

GEOGRAPHY

Urban Forest Fires in Copacabana (Rio de Janeiro): Remote Sensing and Social Analysis

Incêndios Florestais Urbanos em Copacabana (Rio de Janeiro): Sensoriamento Remoto e Análise Social

Hullysses Sabino¹ , Fernanda Milagres da Rocha Mendonça²  & Juliana Menezes³ 

¹ Universidade Federal Fluminense, Instituto de Geociências, Departamento de Geografia, Laboratório de Cartografia e Geoinformação, Grupo de Pesquisa e Extensão Mapeia, Niterói, RJ, Brasil

² Secretaria de Educação do Rio de Janeiro, Colégio Estadual Aurelino Leal, Grupo de Pesquisa e Extensão Mapeia, Niterói, RJ, Brasil

³ Universidade Federal Fluminense, Instituto de Geociências, Departamento de Análise Geoambiental, Laboratório de Cartografia e Geoinformação, Grupo de Pesquisa e Extensão Mapeia, Niterói, RJ, Brasil

E-mails: hsabino@id.uff.br; nandamilagres@gmail.com; juliana_menezes@id.uff.br

Abstract

Fires aggravate the ecological imbalance by destroying fauna and flora, particularly when they occur in urban forest. In this environmental has the vegetation distinguished by environmental stress and the remnants fragmentation. Urban forest fires also affect society, which is touched and reacts in different ways. In light of the legally protected forest remnants vulnerability that are frequently targeted by fires, the environmental preservation units and forest fragments in the Copacabana neighborhood (Rio de Janeiro) were the subject of this study. Newspapers and social media research was performed in order to describe the fire cases occurred and their social repercussions. Forest fires were identified in four areas: São João Hill, Cabritos Hill, Arpoador and Pavão-Pavãozinho Hill. The first three are legally protected. The events occurred in 2010, 2012, 2021, 2022 and 2024, some years with more than one fire episode. Satellite images from Sentinel 2, Landsat 8 and 9, Amazônia 1 and CBERS S4A and the satellites of the BDQueimadas geoportal of the National Institute for Space Research were consulted, but none succeeded in capturing the occurrence of the fires. Patterns of social response and behavior were identified and described. It is expected that this study will provide information to decision-makers regarding the conservation of urban forests and social management in the Copacabana neighborhood.

Keywords: Urban forests; Environmental conservation; Social management

Resumo

Os incêndios agravam acentua o desequilíbrio ecológico ao ceifar a fauna e flora, particularmente quando ocorrem em remanescentes florestais urbanos. Esse ambiente apresenta vegetação que se distingue pelo estresse ambiental e pela fragmentação dos remanescentes. O incêndio florestal urbano também afeta a sociedade, a qual repercute e reage de diferente forma. Diante da vulnerabilidade dos remanescentes florestais legalmente protegidos, especialmente aos incêndios, as unidades de preservação ambiental e fragmentos florestais do bairro de Copacabana (Rio de Janeiro) foram o objeto de estudo da presente pesquisa. Pesquisa em jornais e redes sociais foi realizada com intuito de descrever os episódios de incêndios ocorridos e as devidas repercussões sociais. Incêndios florestais foram identificados em quatro áreas: Morro de São João, Morro dos Cabritos, Arpoador e Morro do Pavão-Pavãozinho. As três primeiras legalmente protegidas. Os episódios ocorreram em 2010, 2012, 2021, 2022, 2024, tendo alguns anos com mais de um episódio de incêndio. Imagens dos satélites Sentinel 2, Landsat 8 e 9, Amazônia 1 e CBERS S4A e os satélites do geoportal BDQueimadas do Instituto Nacional de Pesquisas Espaciais foram consultados, mas nenhum logrou capturar a ocorrência dos incêndios. Padrões de resposta e comportamento social foram identificados e descritos. Estima-se que esse estudo forneça subsídios aos tomadores de decisão quanto a conservação das florestas urbanas e gestão social no bairro de Copacabana.

Palavras-chave: Florestas urbanas; Conservação ambiental; Gestão social

Received: 21 October 2024; Accepted: 19 June 2025

1 Introduction

Setting fire to vegetation is prohibited by Brazilian Federal Law No. 12,651/12 (Brasil 2012). “Forest fire” is understood as ‘any uncontrolled and unplanned fire that affects forests and other forms of vegetation (...) and which, regardless of the ignition source, requires a response’, according to the National Integrated Fire Management Policy implemented by Law No. 14.944/2024 (Brasil 2024). One of the objectives of this policy is to “promote the conservation and recovery of native vegetation and its ecological and social functions in urban and rural areas affected by fire” (Brasil 2024).

Numerous Brazilian forest fires have their genesis in the mismanagement of ‘controlled burning’, which is the “planned, monitored and controlled use of fire, carried out for agroforestry purposes in specific areas and under specific conditions”, regulated by IBAMA (1998) Ordinance No. 94-N/98 and its restricted applications limited by Law No. 12.651/12 (Brasil 2012).

Brazilian legislation, through Law No. 9.605/98, considers it crimes against the flora to destroy or damage permanent preservation forests (Art. 38), to directly or indirectly damage conservation units (Art. 40), to cause fires in forests or other vegetation (Art. 41), and to use balloons with the potential to set fire to forests and other vegetation (Art. 42) (Brasil 1998).

Brazil recorded around 110,000 fires in the first eight months (Jan – Aug) of 2024. Mato Grosso State was the record holder and Rio de Janeiro, in 17th place, as detected by the AQUA Tarde satellite and made available by the Programa Queimadas of the National Institute for Space Research (INPE 2024a). The number of fires increased by 141% and 78% compared to the same period in 2018 and 2023, respectively. In August and September 2024, multiple fires in the Amazon generated smoke that covered 5 million square kilometers, equivalent to about 60% of Brazil’s area, also covering parts of Peru, Bolivia, Paraguay, Argentina and Uruguay (Casemiro & Longo 2024).

According to data from the Rio de Janeiro Fire Department, 1,595 calls to fight fires in vegetation were made between January and August 2024 in the state of Rio de Janeiro, an increase of 83.2%, compared to 7,417 calls in the same period in the previous year (Agência Brasil 2024). Rio de Janeiro, the capital, is the leader among the municipalities with the highest number of fires, with a total of 4,513 by August 2024. In 2023, the Fire Department fought 1,037 fires. Fire Department spokesman Major Fábio Contreitas reported that 95% of the Rio de Janeiro fires are caused by humans, especially balloons (Lourenço 2024).

Fires also affect or even impede leisure and sports activities in the parks due to the risk to life and sometimes as a measure to prevent new fires, as the Rio de Janeiro Environment Secretariat did when 330 fires were reported in just 24 hours on September 14, 2024 (Barreira 2024). The Rio de Janeiro Fire Department created a crisis cabinet after registering 460 fires cases in a single day, such as in cities of Nova Friburgo, Petrópolis, Valência, Niterói (Andorinhas Hill), including in the capital of Rio, such as in São João Hill (Botafogo and Copacabana neighborhoods), Dona Marta Viewpoint (Laranjeiras/Botafogo), Tijuca National Park (Barra da Tijuca/Joá), Pedra Branca State Park (Realengo) (Jornal Nacional 2024; Monteiro 2024).

Beyond natural landscapes, fires also strike areas intended for human coexistence, for instance, the Rio de Janeiro’ oldest quilombo (São José da Serra one) experienced in September 2024 (G1 Sul do Rio e Costa Verde 2024). The severity of fires increases when they occur in urban areas. Urban forests, which appear more similar to native vegetation fragments, preserve the city’s inhabitants’ life quality by attenuating the climate, fixing carbon, generating water for rivers and intercepting atmospheric pollutants. (Guedes-Bruni & Oliveira 2010).

Copacabana is one of the most popular neighborhoods in Rio de Janeiro and Brazil due to its socio-cultural and economic influence. As a result, incidents in this neighborhood have a large repercussion on society and the media, turning the neighborhood into a reference area for others. The neighborhood has a population of around 140,000 residents, as well as a large number of tourists (Prefeitura do Rio de Janeiro 2024). In addition, the neighborhood is partially or totally home to several environmental preservation units and forest fragments. Therefore, the aim of this work was to record and discuss fire cases in order to help managers to take decisions about fires in urban forests, such as those in Copacabana.

2 Methodology

2.1 Study Area

Copacabana is one of the most famous neighborhoods in the capital and state of Rio de Janeiro and in Brazil. It is located in the ‘South Zone’, the most economically active part of the city. Copacabana’s population is estimated to be around 142,000 residents in 2022, a decrease of 21,000 residents since the 2010 demographic census, according to IBGE data exposed by the Prefeitura Do Rio de Janeiro (2024) data portal (2024). The Copacabana Administrative

Region, which includes the neighborhood of the same name and Leme, has higher socio-economic indicators than the city of Rio, with a low infant mortality rate (31/1000), high longevity (77.7 years), high literacy rate (98.5%) and average years of schooling (10 years), culminating in a high human development index (0.96) (Sebrae 2011).

The neighborhood covers around 4 km², most of which is covered by urban areas (2.68 km², 65.5%), followed by medium-stage dense ombrophilous forest (0.63 km², 15.4%) according to data extracted from the Data.Rio (2024) files (Table 1). The uses and coverages of Copacabana were illustrated in Figure 1.

Geoprocessing tools of the Geographic Information System QGIS v. 3.28.1 were employed. Vegetation cover shapefile of Data.Rio (2024) had its geometry corrected with the Correct Geometry processing algorithm. Shapefiles of neighborhood boundaries and vegetation cover were joined

so that the new shapefile had both boundaries. Features were dissolved by the “Class” data column, which describes the vegetation cover and land use classes. Each feature’ area was calculated from the Attribute Table Field Calculator. Attribute table was exported in spreadsheet format to calculate the total area of the Copacabana neighborhood. Once the neighborhood area was known, a new data column was created to find out what percentage each area covers in relation to the total area.

Copacabana is totally or partially home to an Environmental Protection and Urban Recovery Area (APARU, in Portuguese), 4 natural parks (3 municipal and 1 state) and 7 Environmental Protection Areas (APAs, in Portuguese), as illustrated in Figure 2. The oldest protection zone is the Chacrinha State Park, from 1969, and the most recent, Paisagem Carioca Municipal Natural Park and APA Paisagem Carioca, from 2013.

Table 1 Territorial coverage of each land use and coverage in the Copacabana neighborhood, Rio de Janeiro, in 2018, according to Data.Rio (2024). Data.Rio (2024).

Classes of use and coverage	Area		
	m ²	km ²	%
Urban Areas	2684451.4	2.684	65.5
Dense Ombrophilous Forest, Middle Stage	630458.4	0.630	15.4
Rocky Outcrop	333322.7	0.333	8.1
Beach	297150.1	0.297	7.2
Reforestation	96645.5	0.097	2.4
Non-forest tree vegetation	36493.8	0.036	0.9
Dense Ombrophilous Forest, Initial Stage	22121.3	0.022	0.5

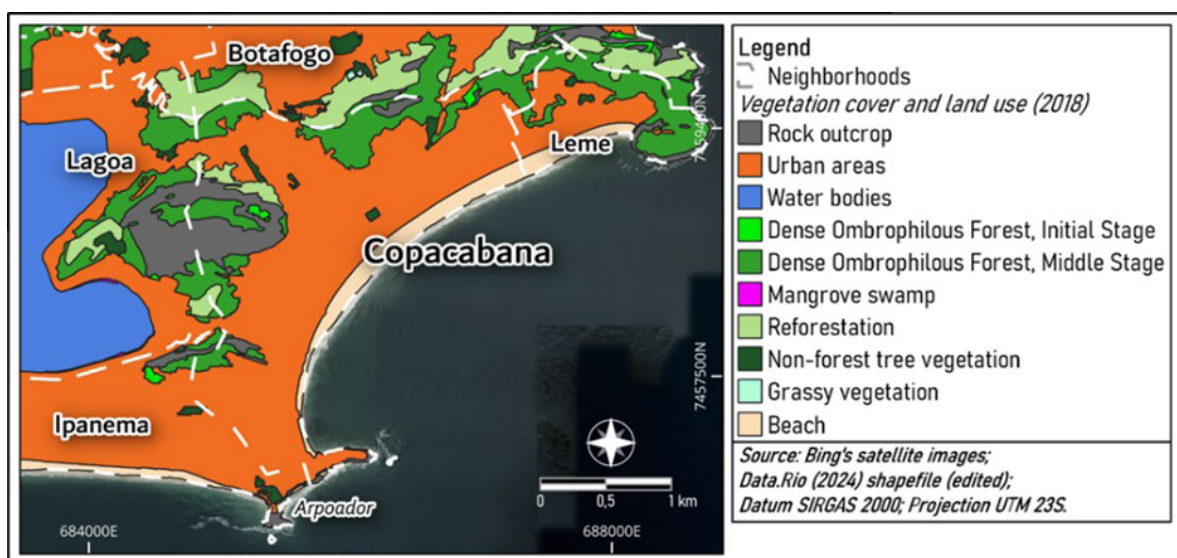


Figure 1 Vegetation cover and land use in Copacabana and surrounding neighborhoods. Data edited from Data.Rio (2024). Map: author H. (2024).

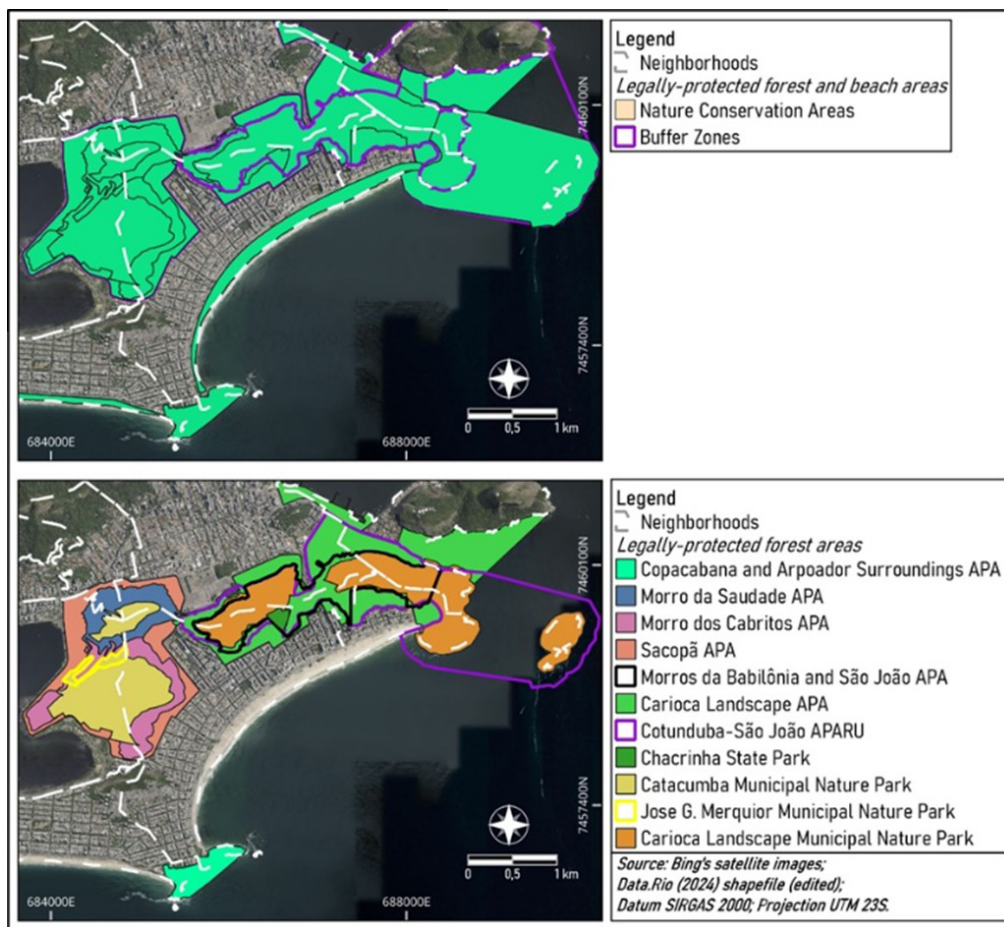


Figure 2 Legally protected areas in the Copacabana neighborhood. Top map illustrates legally protected forest and beach areas. Bottom map illustrates the protected forest areas, such as APAs and natural parks. Data edited from Data.Rio (2024). Map: author H. (2024).

2.2 Data Source

Orbital images were used to evaluate the spatial dimension of the fire smoke plumes in Copacabana. Satellite images from multiple satellites were used in this study. Sentinel 2 images were obtained from the European Space Agency's Copernicus website (ESA 2024). Landsat 8 and 9 images were accessed from the EarthExplorer website of U.S. Geological Survey (2024). While the Amazonia 1 and CBERS S4A images were observed on the webportal of INPE (2024b) Divisão de Geração de Imagens (Image Generation Division) (2024b).

The attempt to visualize the fires and, above all, the smoke plumes using remote sensing images was made using more conventional satellite images and also BDQueimadas data (INPE 2024a). BDQueimadas geoportal monitors and models the occurrence and classification of active fire in vegetation, its risk and extent, using remote sensing, geoprocessing and numerical modeling. This geoportal is fed by a set of satellites with multiple spatio-temporal

resolution characteristics: Terra Morning and Afternoon, Aqua Morning, GOES-16, NOAA-18 Morning and Afternoon, MSG-03, METOP B and C, NOAA-19 Morning and Afternoon, NOAA-20 and 21, NPP-375 Morning and Afternoon. This geoportal provides information from January 2014 onwards. Therefore, the analysis of the 2010 fire through this portal was not accessible.

Research was conducted online to obtain information and comments from citizens in order to verify the fires' social impact between the dates of October 4 and 7, 2024. Online newspaper reports and posts by common citizens on social media (Facebook and Instagram) were considered. The X platform (formerly Twitter) was unavailable. This study only considered recent fires as a way of ensuring access to the population's responses and comments. The comments posted on the social media were originally written in Portuguese, but translated into English for this study. The free translation into English does not allow the commenting users to be identified, preserving their privacy.

3 Results and Discussion

3.1 Fires spatial distribution in Copacabana neighborhood

Fires were reported in São João Hill (Copacabana/Botafogo neighborhood), Cabritos Hill (Copacabana/Lagoa), Arpoador and Pavão-Pavãozinho Hill (both Copacabana/Ipanema), as seen in Figure 3. The fires reported in Arpoador, Ipanema and Lagoa were considered in this study because they occurred in areas bordering the Copacabana neighborhood and are encompassed by the Copacabana

Administrative Region and managed by the same Sub-Secretariats as the South Zone of Rio de Janeiro.

3.1.1. São João Hill – Copacabana/Botafogo Neighborhood

Fires were recorded on September 13, 2024 on São João Hill on both the Botafogo and Copacabana sides, near the Tabajaras community (Figure 4) (Monteiro 2024). The reasons behind the phenomenon have yet to be identified. This fire caused surprise and strangeness due to the rarity of the phenomenon in this location and apprehension among the residents of the harness makers, aggravated by the smoke remaining even after the fire was controlled (Monteiro 2024; Zona Sul Urgente 2024).



Figure 3 Areas historically affected by fires: A. Wide view of Copacabana neighborhood and surroundings; B. Top: São João Hill (Copacabana/Botafogo border). Base: Cabritos Hill (Copacabana/Lagoa border); C. Garota de Ipanema Park (Copacabana/Arpoador-Ipanema border); D. Pavãozinho Hill (Copacabana/Ipanema border). Dashed line from Data.Rio (2024) indicates the division between Copacabana and the surrounding neighborhoods. Map: author H. (2024).



Figure 4 Fire on São João Hill facing Botafogo in 2024: A. Fire recorded at night; B. Phenomenon (highlighted in yellow) recorded during the day and near homes. Images edited from O Globo/Monteiro (2024).

3.1.2. Cabritos Hill – Copacabana/Lagoa Neighborhood

The fire that covered a large area of Cabritos Hill occurred on June 20, 2010 (Figure 5). The dry weather common at the period and the fall of a balloon were the reasons for the fire (Gente Carioca 2010; O Globo 2010; Ramalho 2010). However, there were suspicions that it was not a fire caused by a balloon, but originated from issues against local police actions (Freire 2010a).

In December 2022, another fire burned in Cabritos Hill, near Cinco de Julho street, where the houses are very close to the rock massif. This fire destroyed part of the vegetation that had been replanted (Ferreira 2022). There are suspicions that it was fireworks launched in celebration of the Brazilian national soccer team match that caused this fire (Jansen 2022). The proximity of this fire to a large hospital caused concern among the public forces and the hospital, but there were no incidents of accidents. According to INPE's Monitoring and Risk of Forest Fires Bulletin (INPE 2024c), also known as InforQueima, the Cabritos Hill region had a climate anomaly that reduced rainfall by between 25 and 49 mm in December 2022, conducting the fire occurrence and spread.

Cabritos Hill is covered by several protected areas (Figure 2), despite reports of deforestation and fires (Figures 5 and 6). Rio City Decree No. 49890/2021, considering the need to reduce overlaps between Conservation Units in order to better implement land-use planning and environmental protection instruments, among other points, expanded the Catacumba Municipal Natural Park, including the territory

of the Cabritos Hill, Saudade Hill and Sacopã APAs, the José G. Merquior Municipal Natural Park and Fonte da Saudade in its original area. In addition, this Decree also extended the Sacopã APA, including in its original area the territory of the Cabritos Hill and Saudade Hill APAs, and the Catacumba Municipal Natural Park buffer zone (Prefeitura do Rio de Janeiro 2021a).

3.1.3. Garota de Ipanema Park – Copacabana/Arpoador in Ipanema

Fires in the vegetation of this park were recorded in several years: 2012, 2021 and 2022 (Figure 7) (Paskin 2012; Guarda Municipal do Rio de Janeiro 2021; LuLacerda 2021; Vidon 2022). One of the fires reportedly started after a cigarette butt was thrown onto the site (Guarda Municipal do Rio de Janeiro 2021). Sometimes, the succession of fires recurred over a short period of time (Paskin 2012). However, it seems that the small magnitude of these fires has produced little information available about them, limiting the discussion.

3.1.4. Pavão-Pavãozinho Hill – Copacabana/Ipanema

On August 7, 2024, a large fire hit Pavão-Pavãozinho Hill late in the morning, and by 1 pm it reached large proportions (Figure 8). This episode occurred after a period of more than seven days without rain, in high heat, low humidity and on a windy day. Fighting the fire was also arduous due to the difficulty of access and the large volume



Figure 5 Record of the fire on Cabritos Hill in 2010 (top) and the approximate equivalent area delimited by the red dashed line (bottom). Sources: Top image: Twitter feed of @alessandrolb by Freire (2010b); Lower image edited from ©2024 Google, TerraMetrics, Data SIO, NOAA, U.S. Navy, NGA, GEBCO, Airbus, Landsat/Copernicus.

of garbage discarded at the site (Teodoro 2024). Unofficial information says that the fire started when a man set fire to a pile of garbage (O Dia 2024).

This event had impact on the daily lives of the neighborhood's residents, as three streets were closed, including one of the main thoroughfares, Barata Ribeiro Street, and around 50 firefighters were called to the area, and people were taken to hospital for smoke inhalation (G1

Rio 2024). Stone fragments fell from the massif, justifying the closure of the surrounding roads. Around four buildings were affected, two of which were the Ninho das Águias Community Library and the Bar do Jardim lookout point. No human lives were lost, but some animals died (G1 Rio 2024; Teodoro 2024). Even after the fire was extinguished, the intense smell of burning plagued local residents for at least another day. This hill has no environmental protection area.



Figure 6 Records of the fire on Cabritos Hill and its proximity to homes in December 2022. Sources edited from: A. Ferreira (2022); B. G1 Rio (2022).



Figure 7 Fires in Garota de Ipanema Park (Arpoador/Ipanema): A. Fire near a building with people on the terrace in 2012; B. Fire being controlled with a smotherer by Rio de Janeiro Municipal Guard officers in 2021..

3.2 Remote Sensing

The different satellites that compose the BDQueimadas geoportal were unable to capture any of the fire cases recorded after 2010 in Copacabana. Other satellite images available for the dates of the fires were verified (Table 2). The orbital images should have been captured on the same day and during the fires. However, it was not possible to achieve this coincidence in the fires analyzed. In the Pavão-Pavãozinho Hill fire, the passage

of the CBERS S4A satellites coincided with the date, but took place around twenty minutes before the start of the fire. Therefore, it was also not possible to achieve spatial analysis using orbital images of this episode.

3.3 Social Repercussions

Collective concern and fear are standard in these situations, as one internet user posted: “Without you, the whole neighborhood would have gone up in flames! You



Figure 8 Fire that hit Pavão-Pavãozinho Hill in August 2024. Yellow arrow shows the same position of the hill as seen from the wide and a more focused view. Orange arrow indicates the fire location that hit buildings. Edited images from: A. G1 Rio (2024); B. Ventura (2024); C. Teodoro (2024).

Table 2 Satellites employed in an attempt to visualize urban forest fires in the Copacabana district (RJ). The “-” symbol indicates that the satellite was not operating during the period. CBERS S4A sensors investigated were MUX L2/L4, WFI L2/L4, WPM L2 and L4, AWF1 L2 and L4 (INPE 2024b).

Cases (MM/DD/YEAR)	Satellites			
	Sentinel 2	Landsat 8/9	Amazonia 1	CBERS S4A
Arpoador (06/20/2010)	–	–	–	–
Cabritos Hill (12/02/2022)	12/04/2022	12/01/2022	12/03/2022	12/1/2024 and 12/03/2024
Pavão-Pavãozinho Hill (08/07/2024)	08/05/2024	08/08/2024	08/06/2024	Image captured around 20 minutes before the height of the fire (1pm) by the MUX L2 and AWF1 L4 sensors

were essential!”. The disorientation drives the population into the streets for fear of the possibility of a residential fire (UOL Notícias 2010).

Comments wishing for the fire to be extinguished quickly are routine and similar (“May it be extinguished soon”, “I hope the firefighters arrive soon”, “the firefighters will take care of it”). Acclamations to God and other deities are commonplace (“Why this fire, my God?”, “Thank God it’s over, but it’s caused damage”, “Mercy Lord!”, “May God protect it”).

Comments that nature needs to be finally respected or that the episode is nature’s revenge on humans are also common (“This is a consequence of mistreatment of nature”, “When will humanity learn? When will it understand that for every action there is a reaction? Here’s the result! How long will there be life there?”).

In addition, there are comments saying that the fires are deliberate in order to increase the area of the favelas (“I heard they burned to build shacks”, “It’s to make the favela bigger”) or that all the residents are responsible (“Why did they set fire to the forest? Can the residents do this? Isn’t this an environmental crime?”, ‘Residents set fire to the forest, I think it’s absurd’, ‘It’s a deliberate fire’). Thinking about the local ecosystem is also frequent (“My God! Since it’s in the forest, I only think about the animals... Poor creatures”, ‘I only think about the animals too, how cruel’).

Some famous personalities have also been influenced by the fires. With regard to the 2010 fire on Cabritos Hill, actress and presenter Fernanda Paes tweeted “A lot of fire in Lagoa! Things are bad” and businesswoman Flora Gil, Gilberto Gil’s wife, also posted “Mega fire at Fonte da Saudade! Sacopã Street... Hot and strange wind!” (Terra 2010).

Fires frighten and worry the population in general, but they bring to light the environmental issues surrounding the importance of vegetation and its preservation. Losses of property have also been recorded, as in the case of the fire on Pavão-Pavãozinho Hill. As a result of this episode, some buildings were burned and many damaged. Between 4,000 and 5,000 books from the Ninho das Águias Community Library in Pavão-Pavãozinho Hill were burned. This library will need to be rebuilt, as it brought education for children to a part of the community that is far from other educational points. In addition, a bar used to serve as an entertainment point for visitors to a belvedere, which was recently integrated into the tourist routes and would generate jobs and income for local residents, will also need to be rebuilt (Teodoro 2024).

4 Conclusion

This study concluded that the fires that occurred in the Copacabana neighborhood were related to dry weather, but the human factor, such as the presence of balloons (2010 case), fires (2022) and the burning of garbage (2024), is the main cause of this phenomenon. Therefore, the penalties provided for in Federal Law No. 9.605/98 must be toughened in order to curb and penalize those who cause forest fires, whether intentionally or not.

Climate change is resulting in more intense, long-lasting and frequent droughts, which has aggravated the magnitude of fires. Therefore, proper management of anthropogenic activities, especially those close to urban forests, is essential for preserving the scarce forest remnants. By interpreting the comments posted on social networks, it was possible to determine the main forms of the fires’ social repercussions.

It is recommended that the BDQueimadas be affiliated with satellites with spatio-temporal resolutions capable of identifying smaller fires. Given Brazil’s large spatial dimension, perhaps this more detailed analysis should be reserved for the country’s metropolitan areas and other environmentally sensitive regions.

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Author contributions

Hullysses Sabino: conceptualization; formal analysis; methodology; validation; writing-original draft; writing – review and editing. **Fernanda Milagres da Rocha Mendonça:** formal analysis; writing – review and editing. **Juliana Menezes:** writing – review and editing; supervision.

Conflict of interest

The authors declare no conflict of interest.

Data availability statement

All data included in this study are publicly available in the literature.

How to cite:

Sabino, H., Mendonça, F.M.R. & Menezes, J. 2025, 'Urban Forest Fires in Copacabana (Rio de Janeiro): Remote Sensing and Social Analysis', *Anuário do Instituto de Geociências*, 48:65908. https://doi.org/10.11137/1982-3908_2025_48_65908

Funding information

Not applicable.

Editor-in-chief

Dr. Claudine Dereczynski

Associate Editor

Dr. Gerson Cardoso da Silva Jr.