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Fire prevention through neighborhood analysis and remote sensing

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SUMMARY

Preventing fires is just as important as putting them out, if safely contained, it is possible to prevent them from becoming a tragedy. In this way, the present work offers a methodology to evaluate the potential of fire spread at the edge of corn crops. Due to the frequent occurrence of fires in Brazil, the proposal was applied to agricultural lands in the central west of Brazil Entre Rios and Maringá, located in Cristalina - GO. Data from the RESOURCESAT-1 and LANDSAT-5 satellites were used to determine land use and occupation maps. Using the NDWI index and temperature data from the LANDSAT-5 thermal band, the flammability potential of each property was determined. The relationship between land use and the potential for flammability resulted in fire risk maps. To assess the potential for fire spread, points spaced 1 km from the perimeter were selected, analyzed clockwise, in an area of influence of 800 m. The results showed that Entre Rios has a critical point occurrence rate of 7km with an efficiency against the spread of fires at the edge of 63%. Maringá presented a rate of 1km with an efficiency of 8%. Through the proposed methodology, it was possible to determine occurrence rates, critical points and edge efficiency in the land, thus we can conclude that the methodology proved effective in evaluating the potential of fire spreading in crops, allowing it to be applied to several regions of Brazil, avoiding fires in the rate that occurred this year.

KEYWORDS: GIS. Flammability. Fire

1. INTRODUCTION

Fire was considered one of the greatest human achievements in prehistory. Scientists explain that its discovery on Earth dates back millions of years, and its use in daily life has been with us since. What we did not know, at the time of its discovery, is how harmful fire and its spread could be in certain situations. Unfortunately, countless national tragedies were necessary to understand the importance and urgency of developing fire prevention actions used to minimize serious consequences (COSTA et al., 2017; INPE, 2018, WWF-BRASIL, 2020).

The highest occurrences of wildfires are associated with tropical regions, which have an annual variability in the number of outbreaks related to the hydrological regime (CHEN et al., 2011; REIS et al., 2019). In regions with low rainfall during dry seasons, concerns with fire are constant, which are responsible for causing various damage. Favorable environmental conditions combined with organizational unpreparedness make fires frequent in the Brazilian territory. According to NGO WWF-BRASIL (2020), the occurrence of fires this year were higher than in the last 10 years, with more than 20 thousand fires, which means an increase of 86% in relation to the same period in 2019. The occurrences of wildfires, especially those of great magnitude, cause economic, ecological and landscape damage, in addition to being a threat to human life (KOVALSYKIET al. 2016; REIS et al., 2019).

Fire is a natural element, commonly used in the management of agro-pastoral environments, as it is economically viable and already part of the agricultural culture of several civilizations. However, the best way to mitigate its negative impact is to gather information on the specific degrees of risk for each region (RIBEIRO et al., 2008). Action plans aimed at fighting fires require concise data and information (PEREIRA et al., 2020). According to the Forest Code, sanctioned on April 10, 2012, Law No. 12,608, the National Civil Protection and Defense Policy (PNPDEC), authorizes and encourages the creation of information and disaster monitoring systems, as a form of preventive measure and situational risk mitigation (REIS et.al 2019; LEON et. al., 2019).

The knowledge of how the environment is occupied, its physical, biological and climatic characterization can help detect locations that are more susceptible to fire, facilitating the planning of strategies for prevention and combat (PEZZOPANE et al., 2001). Several preventive and combat measures have been adopted to minimize the negative effects of fire (CHEN et al., 2011; KOVALSYKI et al. 2016; COSTA et al. 2016; REIS et.al 2019). The topic is discussed in industrial risk management and in the evaluation of wildfires (NUNES et al., 2007; CUNHA et al., 2007; CETESB, 2008; SILVA et al., 2011), but the application of existing methodologies and tools in agricultural environments are still limited. In this way, fire risk zoning, or risk maps, are fundamental instruments for planning necessary actions in regions of high susceptibility. Visualizing the spatial distribution of risk in maize crops makes it possible to adapt resources and equipment intended for prevention and combat according to the level of danger, constituting an important tool for farmers (RIBEIRO et al., 2008).

The current technological level offers effective tools for conducting studies related to spatial distributions, Geographic Information Systems (GIS) enable the integration, relationship and processing of data linked to spatial information with application in various areas of knowledge. Allied to Remote Sensing, its use allows the construction of models that represent geographical reality, simulate future conditions and the evolution of complex phenomena (MOREIRA, 2007; LEON et. Al., 2019).

Thus, through forest fire detection systems made using remote sensing data, it is possible to map, monitor and estimate areas of occurrence of flammability, risk potential and fire spread (REIS et al., 2019, PEREIRA et al., 2020). In this context, the work presents a methodological proposal using Geographic Information Systems (GIS) and Remote Sensing (SR) to assess the risk of fire spread in regions bordering corn farms.

2. METHODOLOGY

The methodological design was based on the use of ILWIS GISs, version 3.7 and IDRISI, Andes version, and digital data from ResourceSat-1 satellites, LISS3 sensor, and Landsat-5, TM sensor, to assess the risk of fire spread in regions bordering corn crops. The methodology was developed at the Engineering and Automation Center of the Agronomic Institute of Campinas and tested in the lands, Entre Rios and Maringá, located and Cristalina GO. The work was developed in two stages:

STEP 1 - Data collection and processing

The lands already had geographic databases, consisting of: Google Earth image of unknown date, Map of Use and Occupation of the farm, Property limits, Hydrographic Network, Digital Elevation Model.

Due to the nature of the study, it was necessary to acquire additional data. We opted for the acquisition of images from the ResourceSat-1 satellite, captured on 7/21/2010, orbit 329, point 089; and Landsat-5, captured on 07/05/2010, orbit 221 (INPE, 2011).

Using the Land Limits, a radius of 10 km around the perimeter was established through the "Distance Calculation" operation of the ILWIS program to determine the surrounding rectangle.

The satellite images were adapted to the Projection System and datum of the existing database, Universal Transverse Mercator (UTM) projection and datum "World Geodetic System 1984" (WGS 84). The images were georeferenced and submitted to the process of dimensionality reduction.

The Ressource Sat-1 images were subjected to a process of assisted classification to determine the use and occupation maps for 2010. In choosing the classifier, Iwai (2003) was used as a reference, adopting the approach supervised by the maximum likelihood method. The accuracy of the process was assessed between the comparison of the map produced and the map already existing in the databases of the farms.

Using bands 4 and 5 of the RessourceSat-1 scenes, the NDWI (Normalized Difference Water Index) was determined. The index expresses the water content present in the features of the environment through the relationship expressed in equation I (HOLANDA, 2010; SILVA, 2011).

Equation I $$NDW = \frac{Band\ 4 - Band\ 5}{Band\ 4 + Band\ 5}$$

Where:

Band 4 - Corresponds to the near infrared band;

Band 5 - corresponds to the middle infrared band.

The values obtained were grouped and classified, using Table 1 as a reference.

Table 1. NDWI humidity ranges

'Humidity classes	Interval NDWI
Dry	>-0,3
Very low humidity	-0,3 - 0,3
Low humidity	0,0 - 0,3
Moderate humidity	0,3 - 0,6
High humidity	<0,6

Fonte: (HOLANDA, 2010; SILVA, 2011).

Band 6 of the Landsat-5 satellite was converted into a temperature map expressed in ° C using the "Thermal to blackbody conversion" command of the IDRISI program. The temperatures were grouped into five classes according to Table 2.

Table 2. Temperature classes

Temperature classes (°C)
10-14
14-18
18-22
22-26
26-30

Font: Author

The regions were classified according to the degree of flammability through the overlap between the temperature classes and the moisture content classes, using the Cross command of the ILWIS program.

The fire risk map was obtained through the overlap between the flammability map and the 2010 use and occupation map using the "Cross" command of the ILWIS program.

STEP 2 - Data analysis

In order to assess the risk of fire spread in the border region, points spaced 1 km from the perimeter were defined. At each point, an area of influence of 800 m was determined, using the "Distance Calculation" and "Slicing" commands of the ILWIS program. The analysis was performed in a clockwise direction starting at the starting point 16 ° 43'46''S, 47 ° 32'27''W at the Entre Rios farm and 15 ° 58'49''S, 47 ° 33'30 ' 'W on the Maringá farm. Two criteria were used to assess the points: magnitude of the risk and location of the internal or external focus to the farm boundary.

The points were classified according to their risk of spreading: very low, low, moderate, high and very high, with scores from 1 to 5 associated. The higher the spread potential, the lower the note. Through equation II, the risk of fire spread in the border region was determined.

$$\text{Equation II} \quad Eff = \frac{\sum_{i}^{n} 1\, No}{Nmax\ x\ n}$$

Where:
Eff – represents the edge protection efficiency;
No – represents the score obtained at the point;
Nmax – represents the maximum grade value
n – represents the total number of points.

The occurrence rate of points with high and very high fire spread risk was determined using equation III.

$$\text{Equation III} \quad Tx = \frac{Npalt}{P}$$

Where:

Tx – represents the rate of occurrence of points with high or very high risk;
Npalt – represents the number of points with high or very high potential;
P – represents the size of the perimeter expressed in km.

3. RESULTS

The results of the fire spread risk assessment are shown in Table 2.

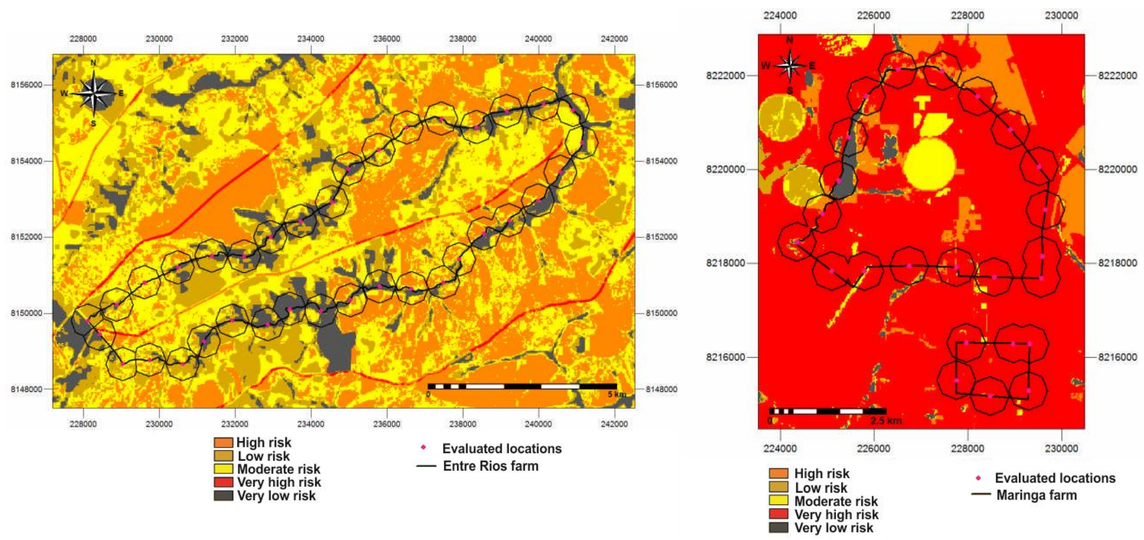
Table 2. Results of fire risk assessment.

	Farm Entre Rios	Farm Maringá
Notes obtained	91	8
Notes maximum	144	96
Edge protection efficiency (%)	63	8
Total points with high or very high potential	5	22
Occurrence rate (km)	7	1

Font: Author

Figure 1 shows the fire risk maps obtained. Figure 1 “a” corresponds to the Entre Rios farm map and Figure 1 “b” to the Maringá farm map.

Figure 1. Fire risk maps



(a) **(b)**

The Entre Rios farm has a barrier with high efficiency in protecting the edge, but there are critical points that indicate areas susceptible to the spread of fire from neighbors. Its southeastern and northern regions are highly susceptible to the spread of fires initiated in regions outside the property. In the northern region of the farm, the occurrence of continuous areas with high risk inside the farm and in its external region indicate a high probability of spread of fires started internally or externally.

The Maringá farm is located in a dry region with occupations that are conducive to fires, combined with low efficiency of protection at the edge indicates great susceptibility to the spread of fire coming from the neighbors. The northeastern region has greater protection in regards to spread of fire, while the south region presents a higher risk. This diagnosis of occurrences of fires in the region justifies the use of a monitoring system, as a measure of preventing and mitigating risk situations in the occurrence of fires, becoming a source of ignition for large fires.

For Costa et al., (2017) the identification of areas where fires occur, contribute effectively to the prevention, monitoring and combat of these events. From these data, information and estimates about the location, period and frequency tha fires are generated, showing their dynamic space / time in the area of occurrence. Considering that the hot spots are the main tools for monitoring fires in Brazil and have limitations that can distort the real incidence of fire in certain places, it is therefore important to promote work on the validation of these products that allow technological improvement of fire monitoring.

In general, through the data obtained, it was possible to observe that in both farms it is necessary to adopt a management model targeted towards the prevention and control of fires in their most critical regions. As this is an initial work, it is suggested to carry out further endeavors to validate a method that enables technological improvement, making the model widely applicable, in addition to standardizing the protocols for determining the flammability and susceptibility of fires.

4. CONCLUSION

Even with some limitations in the use of remote sensing in the detection and prevention of forest and agricultural fires, the methodology represents a good option, allowing the monitoring of large areas quickly several times a day. Through the proposed method it was possible to create a monitoring system, which integrated the phases of data collection and the crossing with geographic data, through an analysis model, capable of generating detection of flammability potential and the occurrence of burning in a property rural.

Therefore, the methodology proved to be practical and effective in assessing the risk of fire spread, allowing to estimate occurrence rates and efficiency in the protection at the edge, in addition, the results made it possible to identify critical regions. Thus, the proposal can be used to develop fire prevention and control plans.

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