Geotemas, Pau dos Ferros, RN, Brasil
ISSN: 2236-255X, v. 15, 2025.

FIRE RISK IN THE ARAPUÃ RESERVOIR MICRO-WATERSHED, IN THE POTIGUAR SEMIARID REGION

Risco de incêndio na microbacia hidrográfica do açude Arapuã, no Semiárido Potiguar

Riesgo de incendio en la microcuenca hidrográfica del embalse Arapuã, en el Semiárido Potiguar

Hélison Amadeus da Silva Costa
Universidade Federal Rural do Semi-Árido (UFERSA)
E-mail: helisonsilvajp@gmail.com

Joel Medeiros Bezerra
Universidade Federal Rural do Semi-Árido (UFERSA)
E-mail: joel.medeiros@ufersa.edu.br

Larissa de Oliveira Fontes
Universidade Federal Rural do Semi-Árido (UFERSA)
E-mail: larissa.fontes@ufersa.edu.br

Ingrid Fialho de Miranda
Universidade do Estado do Rio Grande do Norte (UERN)
E-mail: imiranda1704@gmail.com

Article History
Received: 15 august, 2025
Accepted: 03 december, 2025
Published: 29 december, 2025

ABSTRACT

O This study aimed to assess wildfire risk in the Angicos Reservoir Micro-Watershed (MHAA), located in the semiarid region of Rio Grande do Norte, Brazil, which covers an area of 142.1 km² and has a perimeter of 80.95 km. The analysis was conducted through the integration of geospatial data and multicriteria methods. Sentinel-2 and ALOS PALSAR satellite imagery were used to characterize physical variables, including land use and land cover, elevation, slope, and aspect. Data processing and thematic reclassification were performed using QGIS software, and the Analytic Hierarchy Process (AHP) was applied to assign weights to the selected criteria. The results indicated marked seasonal variation in wildfire risk, with higher susceptibility during the dry period, particularly in areas with dense vegetation and steep slopes. The municipalities of Luís Gomes and Major Sales were identified as the most vulnerable to wildfire occurrence. The proposed model proved effective in identifying priority areas for preventive actions, demonstrating the potential of geotechnologies to support environmental and territorial management of watersheds in semiarid regions.

Keywords: Wildfires; Geotechnologies; AHP; Semi-arid.

https://doi.org/10.33237/2236-255X.2025.7417

RESUMO

O presente estudo teve como objetivo avaliar o risco de incêndios florestais na Microbacia Hidrográfica do Açude Angicos (MHAA), localizada na região semiárida do Rio Grande do Norte, com área total de 142,1 km² e perímetro de 80,95 km, por meio da integração de dados geoespaciais e análise multicritério. A metodologia empregou imagens de satélite Sentinel-2 e ALOS PALSAR para a caracterização de variáveis físicas, como uso e ocupação do solo, altimetria, declividade e orientação das vertentes. Utilizou-se o software QGIS para o processamento e reclassificação dos dados, enquanto a técnica Analytic Hierarchy Process (AHP) foi aplicada para a atribuição de pesos aos critérios selecionados. Os resultados indicaram variações significativas no risco de incêndio entre os períodos chuvoso e seco, com maior suscetibilidade associada à presença de vegetação densa e áreas com declividade acentuada. Destacaram-se os municípios de Luís Gomes e Major Sales como os mais vulneráveis ao risco de incêndios. O modelo proposto demonstrou ser eficaz na identificação de áreas prioritárias para ações de prevenção, evidenciando o potencial das geotecnologias na gestão ambiental e territorial de bacias hidrográficas em regiões semiáridas.

Palavras-chave: Incêndios florestais; Geotecnologias; AHP; Semiárido.

RESUMEN

El presente estudio tuvo como objetivo evaluar el riesgo de incendios forestales en la Microcuenca Hidrográfica del Açude Angicos (MHAA), ubicada en la región semiárida de Rio Grande do Norte, la cual presenta un área total de 142,1 km² y un perímetro de 80,95 km, mediante la integración de datos geoespaciales y análisis multicriterio. La metodología empleó imágenes satelitales Sentinel-2 y ALOS PALSAR para la caracterización de variables físicas, como el uso y ocupación del suelo, altimetría, pendiente y orientación de vertientes. Se utilizó el software QGIS para el procesamiento y reclasificación de los datos, mientras que la técnica Analytic Hierarchy Process (AHP) fue aplicada para la asignación de pesos a los criterios seleccionados. Los resultados indicaron variaciones significativas en el riesgo de incendio entre los períodos lluvioso y seco, con mayor susceptibilidad asociada a la presencia de vegetación densa y áreas con pendientes pronunciadas. Los municipios de Luís Gomes y Major Sales se destacaron como los más vulnerables al riesgo de incendios. El modelo propuesto demostró ser eficaz en la identificación de áreas prioritarias para acciones de prevención, evidenciando el potencial de las geotecnologías en la gestión ambiental y territorial de cuencas hidrográficas en regiones semiáridas.

Palabras clave: Incendios Forestales; Geotecnologías; AHP; Semiárido.

1 INTRODUCTION

Climate change is among the most significant environmental challenges of the contemporary era, exerting widespread impacts on ecosystems, economies, and societies at the global scale. The intensification of extreme events, including heat waves, prolonged droughts, and wildfires, underscores the urgent need to understand and mitigate these phenomena (Santos, 2022).

In semiarid regions, such as the western portion of the state of Rio Grande do Norte, these impacts are particularly pronounced, exacerbating local socio-environmental vulnerability. Within the Caatinga biome, an exclusively Brazilian dryland ecosystem, the combination of naturally arid conditions and changes in rainfall and temperature regimes further intensifies environmental susceptibility (Oliveira Júnior et al., 2021).

The increasing intensity and frequency of drought events elevate wildfire risk, causing severe and often irreversible damage to native vegetation, threatening endemic species, and disrupting natural regeneration processes (Fidalgo; Fernandes, 2023). Data from INPE's Fire Monitoring Program indicate a significant increase in heat focal points in the Caatinga, especially during prolonged dry periods, reinforcing the need for continuous and systematic monitoring (INPE, 2023). In addition, ICMBio reports growing fire vulnerability within protected areas of the biome, highlighting the demand for targeted prevention and response strategies (ICMBio, 2022).

Effective watershed management becomes essential in this scenario, as fire susceptibility represents an additional challenge to environmental conservation and sustainable land-use planning (Vendruscolo et al., 2022). Small watersheds, such as that of the Arapuã Reservoir in José da Penha/RN, play a strategic role in the maintenance and supply of water resources for local communities. Consequently, the integration of geoprocessing and remote sensing tools is fundamental for comprehensive environmental monitoring and spatial analysis, contributing to the mitigation of climate change impacts and to more efficient natural resource management (Coelho et al., 2024). The articulation between continuous monitoring and territorial planning also fosters advances in ecosystem protection and sustainability in vulnerable regions (Ferreira; Rosa; Carmo, 2023).

Moreover, the mapping of fire-risk areas using geospatial techniques constitutes an approach aligned with the Sustainable Development Goals (SDGs), particularly SDGs 13, 15, and 11, as it provides critical support for natural disaster prevention, biodiversity conservation, and the strengthening of community resilience (Silva; Conde; Viseu, 2022).

Given the increasing propensity for wildfires in the Brazilian semiarid region, this study proposes the mapping of areas with potential fire risk in the Arapuã Reservoir Watershed through the application of Geographic Information Systems (GIS) and remote sensing techniques. From this perspective, this study aimed to identify the most vulnerable areas and to support prevention and mitigation strategies, thereby contributing to sustainable territorial management and climate change adaptation in the region.

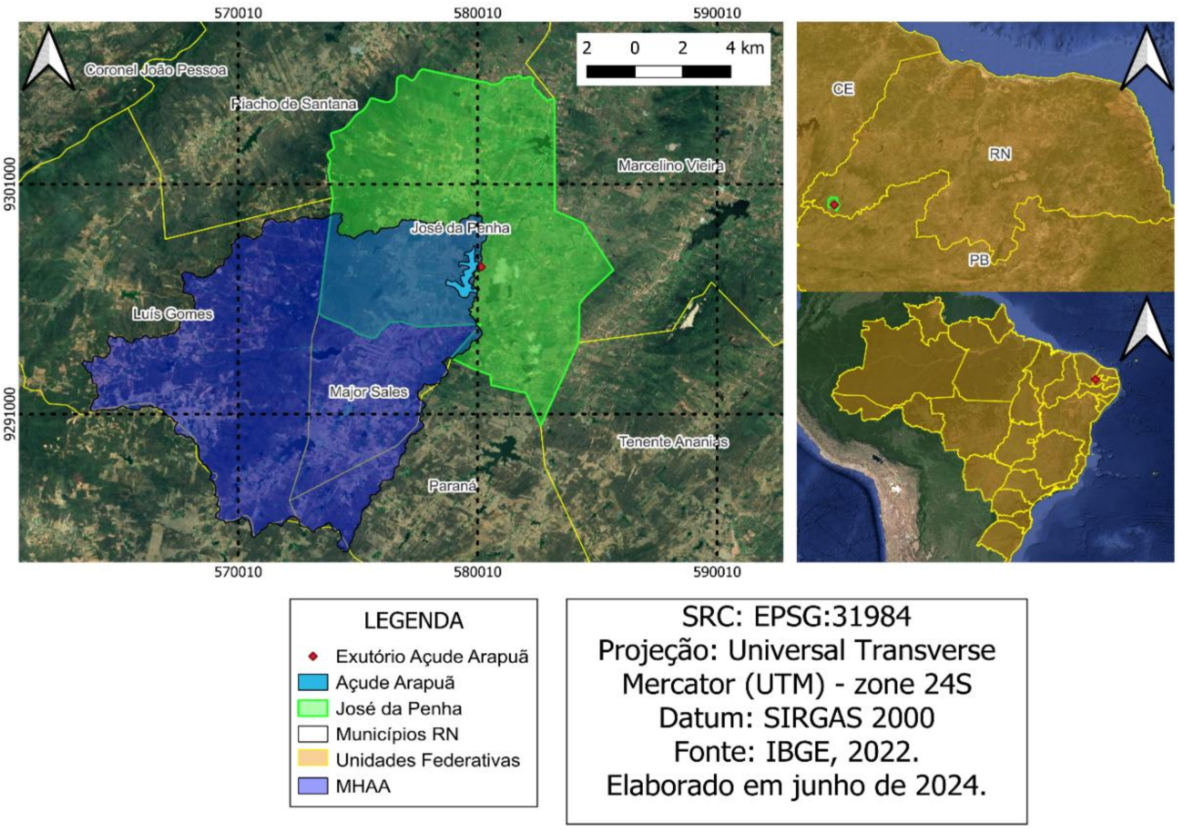
2 METHODOLOGY

2.1 Study Area

The research was conducted in the Arapuã Reservoir Watershed (MHAA), located in the municipality of José da Penha, in the Alto Oeste Potiguar region of the state of Rio Grande do Norte, Brazil. Locally known as Açude Angicos, the reservoir was completed in 1920 and has a storage capacity of 4,295,000 m³, having played a fundamental role in regional water supply until 1983 (Barbosa, 2024).

Currently managed by the National Department of Works Against Drought (DNOCS), the MHAA includes areas within the municipalities of José da Penha, Major Sales, Luís Gomes, and Paraná, all of which contribute surface runoff to the reservoir (Figure 01). The watershed covers a total area of 142.1 km² and has a perimeter of 80.95 km (Barbosa, 2024).

Figure 01 – Location of the Arapuã Reservoir Watershed and its water body



Source: Prepared by the authors (2024).

According to the Institute for Sustainable Development and Environment (IDEMA, 2008), the region exhibits a hot semiarid climate, with annual precipitation ranging from 600 to 800 mm, temperatures reaching up to 31 °C, and approximately 2,700 hours of annual sunshine. The predominant vegetation is Hyperxerophilic Caatinga, and the dominant soils are Alfisols (Luvissolos) developed over crystalline rocks (Embrapa, 2006). From a socioeconomic perspective, the area is primarily characterized by family farming and small-scale commercial and service activities, in addition to cattle raising and the cultivation of crops such as corn, beans, and sorghum (Estevam, 2023)

2.2 Methodological Procedures

The study adopted a qualitative–quantitative approach based on environmental analyses, meteorological data, and the processing of orbital imagery within a GIS environment. All procedures were carried out using QGIS 3.22.11 Białowieża, including cartographic standardization, geometric correction, clipping, reprojection, and thematic extraction.

The selection of satellite images was guided by rainfall data obtained from EMPARN for the municipalities of José da Penha, Major Sales, Luís Gomes, and Paraná, adopting a cloud-cover threshold of less than 15% (Table 01). Two scenes were selected: 25 October 2023, representing the dry season, and 11 June 2024, representing the rainy season.

Table 01 – Rainfall incidence for the years 2023 and 2024 in the municipalities comprising the MHAA

MUNICIPALITY	JOSÉ DA PENHA		MAJOR SALES		LUÍS GOMES		PARANÁ	
Values in millimeters (mm)								
YEAR/MONTH	2023	2024	2023	2024	2023	2024	2023	2024
JANUARY	115.7	61.8	155.7	82.1	242.8	113.6	180	84.5
FEBRUARY	139.3	202	167.4	194.2	154.8	221.6	144.7	119.7
MARCH	244.6	269.6	229.3	230.8	254.4	250.2	268.8	355.8
APRIL	207.4	110.7	191.8	145.4	168	220.4	171	94.3
MAY	76.7	74.8	110	63.4	117.8	266.8	139.5	58
JUNE	44.2	28.9	36.9	32	73.6	42.6	25.5	13.1
JULY	66.9	0	60.2	3	36.4	17.6	28.5	0.6
AUGUST	0	0	0	0	3	0	0	0

SEPTEMBER	0	0	0	7	0	3.2	0	0
OCTOBER	0	0*	0	0*	0	0*	0	0*
NOVEMBER	0	-	0	-	4.2	-	0	-
DECEMBER	97	-	44.5	-	79.6	-	5	-
TOTAL	991.8	747.8	995.8	757.9	1134.6	1136	963	726

Source: EMPARN (2023–2024)*: Partial monthly value; “–”: Value not yet recorded.

For land use and land cover (LULC) characterization, bands from the Sentinel-2 MSI sensor were used, with spatial resolutions of 10 m, 20 m, and 60 m, in accordance with the original specifications. No spectral filtering or smoothing was applied, thereby preserving the radiometric integrity of the data.

LULC classification was performed using supervised classification, with training samples manually defined based on visual interpretation of the images. Subsequently, the classified raster was reclassified to generate the thematic variable used in the model.

Geomorphological characterization employed the ALOS PALSAR product (scene AP_27014_FBS_F7050_RT1, April 2011), enabling the extraction of elevation, slope, and aspect variables. All layers were integrated within a GIS environment, forming the analytical basis of the spatial model.

2.3 Risk Classification for the Adopted Factors

The classification of fire risk factors followed a methodology adapted from Magalhães, Cordeiro, and Oliveira (2023). The “Reclassify by table” tool in QGIS was applied to assign numerical values to the defined ranges of each variable.

Reclassification was structured into three categories—low, medium, and high risk—as presented in Table 02. The class intervals were defined based on: typical physiographic patterns of the semiarid region; the natural distribution of values observed in the primary layers; thresholds adopted in previous studies, ensuring methodological consistency with the literature; and the expected response of each variable to fire propagation.

Table 02 – Classification of the parameters for each variable analyzed in the identification of fire risk

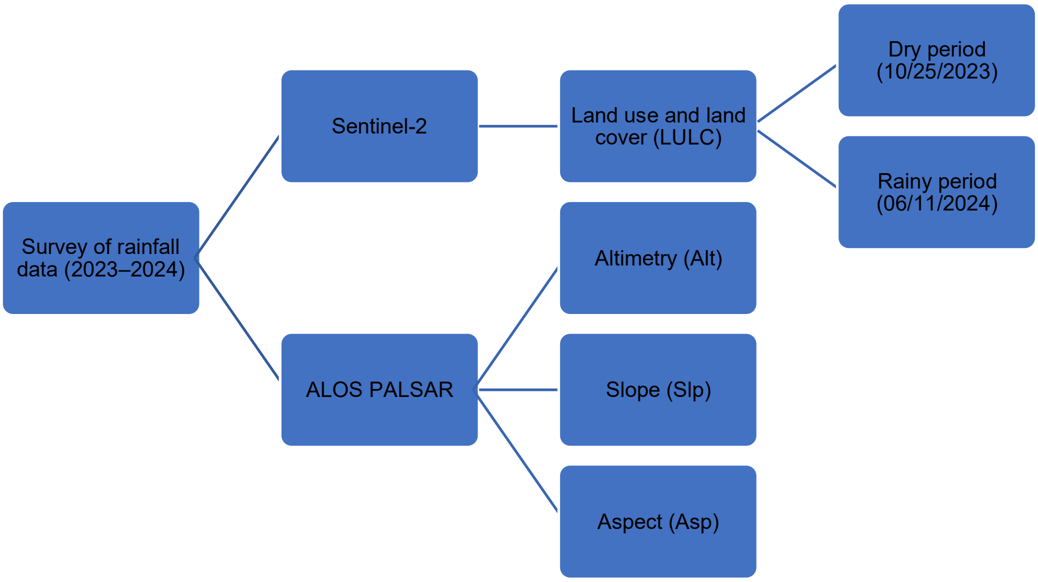
VARIABLE	PARAMETER	CLASSIFICATION	FIRE RISK LEVEL
Land Cover	Forest Pasture Urban/Exposed/ Water	3 2 1	High fire risk Medium fire risk Low fire risk
Slope	0 to 600 m 600 to 800 m Above to 800 m	3 2 1	High fire risk Medium fire risk Low fire risk
Aspect	0 to 12º 13º to 40º Above de 40º	1 2 3	Low fire risk Medium fire risk High fire risk
Aspect Orientation	0 to 45º - N 46º to 135º - L 136º to 225º - S 226º to 315º - O 316º to 360º - N	3 2 1 2 3	High fire risk Medium fire risk Low fire risk Medium fire risk High fire risk

Source: Adapted from Magalhães, Cordeiro, and Oliveira (2023).

The reclassification intervals presented in Table 02 were defined considering: typical physiographic patterns of the semiarid region, in which relatively small topographic variations can significantly influence fire dynamics; the statistical distribution of values observed in the primary layers, ensuring internal consistency of the classification; their application in previous studies, reinforcing methodological alignment with the literature (Magalhães, Cordeiro, & Oliveira, 2023); and the expected response of each factor to wildfire risk, such as steeper slopes favoring greater fire spread, north- and northwest-facing slopes receiving higher solar radiation and thus presenting increased risk, and exposed soils and dry vegetation exhibiting higher flammability.

The flowchart presented in Figure 02 illustrates the methodological organization, from image processing to the development of the final fire-risk map.

Figure 02 – Representation of the steps corresponding to the organization of the input data for risk classification and subsequent analysis of the MHAA



Source: Prepared by the authors (2024).

2.4 Identification of the Most Vulnerable Areas to Wildfires in the MHAA

Following the thematic reclassification of the influencing factors, the weighting stage was conducted, which is essential for the construction of the integrated wildfire risk model for the MHAA. For this purpose, the Analytic Hierarchy Process (AHP)—a method developed by Thomas Saaty in the 1970s and widely applied in multicriteria decision-support analyses within environmental and territorial contexts—was employed (Lira; Francisco; Feiden, 2022).

The application of the AHP methodology required the definition of criteria and subcriteria hierarchically representing the environmental factors with potential influence on wildfire propagation. Each criterion was compared pairwise with the others to determine its relative importance in the decision-making process. According to Posser et al. (2023), this technique enables the assignment of weights through comparison matrices, ensuring greater analytical consistency and reliability of the results.

After constructing the judgment matrix, the criterion weights were calculated and normalized. The values assigned to each variable are presented in Table 03, which summarizes the weighting results obtained through the AHP methodology, considering the factors elevation, slope orientation, slope steepness, and land use and land cover.

Table 03 – Weights assigned to the criteria analyzed after applying the AHP methodology for the MHAA

Altimetry	OV	Slope	UOS
1.000.000	0.333333	0.250000	0.200000
3.000.000	1.000.000	0.333333	0.250000
4.000.000	3.000.000	1.000.000	0.333333
5.000.000	4.000.000	3.000.000	1.000.000
0.068413	**0.134221**	**0.268121**	**0.529246**

Source: Goepel (2018).

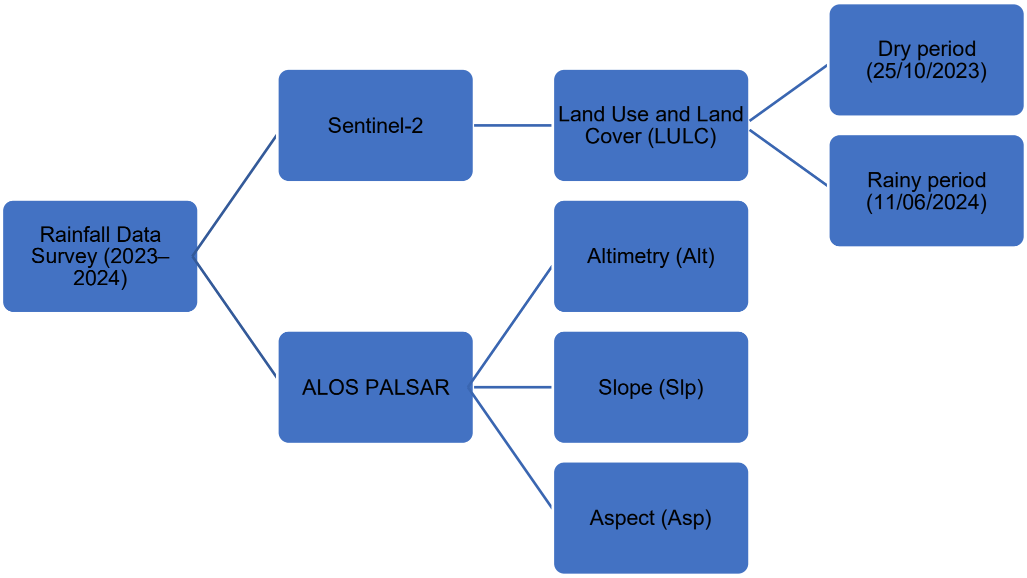
Based on the results, the following weights were assigned to each criterion: Elevation (0.068413), Slope Orientation – SO (0.134221), Slope Steepness (0.268121), and Land Use and Land Cover – LULC (0.529246). These weights were applied as coefficients in the weighted combination of thematic layers using the Raster Calculator tool within the QGIS software environment.

The criteria integration equation resulting from the multicriteria analysis is presented in Equation 1 and was used to generate the final wildfire risk maps corresponding to the two seasonal scenarios analyzed (dry and rainy periods).

$$RISK = 0.068413 * Alt + 0.134221 * OV + 0.268121 * Dec + 0.529246 * UOS \quad \text{Eq. 01}$$

The execution of this stage enabled the production of thematic maps representing spatialized wildfire risk for the MHAA, synthesizing the combined effects of environmental factors into distinct susceptibility levels. The methodological organization of the output data and the representation of the integrated model are shown in Figure 03, which illustrates the sequence of the final analytical operations.

Figure 03 – Representation of the steps corresponding to the organization of output data for the analysis of the MHAA



Source: Prepared by the authors (2024).

Based on the application of the multicriteria equation and the generation of thematic wildfire-risk maps, two scenarios were produced for 25 October 2023 (dry season) and 11 June 2024 (rainy season). To quantify the spatial extent of each risk class, the maps were vectorized using the r.to.vect tool from the GRASS GIS package within the QGIS environment. This procedure enabled the classification of the MHAA into low-, medium-, and high-risk zones, whose spatial distribution and environmental characteristics were analyzed individually.

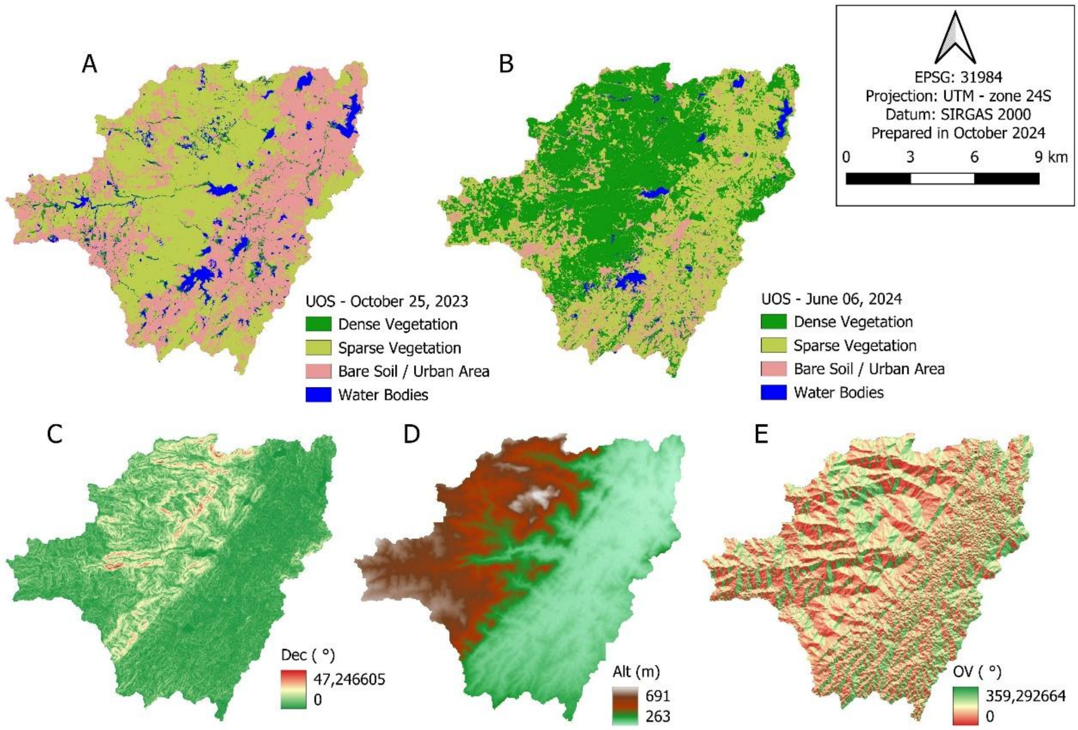
The resulting assessment supported the spatial delineation of areas with greater and lesser vulnerability to wildfires, providing a technical basis for preventive actions and mitigation strategies adapted to local environmental conditions.

3 RESULTS AND DISCUSSION

3.1 Representation of the Physical Aspects of the MHAA

The physical characterization of the Arapuã Reservoir Watershed (MHAA) was based on the analysis of geospatial data related to elevation, slope, aspect, and land use and land cover. Figure 04 presents a synthesis of the structural and environmental characteristics of the MHAA, highlighting topographic gradients, terrain aspect complexity, and distinct land use and land cover patterns, elements essential for an integrated interpretation of the landscape and for the environmental diagnosis of the watershed.

Figure 04 – Characterization of the MHAA for: A – Land use and land cover (10/25/2023); B – Land use and land cover (06/11/2024); C – Slope in degrees; D – Elevation in meters; and E – Aspect in degrees



Source: Prepared by the authors (2024).

The land use and land cover representations shown in Figures 04-A and 04-B reveal marked contrasts between the rainy and dry seasons. The image from 11 June 2024 (Figure 04-B), corresponding to the rainy period, indicates a predominance of dense vegetation, resulting from increased water availability. In contrast, the image from 25 October 2023 (Figure 04-A), acquired during the dry season, shows a greater occurrence of sparse vegetation, exposed soil, and urbanized areas. This pattern reflects the seasonal rainfall variability typical of semiarid regions.

According to Nascimento and Calheiros (2024), Caatinga vegetation is highly adapted to climatic oscillations in semiarid environments, exhibiting pronounced seasonal dynamics. During rainy periods, rapid regeneration of vegetation cover occurs, contributing to reduced surface runoff and increased infiltration. Conversely, during the dry season, leaf senescence decreases evapotranspiration, exposes the soil surface, and intensifies erosive processes, thereby altering the hydrological balance and limiting aquifer recharge. These variations are quantitatively presented in Table 04.

Table 04 – Representation of area (in hectares) for each land use and land cover (LULC) class in the two periods analyzed

LULC CLASS	LULC 25/10/2023	LULC 11/06/2024
Dense vegetation	575,441	6.759,70
Sparse vegetation	6.925,36	5.577,84
Exposed soil/Urban	6.045,32	1.589,23
Water bodies	667,191	286,542

Source: Prepared by the authors (2024).

The differences observed between the two periods are particularly notable in the increase in dense vegetation and the marked reduction of exposed soil during the rainy season. Such behavior is expected in Caatinga environments, where phenological responses to rainfall are rapid and pronounced. During the wet season, green biomass expansion, canopy closure, and vegetation regeneration increase the proportion of dense vegetation classes. In the dry period, the opposite process occurs, with leaf senescence exposing extensive soil surfaces, reducing vegetation cover, and expanding sparsely vegetated or bare soil areas. Therefore, the observed variations reflect the intrinsic ecological dynamics of hyperxerophilic environments rather than classification inconsistencies.

Altimetric analysis of the MHAA (Figure 04-D) indicates elevations ranging from 263 m in the lowest areas to 691 m in the highest sectors. The color scale highlights this gradient, with cooler tones (green) representing lower elevations and warmer tones (red to burgundy) indicating higher altitudes. According to Pereira (2021), elevation directly influences watershed hydrological behavior, particularly surface runoff velocity and susceptibility to erosion.

Higher-altitude areas tend to favor increased runoff and reduced infiltration, whereas lower-lying zones promote water and sediment retention, resulting in higher soil moisture and enhanced recharge potential. The slope variable (Figure 04-C) exhibits inclinations of up to approximately 47.25°, with the steepest slopes concentrated in mountainous sectors. Warmer colors (yellow to red) denote high-slope areas, while green tones represent gentler inclinations.

As emphasized by Oliveira and Aquino (2021), slope exerts a decisive influence on soil hydrodynamics: steeper slopes intensify runoff and erosion processes, whereas flatter areas enhance infiltration and water retention, contributing to ecosystem stability.

Finally, the aspect map (Figure 04-E) reveals a broad distribution of slope orientations, with angular values ranging from 0° to 360°. Different colors represent cardinal and intercardinal directions, with north- and northwest-facing slopes highlighted in reddish tones, east-facing slopes in yellow, and south- and southwest-facing slopes in greenish hues. In the Southern Hemisphere, north-facing slopes receive greater solar radiation, resulting in higher surface temperatures and lower moisture availability, thereby increasing susceptibility to wildfires.

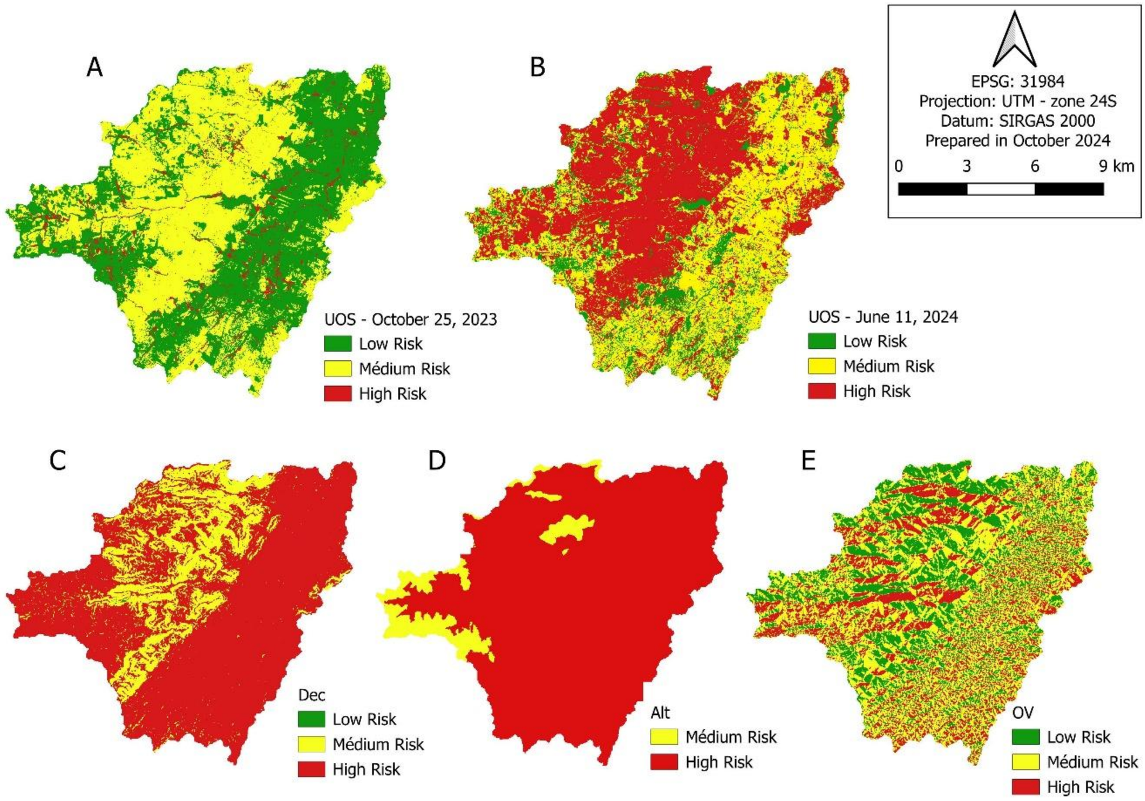
3.2 Classification and Determination of Fire Influence in the MHAA

Based on the assignment of wildfire risk factors for each analyzed criterion, the geospatial data were reclassified using the “Reclassify by table” tool in the QGIS software environment. The outcome of this stage is presented in Figure 05, which illustrates the spatial distribution of risk levels (low, medium, and high) attributed to each variable considered: land use and land cover (LULC) for the two temporal scenes, slope, elevation, and aspect.

Regarding the reclassification of elevation (Figure 05-D), an area of 13,045 hectares was classified as high risk and 1,166.29 hectares as medium risk. No areas were classified as low risk, as this category requires elevations above 800 m, which are absent within the morphometric profile of the MHAA.

According to Ribeiro et al. (2008), altitude significantly influences microclimatic conditions and soil moisture, with lower-elevation areas generally exhibiting higher fire susceptibility due to increased exposure to solar radiation and lower humidity indices. In addition, both mountaintops and valley bottoms experience marked thermal and moisture fluctuations throughout the day, which may favor fire propagation under specific atmospheric conditions.

Figure 05 – Representation of the criteria after reclassification of wildfire risk levels: A – Land use and land cover (LULC – 10/25/2023); B – Land use and land cover (LULC – 06/11/2024); C – Slope (Dec); D – Elevation (Alt); E – Aspect (OV).



Source: Prepared by the authors (2024).

Regarding slope (Figure 05-C), spatial analysis indicated that approximately 10,979.1 hectares of the MHAA were classified as high fire risk, 3,116 hectares as medium risk, and only 8 hectares as low risk.

For aspect (Figure 05-E), reclassification showed that 3,509.37 hectares of the watershed were categorized as high risk, 6,786.45 hectares as medium risk, and 3,913 hectares as low risk. This spatial distribution is directly related to differential solar exposure across slope orientations.

According to Conjo (2021), north-facing slopes in the Southern Hemisphere receive greater solar incidence, resulting in higher surface temperatures and reduced soil moisture, which favor ignition and fire spread. Conversely, south-facing slopes tend to retain higher moisture levels and are therefore less susceptible to burning.

With respect to the land use and land cover (LULC) criterion (Figures 05-A and 05-B), reclassification enabled a comparison between two distinct periods: the dry season

(25/10/2023) and the rainy season (11/06/2024). The results presented in Table 05 indicate significant variation in the areas associated with each fire risk level as a function of rainfall seasonality.

Table 05 – Representation of the areas for the LULC scenes analyzed in the MHAA for each fire risk level

FIRE RISK LEVEL	SCENE	
	LULC 25/10/2023	**LULC 11/06/2024**
	AREA (ha)	
Low	6,716.62	1,877.49
Medium	6,924.19	5,576.73
High	572.668	6,757.45

Source: Prepared by the authors (2024).

The comparison between the two periods underscores the fundamental role of Caatinga vegetation in the hydrological cycle and in the dynamics of environmental risk. During the rainy season, a substantial increase in vegetation density is observed, which acts as a natural barrier to fire spread. Conversely, during the dry season, this accumulated biomass becomes highly flammable, significantly increasing ignition potential and wildfire risk.

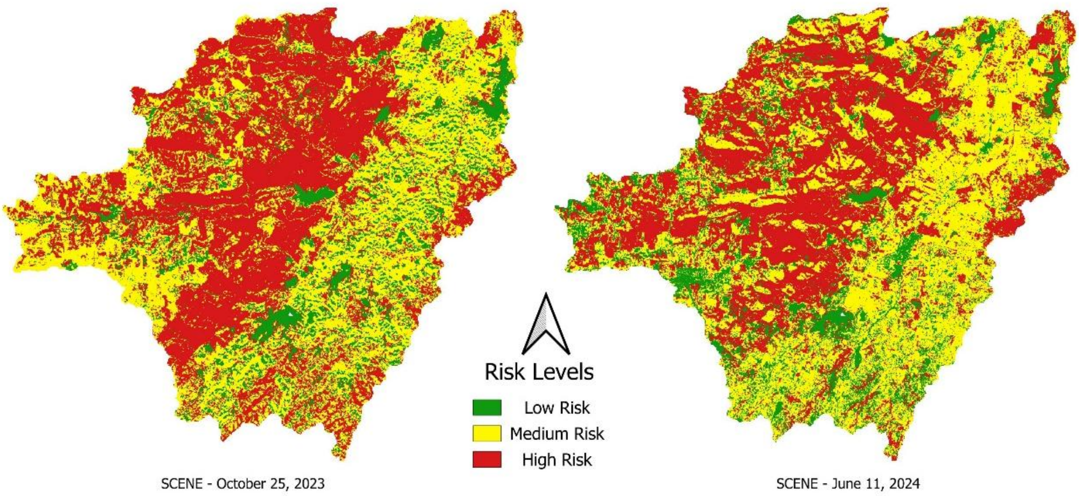
3.3 Creation of the Integrated Fire Risk Model

The integrated fire risk model for the MHAA was developed through the consolidation of all previously analyzed and reclassified criteria, based on the risk levels assigned to each subcriterion. This process was grounded in the Analytic Hierarchy Process (AHP) methodology, developed by Thomas Saaty in the 1970s. For computational implementation, the AHP Online System was used—a digital tool available on the BPMSG – Business Performance Management Singapore platform, developed by Klaus D. Goepel (2018)—which facilitates pairwise comparisons and automatically generates relative weights among the defined criteria.

The application of the AHP methodology enabled the determination of relative weights for each criterion (elevation, slope, aspect, and land use and land cover), ensuring a coherent weighting scheme consistent with the influence of each variable on wildfire risk.

With the multicriteria equation calibrated and implemented using the “Raster Calculator” tool in QGIS, the factors were integrated into a single spatial model, resulting in the generation of wildfire risk maps for two distinct scenarios: the dry period (25/10/2023) and the rainy period (11/06/2024), as shown in Figure 06.

Figure 06 – Fire risk map of the MHAA for the scenes: A – 25/10/2023; and B – 11/06/2024



Source: Prepared by the authors (2024).

Spatial analysis of the generated models revealed a pronounced seasonal shift in the distribution of fire-susceptible areas, strongly influenced by the phenological dynamics of the Caatinga biome. In the October 2023 scenario, corresponding to the dry season, extensive areas classified as high fire risk were identified, reflecting reduced soil moisture, loss of green vegetation cover, and the accumulation of dry, highly flammable biomass.

In contrast, the June 2024 scenario, representative of the rainy season, exhibited a predominance of areas classified as low to medium risk, primarily due to vegetation regeneration, which enhances soil moisture retention and reduces fuel flammability. This seasonal variability is characteristic of Caatinga ecosystems, whose dynamics are highly sensitive to rainfall regimes. The presence or absence of precipitation not only alters vegetation density and biomass volume but also modifies hydrological processes and soil thermal conditions—factors directly associated with wildfire propagation in semiarid watersheds.

The quantification of areas by risk level for each scenario is systematized in Table 06, allowing a comparative assessment of spatial changes in wildfire vulnerability throughout the hydrological cycle.

Table 06 – Representation of areas and their respective fire risk levels for the scenarios of 25/10/2023 and 11/06/2024 in the MHAA

FIRE RISK LEVEL	SCENE	
	MAP 25/10/2023	MAP 11/06/2024
	AREA (ha)	
Low	1,844.31	2,183.73
Medium	5,847.86	6,278.74
High	6,410.01	5,639.53

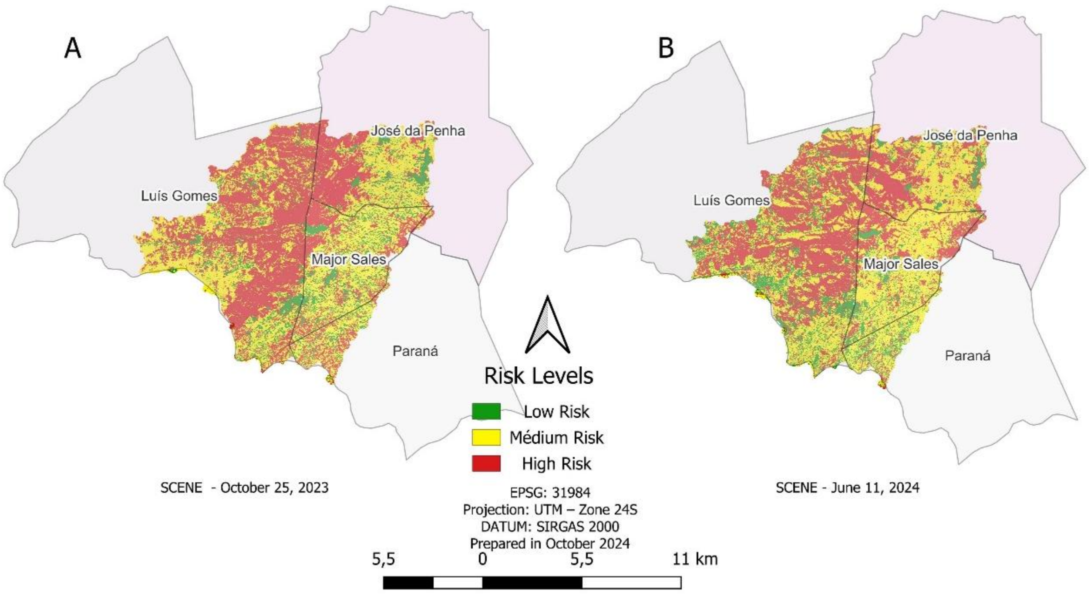
Source: Prepared by the authors (2024).

The results demonstrate that fire risk in Caatinga environments is not static but dynamic, being directly associated with climatic variability and local environmental conditions. In this context, the application of the AHP model proved effective by integrating multiple criteria and providing a robust spatial analysis, with clear potential for application in environmental planning, wildfire prevention, and the sustainable management of natural resources.

3.4 Identification of the Areas of Highest Fire Vulnerability in the MHAA

Based on the analysis of fire risk maps generated for the two evaluated periods (25/10/2023 and 11/06/2024), it was possible to identify the areas most vulnerable to wildfire occurrence within the municipalities comprising the Angicos Reservoir Microbasin (MHAA). Although the municipality of Major Sales has most of its territory within the MHAA, the largest spatial extent of areas classified as high fire risk is concentrated in the municipality of Luís Gomes. Conversely, the municipality of Paraná contributes the smallest territorial portion to the microbasin and also exhibits the lowest extent of high-risk areas, as illustrated in Figure 07.

Figure 07 – Occupation of fire risk areas in the municipalities comprising the MHAA



Source: Prepared by the authors (2024).

The quantitative distribution of areas according to fire risk levels (low, medium, and high) for each analyzed municipality is summarized in Table 07.

Table 07 – Areas corresponding to fire risk levels for each municipality within the MHAA

MUNICIPALITY	AREA (m)					
	Low Risk		Medium Risk		Medium Risk	
	25/10/2023	11/06/2024	25/10/2023	11/06/2024	25/10/2023	11/06/2024
José da Penha	434.171	296.853	1275.76	296.853	1275.76	1467.4
Major Sales	675.401	477.554	1636.44	477.554	1636.44	1860.89
Luís Gomes	586.794	1143.45	2454.13	1143.45	2454.13	2391.62
Paraná	240.908	240.908	509.714	240.908	509.714	509.714

Source: Prepared by the authors (2024).

Spatial analysis of the reclassified and processed imagery revealed that areas with the highest susceptibility to wildfire occurrence are predominantly associated with zones of dense and sparse vegetation. This vegetation functions as combustible material, favoring fire spread, particularly during prolonged drought periods. Additionally, areas characterized by higher slope values exhibited greater vulnerability, as steep terrain facilitates upward flame movement and fire propagation, thereby increasing risk and complicating containment efforts.

These findings reinforce the importance of systematic monitoring of vegetation cover and terrain characteristics in semiarid regions, especially in watershed microbasins with conditions similar to those of the MHAA, to support wildfire prevention and mitigation planning.

4. CONCLUSION

The integrated analysis of physical and environmental factors within the Angicos Reservoir Watershed (MHAA) enabled the development of a spatial wildfire risk model based on orbital data, geoprocessing techniques, and multicriteria analysis. The results demonstrate that variables such as land use and land cover, slope, elevation, and aspect exert a direct influence on the spatial distribution of fire risk, highlighting the interaction between intrinsic landscape characteristics and the seasonal dynamics of the semiarid environment.

Marked contrasts between dry and rainy periods were observed, confirming that seasonality plays a decisive role in wildfire propagation. Municipalities such as Luís Gomes and Major Sales exhibited a higher concentration of areas classified as high risk, indicating the need to prioritize these locations in prevention and management strategies.

The application of geotechnological tools and methodologies such as the Analytic Hierarchy Process (AHP) proved effective in supporting environmental assessments in semiarid microbasins. It is therefore recommended that public policies and management strategies aimed at wildfire prevention and mitigation be strengthened through continuous environmental monitoring, appropriate vegetation management, and community-based training initiatives, thereby promoting greater socio-environmental safety and the conservation of natural resources within the MHAA.

REFERENCES

BARBOSA, S. M. **Avaliação de anomalias em barragem de terra: estudo de caso da Barragem Angicos da cidade de José da Penha – RN**. 2024. Trabalho de Conclusão de Curso (Graduação em Engenharia Civil) – Universidade Federal Rural do Semi-Árido, Pau dos Ferros, 2024. Disponível em: https://repositorio.ufersa.edu.br/handle/prefix/11343. Acesso em: 24 jul. 2025.

COELHO, G. de S.; LIÁ, S. de L. S.; LIÁ, F. S., de ALMEIDA, L. R.; de BRITO, L. G.; SANTOS, I. B.; da SILVA, W. A.; da SILVA, C. M. Análise do uso e ocupação do solo em diferentes períodos no município de Cidelândia – MA. **Contribuciones a las Ciencias Sociales**, v. 17, n. 1, p. 8077–8093, 2024. DOI: 10.55905/revconv.17n.1-488. Disponível em: https://ojs.revistacontribuciones.com/ojs/index.php/clcs/article/view/4808. Acesso em: 15 out. 2024.

CONJO, M. P. F. Mapeamento da susceptibilidade à incêndios florestais na região sul de Moçambique. **Revista Ibero-Americana de Humanidades, Ciências e Educação**, v. 7, n. 11, p. 1669–1689, 2021. DOI: 10.51891/rease.v7i11.3243. Disponível em: https://periodicorease.pro.br/rease/article/view/3243. Acesso em: 16 out. 2024.

EMBRAPA. **Sistema Brasileiro de Classificação de Solos**. 2. ed. Rio de Janeiro, 2006. 306 p.

EMPRESA DE PESQUISA AGROPECUÁRIA DO RIO GRANDE DO NORTE (EMPARN). **Dados pluviométricos dos municípios do Rio Grande do Norte – Série histórica 2023–2024**. Natal, 2024.

ESTEVAM, S. M. **Pluriatividade e sustentabilidade na agricultura familiar no Alto Oeste Potiguar.** 2023.132 f. Dissertação (Mestrado em Desenvolvimento e Meio Ambiente) – Universidade Federal do Ceará, Fortaleza, 2023. Disponível em: https://repositorio.ufc.br/handle/riufc/76120. Acesso em: **04 dez. 2025**.

FERREIRA, B. R. S.; ROSA, D. J. Q.; CARMO, J. C. S. Uso de RPA (Remotely Piloted Aircraft System) aplicado ao georreferenciamento de imóveis rurais. **Paramétrica**, v. 15, n. 2, 2023.

FIDALGO, A.; FERNANDES, A. S. **Efeito dos incêndios florestais no ecossistema: revisão integrativa**. Territorium, n. 30 (II), p. 5-13, 2023.

INSTITUTO DE DESENVOLVIMENTO SUSTENTÁVEL E MEIO AMBIENTE DO RIO GRANDE DO NORTE (IDEMA). Natal – RN, 2008. Disponível em: http://adcon.rn.gov.br/ACERVO/idema/DOC/DOC000000000015000. Acesso em: 23 jun. 2024.

ICMBio. Instituto Chico Mendes de Conservação da Biodiversidade. **Plano Integrado de Prevenção e Combate a Incêndios Florestais no Bioma Caatinga** – *2022.* Brasília, 2022. Disponível em: https://www.gov.br/ibama/pt-br/assuntos/fiscalizacao-e-protecao-ambiental/manejo-integrado-do-fogo/prevfogo. Acesso em: 04 dez. 2025.

INPE. Instituto Nacional de Pesquisas Espaciais. **Programa Queimadas: Monitoramento de focos ativos no Brasil – Relatório Anual** *2023.* São José dos Campos, 2023. Disponível em: https://www.gov.br/pt-br/servicos/obter-dados-de-queimadas. Acesso em: 04 dez. 2025.

LIRA, K. C. S.; FRANCISCO, H. R.; FEIDEN, A. Classification of environmental fragility in watershed using Fuzzy logic and AHP method. **Sociedade & Natureza**, v. 34, p. e62872, 2022.

MAGALHÃES, M. R. C. de; CORDEIRO, C. L. de O.; OLIVEIRA, R. R. Mapeamento de susceptibilidade a incêndios no Monumento Natural Serra dos Mascates, Valença - RJ. In: Simpósio Brasileiro de Sensoriamento Remoto, 20,, 2023, Florianópolis. **Anais**... São José dos Campos, INPE, 2023. Disponível em: https://proceedings.science/sbsr-2023/trabalhos/mapeamento-de-susceptibilidade-a-incendios-no-monumento-natural-serra-dos-mascat. Acesso em: 08 jul. 2024.

NASCIMENTO, M. A. D. do; CALHEIROS, A. S. **Monitoramento do estado de conservação da caatinga alagoana por meio do índice de cobertura vegetal**. 2024.

OLIVEIRA, L. N.; AQUINO, C. M. S. Análise dos fatores de erodibilidade e declividade na sub-bacia hidrográfica do rio Gurgueia, Piauí - Brasil. **Terr@ Plural**, v. 15, p. 1–14, 2021. Disponível em: https://revistas.uepg.br/index.php/tp/article/view/16655. Acesso em: 16 out. 2024.

OLIVEIRA JÚNIOR, J. G. de; SANTOS, J. M.; Policarpo, J. S. M.; Lopes, P. M. O. Mapeamento espectral de cicatrizes de queimadas na caatinga através de dados orbitais MODIS e LANDSAT. **Revista Brasileira de Agricultura Irrigada**, 2021. Disponível em: https://www.inovagri.ou.br/revista/index.php/rbai/artigo/ver/1164.

PEREIRA, P. S. P. M. L. **Mapeamento geoecológico da suscetibilidade a enchente associado à dinâmica de uso e cobertura da terra na bacia hidrográfica do Rio da Guarda-RJ**. 2021. Dissertação (Mestrado em Geografia) – Universidade Federal Rural do Rio de Janeiro, Seropédica, 2021.

POSSER, T. G. P., COSTA, V. M. F., WEGNER, R. DA S., BORBA, S. N., & RICHTER, J. Investigação e modelagem da incivilidade no trabalho na percepção dos professores de instituições públicas e privadas. **Revista de Gestão e Secretariado**, v. 14, n. 4, p. 5049–5068, 2023. DOI: 10.7769/gesec.v14i4.1967. Disponível em: https://ojs.revistagesec.org.br/secretariado/article/view/1967. Acesso em: 16 out. 2024.

RIBEIRO, L. KOPROSKI, L de P.; STOLLE, L.; LINGNAU, C.; SOARES, R. V.; BATISTA, **A. C.** Zoneamento de riscos de incêndios florestais para a Fazenda Experimental do Canguiri, Pinhais (PR). **Floresta**, set. 2008. Disponível em: https://revistas.ufpr.br/floresta/article/view/12430. Acesso em: 16 out. 2024. DOI: http://dx.doi.org/10.5380/rf.v38i3.12430.

SANTOS, A. M. Meio ambiente, mudanças climáticas e seus impactos na saúde coletiva. **Revista Foco**, v. 15, n. 1, p. e329-e329, 2022.

SILVA, A. C. P.; CONDE, F.; VISEU, C. O desenvolvimento sustentável e sustentabilidade municipal: o caso de Portugal. **Revista Gestão & Sustentabilidade Ambiental**, v. 11, n. 4, p. 429-458, 2022.

VENDRUSCOLO, J. CAVALHEIRO, W. C. S.; SANTOS, N. R. F. dos; SILVA, E. D. da. Microbacia do rio Cachara: características hidrogeomorfométricas e dinâmica da cobertura do solo como subsídios para o planejamento e a gestão dos recursos naturais. **RECIMA21**, v. 3, n. 4, p. e341306, 2022.

***