SYSTEM FOR CALCULATING AND DEFINING CLASSES IN MODIFIED MONTE ALEGRE FORMULA - FMA+ SISCLASS

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Resumo

Sistema de cálculo e definição de classes na fórmula monte alegre modificada - FMA + Sisclass. O objetivo deste trabalho foi desenvolver um sistema computacional para cálculo, armazenamento e definição de novas classes para o índice de perigo de incêndios florestais calculado pela Fórmula de Monte Alegre Alterada – FMA+, que vise armazenar a ocorrência de incêndios florestais, permitindo a geração de estatísticas sobre o índice de perigo e a sua ocorrência, além de gerar plotagens gráficas e estatísticas do desempenho da FMA+, da matriz de contingência e da análise mensal das classes de perigo propostas por Nunes *et al.* (2006) e Eugenio *et al.* (2020 a). A aplicação do Sisclass FMA+ obteve excelentes resultados em testes prévios, conseguindo um incremento de até 31,30% na porcentagem de sucesso do índice FMA+. O Sisclass FMA+ é acessível à comunidade científica e disponibilizado de forma gratuita.
Palavras-Chave: Incêndios florestais, Proteção florestal, Variáveis Meteorológicas.

Abstract

The objective of this work was to develop a computational system for the calculation, storage, and definition of new classes for the forest fire hazard index, classified by the Monte Alegre Altered Formula - FMA+, which aims to store the occurrence of forest fires, allowing the generation of statistics on the hazard index and its occurrence, in addition to generating graphical plots and statistics on the performance of the FMA+, the contingency matrix and the monthly analysis of the hazard classes demanded by Nunes *et al.* (2006) and Eugenio *et al.* (2020 a). The Sisclass FMA+ application obtained excellent results in previous tests, achieving an increase of up to 31.30% in the percentage of success of the FMA + index. Furthermore, Sisclass FMA+ is accessible to the scientific community and available free of charge.
Keywords: Forest fires, Forest protection, Meteorological Variables.

INTRODUCTION

When controlled, forest fires are essential for the existence of ecosystems and the performance of an intrinsic role in maintaining their structure and function. These were recurrent in many parts of the world and received more attention after destroying areas considered in California, Australia (NOLAN *et al.* 2020; VAN WAGTENDONK, 2018), and the Amazon and Pantanal biomes in Brazil.

Climatic conditions directly influence the occurrence of forest fires and the propagation model (TORRES *et al*., 2019). For example, in steep terrain forest landscapes, high wind speed and the availability of flammable material in the forest are responsible for significant damages and the extensive spread of forest fires. In addition, fires represent a significant increase in gas and aerosol particles worldwide, as the large amounts of smoke emitted by fires impact air quality and affect global warming due to increased emissions of gases into the atmosphere (FILIPPONI, 2019).

Other impacts of a forest fire affect, in addition to the environmental sphere, also the social and economic sectors, aggravating the phenomenon of erosion, greater susceptibility of areas to flooding, increasing the number of nutrients that can alter the properties of water, destruction of fauna and flora, threatens the safety of people, such as housing and other goods (REZENDE and DE OLIVEIRA, 2015). Therefore, there are means to indicate the degree of danger of occurrence and fire prevention measures, all of which have their characteristics, depending on the present atmospheric conditions and meteorological data (OLIVEIRA *et al*., 2016).

An important method, which contributed to decision-making on fires' danger, was proposed by Soares and Paz (1973), is called the Monte Alegre Formula - FMA. In a simplistic view, it can be said that an FMA is an accumulative index that it uses as meteorological variables and is related to the need. Nunes *et al*. (2006) incorporated wind speed into the FMA, a factor of great importance for prevention, especially for fighting forest fires, thus developing the Monte Alegre Altered Formula (FMA+), tested and approved for use in the region of Telêmaco Borba in the state of Paraná, Brazil.

Since its creation, an FMA+ has been used by researchers and companies in Brazil, being one of the most used indexes in the entire national territory. Among the studies, those of Soares and Batista (2007) stand out; Nunes *et al*. (2010); In Eucalyptus plantations, in the northern state of Espírito Santo - Brazil, Borges *et al*. (2011) evaluated the efficiency of the Nesterov (N), Monte Alegre Formula (FMA) and Modified Monte Alegre Formula (FMA+) indices, finding greater efficiency for FMA+. In the north and northeast regions of the Mato Grosso Amazon, Souza *et al*. (2012), using the data from the NOAA / AVHRR system, together with the FMA and FMA+ indices, concluded that FMA + had a better performance for assessing fire risks in these regions. Still, in the Pantanal Biome, Soriano *et al*. (2015) tested the efficiency of the Angström indices (B), Telitsyn Logarithmic Index (I), Nesterov Index (G), FMA and FMA +, with data on NOAA12-night and NOAA15 -o satellite fire outbreaks, concluding at night the greatest efficiency of the Monte Alegre Formula in the Pantanal Biome.

Torres *et al.* (2017) tested the efficiency of seven fire risk indexes (Fire Weather Index (FWI), Telitsyn Index (I), Nesterov Index (N), Cumulative Precipitation Rate minus Evapotranspiration (P-EVAP), and Split Evapotranspiration Precipitation (EVAP / P), FMA and FMA+, in Viçosa – MG – Brazil. They concluded that the FWI index correlates with the sum of fires recorded in the month. However, the Telitsyn index is more efficient in previous hits of fire outbreaks. Eugenio *et al.* (2019; 2020 a) selected the forest fire risk models FWI, FMA+, and RIF-Database for Eucalyptus plantations, on the north-central coast of the state of Espírito Santo and the south coast of Bahia, Brazil. The authors observed a greater sensitivity of the FMA+ model in forest fires, modifying success rates above 60% for all sub-areas. However, it presented the worst results for the days without forest fires and, consequently, fearing the worst results for an overall success rate.

Associated with the class definition problem for different areas of study, there is a need to automate the calculation of FMA+ and its class system. Nunes *et al.* (2007) report that Brazil, despite being a continental country, has a flawed meteorological monitoring network, lacking integrated information at a national and regional level, where the absence of computational tools is some of the severe problems for the technicians who work.

Given the above, considering the need to adjust the fire risk classes provided by FMA+ for any area other than the one developed, this study aimed to present a computer system for calculating, storing, and defining new classes for the hazard index of forest fires calculated by the Monte Alegre Altered Formula - FMA+.

MATERIAL E METHODS

The language used for the development of the Sisclass FMA+

The program was written in VBA (Visual Basic for Applications) using Microsoft Excel® 2007 software. It can be used in the software version of that year or later and is available in the Portuguese version. It contains macros consisting of a series of commands, so Excel security settings must be adjusted to enable them. According to Botchkarev (2015), Excel software has gained popularity for simple language, easy visualization, data manipulation, the possibility of solving various problems and being a program generally available by companies and students.

Data Flow Diagram

The Sisclass FMA+ receives as input meteorological data and data on the occurrence or non-occurrence of daily wildfires (Figure 1), which feeds the Modified Monte Alegre Formula (FMA+), thus producing the index on the danger of wildfires and, later, it is grouped into five distinct classes, and its nomenclature depends on the system of classes employed.

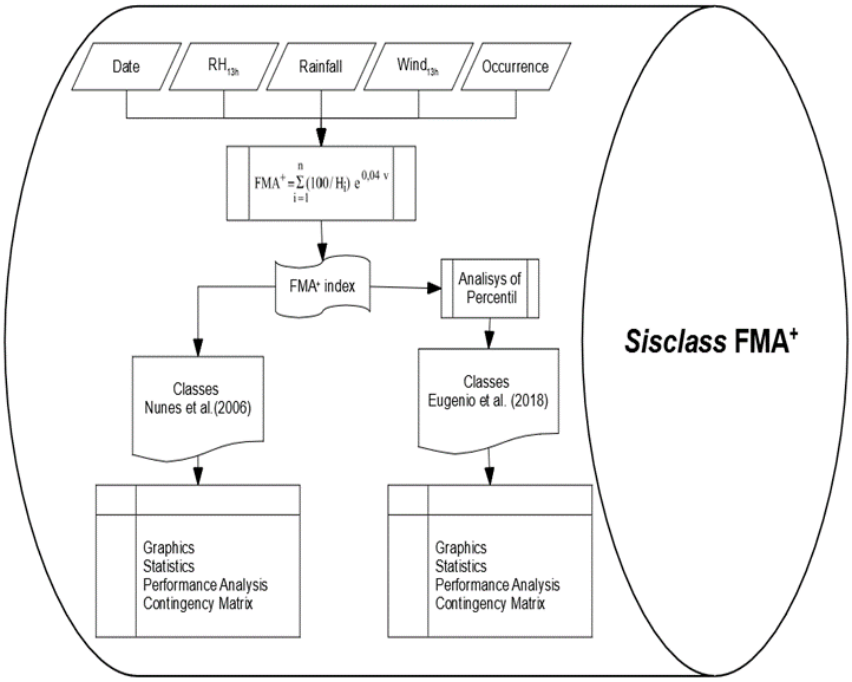


Figure 1. Data flow diagram.
Figura 1. Diagrama de Fluxo de Dados.

Risk calculation

The FMA+ was used for the daily calculation of the risk of occurrence of wildfires, according to equation 1, conceived by Nunes *et al*. (2009):

$$FMA^{+} = \sum_{i=1}^{n} (100/H_i)e^{0,04V} \quad (1)$$

In which,

FMA^{+}: Monte Alegre Altered Formula;
H : air relative humidity (%) measured at 13 o'clock;
n: number of days without rainfall greater than or equal to 13.0 mm;
V : wind speed in m/s, measured at 13 o'clock.

Since FMA+ is a cumulative index, relative humidity is subject to precipitation restrictions (Table 1).

Table 1. FMA+ restrictions, according to the amount of rain of the day and its modifications as a result of relative air humidity (H) at 1 P.M.
Tabela 1. Restrições FMA+, de acordo com a quantidade de chuva do dia e suas modificações em função da umidade relativa do ar (H) às 13h.

Rain of the Day (mm)	Modification in the calculation
< 2.4	None
2.5 to 4.9	Deduct 30% of the value of FMA+ calculated the day before and add (100/H) of the day
5.0 to 9.9	Deduct 60% of the value of FMA+ calculated the day before and add (100/H) of the day
10 to 12.9	Deduct 80% of the value of FMA+ calculated the day before and add (100/H) of the day
> 12.9	Interrupt the calculation (FMA+=0), started in the day before

Fonte: Adaptado de Nunes *et al.* (2006).
Source: Adapted from Nunes *et al.* (2006).

Risk classes

The classes designed by Nunes *et al*. (2006) were used for this methodology: Null: ≤ 3.0; Small: 3.1-8.0; Average: 8.1-14.0; High: 14.1-24.0 and Very High: ≥ 24.0.

For the classes proposed by Eugenio *et al*. (2020 a), the statistical analysis of all the days in which wildfires occurred and analyze the percentiles 20, 40, 60, 90 is made. It uses the values of the percentiles for the class limits: Low; Average; High; Very High and Extreme.

Presentation of results by each methodology

At the end of the calculations carried out by Sisclass FMA+, the system itself presents the graphs of the temporal evolution of the FMA+ index since the beginning of the database, proportionality graphs of each class during the period and also per month selected; the statistical data of maximum, minimum, sum, average, variance, median and standard deviation; performance analysis; and, the contingency matrix.

Presentation of the Sisclass FMA+

The elaboration of the system presents a simple interface, easy for the user to understand. As shown in figure 2, when starting the system, there are four options: insert data view graphs, proposed by Nunes (2005), view graphs by Eugenio *et al.* (2020 a), and the option close.

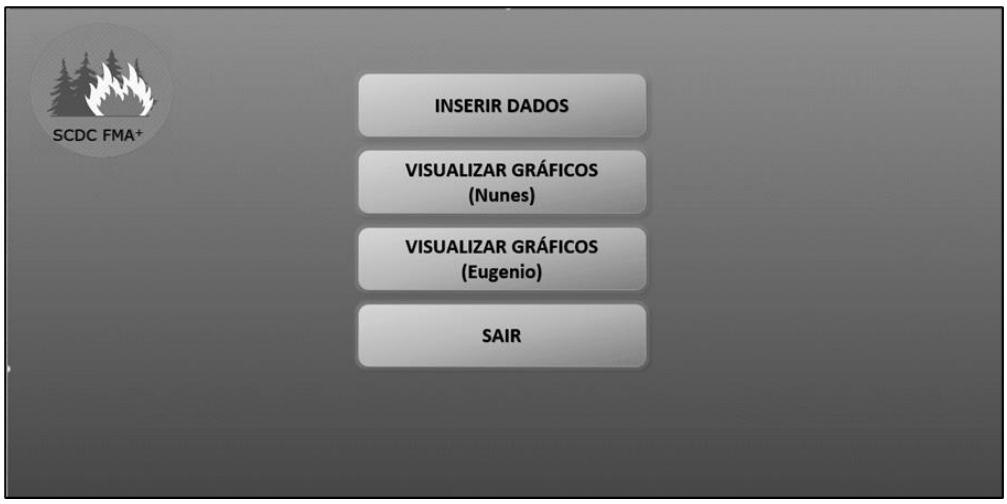
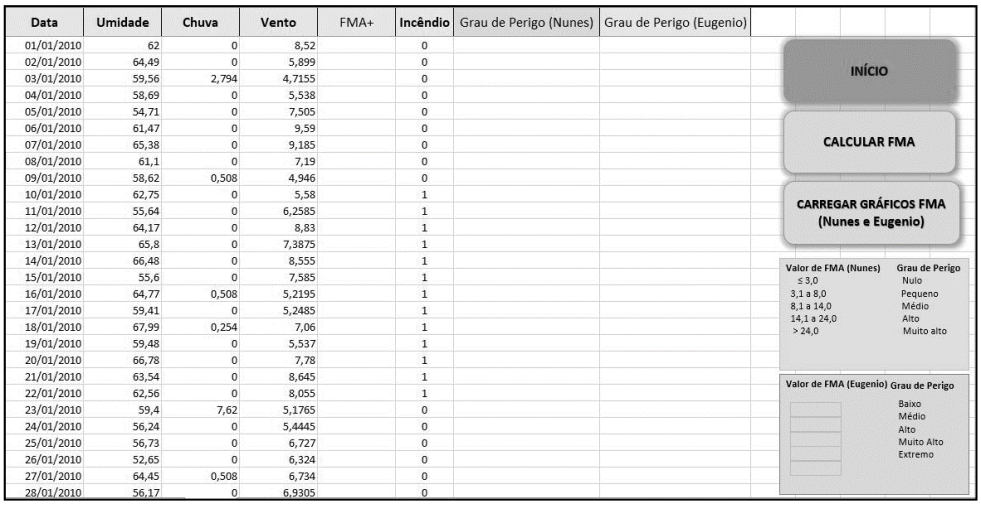


Figure 2. Control panel of Sisclass FMA+.
Figure 2. Painel de controle do Sisclass FMA+.

The user is shown and allowed to fill out a spreadsheet regarding the date, humidity, rain, wind, and fire information (Figure 3). After inserting the data, it is necessary to click on the function Calculate FMA. Therefore, the Sisclass FMA+ will calculate the index, perform the percentile analyzes, and fill in the columns referring to the value of the FMA+, the degree of fire hazard proposed. Nunes and Eugenio, as shown in Figure 4.



Data	Umidade	Chuva	Vento	FMA+	Incêndio	Grau de Perigo (Nunes)	Grau de Perigo (Eugenio)
01/01/2010	62	0	8,52		0		
02/01/2010	64,49	0	5,899		0		
03/01/2010	59,56	2,794	4,7155		0		
04/01/2010	58,69	0	5,538		0		
05/01/2010	54,71	0	7,505		0		
06/01/2010	61,47	0	9,59		0		
07/01/2010	65,38	0	9,185		0		
08/01/2010	61,1	0	7,19		0		
09/01/2010	58,62	0,508	4,946		0		
10/01/2010	62,75	0	5,58		1		
11/01/2010	55,64	0	6,2585		1		
12/01/2010	64,17	0	8,83		1		
13/01/2010	65,8	0	7,3875		1		
14/01/2010	66,48	0	8,555		1		
15/01/2010	55,6	0	7,585		1		
16/01/2010	64,77	0,508	5,2195		1		
17/01/2010	59,41	0	5,2485		1		
18/01/2010	67,99	0,254	7,06		1		
19/01/2010	59,48	0	5,537		1		
20/01/2010	66,78	0	7,78		1		
21/01/2010	63,54	0	8,645		1		
22/01/2010	62,56	0	8,055		1		
23/01/2010	59,4	7,62	5,1765		0		
24/01/2010	56,24	0	5,4445		0		
25/01/2010	56,73	0	6,727		0		
26/01/2010	52,65	0	6,324		0		
27/01/2010	64,45	0,508	6,734		0		
28/01/2010	56,17	0	6,9305		0		

Figure 3. Area of data insertion in the Sisclass FMA+.
Figura 3. Área de inserção de dados no Sisclass FMA+.

Data	Umidade	Chuva	Vento	FMA+	Incêndio	Grau de Perigo (Nunes)	Grau de Perigo (Eugenio)
01/01/2010	62	0	8,52	2,267858062	0	Nulo	Baixo
02/01/2010	64,49	0	5,899	4,231144873	0	Pequeno	Médio
03/01/2010	59,56	2,794	4,7155	4,640780591	0	Pequeno	Médio
04/01/2010	58,69	0	5,538	6,767160226	0	Pequeno	Médio
05/01/2010	54,71	0	7,505	9,234951866	0	Médio	Médio
06/01/2010	61,47	0	9,59	11,62239013	0	Médio	Alto
07/01/2010	65,38	0	9,185	13,83097899	0	Médio	Alto
08/01/2010	61,1	0	7,19	16,01301484	0	Alto	Alto
09/01/2010	58,62	0,508	4,946	18,09211306	0	Alto	Muito Alto
10/01/2010	62,75	0	5,58	20,08425738	1	Alto	Muito Alto
11/01/2010	55,64	0	6,2585	22,39278014	1	Alto	Muito Alto
12/01/2010	64,17	0	8,83	24,61128697	1	Muito Alto	Muito Alto
13/01/2010	65,8	0	7,3875	26,65353331	1	Muito Alto	Muito Alto
14/01/2010	66,48	0	8,555	28,77152651	1	Muito Alto	Muito Alto
15/01/2010	55,6	0	7,585	31,2075987	1	Muito Alto	Muito Alto
16/01/2010	64,77	0,508	5,2195	33,10998235	1	Muito Alto	Muito Alto
17/01/2010	59,41	0	5,2485	35,18640726	1	Muito Alto	Muito Alto
18/01/2010	67,99	0,254	7,06	37,13714875	1	Muito Alto	Muito Alto
19/01/2010	59,48	0	5,537	39,23520237	1	Muito Alto	Muito Alto
20/01/2010	66,78	0	7,78	41,27932067	1	Muito Alto	Muito Alto
21/01/2010	63,54	0	8,645	43,50330551	1	Muito Alto	Muito Alto
22/01/2010	62,56	0	8,055	45,70944486	1	Muito Alto	Muito Alto
23/01/2010	59,4	7,62	5,1765	19,96727963	0	Alto	Muito Alto
24/01/2010	56,24	0	5,4445	22,17800777	0	Alto	Muito Alto
25/01/2010	56,73	0	6,727	24,48500555	0	Muito Alto	Muito Alto
26/01/2010	52,65	0	6,324	26,93102979	0	Muito Alto	Muito Alto
27/01/2010	64,45	0,508	6,734	28,96225763	0	Muito Alto	Muito Alto
28/01/2010	56,17	0	6,9305	31,31129914	0	Muito Alto	Muito Alto

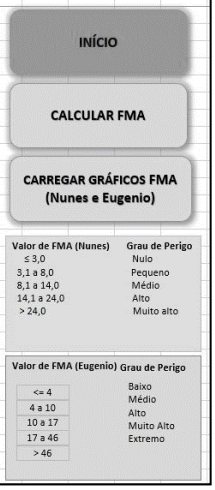
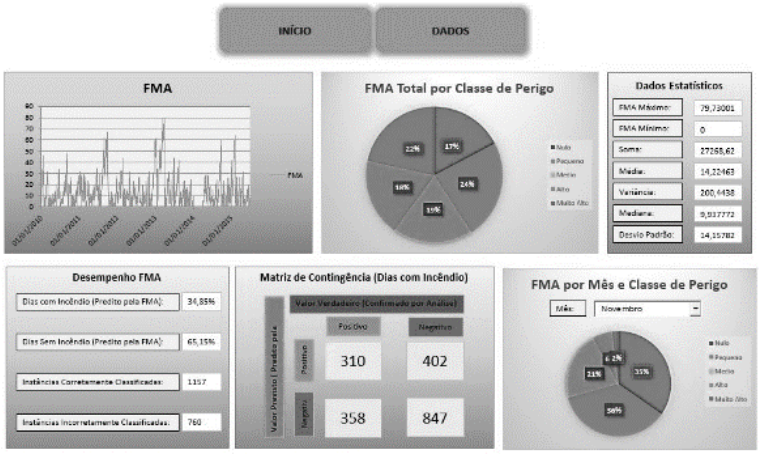
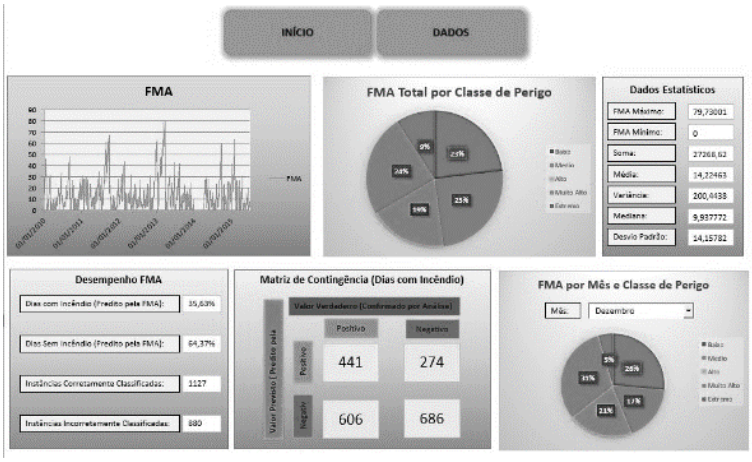


Figure 4. Area for data insertion in the Sisclass FMA+ after the calculation and automatic filling.
Figura 4. Área para inserção de dados no Sisclass FMA+ após o cálculo e preenchimento automático.

In the graphics display area (Figure 5), the user can extract information from the graphs of the time evolution of the FMA+ index since the beginning of the database, graphs of proportionality for each class during the period and also by selected month; the statistical data of maximum, minimum, sum, average, variance, median and standard deviation; performance analysis; and, the contingency matrix.



(a)



(b)

Figure 5. Graph visualization area of the FMA+ Sisclass after the calculation and automatic completion for the classes defined by: (a) Nunes *et al.* (2006) or (b) Eugenio *et al.* (2020 a).
Figura 5. Área de visualização gráfica do FMA+ Sisclass após o cálculo e preenchimento automático das classes definidas por: (a) Nunes *et al.* (2006) ou (b) Eugenio *et al.* (2020 a).

Presentation of results found by Eugenio *et al.* (2020 a).

The study area extends from the central-north coast of the State of Espirito Santo to the south coast of Bahia, where a 70 km buffer from the coast was applied, for delimitation, since within this buffer, it is the region where there is the most significant number of planted eucalyptus forests and all the weather stations of the forestry companies. As the study area could have different climatic types, and as a consequence, different wildfire regimes, Eugenio et al. (2020 b) carried out a case study about the methodology towards the delimitation of areas with a homogeneous climate in eucalyptus plantations for wildfire studies, the authors verified the existence of are three different climatic subzones, which generate three different wildfire regimes.

In line with the previous study, Alvarez *et al*. (2013), evidence three types of climate in the study region, where: a) on the North Coast of the area, the Af climate is predominant (Humid Tropical Climate); b) the Am (Monsoon) climate appears further inland in the north, and to the south it reverses, covering the entire coast and c) the Aw (Tropical Climate with dry summer season) predominates the Continental region in the southern region of the study area.

After verifying the existence of different climatic types, the study area was divided into three sub-areas, which allows the preparation of the database for each sub-area and the observation of the models' response in three different wildfire situations. After preparing the data, the risks were calculated for all subzones and classified using the limit classes proposed by Nunes (2009) and Eugenio *et al.* (2020 a). (Table 2).

Table 2. Results were found with the FMA+ limit values for the classes.
Tabela 2. Resultados encontrados com os valores limite FMA+ para as classes.

Subzone	Limit values of classes (FMA+) by Nunes *et al*. (2006)				
	Null	Small	Average	High	Very high
1	≤3.0	3.1 - 8.0	8.1 - 14.0	14.1 - 24.0	≥24.0
2	≤3.0	3.1 - 8.0	8.1 - 14.0	14.1 - 24.0	≥24.0
3	≤3.0	3.1 - 8.0	8.1 - 14.0	14.1 - 24.0	≥24.0
Subzone	Limit values of classes (FMA+) by Eugenio *et al*. (2020)				
	Low	Average	High	Very high	Extreme
1	0 - 10	10.1 - 17	17.1 - 25	25.1 - 56	>56
2	0 - 14	14.1 - 23	23.1 - 35	35.1 - 78	>78
3	0 - 14	14.1 - 23	23.1 - 35	35.1 - 63	>63

As shown in Table 2, the limit values for each class do not differ in the approach proposed by Nunes *et al*. (2006). Therefore, the limits proposed by the authors are fixed. However, within limits proposed by Eugenio *et al.* (2020 a), the values are different for each subzone since there will be the application of percentiles for the development of limits for new classes in each study area, which implies a greater accuracy of the FMA+ index. The results for the percentage of success of the days with and without fire, general, and the skill score test are in Table 3.

Table 3. Results obtained by the percentage success and skill score tests for the class values proposed by Nunes *et al*. (2006) and Eugenio *et al.* (2020 a).

Tabela 3. Resultados obtidos pelos testes de porcentagem de sucesso e de escore de habilidade para os valores das classes propostas por Nunes *et al*. (2006) e Eugenio *et al.* (2020 a).

Classes	Subzone	Percentage of success (%)			Skill score
		With fire	Without fire	General	
Nunes *et al.* (2006)	1	87.36	47.08	51.88	0.1306
	2	90.24	34.98	41.11	0.0779
	3	92.41	37.26	40.64	0.0545
Eugenio *et al.* (2020)	1	61.39	72.50	71.18	0.1979
	2	59.83	63.17	62.64	0.1408
	3	58.29	73.05	71.94	0.1346

As shown in Table 3, for all sub-areas, there was an increase in the percentage of success, with an increase of 19.30%, 21.53%, and 31.30 for sub-areas 1, 2, and 3, respectively. In addition, it is also observed that there was an increase in the skill score for all studied sub-areas.

DISCUSSION

As reported by Nunes *et al.* (2010), the mismatch observed in a forest fire risk is a factor that interferes with its performance, and this mismatch is probably caused by the change in rainfall regimes and consequently relative humidity over time. However, a prior adjustment is necessary to avoid using an inappropriate risk index, which may lead to wrong decisions concerning the procedures for preventing and fighting forest fires.

The automatic calculation performed by Sisclass FMA +, presented by the results obtained by Eugenio *et al.* (2020 a), demonstrated that adjusting the limit values of the classes is equivalent to a substantial gain compared to the classes of origin of the index presented in Table 2.

The average percentage of success of the FMA + by the original classes was 44.54%. In contrast, the classes obtained by the Sisclass FMA + were 68.59%. Another critical point to be highlighted is the gain obtained in the results of the skill score test.

It is essential to highlight that, even though it does not cover other wildfire risk indices, the present study demonstrates the need for a correction of the class limit values in areas other than the one used in the development of the index.

Acquisition of Sisclass FMA +

To download the software, access the website www.mundogeomatica.com.br/SisclassFMA; it is possible to download the model free of charge on this website. The system in question is free for two reasons: The first is based on the understanding that this format allows the best synergy between researchers to improve it, whether from new tools or the incorporation in other programs. The second is based on the understanding that the knowledge historically produced by humanity, which includes the production of science and technology in public universities, must be at the service of society and accessible to the scientific community to contribute, albeit in a way potential and punctual, with the scientific advancement of our time.

To use the Sisclass FMA+, the user must enter the following information: date, relative humidity (%), precipitation (mm), wind speed (m / s), and the information on the occurrence of fire (value 0 for non-wildfire) and value 1 for wildfire). After filling in the information, the user has to click on calculate FMA and load graphs, and all data will be loaded automatically by the system.

As it is free software, there is the possibility of including new tools. For this, the user will access the source code, programmable in VBA, and modify it according to his needs.

CONCLUSIONS

- The Sisclass FMA+ was developed to offer its user a simplification for calculating, storing, and defining new classes for the forest fire hazard index calculated by the FMA+.
- The system stores the occurrence of forest fires, allowing the generation of statistics on the hazard index and its occurrence, in addition to generating graphical plots and statistics on the performance of the FMA+, the contingency matrix, and the monthly analysis of the hazard classes proposed by Nunes *et al.* (2006) and Eugenio *et al*. (2020 a).
- The Sisclass FMA+ application obtained excellent results in previous tests, achieving an increase of up to 31.30% in the percentage of success of the FMA+ index. It is reiterated the concern of the authors in search of a better synergy between researchers on the subject, in order to improve the Sisclass FMA+, and also the understanding that knowledge must be at the service of society and accessible to the scientific community; therefore, it is even available free of charge.

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