the distribution of the recurrence percentages. Altogether, almost half of the Mozambique area had a burning recurrence record greater than 2, and 3.4% burned in every year evaluated (Figure 4).

We identified the greatest fire recurrence in the central-northern part of the country, and a certain concentration of hotspots in its extreme south (Figure 5). Overall, African savanna regions are densely affected by fire events (Dwyer et al., 2000), and Mozambique was among the three countries with the highest fire activity in southern Africa between 2001 and 2008 (Archibald et al., 2010). According to Nhongo et al. (2019), vegetation vigor, air temperature, and precipitation are variables intrinsically associated with fire occurrence.

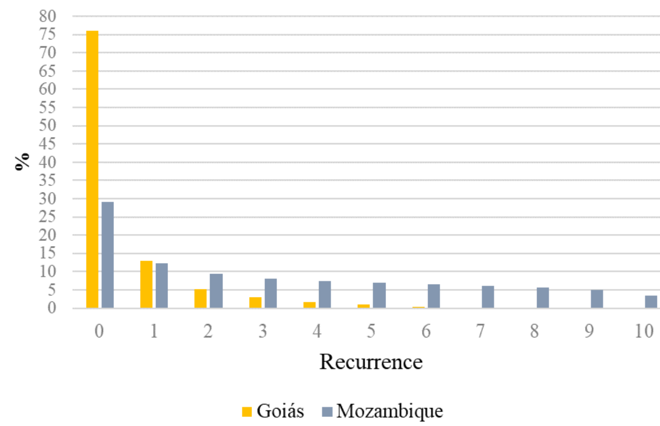


Figure 4 – Burnt area recurrence in Goiás and Mozambique between 2010 and 2019.

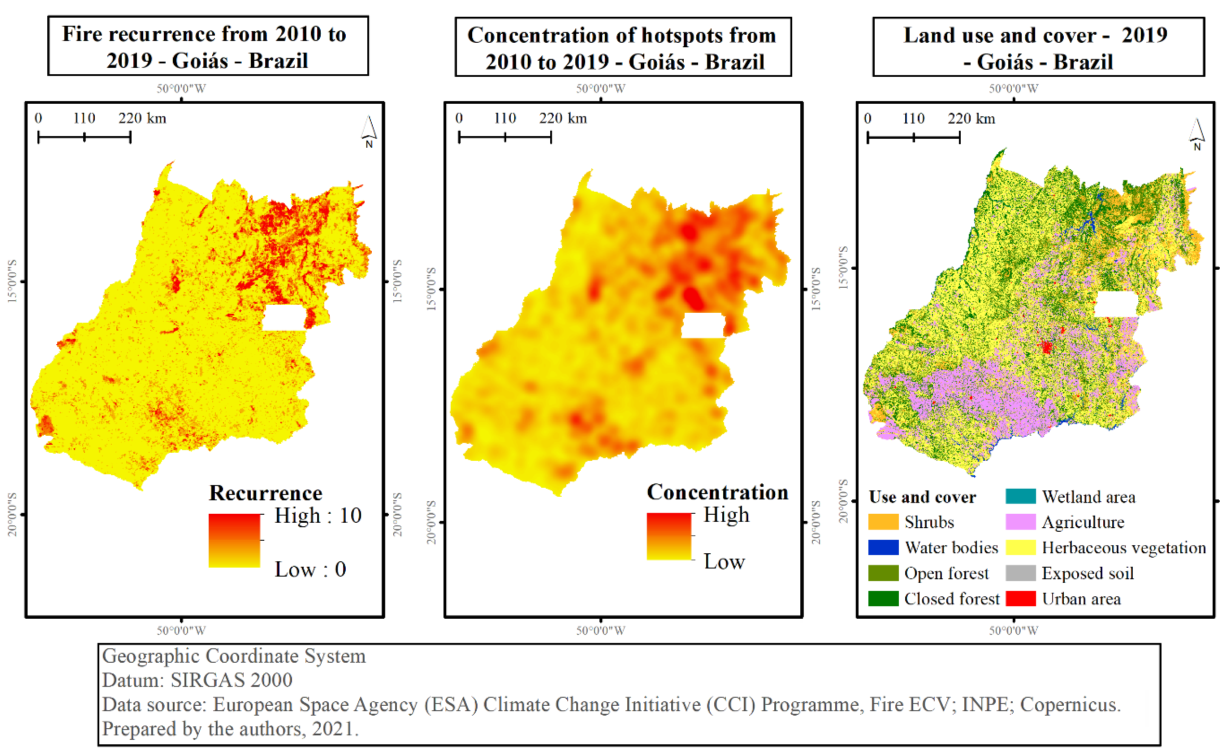


Figure 3 – Recurrence of burnt areas and concentration of hotspots from 2010 to 2019, and 2019 land use and cover in Goiás.

As vegetation vigor decreases and biomass accumulation increases, there is an increase in fire risk. In addition to these natural factors, the influence of anthropogenic factors is present in southern Africa, with many livelihood activities still involving the use of fire (Shaffer, 2010).

The type of vegetation cover that predominates in Goiás is the herbaceous type, followed by the managed crop (agriculture), classes that, along with shrubs, are the most affected by fire events in the state. However, when we evaluate the burning percentage regarding the total area of each use and cover class, we notice that the shrub vegetation, followed by closed forests and open forests, are the most affected by fires. The urban area and herbaceous vegetation classes are the least affected.

It is noteworthy that although the herbaceous vegetation class is predominant in the state, it has comprised the second lowest burnt area percentage in recent years. When looking at other use maps, we noted that this class is associated with pastures, a type of use that occupied in 2020 approximately 40% of the Goiás state area (Mapbiomas, 2021). Meanwhile, even though the forest classes together cover less than 30% of the state, they have had about 55% of their area burned in the last 10 years.

The portion of the state of Goiás in which the natural cover is most preserved is in the Northeast, and it is home to a series of protected areas, such as the Area of Environmental Protection of the Rio Vermelho Springs and the Chapada dos Veadeiros National Park, in addition to the Kalunga Quilombola Territory and the Avá-Canoeiro Indigenous Land. Northeast Goiás is also the portion of the state most affected by fire events during the analyzed period. In the Cerrado, the protected areas suffer fire events with a certain frequency, and this may be related to the presence of more remnants of native vegetation, which means more available biomass, in addition to the practice of natural pasture grazing and land conflicts (Oliveira et al., 2022). In the Chapada dos Veadeiros National Park, for example, among the main causes for fire occurrence we found: fires of unknown and criminal origin, pasture renewal, and lightning (Fiedler et al., 2006).

In Mozambique the open forest class predominates, occupying more than 50% of the country, followed by the closed forest class. On the other hand, regarding the burnt area percentage of each type of use and cover, the herbaceous vegetation, which corresponds to a little more than 3% of the country's territorial area, registered the largest burnt area, followed by closed forest, open forest, and shrubs. The class that has burned the least in the last 10 years was exposed soil (Table 2).

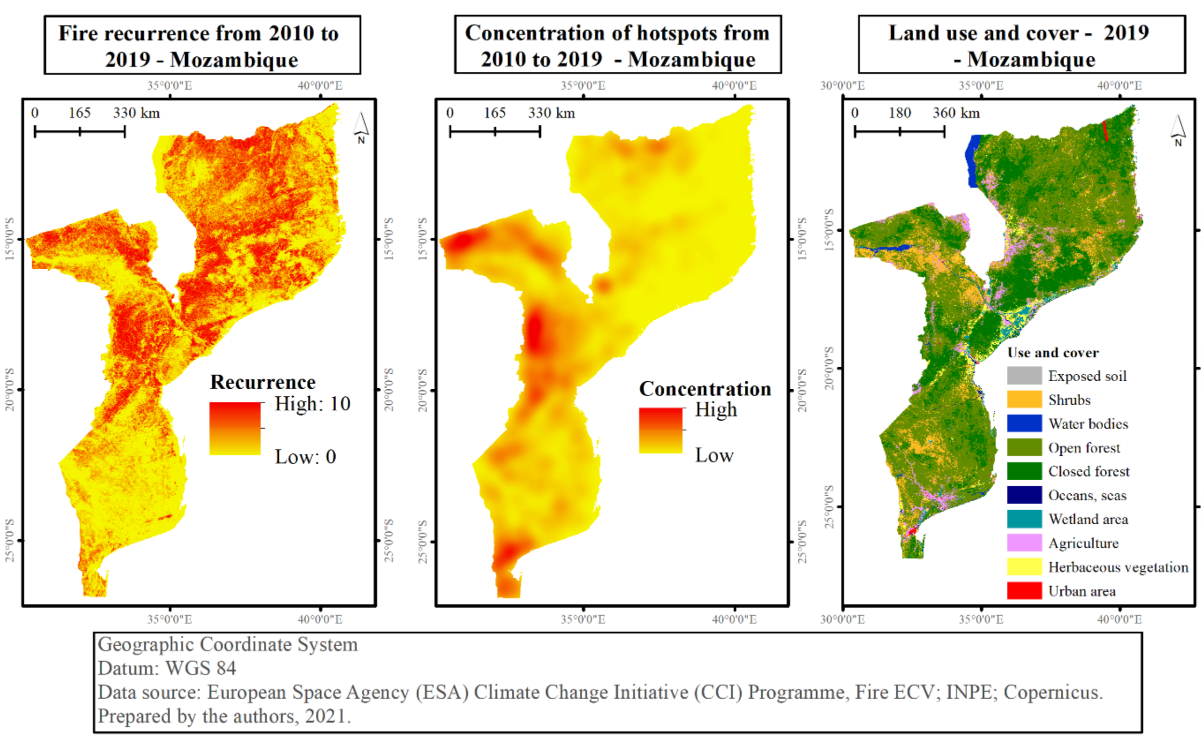


Figure 5 – Burnt area recurrence and hotspot concentration from 2010 to 2019, and 2019 land use and cover in Mozambique.

Table 2 – Total burnt area percentage between 2010 and 2019 of each use and cover class in Goiás and Mozambique.

Use and cover class	% type of use and cover regarding the total area		% burnt area regarding the total area of land use and cover type		% burnt area regarding the total burnt area	
	Goiás	Mozambique	Goiás	Mozambique	Goiás	Mozambique
Shrubs	8.16	9.85	63.11	70.46	21.43	9.79
Herbaceous vegetation	43.50	3.29	15.17	90.67	27.43	4.20
Cultivated and managed vegetation (agriculture)	18.94	4.50	23.53	54.55	18.53	3.46
Urban area	0.45	0.38	9.07	23.84	0.17	0.13
Bare, sparse vegetation, exposed soil	0.01	0.01	16.58	8.36	0.00	0.00
Herbaceous Pantanal, wetland area	0.38	1.66	16.38	54.65	0.26	1.28
Closed forest	13.33	23.91	28.28	74.50	15.68	25.12
Open forest	14.54	54.81	26.90	72.37	16.26	55.94

Oliveira (2020) observed that the Miombo is affected by more fire events than the Cerrado, although the former presents a more preserved natural vegetation cover. The fire return interval (FRI) is influenced by the amounts of herbaceous vegetation present in the ecosystem, which may be one explanation for the burning frequency of African savannas (Chuvieco et al., 2021). Andela et al. (2019) found that the low presence of large fires in North and South America between 2003 and 2016, compared to other regions, can be explained by management practices in these regions, characterized by fragmented landscapes and fire suppression policies.

Conclusions

In the two savannas under study, fire is present annually, but in different frequencies and proportions. Moreover, in both areas there is no clear temporal trend in fire activity. There is some alternation between years of more intense burning and years of less intense burning, but without a precise pattern.

While in Goiás the fire events affect a smaller percentage of the state and the recurrence levels are considerably low, in Mozambique about 30% of the country burns annually, and the recurrence levels are higher. Factors related to the specificities of the Goiás' Cerrado and the Mozambican Miombo may explain these differences. In Mozambique fire is still used as a method for managing agricultural activities. In Goiás, land uses in which fire is no longer so convenient predominate, in addition to the presence of fire containment policies.

Mozambique presents more conserved natural vegetation than Goiás. It is interesting to note that in both focuses, the classes corresponding to natural vegetation are the ones that burn the most.

The results presented here provide a better understanding of the fire regime in different savannas, and may contribute to discussions on the subject, motivating research for further clarification. Furthermore, the information presented can be used by the sectors involved as a tool for developing programs and policies to control and monitor fire events.

Contribution of authors:

SANTOS, S. A.: Investigation; Methodology; Software; Formal analysis; Writing — original draft; Writing — review & editing. OLIVEIRA, W. N.: Conceptualization; Supervision; Investigation; Writing — original draft; Writing — review & editing. RIBEIRO, N. V.: Supervision; Investigation; Visualization; Writing — original draft; Writing — review & editing. FERREIRA, N. C.: Conceptualization; Supervision; Investigation; Writing — original draft; Writing – review & editing.

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