

# MAPPING THE RISK OF FOREST FIRES IN THE RIO PRETO NATIONAL FOREST IN THE ATLANTIC FOREST

Leonardo Duarte Biazatti<sup>1</sup>, Nilton Cesar Fiedler<sup>1</sup>, Antonio Henrique Cordeiro Ramalho<sup>1\*</sup>, Taís Rizzo Moreira<sup>1</sup>, Gabriel Fernando Rezende<sup>2</sup>

<sup>1</sup>Universidade Federal do Espírito Santo - UFES, Departamento de Ciências Florestais e da Madeira, Jerônimo Monteiro, Espírito Santo, Brasil - leo-biazatti@live.com; fiedler@cnpq.pq.br; henriquecr2012@hotmail.com\*; taisr.moreira@hotmail.com

<sup>2</sup> Instituto Chico Mendes de Conservação da Biodiversidade - ICMBio, Núcleo de Gestão Integrada, São Mateus, Espírito Santo, Brasil - Gabriel.rezende@icmbio.gov.br

Received for publication: 26/09/2020 – Accepted for publication: 03/12/2020

## Resumo

*Mapeamento do risco de ocorrência de incêndios florestais na Floresta Nacional do Rio Preto no bioma Mata Atlântica.* O bioma Mata Atlântica é anualmente exposto a incêndios florestais que danificam milhares de hectares de floresta, fomentam a formação de fragmentos florestais, a destruição da biodiversidade, a compactação do solo, o escoamento superficial e o assoreamento de corpos d'água. Desta forma, a predição e supressão dos focos de incêndios são importantes para minimizar os danos causados pelo fogo. Nesse sentido, com o presente estudo objetivou-se a análise e modelagem de risco de ocorrência de incêndios florestais na Floresta Nacional do Rio Preto e sua zona de amortecimento, por meio da técnica de inteligência artificial *Fuzzy*. Para tal foram utilizadas as variáveis de uso e ocupação da terra, proximidade de estradas, declividade e orientação do relevo para compor o modelo. Com o auxílio dos sistemas de informações geográficas (SIG), determinou-se a influência de cada variável nos episódios de queimada, bem como a distribuição espacial de cada uma das classes de risco (muito baixa, baixa, moderada e alta). Para a análise comparativa do modelo, foi utilizada uma série histórica de focos de incêndios entre os anos de 2010 e 2020. Os resultados mostraram que a área de estudo não apresenta riscos preocupantes acerca da ocorrência de incêndios, haja vista que é coberta, em sua maioria, pelas classes de risco muito baixo e baixo. Assim, pode-se concluir que a aplicação da modelagem *Fuzzy* permite a avaliação da distribuição espacial das classes de risco de incêndio para áreas de unidade de conservação, que a análise comparativa proposta indicou eficácia do modelo.

*Palavras-Chave:* Proteção Florestal, Sistemas de Informações Geográficas, *Fuzzy*; Unidades de Conservação, Zoneamento de Risco.

## Abstract

The Atlantic Forest biome is annually exposed to forest fires that damage thousands of hectares of forest, promote the formation of forest fragments, the destruction of biodiversity, soil compaction, runoff and silting of water bodies. Thus, the prediction and suppression of fire outbreaks are important to minimize the damage caused by fire. In this sense, this study aimed to analyze and model the risk of forest fires occurring in the Rio Preto National Forest and its buffer zone using the Fuzzy artificial intelligence technique. To do so, the land use and occupation, proximity to roads, slope and relief orientation variables were used to compose the model. Thus, the influence of each variable on burning episodes was determined with the aid of geographic information systems (GIS), as well as the spatial distribution of each of the risk classes (very low, low, moderate and high). a historical series of fires between the years 2010 and 2020 was used to perform a comparative analysis of the model. The results showed that the study area does not present worrisome risks regarding the occurrence of fires, since it is mostly covered by very low and low risk classes. Thus, it can be concluded that the application of Fuzzy modeling enables evaluating the spatial distribution of fire risk classes for the protected area areas, for which the proposed comparative analysis indicated the model's effectiveness.

*Keywords:* Forest Protection, Geographic Information Systems, *Fuzzy*, Conservation units, Risk Zoning.

## INTRODUCTION

The Atlantic Forest biome is known worldwide for the fact that its biodiversity is ranked among the richest in the world (DELGADO *et al.*, 2018). However, climate change (ROCHA *et al.*, 2018), increasing human interference (CLEMENTE *et al.*, 2017), and the unbridled exploitation of natural resources have caused much of the biome's original cover to be destroyed over the years (REZENDE *et al.*, 2018).

Thus, in aiming to protect environments of great ecological relevance with reduced anthropic alteration and with unique fauna and flora, Brazilian government entities instituted Law N°. 9985 on July 18, 2000, through the National System of Conservation Units (SNUC), which establishes criteria and standards for the creation, implementation, and management of Conservation Units in Brazil (BRASIL, 2000). However, not even the power of the law has been able to ensure the protection of these areas of high ecological, economic, and social value against forest fires (TORRES *et al.*, 2017a).

Every year large forest areas are affected by forest fires, and despite the efforts of international organizations, this phenomenon is occurring globally with an increasing trend, causing great economic losses and

ecological damage which influences climate change. Fiedler *et al.* (2020) classify forest fires as any uncontrolled fire which occurs in vegetation, whether or not of anthropogenic origin. Forest fires promote forming forest fragments, destroy biodiversity, cause soil compaction, surface runoff, erosive processes, and consequently silting up of water bodies. In addition, fires are responsible for destroying millions of hectares of planted forests, machinery, equipment, improvements, physical facilities, and human lives (CANZIAN *et al.*, 2018; TORRES *et al.*, 2017a).

Thus, the development of methodologies capable of assisting in predicting and preventing fires with less and less uncertainty and according to specific climatic conditions is currently a matter of global importance. To this end, Eugenio *et al.* (2016) and Torres *et al.* (2017b) suggested the use of geotechnologies as a methodological tool to minimize the adverse effects of forest fires. In the universe of geotechnologies, Fuzzy logic has proven highly efficient in elaborating zoning of forest fire occurrence risks (EUGENIO *et al.*, 2016; WHITE; WHITE; RIBEIRO, 2016).

Zoning forest fire occurrence risks consists in a prepared set of information in order to reduce damage caused by forest fires by combining data from different variables of influence (meteorological, topographic and environmental) (WHITE; WHITE; RIBEIRO, 2016) and creating zones with similar characteristics that culminate in the same fire risk. Thus, through the zoning maps it is possible to establish the spatial distribution of classes of risk of fire occurrence and thereby enable applying prevention techniques, the strategic allocation of brigades, and consequently reduce damage caused by forest fires (RAMALHO *et al.*, 2021).

This study was developed from the hypothesis that the application of fuzzy modeling can indicate areas which are most susceptible to the occurrence of fires within and in the buffer zone of the National Forest of Rio Preto and its buffer zone, seeking the applicability of this modeling for decision making in these areas. To this end, the objective of this study was to model the areas at risk of forest fires in the Rio Preto National Forest and its buffer zone through fuzzy logic modeling.

## MATERIAL AND METHODS

### Study area

The present study was conducted in the Floresta Nacional do Rio Preto and its buffer zone, both located in the municipality of Conceição da Barra, in the north of Espírito Santo state, Brazil. The study area comprises a total of 13,162.02 hectares of protected areas and is located between the meridians 18°19'30" to 18°27'20" West Greenwich longitude and the parallels 39°46'00" to 39°55'20" South latitude (Figure 1).

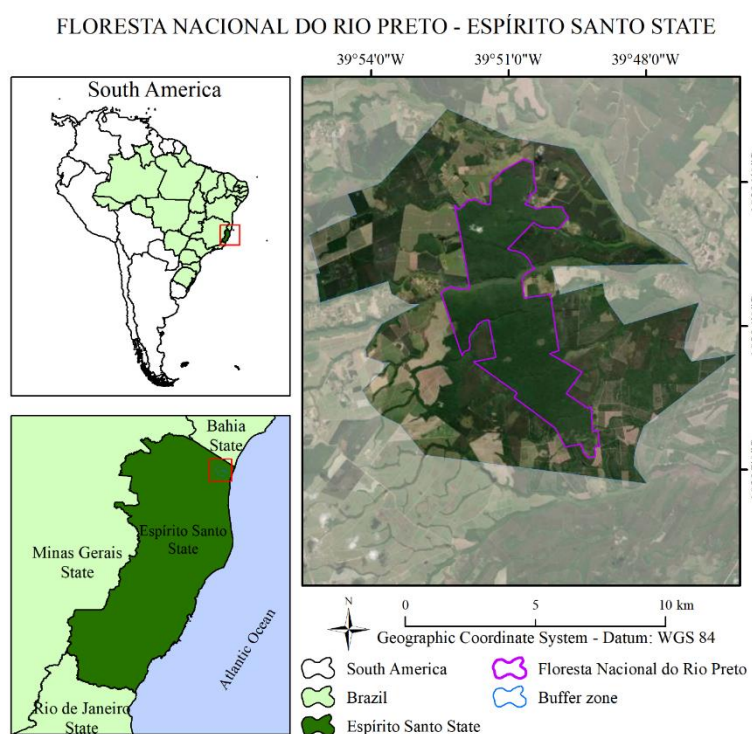


Figure 1. Location of the study area.

Figura 1. Localização da área de estudo.

The Rio Preto National Forest is a Conservation Unit (CU) located in the Atlantic Forest biome, created by Decree No. 98,845 on January 17, 1990 (BRASIL, 1990). According to Souza and Resende (1999), the phytogeological region in which the CU is located is classified as Tropical Fluvial Forest. According to Kottek *et al.* (2006), the climate of the study area culminates in a rainy summer and dry winter, being labeled as humid tropical (Af) according to the Köppen climate classification. The average annual temperature is 22° C (ALVARES *et al.*, 2014), the relief varies from flat to strongly undulated and the average annual precipitation is 1,333 mm.

### Methodological steps

The methodological flowchart that represents the steps taken to model the risk of forest fire occurrence in the Rio Preto National Forest and its buffer zone is presented in Figure 2.

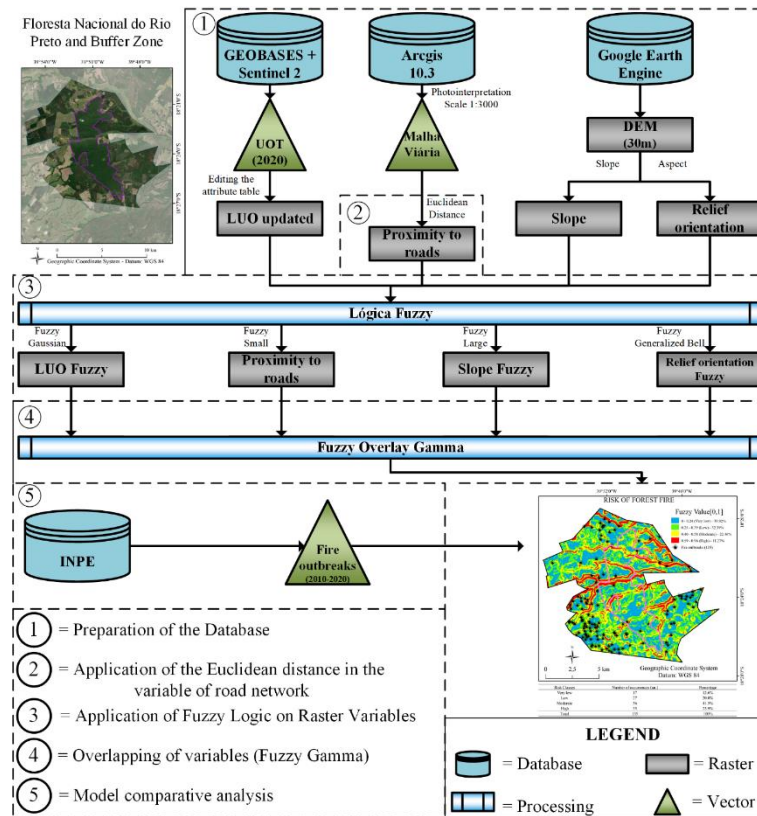


Figure 2. Methodological flowchart.  
 Figura 2. Fluxograma metodológico.

#### Step 1. Preparation of the database

The following variables were used to prepare the risk zoning of forest fire occurrence (ROIF) for the study area: land use and occupation, road network, slope and relief orientation. Land use and occupation (LUO) was used for understanding the organizational pattern of space based on the size of the area occupied by each class, besides the fact that variation in land cover implies changes in several aspects of fire behavior. Authors such as Ribeiro, Soares, and Bepler (2012) explained that the variable of proximity to roads should be included in the model due to the intense movement of people that can contribute to increased ignition risk. Torres *et al.* (2016) stated that landform orientation and slope influence the spread of flames due to the variation in solar incidence on different faces of the area and the speed of spread is related to the terrain slope. However, it should be known that other variables have significant influence on fire behavior, such as wind speed, surface temperature, severity of the flames, ground cover, and weather conditions, among others.

Thus, the variable land use and occupation for the year 2020 was obtained by crossing the information from images obtained by the Sentinel 2 satellite for that year, acquired from the Earth Explorer platform of the U.S. Geological Survey program, and the file of land use and occupation (UOT) provided by the Integrated System of Geospatial Databases of the State of Espírito Santo (GEOBASES) for the year 2015, in vector format at a scale of 1:25,000 and spatial resolution of 25 cm. The file had a total of 26 classes. However, after updating the attribute, table 9 classes remained in the study area (agriculture, wetland, planted forests, macega, water body, native forest,

others, pasture, and exposed soil). Marshes are flooded areas composed of grass and herbaceous vegetation and macegas are native areas in regeneration that have suffered some disturbance.

Mapping of the roads present in the region was based on photointerpretation techniques of the basemaps available in the ArcGis® version 10.3 software program. The images used had a spatial resolution of 1 m and the scale used for photointerpretation was 1:3,000. The road classes were defined according to dimensional characteristics and geographical arrangement, being classified as: primary (the longest roads, which cross practically the entire Flona and its buffer zone); secondary (smaller roads for access to properties); and tertiary (forest stand roads). After the road classes were defined, a buffer was applied to establish the area of influence of each class on the ignition of fire action in relation to the traffic flow of each one. Thus, a 50-meter buffer was used for the primary roads, 25 meters for the secondary roads, and 12.5 meters was applied for the tertiary roads or access roads, with these distances being the influences of each class. These values were defined based on the methodology proposed by Juvanhol, Fiedler and Santos (2015).

The slope and relief orientation variables were obtained from processing the Digital Elevation Model (DEM) file obtained on the Google Earth Engine platform from the Shuttle Radar Topographic Mission (SRTM) with a spatial resolution of 30 meters. The slope was prepared based on the “Slope” tool and the relief orientation was determined from the “Aspect” tool, both present in the ArcGis® version 10.3 software program.

### Step 2. Applying Euclidean distance to the road network variable

After determining the areas of each class of roads, the Euclidean distance was applied to determine the influence of each one on the ROIF. This methodology determines the linear distance between the center of two cells from the Pythagorean Theorem [ $D_{AB} (X_A, Y_A) e (X_B, Y_B)$ ].

### Step 3. Application of fuzzy logic in the matrix variables

The methodologies based on the application of Fuzzy logic proposed by Ramalho *et al.* (2021) were used to elaborate the modeling of forest fire occurrence risks in the study area. Gaglione *et al.* (2019) explained that Fuzzy logic makes it possible to translate a qualitative value into a numeric one inserted in a set of values in the range between 0 and 1.

Thus, the use of the aforementioned methodology enables elaborating accurate research in imprecise scenarios (i.e. it is possible to accurately calculate the risk classes of forest fire occurrence in different areas without requiring data collected in the field). To do so, different membership functions were defined for applying fuzzy in each of the variables of interest. However, the risk in each of them was considered high when the variable assumed values in the fuzzy set close to 1 and very low when approaching 0.

Next, we used the Fuzzy Gaussian function for the land use and land cover variable, which determines the influence of the UOT classes from a normal distribution of the set around a midpoint that assumes a value of 1 in the Fuzzy set (i.e. the greatest influence on the ROIF, being the values that lie between the limits in the transition zone of the set assume the same value of pertinence). The slope value of the curve is defined between the range 0.01 to 1 (Equation 1).

$$\mu(x) = \exp^{-\sigma \times (x - a)^2} \quad (1)$$

In which:  $\sigma$  is the parameter that models the propagation of the curve;  $x$  refers to the value of the land use and land cover class in the matrix image;  $a$  is the midpoint value, which indicates the center point of the function where  $\mu(x)$  is equal to 1.

The class defined as central point (value 5) was the “planted forest” class, which is considered the class with the highest risk. The value of the slope of the curve is defined between the range 0.01 to 1 (Table 1).

Table 1. Lan use and occupation reclassified according to the influence on the risks of forest fires occurrence (RFFO).

Tabela 1. UOT reclassificado de acordo com a influência sobre os riscos de ocorrência de incêndios florestais (ROIF).

LUO classes	Reclassified Value	LUO classes	Valor reclassificado
Exposed soil	1	Pasture	6
Swamp	2	Native forest	7
Agriculture	3	Others	8
Macega	4	Water bodies	9
Planted Forest	5	-	-

According to White, Ribeiro, and Souza (2014), planted forests have favorable characteristics for the occurrence of forest fires due to the accumulation of combustible material in these areas, thus facilitating the spread of fire and increasing its intensity. A similar situation occurs in areas covered by pasture and agriculture. However, pasture and macega receive a higher risk classification than agriculture due to their lower ignition temperature. On

the other hand, agriculture requires soil preparation and cleaning activities for its implementation, which is often done with the use of fire, thus presenting potential for ignition. However, due to the higher relative humidity derived from the constant irrigation of crops, this class presents a lower risk of fire occurrence than the pasture and meadow, and higher than the water bodies and exposed soil.

We applied the small fuzzy membership function (Eq. 2) to analyze the influence of proximity to roads in the occurrence of forest fires because according to Ribeiro, Soares and Beppler (2012), the closer to the roads, the greater the risk of occurrence of anthropic fires (closer to 1) due to the greater flow of vehicles and people, and the further away, the lower the risk (closer to 0).

$$\mu(x) = \frac{1}{1 + \left(\frac{x}{c}\right)^b} \quad (2)$$

In which: x is the value of the distance to roads in meters in the matrix image; b refers to the parameter that models the propagation of the curve; c is the midpoint value that indicates the center point of the function where  $\mu(x)$  is equal to 0.5.

The modeling of the influence of slope on fire risk was done by applying Fuzzy Large modeling (Eq. 3).

$$\mu(x) = 1 - \left[\left(\frac{1}{d}\right) \times x\right] \quad (3)$$

In which: d is the maximum slope value; x refers to the matrix image slope values.

This pertinence function was based on the study by Chandler *et al.* (1983), who stated that the greater the slope of the terrain, the greater the speed of fire propagation, which is twice as high for each increment of 15° of slope. Thus, the midpoint used for curve fitting was 15.

Next, we applied the Generalized Bell Fuzzy membership function (Eq. 4) to analyze the influence of the relief orientation.

$$\mu(x) = \frac{1}{1 + \left(\frac{x-f}{g}\right)^{2h}} \quad (4)$$

In which: x is the value of the orientation of the relief (in degrees) in the matrix image; g refers to the parameter that models the propagation of the curve; f is the midpoint value, which indicates the center point of the function where  $\mu(x)$  is equal to 1; h is the amplitude of the center point.

The central value in this function refers to the point of least influence on the risk of occurrence of forest fires. Thus, the north face was classified as having the highest risk and the south face as having the lowest risk. The flat relief will be considered as very low risk (Table 2).

Table 2. Relief orientation reclassified according to the influence on the risks of forest fires occurrence (RFFO).  
Tabela 2. Orientação do relevo reclassificado de acordo com a influência sobre os ROIF.

Relief orientation	Face	RFFO	Relief orientation	Face	RFFO
-1 – 0°	Plan	Very low	157.5 – 202.5°	South	Very low
0 – 22.5°	North	Very high	202.5 – 247.5°	Southwest	Low
22.5 – 67.5°	Northeast	High	247.5 – 292.5°	West	Moderate
67.5 – 112.5°	East	Moderate	292.5 – 337.5°	Northwest	High
112.5 – 157.5°	Southeast	Low	337.5 – 360°	North	Very High

#### Step 4. Superposition of variables (Fuzzy Gamma)

The Fuzzy Gamma overlay was applied to model the risk of occurrence of forest fires and analyze the probability that the matrix image cell of a variable belongs to each final Fuzzy set. This method can be translated as the algebraic product of the sum and the Fuzzy product, both raised to the Fuzzy power (Equation 5).

$$\mu(x) = \left\{1 - \prod_{i=1}^n (1 - \mu_i)\right\}^y \times \left\{\prod_{i=1}^n (\pi_i)\right\}^{1-y} \quad (5)$$

In which:  $\mu_i$  are the fuzzy association values for  $i = 1, 2, 3, 4$ ; n refers to the number of variables in the study; y is the coefficient value between 0 and 1.

Fuzzy Gamma provides the fitting between the sum and the fuzzy product, thus avoiding returning to the value of a single fuzzy set. The standard value of 0.9 was used for the coefficient “y” in order to achieve the combined effect of the Fuzzy Gamma product. Thus, four classes of risk of fire occurrence were subsequently created: very low, low, moderate, high.

*Step 5. Comparative analysis of the model*

A comparative analysis procedure was applied to increase the model's reliability using data which proves the occurrence of fire outbreaks. To do so, the vector files were obtained referring to the geographical points of occurrence of hotspots made available by the National Institute for Space Research (INPE) in a historical period of 10 years (2010 to 2020).

**RESULTS**

Figure 3 presents the maps of geographic distribution of land use and land cover classes, road network, slope and relief orientation. This figure shows the location of each type of vegetation, the road classes (primary, secondary and tertiary), slope classes and relief orientation, as well as their respective occupation percentages of the area.

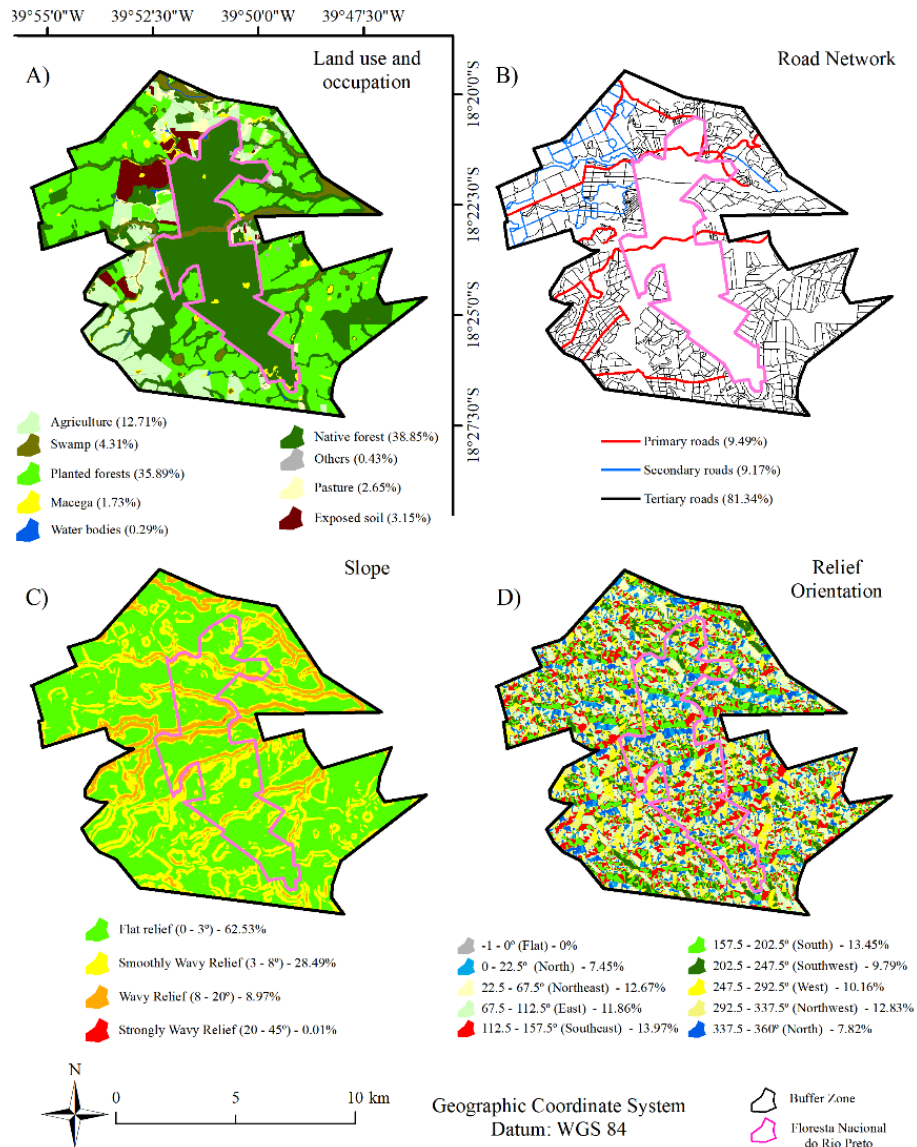


Figure 3. Spatial distribution of the influence variables on the risk of forest fire occurrence in the study area.  
 Figura 3. Distribuição espacial das variáveis de influência sobre o ROIF na área de estudo.

Figure 4 presents the geographical distribution of risk classes influenced by land use and occupation, road network, slope and relief orientation. This figure shows that the UOT mostly culminates in moderate risk, the road network influences the very high risk, the slope and the orientation of the relief fit in the class as very low risk.

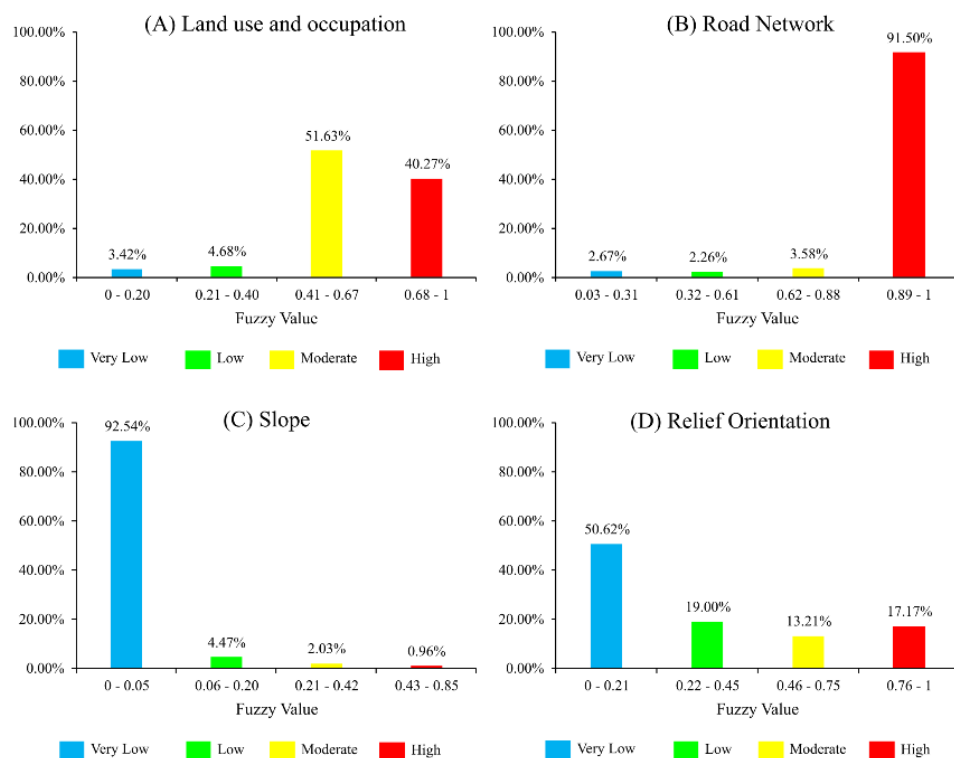


Figure 4. Fuzzy values for the variables of Land Use, road network, slope and relief orientation.

Figura 4. Valores *Fuzzy* para as variáveis de UOT, malha viária, declividade e orientação do relevo.

There were 135 hotspots recorded in the study area between January 1, 2010 and July 15, 2020, as shown in Table 3, along with the average annual precipitation. According to Table 3, the year which had the most rainfall was 2018, and the years which had the least rainfall were 2015 and 2020; however, the year 2020 was only accounted for through the month of July.

Tabela 3. Focos de calor e precipitação média anual na área de estudo entre os anos de 2010 e 2020.

Table 3. Fires and average annual precipitation in the study area between the years 2010 and 2020.

Year	Number of occurrences		Average annual precipitation (mm)
	Inside the Conservation Unit	Buffer Zone	
2010	1	8	1033.1
2011	3	10	1436.7
2012	2	13	1142.0
2013	-	16	1184.9
2014	-	5	1112.2
2015	-	31	797.3
2016	1	28	822.9
2017	-	3	1425.9
2018	-	4	1525.9
2019	-	10	1376.4
2020	-	-	617.5*
<b>Total</b>	<b>7</b>	<b>128</b>	<b>-</b>

\* Data collected until the month of July 2020.

The map of forest fire risk for the study area and the hotspots by risk class are shown in Figure 5. It can be seen that the area is generally in the very low (33.90%) and low (32.30%) risk classes.

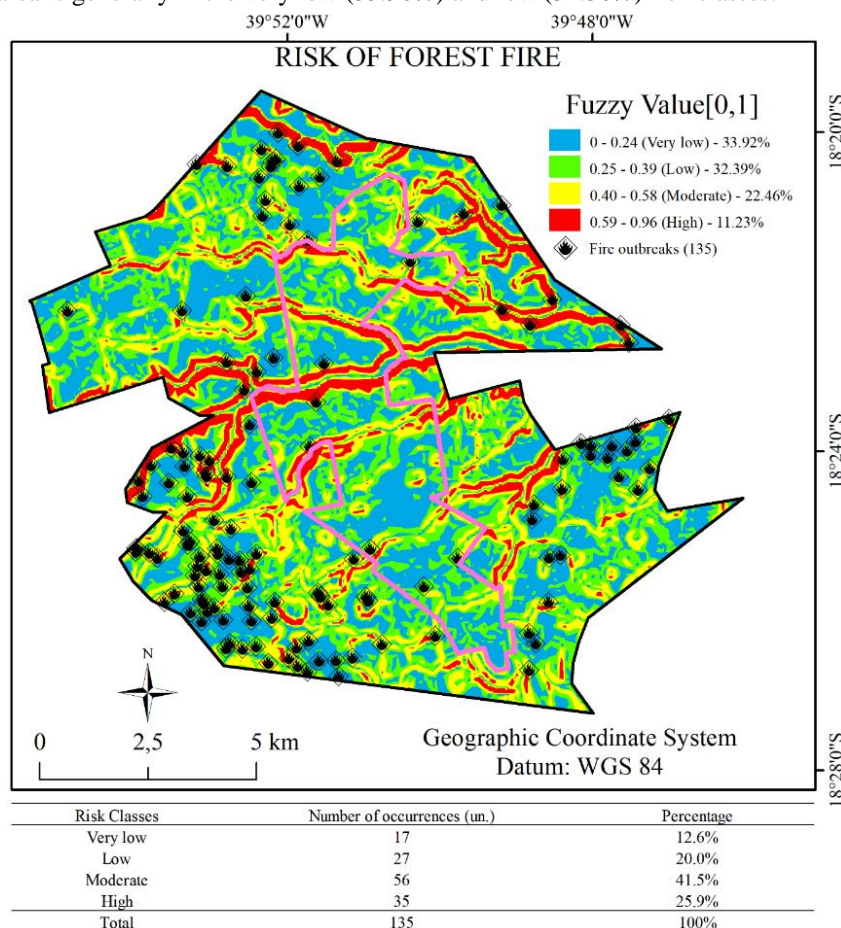


Figure 5. Spatial distribution of fire risk classes in the study area and fire outbreaks recorded between 2010 and 2020.

Figura 5. Distribuição espacial das classes de ROIF área de estudo e focos de calor registrados entre 2010 e 2020.

## DISCUSSION

After modeling the risk zones for fire occurrence in the Rio Preto National Forest and its buffer zone, it was observed that the study area has a wider spatial distribution of the reduced risk classes, which in this case are: Very Low and Low. Figure 5 shows that together these two classes represent 66.31% of the study area's coverage, having a uniform distribution along the FLONA's boundaries and its buffer zone.

The greater proportion of areas with milder risk classes (very low and low) are mainly influenced by the topographic characteristics of the area. This is because according to Koproski *et al.* (2011), the lower the terrain slope, the lower the fire spread rate. The study area has more than 90% of its extension covered by slopes lower than 10° (Figure 3). The gentler relief classes present in the area culminated in a percentage value of 97.01% in the Fuzzy interval between 0 and 0.20, which represent very low to low risk of fire occurrence (Figure 4C).

Furthermore, Torres *et al.* (2014) stated that landform orientation directly influences solar incidence and wind frequency and consequently the drying of combustible material. Torres *et al.* (2016) stated that north-facing faces have higher solar incidence rates and south-facing slopes receive lower solar rates which culminates in moisture retention 1.6 times higher than northern areas, causing the fuel material to remain at an average of 41% more moisture in these areas.

Thus, the most frequent relief faces in the study area are those with lower wind incidence and naturally lower risk of fire occurrence (Table 2). Figure 3 shows that these faces cover 59.23% of the study area. After Fuzzy modeling, it was realized that 69.62% correspond to the range between 0 and 0.45, which indicate very low and low risk of fire occurrence.

On the other hand, there is an extension corresponding to 11.23% of the study area covered by the high risk class. Since this study aims to define the areas at risk of fire occurrence, even though the high risk class is not



very representative, it is recommended that FLONA's managers establish forest fire containment plans for these areas, because if fires do occur, the other areas have combustible material which can spread the flames even though they are of low risk.

The representative portion of high risk is mainly derived from the high density and spatial distribution of roads throughout the study area, in addition to the significant presence of planted forests, especially in the buffer zone (Figure 3). The influence of roads is corroborated by Koproski *et al.* (2011) when they explained that adjacent areas present a high risk of fires, as they are subject to fires caused by vehicles, by campfires or disposal flammable material by visitors.

According to Figure 3, planted forests accounted for a large portion of land use and occupancy (35.89%). In turn, the pasture and macega classes also present relatively high risk characteristics (Table 1), and cover about 4.38% of the area (Figure 3).

The areas covered by planted forests have favorable characteristics for fire propagation due to the high production and deposition of combustible material on the ground (branches, bark, leaves), in addition to having thin canopies which allow solar radiation to enter the stands. Moreover, harvesting activities provide a high risk of fire because machinery is used, which can produce sparks or even spill flammable fuel throughout the area. According to Juvanhol *et al.* (2015), there are records that the temperature increases by 10 °C in pasture areas above forest regions, and the humidity decreases by about 35%, greatly increasing the probability of fire occurring and providing the ideal environment for its propagation.

According to the Fuzzy modeling (Figure 4B), 91.50% of the study area has risk of forest fire occurrence inserted in the interval between 0.89 and 1 (high risk) when it comes to the influence of the road network. It is important to elucidate that this risk is not very present in the interior of the FLONA due to the smaller portion of roads present. Figure 4A shows that approximately 40.27% of the study area is classified as high risk (0.68 - 1) for the occurrence of fires in relation to the UOT classes due to the proportion and spatial distribution of the land use and occupation classes.

From Figure 5 and Table 3 it is possible to evaluate the quantity, spatial distribution and year of occurrence of hotspots in the study area. A total of 135 hot spots were observed during the period between January 1, 2010 and July 10, 2020, distributed both inside the FLONA and in the buffer zone. An interesting fact to be observed in Table 3 is that the two years with the lowest average annual rainfall (2015 and 2016) were also those with the highest number of fires, 31 and 29, respectively. This can be explained by the information provided by White and Ribeiro (2011). The authors stated that the average rainfall has a direct relationship with the occurrence of forest fires, because prolonged periods of drought influence the ability to ignite and spread fires and promote progressive drying of both the combustible material on the ground and still green material.

White and Ribeiro (2011) further elucidated that precipitation is an important variable in reducing the potential occurrence and spread of forest fires. According to these authors, the amount and frequency of precipitation can completely eradicate the possibility of occurrence of fires in a given period; however, this reversal is more complex in places with critical characteristics of flammability, because combustible material loses much of the acquired moisture after a certain period of drought and becomes highly flammable again.

Another point presented in Table 3 is the importance of the existence of the buffer zone in the Conservation Units. As observed, about 94% of the fire outbreaks in the evaluated period occurred in the buffer zone, thus avoiding the destruction of the protected vegetation inside the FLONA. The results of the comparative analysis proposed in Figure 5 show that 91 of the 135 hotspots that occurred in the study area were verified in locations classified as moderate to high risk, which corresponds to 67.4%. It can be seen that there is a high rate of fires in the buffer zone area where forestry activities are concentrated (45.62%), proving that such activities (and added to human presence) are potential elevators of the risk of forest fires.

## CONCLUSIONS

- The application of fuzzy modeling is an efficient tool to assist in predicting the occurrence of forest fires in protected areas due to its potential for defining risk classes by inserting each of the variables from determining consistent weights for each as a function of individual characteristics;
- The characteristics of the area which ensured the most significant spatial distribution of very low and low risk classes were the relief with milder slope and the predominantly south-facing relief faces;
- The registered hotspots showed a higher proportion in the moderate and high risk classes, showing that the model is well structured, effective and representative; and
- The proposed methodology can be applied to other areas and land cover types.

## ACKNOWLEDGMENTS

The authors thank the United States Geological Survey (USGS), the Sistema Integrado de Bases Geoespaciais do Estado do Espírito Santo (GEOBASES), the Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio), the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), funding code 001, the Fundação de Amparo à Pesquisa e Inovação do Espírito Santo (FAPES), and the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq).

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