Universidade Federal do Paraná
Setor de Ciências Agrárias
Pós-graduação em Engenharia Florestal
Revista Floresta

PERFORMANCE OF THE FMA+ FOREST FIRE HAZARD INDEX FOR THE SERRA DO TOMBADOR NATURAL RESERVE, GOIÁS, BRAZIL

Diego Freire Almeida[*], Bruna Kovalsyki[2], Fernanda Moura Fonseca Lucas[3], João Francisco Labres dos Santos[4], Alexandre França Tetto[5]

[1*]Postgraduate Program in Forestry Sciences at the Federal University of Paraná (UFPR), Curitiba, Brazil – diegoofreire@hotmail.com
[2]Postgraduate Program in Forestry Sciences at the Federal University of Paraná (UFPR), Curitiba, Brazil - kovalsyki.b@gmail.com
[3] Postgraduate Program in Forestry Sciences at the Federal University of Espírito Santo (UFES), Jerônimo Monteiro - fernanda-fonseca@hotmail.com
[45]Postgraduate Program in Forestry Sciences at the Federal University of Paraná (UFPR), Curitiba, Brazil - joaolabres@ufpr.br
[5]Postgraduate Program in Forestry Sciences at the Federal University of Paraná (UFPR), Curitiba, Brazil - tetto@ufpr.br

Received for publication: 31/03/2021 – Accepted for publication: 04/04/2022

Resumo

Desempenho e ajuste do índice de perigo de incêndio florestal FMA+ para Reserva Natural Serra do Tombador, Goiás, Brasil. O objetivo deste trabalho foi verificar o desempenho e ajuste da FMA+ para região da Reserva Natural Serra do Tombador, Cavalcante – GO. O presente trabalho foi composto a partir de dados meteorológicos e de focos de calor, para o período de 2016 a 2020, para área de influência de 50 km da estação meteorológica presente na reserva. O desempenho do índice foi calculado por meio de *skill score* e porcentagem de sucesso, enquanto o ajuste foi realizado através da modificação da amplitude das classes de perigo de incêndios da FMA+, onde: a) a distribuição do número de dias por cada classe apresentasse comportamento decrescente; e b) a quantidade de dias com foco de calor por classe de perigo apresentasse comportamento crescente. A FMA+ apresentou *skill score* de 0,5 e porcentagem de sucesso 75%, entretanto foi necessário o reajuste das classes para cumprimento das premissas mencionadas. Os resultados indicaram que a FMA+ ajustada apresentou aptidão para uso na região de estudo.
Palavras-chave: monitoramento florestal; unidade de conservação; Cerrado.

Abstract

The aim of this work was to evaluate the performance of the FMA+ fire index for the Serra do Tombador Natural Reserve region in Cavalcante, Goiás. The dataset was composed of records provided by the reserve's meteorological station and hotspot detection by satellites. The period analyzed was from 2016 to 2020. The index was fitted by modifying the limits of the fire hazard classes of the FMA+, where: a) the distribution of the number of days in each class presented decreasing behavior; and b) the number of days with hotspots by hazard class presented increasing behavior. The performance was evaluated through the skill score and accuracy methods. The FMA+ index received a skill score of 0.5 and accuracy of 75%, but it was necessary to adjust the classes to reach those levels. The results indicated that the adjusted FMA + index was suitable for use in the study region.
Keywords: RPPN; protected area; Cerrado.

INTRODUCTION

The impacts caused by forest fires are many, such as loss of biodiversity, decrease in vegetation cover, change in the chemical and physical characteristics of soil and water, and reduction of food sources and shelter for fauna (GUIMARÃES, 2014). In Brazil, due to the increase in the incidence of forest fires, there is strong concern to establish Conservation Units (UCs), which are protected areas for preservation, due to the non-conformity of fire events and the resilience of the affected areas, which cause degradation of the landscape (ADÁMEK *et al.*, 2015). In these places, the action and effects of fire must be carefully evaluated to adjust guidelines that ensure the best way to restore the modified areas (TEBALDI *et al.*, 2013).

A method that helps to prevent and fight forest fires is the use of fire hazard indices, which enable applying prior measures on technical and economic bases (MBANZE *et al.*, 2017). These indices are used to understand the danger, regulate the use of forests, and apply operations that involve the use of fire, in addition to formulating prevention and protection plans (TEBALDI *et al.*, 2013). Fire hazard indices are defined from the atmospheric conjuncture of a day, or a sequence of days, that makes it possible for a fire to occur in each location (SOARES; BATISTA; TETTO, 2017).

One of the main fire hazard indices in Brazil is the Monte Alegre Formula (FMA). According to Mbanze *et al.* (2017), even though it is generally used in Brazil's southern region, where it was developed, it has performed well in other regions with adaptation of the hazard scale. To improve evaluation of the propagation of fire, another index was created from the FMA, the FMA+ (Altered Monte Alegre Formula) (NUNES; SOARES; BATISTA, 2006), which contains the wind speed in its structure, to improve prediction and combating of fires through evaluation of their spread.

The Cerrado (savanna) biome is naturally prone to fires, and its biodiversity is under increasing threat. In 2020, fires in the UCs in these biome areas represented about 26.9% of the total fires in Brazil (INPE, 2020). Consecutive fire has been triggering the fragmentation of the landscape, so the use of practices that can promote the prevention and combat of forest fires in the Cerrado are increasingly significant for the survival of local UCs. The objective of this work was to verify the performance of FMA+ for the Serra do Tombador Natural Reserve.

MATERIALS AND METHODS

Study area

The Serra do Tombador Natural Reserve (RNST) is a Private Natural Heritage Reserve (RPPN) in the category of sustainable use, according to the National System of Conservation Units (BRASIL, 2000). Maintained by the Boticário Group Foundation (*Fundação Boticário de Proteção a Natureza*), the RPPN was created by Decree 26 of May 8, 2009 (BRASIL, 2009), with a total area of 8,730.46 ha, located in the municipality of Cavalcante, Goiás state (Figure 1). According to the Ministry of Environment (MMA, 2018), the RNST is in a very high priority region for biodiversity conservation.

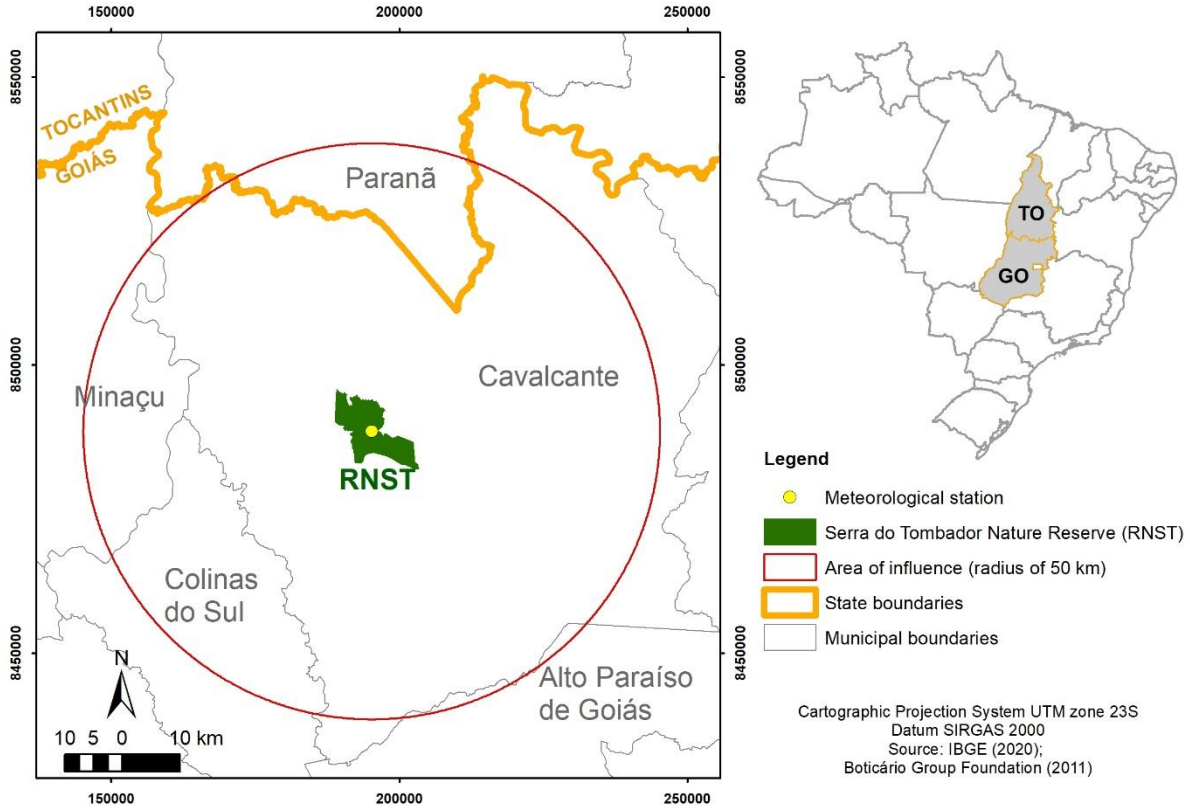

Figure 1. Location of the Serra do Tombador Natural Reserve (RNST) - GO and area of influence of the meteorological station.

Figura 1. Localização da Reserva Natural Serra do Tombador (RNST) – GO e área de influência da estação meteorológica.

The region's climate, according to the Köppen-Geiger classification, is Aw (tropical savanna, with a dry winter season). Rainfall varies annually from 1500 to 1750 mm, with the rainy season occurring between November and March and the dry period extending from June to August. The other months are considered transitional (FUNDAÇÃO GRUPO BOTICÁRIO, 2011).

The RNST is located in an area of classic Cerrado vegetation, in its distinct formations, which are strongly influenced by altitude, associated with edaphic aspects and the different levels of water availability. These factors contribute to high physiognomic diversity, consisting of a mosaic of natural landscapes, where it is possible to find forest, savanna and grassland formations, as well as ecotones. The landscape around the reserve consists of grassland, savanna and forest formations. Until 2007, the property was used for cattle grazing, and since then the native vegetation has been regenerating (FUNDAÇÃO GRUPO BOTICÁRIO, 2011).

Obtaining meteorological data

To calculate the fire danger index FMA+, the meteorological variables relative humidity (%), precipitation (mm) and wind speed ($m.s^{-1}$) were obtained for the period from 2016 to 2020. The data came from the weather station located within the boundaries of the RNST, under the responsibility of the Boticário Group Foundation.

Obtaining the hotspot data

To evaluate the performance and adjustment of the FMA+, an area of influence of 50 km from the RNST weather station was considered, aiming for a spatial coverage of local-scale data, as mentioned by Siqueira *et al.* (2018), based on the recommendations of the World Meteorological Organization (WMO), which according to which synoptic observations (weather forecasts) should normally be representative of a region of up to 100 km surrounding the weather station, while for small-scale applications, the region considered may have dimensions of 10 km or less (WMO, 2008).

We used data regarding hotspots from all satellites available in the BDQueimadas database of the National Institute for Space Research (*Instituto Nacional de Pesquisas Espaciais*) (INPE, 2020), aiming for better efficiency in the daily coverage.

The hotspot data were acquired in shapefile format for each year from 2016 to 2020 for the states of Goiás and Tocantins. Subsequently, the Arcgis 10.5 software was used to generate the 50 km buffer zone around the central point of the RNST and to perform the cutoff, through the clip function, of the hotspots. The table of these attributes was exported to an Excel spreadsheet, in which the days with occurrence of hotspots were identified (1 - presence of hotspots; 0 - no hotspots) and paired with the respective degree of fire danger resulting from the FMA+ for the same date.

Performance and adjustment of the FMA+

The FMA+ was calculated using the following formula, established by Nunes, Soares and Batista (2006).

$$FMA^{+} = \sum_{i=1}^{n} \left(\frac{100}{H_i}\right) * e^{0,04v}$$

Where:
FMA+ = Altered Monte Alegre Formula
n = number of days without rainfall greater than or equal to 13.0 mm;
Hi = relative air humidity (%), measured at 1 pm;
e = base of natural logarithms (here approximated as 2.718282);
v = wind speed ($m.s^{-1}$), measured at 1 pm.

The FMA+ was calculated based on daily values of relative humidity and wind speed, since there are no hourly meteorological data available for the analyzed period. Thus, we adopted the values recorded at 1 pm.

Rainfall is a variable of indirect use in calculating the FMA+ and was used according to the following restrictions (Table 1).

Table 1. Restrictions on the sum of the Monte Alegre Formula.
Tabela 1. Restrições ao somatório da Fórmula de Monte Alegre.

Rain of day (mm)	Modifications in the calculation
≤ 2.4	None
2.5 - 4.9	Subtract 30% from the FMA+ calculated the day before and add (100/H)*e^0.04v for the day.
5.0 - 9.9	Subtract 60% from the FMA+ calculated the day before and add (100/H)*e^0.04v for the day.
10.0 - 12.9	Subtract 80% from the FMA+ calculated the day before and add (100/H)*e^0.04v for the day.
> 12.9	Interrupt the summation (FMA+ = 0) and restart the calculation the next day or when the rain stops.

Source: Soares, Batista and Tetto (2017).

The interpretation of the degree of danger estimated by the original FMA+ was performed according to the classes defined by Nunes, Soares and Batista (2006): ≤ 3.0 = Very low; 3.1 to 8.0 = Low; 8.1 to 14.0 = Moderate; 14.1 to 24.0 = High; > 24.0 = Very high.

The FMA+ performance was determined using the Skill Score (SS) and Success Percentage (SP) methods (NUNES *et al.*, 2010). This is based on a contingency table that integrates observed and predicted values for an

event in a population (Table 2). Very low and Low danger degrees were considered as not indicating the probability of fire occurrence, while Moderate, High and Very High danger degrees were considered as indicating the probability of fire (NUNES; SOARES; BATISTA, 2006; NUNES *et al.*, 2010).

Table 2. Contingency table.
Tabela 2. Tabela de contingência.

Event		Observed		Expected total
		Fire	No fire	
Foreseen	Fire	a	b	$N_2 = a + b$
	No fire	c	d	$N_4 = c + d$
Total observed		$N_1 = a + c$	$N_3 = b + d$	$N = a + b + c + d$

Source: NUNES *et al.* (2010).
Note: a = correct alarms; b = false alarms; c = errors; d = false negatives; N = total number of samples.

The variables required to perform the calculations are:
N = Total number of observations = a + b + c + d
G = Number of correct alarms in the forecast = a + d
H = Expected number of correct alarms = N * (1 – p) * (1 – q) + N * p * q
p = N1 / N
q = N2 / N
SS = Skill score = (G - H) / (N - H)
PS = Success percentage = G/N

Subsequently, we observed whether the assumptions established by Nunes, Soares and Batista (2006) for FMA+ were satisfied, namely:

(a) the distribution of the number of days predicted in each hazard class should have an inverse relationship with the hazard class, such that the higher the hazard class, the lower the number of days predicted for it will be (decreasing behavior);

b) In relation to the variables days with recorded outbreaks in each hazard class, the premise establishes a direct relationship, so that the higher the hazard class, the higher the values observed for these variables will be (increasing behavior).

It is important to note that the second premise originally incorporated the variables number of fires, area burned, and average burned area, but due to the nature of the data, this principle was adapted. The noncompliance with these premises suggests that the original intervals of the FMA+ danger classes did not reflect the local reality, making it necessary to adjust them. This adjustment was done by changing the range of hazard classes, to meet the pre-established assumptions and result in adequate skill score and success percentage values.

RESULTS

For the period from January 2016 to December 2020, only 1,716 days were analyzed due to the lack of meteorological records in certain periods. For this, 47.5% of the days were concentrated in the Very low and Low hazard classes, while 52.5% were in the Moderate, High, and Very High classes of the original FMA+ (Table 3).

Table 3. Annual behavior of the fire hazard index (FMA +) for the influence area of the RNST meteorological station from 2016 to 2020.
Tabela 3. Comportamento anual do índice de perigo de incêndios (FMA+) para área de influência da estação meteorológica da RNST de 2016 a 2020.

Year	Hazard classes				Total
	Very low + Low		Moderate + High + Very high		
	Number of days	%	Number of days	%	
2016	176	48.1	190	51.9	366
2017	157	43.9	201	56.1	358
2018	162	52.8	145	47.2	307
2019	142	44.1	180	55.9	322
2020	178	49.0	185	51.0	363
Total	815	47.5	901	52.5	1716
Average	163.0	-	180.2	-	-

Figure 2A presents the distribution of the days predicted per fire danger classes of the original FMA+, to verify the fulfillment of the first pre-established premise (decreasing behavior of the classes). Figure 2B refers to the second premise, regarding the distribution of the number of days on which there were fires per hazard classes, with increasing behavior of these classes.

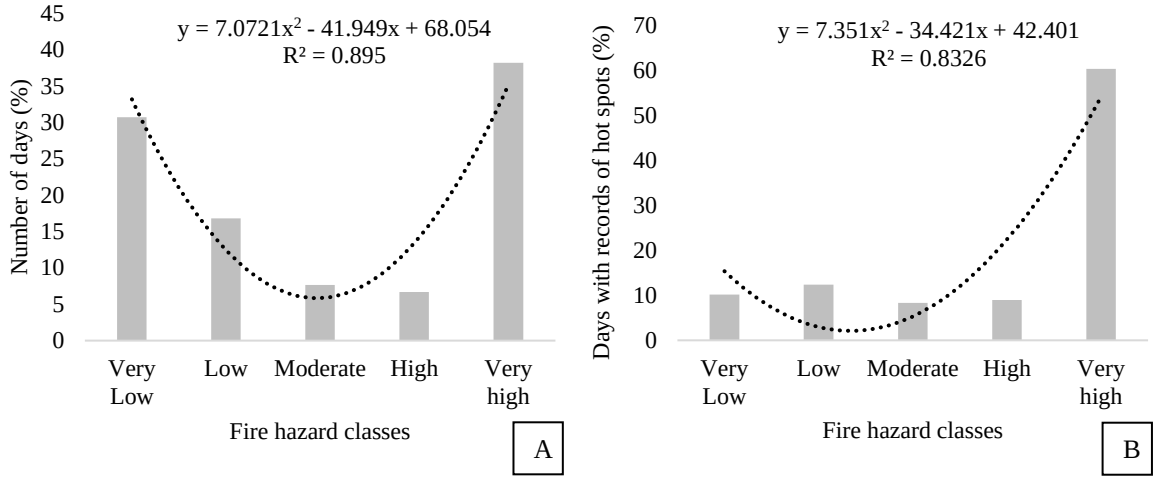

Figure 2. Distribution of days predicted per fire hazard classes (A) and days with records of hot spots (B), by fire hazard classes from the original FMA +, from 2016 to 2020 in the area of influence of the weather station of RNST.

Figura 2. Distribuição dos dias previstos por classes de perigo de incêndio (A) e dos dias com registro de focos de calor (B), por classes de perigo de incêndio da FMA+ original, de 2016 a 2020 na área de influência da estação meteorológica da RNST.

For the number of days predicted per hazard class, the Very High class had representation of 38.2% of the predicted days, followed by the Very low class with 30.7% (Figure 2A). For the days with hotspots, the Very High class concentrated 60.3% of the days with outbreaks, followed by the Low class, with 12.4% (Figure 2B).

Regarding the performance of the FMA+, Table 4 presents the number of days predicted by the index for occurrence and non-occurrence of fires, as well as the observed days, that is, the number of days on which there actually were fires.

Table 4. Contingency for original FMA + for the influence area of the RNST meteorological station from 2016 to 2020.

Tabela 4. Contingência para FMA+ original para área de influência da estação meteorológica da RNST de 2016 a 2020.

Event		Observance		Total Forecast
		Fire	No Fire	
Forecast	Fire	665	236	901
	No Fire	193	622	815
Total Observed		858	858	1716

From these values, the skill score and the success percentage were calculated, resulting in 0.5 and 75%, respectively. Subsequently, the intervals of the fire danger classes were adjusted in order to meet the pre-established assumptions. The new intervals are shown in Table 5.

Table 5. Proposal for new hazard classes for the RNST and area of influence.

Tabela 5. Proposta de novas classes de perigo para FMA+ para RNST e área de influência.

FMA+ Value	Hazard Classes
≤2.5	Very low
2.6 - 8.0	Low
8.1 - 30.0	Moderate
30.1 - 95.0	High
>95.0	Very High

The distribution of predicted days (A) and the number of days on which there were records of hotspots (B) in relation to the new proposed FMA+ hazard classes are shown in Figure 3.

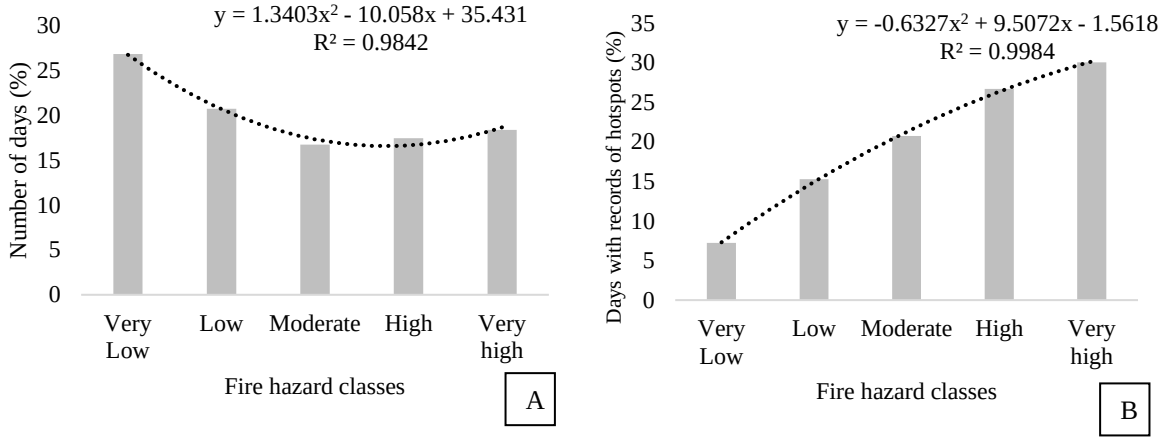

Figure 3. Distribution of days predicted by fire hazard classes (A) and days with records of hotspots (B), by fire hazard classes of the adjusted FMA +, from 2016 to 2020 in the meteorological station's area of influence of RNST.

Figura 3. Distribuição dos dias previstos por classes de perigo de incêndio (A) e dos dias com registro de focos de calor (B), por classes de perigo de incêndio da FMA+ ajustada, de 2016 a 2020 na área de influência da estação meteorológica da RNST.

For the number of days predicted per hazard class, the Very low class represented 26.8% of the predicted days, followed by the Low class with 20.7% (Figure 3A). In turn, for days with records of hotspots, the Very High class concentrated 30.1% of the days with outbreaks, followed by the High class, with 26.7% (Figure 3B). The skill score value and percentage of success did not change, due to the continued presence of the value of the lower limit of the Moderate danger class.

DISCUSSION

Due to the large size and great climatic diversity of Brazil, differences are expected when using fire hazard indices to compare different regions. Thus, it is important to guard against the use of inappropriate hazard indices, since this can lead to wrong decisions regarding preventing and combatting fires (NUNES *et al.*, 2010).

Nunes, Soares and Batista (2006), when elaborating the FMA+ index for the municipality of Telêmaco Borba, Paraná, considered the values of SS (0.1165) and PS (55.64%) satisfactory, and, according to Nunes *et al.* (2010), the performance was better than the original FMA hazard index. Nunes, Soares and Batista (2007), when adjusting the FMA+ index for several municipalities in Paraná, obtained variations of SS between 0.0884 and 0.3340, and PS between 49.27 and 66.67%. Borges *et al.* (2011) also reported better performance of the FMA+ index (SS=0.2055; PS=56.47%) compared to the Nesterov and FMA indices for the state of Espírito Santo. However, the SS and PS values found in the literature were lower than those observed in the present study.

The aforementioned studies were prepared based on the records of the occurrence of corporate forest fires, which, in general present complete and standardized information, but are restricted to their domain area. However, such records do not exist for many protected areas (BONTEMPO *et al.*, 2011), or when they do, there is a lack of data and standardization (TORRES *et al.*, 2016), which can compromise future analyses (LIMA *et al.*, 2018). In this sense, the hotspots proved to be appropriate, since according to INPE (2020), they are indicators of fire occurrence in vegetation, allowing an efficient spatio-temporal coverage of the data, which may have contributed to the performance of the FMA+ index and influenced its SS and PS values. However, it was not possible to analyze the number of fires, as there was no direct relationship with the number of recorded outbreaks, as well as the size of the burned area.

When the SS and PS values were higher than the others, on the other hand, the intervals of the hazard classes of the original FMA+ proved to be inappropriate for the region studied, since it did not satisfy the pre-established premises, which led to the need for adjustment. As for the adjusted FMA+ index, the number of days with hotspots increased due to the presence of the most critical hazard classes, making it possible to use the index as a tool for prevention of fires in the RNST.

CONCLUSION

- The hotspot records allowed the performance analysis and adjustment of the FMA+ index;
- The original FMA+ presented high values of skill score and success percentage;
- The range of hazard classes from the original FMA+ was considered inappropriate for the studied region;
- The adjusted FMA+ satisfied the pre-established assumptions and was considered suitable for use in the RNST region.

ACKNOWLEDGMENTS

We thank everyone who participated directly or indirectly in the conduction of this study. We thank Boticário Group Foundation for the technical assistance, with emphasis on the person in charge of its protected areas Andre Luis dos Santos Zecchin.

This study was financed by the Office to Coordinate Improvement of Higher Education Personnel (CAPES), finance code 001.

REFERENCES

ADÁMEK, M.; BOBEK, P.; HADINCOVÁ, V.; WILD, J.; KOPECKÝ, M. Forest fires within a temperate landscape: a decadal and millennial perspective from a sandstone region in Central Europe. **Forest Ecology and Management**, Amsterdam, v. 336, n. 2015, p. 81-90, 2015.

BONTEMPO, G. C.; LIMA, G. S.; RIBEIRO, G. A.; DOULA, S. M.; SILVA, E.; JACOVINE, L. A. G. Registro de Ocorrência de Incêndio (ROI): evolução, desafios e recomendações. **Biodiversidade Brasileira**, v. 1, n. 2, p. 247-236, 2011.

BORGES, T. S.; FIEDLER, N. C.; SANTOS, A. R.; LOUREIRO, E. B.; MAFIA, R. G. Desempenho de alguns índices de risco de incêndios em plantios de eucalipto no norte do Espírito Santo. **Floresta e Ambiente**, Rio de Janeiro, v. 18, p. 153-159, 2011.

BRASIL. Lei n° 9.985, de 18 de julho de 2000. Regulamenta o art. 225, § 1º, incisos I, II, III e VII da Constituição Federal, institui o Sistema Nacional de Unidades de Conservação da Natureza e dá outras providências. **Diário Oficial da União**, Brasília, DF, 19 jul. 2000.

FUNDAÇÃO GRUPO BOTICÁRIO DE PROTEÇÃO À NATUREZA. **Plano de Manejo da Reserva Natural Serra do Tombador**. Curitiba, 2011.

GUIMARÃES, P. P.; SOUZA, S. M. de; FIEDLER, N. C.; SILVA, A. G. da. Análise dos impactos ambientais de um incêndio florestal. **Agrarian Academy**, Goiânia, v.1, n.01, p. 38-60, 2014.

INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS (INPE). **Portal do Monitoramento de Queimadas e Incêndios Florestais.** 2020. Disponível em: <http://www.inpe.br/queimadas> Acesso em: 20 mar. 2021.

LIMA, G. S.; TORRES, F. T. P.; COSTA, A. G.; FÉLIX, G. A.; SILVA JÚNIOR, M. R. da. Avaliação da eficiência de combate de incêndios florestais em unidades de conservação brasileiras. **Floresta**, Curitiba, v. 48, n. 1, p. 113-122, 2018.

KOVALSYKI, B.; TETTO, A. F.; BATISTA, A. C.; SOUSA, N. J.; TAKASHINA, I. K. Avaliação da eficiência da fórmula de monte alegre para o Município de Ponta Grossa – PR. **Enciclopédia Biosfera**, v.10, n.19; p. 208-218, 2014.

MBANZE, A. A.; BATISTA, A. C.; TETTO, A. F.; AXEL, M. R.; MUDEKWE, J. Desempenho dos índices de nesterov e fórmula de monte alegre no distrito de Lichinga, norte de Moçambique. **Ciência Florestal**, Santa Maria, v. 27, n. 2, p. 687-696, 2017.

MINISTÉRIO DO MEIO AMBIENTE (MMA). **Áreas prioritárias para a conservação da biodiversidade**: 2° atualização. 2018. Disponível em: http://areasprioritarias.mma.gov.br/2-atualizacao-das-areas-prioritarias. Acesso em: 26 mar. 2021.

NUNES, J. R. S.; SOARES, R. V.; BATISTA, A. C. FMA+ - um novo índice de perigo de incêndios florestais para o estado do paraná, Brasil. **Floresta**, Curitiba, v. 36, n. 1, p. 75-91, 2006.

NUNES, J. R. S.; SOARES, R. V.; BATISTA, A. C. Ajustes da Fórmula de Monte Alegre Alterada (FMA+) para o estado do Paraná. **Floresta**, Curitiba, v. 37, n. 1, p. 1-14, 2007.

NUNES, J. R. S.; FIER, I. S. N.; SOARES, R. V.; BATISTA, A. C. Desempenho da Fórmula de Monte Alegre (FMA) e da Fórmula de Monte Alegre Alterada (FMA+) no distrito florestal de Monte Alegre. **Floresta**, Curitiba, v. 40, n. 2, p. 319-326, 2010.

ORGANIZAÇÃO MUNDIAL DE METEOROLOGIA (WMO). **Guide to meteorological instruments and methods of observation**, ed 70. 2008.

SANTOS, J. F. L.; KOVALSYKI, B.; FERREIRA, T. S.; PAJEWSKI, F.; BATISTA, A. C.; TETTO, A. F.; SOARES, R. V. Adaptation of the Fórmula de Monte Alegre for the danger prediction of forest fires in the central region of São Paulo state. **Ci. Fl.,** Santa Maria, v. 31, n. 4, p. 1867-1884, 2021.

SIQUEIRA, A. A.; SANTOS, S. M. dos.; LOPES, I.; LEAL, B. G.; MONTENEGRO, A. A. A. Análise da representatividade estatística de dados meteorológicos para uma região do Submédio São Francisco. **Revista Brasileira de Geografia Física**, Recife, v. 11, n. 3, p. 798-813, 2018.

SOARES, R. V.; BATISTA, A. C.; TETTO, A. F. **Incêndios Florestais:** controle, efeitos e uso do fogo. Curitiba, 2017. 215p.

TEBALDI, A. L. C.; FIEDLER, N. C.; JUVANHOL, R. S.; DIAS, H. M. Ações de prevenção e combate aos incêndios florestais nas unidades de conservação estaduais do Espírito Santo. **Floresta e Ambiente**, Rio de Janeiro, v. 20, n. 4, p. 538-549, 2013.

TORRES, F. T. P.; LIMA, G. S.; COSTA, A. G.; FÉLIX, G. A.; SILVA JÚNIOR, M. R. da. Perfil dos incêndios florestais em unidades de conservação brasileiras no período de 2008 a 2012. **Floresta**, Curitiba, v. 46, n. 4, p. 531-542, 2016.