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CLIMATE ELEMENTS AND FIRE HAZARD INDEXES IN SANTA CATARINA

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Resumo

Elementos Climáticos e Índices de Perigo de Incêndio em Santa Catarina. Os incêndios florestais têm causado enormes prejuízos ambientais, sociais e econômicos ao longo dos anos. Neste contexto, tem-se buscado encontrar relações entre o clima e o controle para a ocorrência e propagação dos incêndios. A atribuição de um índice de perigo de incêndio baseado nas condições meteorológicas é uma maneira de trazer ferramentas para os órgãos responsáveis pela prevenção e combate aos incêndios florestais. Neste trabalho foram utilizadas técnicas computacionais e estatísticas para analisar o desempenho de 3 (três) índices de perigo de incêndio: Fórmula de Monte Alegre (FMA), Fórmula de Monte Alegre Alterada (FMA+) e Ängstrom, para o estado de Santa Catarina, região Sul do Brasil. O período de estudo e validação foi de 2010 a 2022, utilizando as variáveis: precipitação, umidade relativa do ar, velocidade do vento e temperatura do ar, com valores obtidos no Instituto Nacional de Meteorologia (INMET), contemplando 23 estações meteorológicas. Esses dados foram comparados com detecção de incêndios registrados por satélite e obtidos do Instituto Nacional de Pesquisas Espaciais (INPE). Após a análise dos dados utilizando várias técnicas estatísticas, ficou evidente que a FMA e a FMA+ apresentaram alto índice de acertos para os dias com ocorrência detectada, com mais de 80% de acertos, contra cerca de 35% de Ängstrom. Em relação ao total de dias computados, Ängstrom obteve melhor índice de acertos (por volta de 85%), contra valores por volta de 50% para FMA e FMA+.
Palavras-chave: Fórmula de Monte Alegre, Fórmula de Monte Alegre alterada, Ängstrom, incêndio florestal, sensoriamento remoto.

Abstract

Forest fires have caused significant environmental and economic damage over the years. In this context, efforts have been made to establish relationships between climate and control measures for fire occurrence. Assigning a fire danger index based on meteorological conditions is a way to provide tools for organizations responsible for forest fire prevention and combat. In this study, computational and statistical techniques were employed to analyze the performance of three fire hazard indices: the Monte Alegre Formula, the Altered Monte Alegre Formula, and the Ängstrom Risk Factor, for the state of Santa Catarina, located in the Southern region of Brazil. The study and validation period covered from 2010 to 2022, using variables such as precipitation, relative humidity, wind speed, and air temperature, with values obtained from the National Institute of Meteorology (INMET), encompassing 23 meteorological gauges. These data were compared with fire detection records obtained from satellite imagery and provided by the National Institute for Space Research (INPE). After analyzing the data using various statistical techniques, it became evident that both Monte Alegre Formulas exhibited a high accuracy rate for days with detected fire occurrences, with over 80% accuracy, compared to only around 35% for Ängstrom. Concerning the overall number of days computed, Ängstrom achieved a higher accuracy rate (approximately 85%), compared to values around 50% for both Monte Alegre Formulas.
Keywords: Monte Alegre Formula, Altered Monte Alegre Formula, Ängstrom, Forest Fire, Remote Sensing.

INTRODUCTION

A forest fire is a wildfire that spreads uncontrollably, consuming forest fuels and increasing its destructive power, making it difficult to fight (SANTOS *et al.*, 2017).

The meteorological variables have a significant impact in these cases. Low relative humidity and high temperature favor plants' evaporative power, which causes them to become drier and more susceptible to combustion. Reduced rainfall can decrease soil moisture and dead and living fuels to create more material available for fires. Winds can also play a role in spreading fires by feeding and directing them (TORRES *et al.*, 2020).

Regarding the causes of forest fires, Torres *et al.* (2016) conducted a study using data from the Brazilian Conservation Units between 2008 and 2012. The results indicated that the "miscellaneous" category reached the highest percentage (37,3%), followed by "burning for cleaning" at 27,38%, "arsonists" at 25,63%, "forestry operations" reached 6,05%, "lightning" at 2,45%, and "recreational fires" at 1,73% of the occurrences. They revealed that anthropogenic phenomena have a significant impact on fire occurrences.

Soares and Paez (1973) developed a study to determine a hazard index to obtain a way to measure the probability of fire occurrence. The study covered the period from 1965 to 1971 in Telêmaco Borba, Paraná state, Brazil, and used daily precipitation and humidity measurements taken at 13h (local time, same 16h UTC). It resulted in the development of the Monte Alegre Formula (FMA), which became a reference for determining the fire hazard index and subsequent studies.

The original FMA was improved in 2005 by adding wind speed, called the Altered Monte Alegre Formula, or FMA+ (NUNES *et al.*, 2006). This study used daily 24-hour accumulated precipitation, relative humidity (measured at 13h), and wind speed (measured at 13h), in addition to data on fire occurrences from 1998 to 2003 also in Telêmaco Borba, Paraná state, Brazil.

In 2016, a study was conducted in Belém, Pará state, Brazil, to compare three fire hazard indices: Ängstrom, Monte Alegre Formula, and Nesterov Index. The study covered 2015 and aimed to determine the convergence of results by comparing the three indices (OLIVEIRA *et al.*, 2016). They showed that rainfall accumulation was a decrease factor in fire hazard, and there was a strong correlation between the indices studied. The Nesterov Index and the Monte Alegre Formula were the most efficient.

Another analysis was presented using FMA+ for 2015, seeking to adjust the index classes for Espírito Santo state's North-central region and the Bahia state's south coast. The class adjustment for the system was observed to have excellent results (EUGENIO *et al.*, 2020).

In 2019, a study evaluated the performance of seven fire hazard indices (FMA, FMA+, Nesterov, Telitsyn, Ängstrom, P-EVAP, and EVAP/P) in a Cerrado-Amazon transition area in Brazil using the Skill Score method (CASAVECCHIA, 2019). The meteorological data used were extracted from INMET's conventional stations from 1972 to 2010. The FMA and FMA+ fire hazard indices presented cumulative dependence on the number of days without rainfall, which may cause prediction errors when lower rainfall accumulations occur. The Ängstrom index presented the best performance for forecasting days with and without the occurrence of hot spots, which is recommended for the Sinop, Mato Grosso state region.

Almeida *et al.* (2022) also evaluated FMA+'s performance for the Natural Reserve Serra do Tombador in Cavalcante, Goiás state, Brazil, from 2016 to 2020. The Skill Score and Success Percentage methods were used, and the amplitude of the fire hazard classes in the Equation was modified, indicating that it was suitable for the study area after adjustments.

Several fire hazard indices have been researched in recent years in various regions of Brazil. Although many studies are available, each reflects the selected region's climate and geographical reality. Therefore, this study aimed to verify the feasibility of using three fire hazard indices for the state of Santa Catarina, Brazil.

MATERIAL AND METHODS

The area selected for this study is Santa Catarina state, located in southern Brazil, covering 95,730,690 km2.The National Institute for Space Research (INPE) provides access to files on its website containing information on fire occurrences detected by satellites. INPE (2023) states that "observing fires through satellite images is beneficial for remote regions without intensive means of monitoring." INPE recommends using the archives of the reference satellite, which in this case is Aqua2 M-T. The research period considered data publicly available from official entities; the data from INPE's reference satellite were available from 2010 onwards.

The reference satellite is used mainly because its revisit time has been stable and can identify fire fronts at least 30m long by 1m wide (INPE, 2023).

The satellite's sensor seeks to identify the radiant energy flux through the energy of the burning material. Its images are in the thermal range from 3,7um to 4,1um within the spectrum, with an average error of approximately 400m and a standard deviation of roughly 3 km (INPE, 2023).

A map was prepared using the QGIS geoprocessing software (QGIS, 2023) to conduct a territorial analysis of the state's municipalities concerning the location of automatic weather stations. Data on the political division of municipalities were obtained from the Brazilian Institute of Geography and Statistics (IBGE, 2023). Then, a layer was added with the location of all the automatic weather stations in the state made available by the National Institute of Meteorology (INMET). As the occurrences collected by the satellites were made available for municipalities individually, they were grouped in the vicinity of the weather stations to analyze the data better. This was done by assessing the distance between the observations and their difference in altitude (as shown in Figure 1).

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Figure 1. Mesoregions defined by grouping municipalities around automatic weather stations.
Figura 1. Mesorregiões definidas agrupando os municípios no entorno das estações meteorológicas automáticas.

The INMET provides data from weather stations approved by the institution throughout Brazil on its internet portal, whether conventional or automatic (INMET, 2023). This study used data from automatic stations in Santa Catarina state from 2010 to 2022. The weather station in Rancho Queimado municipality was discarded because it contained many flaws in the recordings of the variables employed to calculate the indices.

After analyzing the data from all automatic weather stations, an average of 71,06% of data presence and 28,94% of failures was obtained for all stations throughout the studied period.

The total number of days calculated was 80.864, of which 75.106 were without occurrences detected by the satellite (92,88%), while 5.758 were with occurrences (7.12%).

This study utilized the Ruby programming language because it is a scripting language that handles text files easily and does not rely on compilation (RUBY, 2023).

This research uses three fire hazard indices, which have already been widely tested in several studies, to verify the hazard degrees for forest fire events: FMA, FMA+, and Ängstrom. FMA uses relative humidity measured at 13h and daily precipitation, which is cumulative (SOARES; PAEZ, 1973).

$$FMA = \sum_{i=1}^{n} \frac{(100)}{H_i}$$

H is the relative humidity and "n" is the number of days without rainfall greater than or equal to 13mm.

As Table 1 shows, restrictions based on daily precipitation are applied during the calculation formula.

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Table 1. Restrictions on FMA calculation
Tabela 1. Restrições no cálculo da FMA.

Daily Precipitation (mm)	Restrictions on Calculations
<= 2,4	None
2,5 a 4,9	Deduct 30% from the FMA calculated the day before and add up (100/H) per day
5,0 a 9,9	Deduct 60% from the FMA calculated the day before and add up (100/H) per day
10,00 a 12,9	Deduct 80% from the FMA calculated the day before and add up (100/H) per day
>= 13,00	Interrupt the calculation (FMA=0), starting the sum again the next day

Source: Soares and Paez (1973)

The fire hazard degrees defined for FMA are shown in Table 2.
This research also used FMA+, or the Altered Monte Alegre Formula (NUNES *et al.*, 2006).

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

The "n" is the number of days without rainfall greater than or equal to 13mm, H is the relative humidity (measured at 13h), "e" is the base of natural logarithms (2,718282), and "v" is the wind speed (13h).

The restrictions in the daily calculation of FMA+ are the same as those in Table 1, which calculates FMA. The hazard degrees defined for FMA and FMA+ are shown in Table 2.

Table 2. Hazard degrees defined for FMA and FMA+.
Tabela 2. Graus de perigo definidos para a FMA e FMA+.

Calculated FMA Index	Calculated FMA+ Index	Hazard Degree
Up to 1,0	Up to 3,0	Null
From 1,1 to 3,0	From 3,1 to 8,0	Small
From 3,1 to 8,0	From 8,1 to 14,0	Medium
From 8,1 to 20,0	From 14,1 to 24,0	High
Greater than 20,0	Greater than 24,0	Very High

Source: Soares and Paez (1973); Nunes *et al.* (2006)

Ängstrom is a non-cumulative index using relative humidity and air temperature, measured at 13h (ÄNGSTROM, 1949).

$$ANGSTROM = 0{,}05 \cdot RH - 0{,}1 \cdot (T - 27)$$

Where the RH is the relative humidity and T is the air temperature, measured at 13h local time.
The hazard degrees defined for Ängstrom are less than 2.5 = "risk" and greater than 2.5 = "null."

Indices Statistics
A contingency table, where the variables that will be utilized in the calculations are defined (WILKS, 2019), was used to analyze the formulas' performance. In the first step, the values are distributed in forecast/event pairs for the verification situation (Table 3).

Table 3. Contingency table.
Tabela 3. Tabela de contingência.

Contingency table.				
Event		Observation		Total Forecasted
		Fire	not detectable fire	
Forecast	Forecasted	a	b	a + b
	Not Forecasted	c	d	c + d
Total Observed		a + c	b + d	N = a + b + c + d

Fonte: Wilks (2019)

Various statistical techniques can be used to verify the number of sucesses and errors of the indices by defining the variables in the contingency table.

Wilks (2019) presents the following methodology for analyzing the fire hazard indices.

The Proportion Correct (PC) illustrates the fraction of "n" forecast occasions for which the forecast correctly anticipated the subsequent event or non-event. In addition, it satisfies the principle of events equivalence, as it equally credits correct predictions, yes and no, which may not be so desirable when the event's occurrence is small. This is the case of the fires observed in this study, which correspond to 7.12% of the total number of days calculated. The best successes will be close to 1.

$$PC = \frac{a + d}{N}$$

Where "a" is the fire forecasted and observed, "d" is the fire not forecasted and not observed, and "N" is the total days calculated.

The Threat Score (TS) can be used in cases where the event to be predicted occurs substantially less frequently than the non-occurrence, which is the case in this study. The TS, also known as the Critical Success Index (CSI), shows the correct "yes" forecasts divided by the number of occasions on which that event was predicted and/or observed. The best results will be close to 1, and the worst will be close to 0.

$$TS = \frac{a}{a + b + c}$$

The "a" is the fire forecasted and observed, "b" is the fire forecasted and not observed, and "c" is the fire not forecasted but observed.

The Odd Rate (θ) is the product of the number of correct forecasts divided by the product of the number of incorrect forecasts. Larger values indicate more accurate forecasts.

$$\theta = \frac{a \cdot d}{b \cdot c}$$

The "a" is the fire forecasted and observed, "d" is the fire not forecasted and not observed, "b" is the fire forecasted and not observed, and "c" is the fire not forecasted but observed.

The Bias (B) deals with the relationship between the number of "yes" forecasts and the number of "yes" observations. Because it does not correlate the predictions and observations of the event, it is not a measure of accuracy. The most correct predictions of this calculation are found in a result equal to 1. If the number is higher, there is an overforecast; if lower, there is an underforecast.

$$B = \frac{a + b}{a + c}$$

The "a" is the fire predicted and observed, "b" is the fire predicted and not observed, and "c" is the fire not forecasted but observed.

The False Alarm Ratio (FAR) is the proportion of forecasted events that do not materialize. Lower FAR values are preferred as they have a negative orientation. The best possible value for the FAR is zero, and the worst, 1

$$FAR = \frac{b}{a + b}$$

The "b" is the fire forecasted and not observed, and "a" is the fire predicted and observed.

The Hit Rate (H) indicates the probability of a successful hit, showing the detection probability and the distribution between prediction and observation.

$$H = \frac{a}{a + c}$$

The "a" is the fire predicted and observed and "c" is the fire not forecasted but observed.

The False Alarm Rate (F) determines the probability that the system correctly predicts the observed events. Values close to 1 represent a low hit rate.

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$$F = \frac{b}{b + d}$$

The "b" is the fire forecasted and not observed and "d" is the fire not forecasted and not observed.

The Heidke Skill Score (HSS) shows the correct proportion that would be achieved by random forecasts that are statistically independent of the observations. HSS defines the number of standardized correct hits and errors, so random forecasts have zero skill.

$$HSS = \frac{2 \cdot ((a.d) - (b.c))}{(a+c).(c+d) + (a+b).(b+d)}$$

The "a" is the fire forecasted and observed, "d" is the fire not forecasted and not observed, "b" is the fire forecasted and not observed, and "c" is the fire not forecasted but observed.

The Odds Ratio Skill Score (ORSS or Q) elaborates on a Skill Score based on the odd rate. The score will be 1 for perfect forecasts, and for random forecasts, it will be 0.

$$Q = \frac{(a \cdot d) + (b \cdot c)}{(a \cdot d) - (b \cdot c)}$$

The "a" is the fire forecasted and observed, "d" is the fire not forecasted and not observed, "b" is the fire forecasted and not observed, and "c" is the fire not forecasted but observed.

In the Pierce Skill Score (PSS), the reference success rate in the denominator is that for random forecasts that are constrained to be unbiased, differing from Heidke. Perfect forecasts receive a score of 1, random forecasts acquire a zero score, and forecasts inferior to the random receive negative scores.

$$PSS = \frac{(a \cdot d) - (b \cdot c)}{(a + c) \cdot (b + d)}$$

The "a" is the fire forecasted and observed, "d" is the fire not forecasted and not observed, "b" is the fire forecasted and not observed, and "c" is the fire not forecasted but observed.

The Clayton Skill Score (CSS) evidences positive skill to the extent that the event occurs more frequently when forecasted than when not. In CSS, given the yes forecasts, the conditional relative frequency of the yes outcome is larger than the conditional relative frequency given no forecasts. The best values will be close to 1 for CSS.

$$CSS = \frac{(a \cdot d) - (b \cdot c)}{(a + b) \cdot (c + d)}$$

The "a" is the fire forecasted and observed, "d" is the fire not forecasted and not observed, "b" is the fire forecasted and not observed, and "c" is the fire not forecasted but observed.

To calculate the set and errors equation, FMA and FMA+ were defined as hits when the hazard degree is considered "very high" on days when the satellite detected an occurrence. When the hazard degree is considered "high," "medium," "small," or "null," it is considered an error.

Regarding Ängstrom, there is no requirement for an extra filter because the definition of success and error is binary. When the index indicates "risk" and an occurrence is detected, it is considered a success; otherwise, it is an error.

RESULTS

Após a comparação das ocorrências de incêndio registradas pelo satélite de referência, foi possível obter os resultados do total de previsões de graus de perigo para cada índice. Table 4 illustrates that the total number of days calculated was 80.864. FMA and FMA+ indicated roughly half the days as having a "very high" hazard degree. On the other hand, Ängstrom showed 86.29% of the days as having a "null" hazard degree.

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Table 4. Quantity and percentage of days with calculated hazard degrees (from 2010 to 2022).
Tabela 4. Quantidade e porcentagem de dias com graus de perigo calculados (2010 a 2022).

Hazard Degree	FMA		FMA+		Ängstrom	
	Quantity	%	Quantity	%	Quantity	%
Null	10175	12,58	19334	25,18	69777	86,29
Small	9600	11,87	8200	10,54	–	–
Medium	8698	10,76	6089	7,31	–	–
High	10788	13,34	6497	7,64	–	
Very High	41603	51,45	40744	49,33	–	–
Risk	–	–	–	–	11087	13,71
TOTAL	80864	100	80864	100	80864	100

Caption: FMA, Monte Alegre Formula; FMA+, Altered Monte Alegre Formula; Ängstrom.

The values of the hazard degrees were also calculated for the situations with and without occurrence detected for each index (Figure 2). It shows little difference in the hazard degrees attributed by the indices for the overall calculation and the days without occurrence. Regarding the days with occurrences, FMA and FMA+ revealed more than 80% of the attribution to the "very high" hazard degree, denoting that both presented promising results for these cases. On the other hand, Ängstrom indicated more than 65% of the "null" hazard degree, indicating a low forecast rate in these cases.

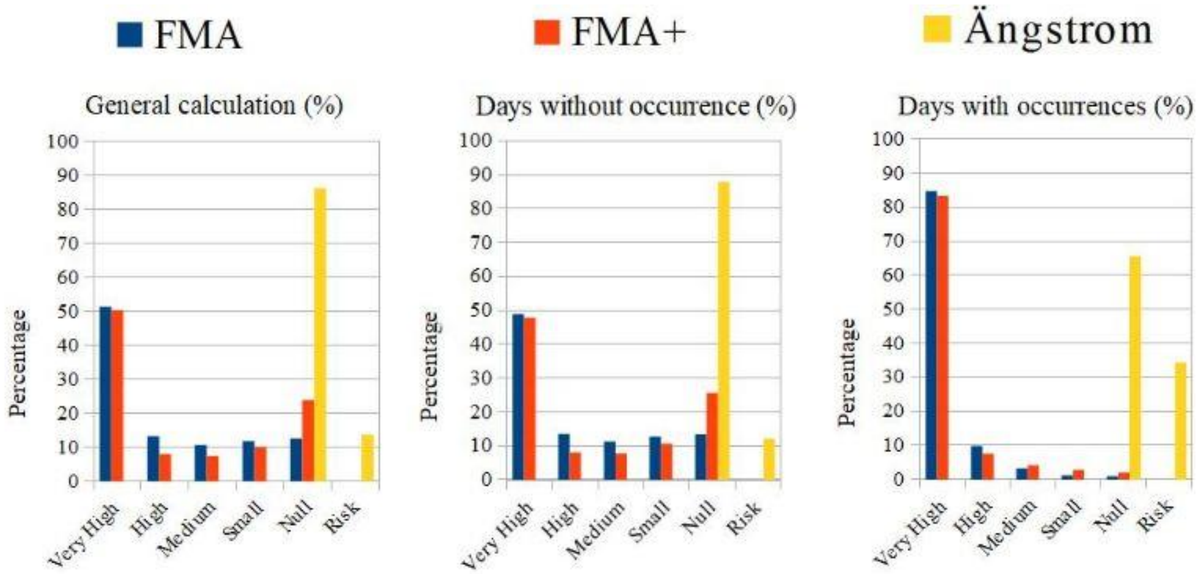

Figure 2. The percentage of hazard degrees calculated for the indices for all days, days without a detected occurrence, and days with a detected occurrence.
Figura 2. Percentual de graus de perigo calculados para os índices para todos os dias, dias sem ocorrência detectada e dias com ocorrência detectada.
Caption: FMA, Monte Alegre Formula; FMA+, Altered Monte Alegre Formula; Ängstrom.

After defining the hazard degrees for the three indices, the data were added to a contingency table, as seen in Table 5.

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Table 5. Values distributed in the contingency table.
Tabela 5. Valores distribuídos na tabela de contingência.

Contingency Table					
Forecast		Observation			
		Fire	not detectable fire	TOTAL	
FMA	Fire	a = 4878	b = 36725	41603	
	not detectable fire	c = 880	d = 38381	39261	
	TOTAL	5758	75106	N = 80864	
FMA+	Fire	a = 4801	b = 35943	40744	
	not detectable fire	c = 957	d = 39163	40120	
	TOTAL	5758	75106	N = 80864	
Ängstrom	Fire	a = 1981	b = 9106	11087	
	not detectable fire	c =3777	d = 66000	69777	
	TOTAL	5758	75106	N = 80864	

Caption: FMA, Monte Alegre Formula; FMA+, Altered Monte Alegre Formula; Ängstrom.

After performing the calculations with the previously described equations, the resulting values were discretized in Table 6.

Table 6. Values calculated using statistical techniques for fire hazard indices.
Tabela 6. Valores calculados com as técnicas estatísticas para os índices de perigo de incêndio.

Index	PC	TS	Θ	B	FAR	H	F	HSS	Q	PSS	CSS
FMA	0,535	0,1148	5,7931	7,2253	0,8827	0,8472	0,489	0,0924	0,7055	0,3581	0,0948
FMA+	0,5437	0,1151	5,4661	7,0761	0,8822	0,8338	0,4786	0,0933	0,6906	0,3552	0,094
Ängstrom	0,8407	0,1333	3,8015	1,9255	0,8213	0,344	0,1212	0,1561	0,5834	0,2838	0,1245

Legenda: PC, Proporção Correta; TS, *Threat Score;* θ, Razão de Probabilidade; B, Razão de *Bias;* FAR, Razão de Falso Alarme; H, Taxa de Acerto; F, Taxa de Falso Alarme; HSS, *Heidke Skill Score*; Q, *Odds Ratio Skill Score*; PSS, *Peirce Skill Score*; CSS, *Clayton Skill Score*.

Table 6 shows that the Proportion Correct (PC) presented over 50% successes for FMA and FMA+ and more than 84% for Ängstrom. Regarding the Threat Score (TS), Ängstrom obtained a better result, while FMA and FMA+ obtained similar values. Regarding the Odd Ratio (θ), FMA and FMA+ achieved better results. In the Bias, there was a considerable overestimation for FMA and FMA+. For the False Alarm Ratio (FAR), the three indices had a high rate of false predictions. FMA and FMA+ had excellent results for the Hit Rate, while Ängstrom got few successes. Regarding the False Alarm Rate (F), FMA and FMA+ obtained less than half of the false indications, while Ängstrom had a low rate of mistaken forecasts.

Finally, there are the Skill Score values. The Heidke Skill Score (HSS) improved Ängstrom's results against FMA and FMA+. On the contrary, the Odds Ratio Skill Score (Q) and Pierce Skill Score (PSS) showed better results for FMA and FMA+ rather than Ängstrom. Ängstrom was more efficient in the Clayton Skill Score (CSS), and FMA and FMA+ obtained similar values to those of HSS.

The FMA and FMA+ Hit Rates (H) are noteworthy, reaching rates above 80% of correct hits on days of occurrence.

DISCUSSION

In the context of FMA and FMA+, a success was assigned whenever the hazard level was marked as "very high" on days when the satellite detected an occurrence. As for Ängstrom, there was no assignment as the initial index only had two hazard levels: "risk" and "null."

In cases where no occurrence happened, any hazard degree other than "very high" was considered a hit for FMA and FMA+.

In the general analysis on a day with and without occurrences, FMA and FMA+ presented around 50% of a "very high" hazard degree, while Ängstrom presented about 85% of a "null" one. In the cases where the satellite detected an occurrence, both FMA and FMA+ achieved a high accuracy (more than 80%).

Using fire hazard indices to prevent and respond to fire incidents effectively is essential. However, since only about 7.12% of the days are prone to such events, it is advisable to focus on the FMA and FMA+ indices for prompt action.

On the other hand, in cases where weather station data, such as wind speed, are unavailable, FMA can still be calculated. In addition, Ängstrom can be used in case of a lack of precipitation data.

Although this research seeks to use the original equations to have initial parameters, it is possible to make class adjustments for the indices, determining new values for the hazard degrees and verifying those that can achieve better results for the region.

The use of techniques for data filling can improve the accuracy of temporal analysis. For example, the ERA5 (2023) from the 5th generation of climate data from the European Centre for Medium-Range Weather Forecasts or MERRA2 (2023), defined as Modern-Era Retrospective Analysis from the National Aeronautics and Space Administration, can be used. In addition, techniques using values from nearby weather stations can also be utilized.

It was noteworthy that a more extended study period would be required to establish a characteristic pattern of cause and effect with statistical significance concerning the effect of El Niño and La Niña on the occurrence or non-occurrence of forest fires. This is due to the limited degrees of freedom in the period, which would be restricted to two to three moderate to strong events of each phase of the El Niño/Southern Oscillation.

CONCLUSIONS

After analysis and discussion, it was possible to conclude that:

- When analyzing the capacity of fire hazard indices to forecast events, a good strategy may be to use the contingency table with associated statistical techniques. This tool demonstrates the index's efficiency in pointing out an expected hazard degree.
- FMA and FMA+ presented consistent results for the days with occurrence detected by the satellite (above 80% of successes), while Ängstrom had relevant results for days without occurrences (around 85% of successes).
- Daily records and history for using and updating statistical analysis can be essential tools in preventing and combating fires.
- Even considering that data may not be obtained successfully in the time series, the results were robust, and the spatial consistency analysis by station and mesoregion showed coherence in the number of successes and errors for the indices.

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