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Assessment of risk index for urban vegetation fires of Juiz de Fora, MG, Brazil

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Abstract

The impact caused by forest fire, although it is an old subject, but increasingly larger proportions, has stimulated the development of new methods for the prevention and reduction of risks in the environment. The use of a reliable index of risk among the existing preventive measures is fundamental to a more efficient planning of prevention and an effective action of fight. The work involving the forest fire prevention must use all the tools available since it is a complex task and one that shows great variability in the time of occurrence. One such tool is the degree of danger by means of an index that reflects the probability of fire occurrence. Meteorological indices have shown good results in predicting events and contributing to the work of forecasting fire in forests. The aim of this study was to analyze 4 descriptive fire risk indices for the period from 01/01/2006 to 12/31/2012. Each of them was built with 4 hazard classes of risk. The indices used were Formula de Monte Alegre (FMA), Index of Nesterov, Index of Telicyn and P-EVAP According to the results, the rate of P-EVAP performed better in accuracy of forecasts of occurrences within the class of High Risk, while the FMA was the most effective in the forecast of no occurrence in classes of Low Risk and No Risk. The days classified as Medium Risk in Telicyn indices and P - EVAP presented closest to the average of occurrences in the entire series averages. Knowledge of descriptive classes of indices for predicting fire is valuable to communicate with public, help the actions of awareness, prevent and plan accident. The results had shown some similarities with studies of Torres *et al*. (2009). They used the Skill Score (SS) method and concluded that the logarithmic index of Telicyn showed the best results for the study area.

Keywords*: Index of danger, descriptive classes, fires*

1. **Introduction**

Forest fires contribute to air pollution, climate change and are among the most damaging to some ecosystems events (Magalhães, Lima & Ribeiro, 2011). In areas of economic development, the pressures that forest areas suffer due to the need for new areas intended for agricultural activities, have greatly increased the number of fires and the extent of burned areas due to bad use of fire as an agricultural tool (Alves & Nóbrega, 2011).

In recent years, debates involving fires have increased significantly because there is a great concern due to the release of CO2 and other gases to atmosphere, which are residues from the vegetation combustion. Brazil, in general, is considered as a great contributor of CO2 emissions resulting from forest fires. Globally fires and emissions cause severe losses of biodiversity, interfere in a water cycle and in carbon cycle in the atmosphere. This cause economic, landscaping and ecological loss, reaching protected areas, farms, roadsides, urban areas and nearby areas of reforestation, besides other places (Souza, Casavecchia & Stangerlin, 2012).

One way to prevent these fires is through knowledge of the degree of the risk, which reflects the possibility of an event to occur. These indices can be supported by environmental variables, usually related to weather conditions and can be estimated by indices constructed with different combinations of variables (Tetto *et al*., 2010).

The risk assessment is based, in general, in an integration of the factors that contribute to the risk of the forest fire model. This method of risk assessment is reflected generally in indexes that can be materialized in maps which are expressed areas or levels of risk (Antunes, Viegas and Mendes, 2011). Besides to allow the correct planning Borges *et al*. (2011) argue that the use of a risk index reliably fire is critical to the establishment and mapping of risk areas, defining the number and location of fire observation towers and public warning level risk, which is considered an important factor in environmental education programs. The first step is determine the danger of fire occurrence. For this, several methods have been developed and refined over the years and in different countries.

According Carapiá (2006), rates of fire risk are influenced by several factors, usually fuels, topography and weather. The choice of variables and methods used in this combination results in a variety of approaches. Faced with this diversity, several solutions have been proposed for classification. Depending on the input data, two main groups of methods may be identified: 1) weather risk, which is based solely on data of weather conditions (like temperature, relative humidity, rainfall and wind speed) and 2) potential risk, when are considered more advanced approach, and includes as input the state of vegetation, type of fuel and its moisture content.

The aim of this study was to compare the efficiency of 4 weather indices: Formula de Monte Alegre (FMA) (Soares, 1972), Logarithmic Index of Telicyn, Nesterov Index and Cumulative Index P-EVAP. Will be analysed the relationship of hazard classes of each index with the occurrences of forest fires in the urban area of Juiz de Fora, MG, Brazil, whereas the use of a reliable index of danger is a fundamental factor for efficient planning of measures prevention and to adopt quick and effective actions in fighting fires, in order to reduce losses and, consequently, of any financial losses resulting from the occurrence of catastrophic events.

2. **Methods**

In this study was analyzed a time series of 01/01/2006 to 31/12/2012. Meteorological data were provided by LabCAA (Laboratory of Climatology and Environmental Analysis) of the Federal University of Juiz de Fora (UFJF). The information on 3,135 occurrences of forest fires in urban area, were provided by the 4th Battalion of Military Firefighters (4th BBM).

An analysis of days according to the hazard class of each index was taken, noting occurrences per day, percentage of days with occurrences and percentage of occurrences of each class in relation to the whole period.

The calculation of each index was performed as follows:

2.1. **Fórmula de Monte Alegra - FMA**

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

where:
FMA = Monte Alegre index.
H = relative humidity (%).
n = number of days analysed

The index value is subject to restrictions according to the precipitation, as shown in Table 1:

Table 1. Modification in the FMA value in agreement with the precipitation

Rain day (mm)	Modification of the calculation
≤2,4	None
2,5 a 4,9	Shoot down 30% in the FMA calculated before and add (100 / H) of the day
5,0 a 9,9	Shoot down 60% in the FMA calculated before and add (100 / H) of the day
10,0 a 12,9	Shoot down 80% in the FMA calculated before and add (100 / H) of the day
>12,9	Interrupt the calculation (FMA=0), starting over the sum in the next day or when rain to cease.

Source: Torres *et al*. (2009)

2.2. Telicyn Logarithmic Index

$$\mathbf{I = \sum_{i=1}^{n} \log (ti - ri)}$$

where:
I = Telicyn index
T = air temperature in °C
r = dew point temperature in °C
log = logarithm to the base 10

Restriction Index: whenever a precipitation equal or higher than 2.5 mm occurs, abandon the sum and start calculating the next day or when the rain stopped. In this case the index value is zero.

2.3. Nesterov Index

$$\mathbf{G = \sum_{i=1}^{n} di \cdot ti}$$

where:
G = Nesterov Index
d = saturation deficit of the air in millibars
T = air temperature in °C
n = number of days analysed

The saturation deficit of the air, in turn, is equal to the difference between the maximum water vapor pressure and the real pressure of water vapor, which can be calculated by the following expression:

$$\mathbf{d = E\,(1-H/100)}$$

where:
d = saturation deficit of the air in millibars
E = maximum pressure of water vapor in millibars
H = relative humidity in%

The sum is limited or changed by the occurrence of precipitation according to Table 2.

Table 2. Modification in the G calculation in agreement with the precipitation

mm Rain day	Modification of the calculation
≤2,0	No
2,1 a 5,0	Shoot down 25% in the G value calculated to the day before and add (dt) of the day
5,1 a 8,0	Shoot down 50% in the G value calculated to the day before and add (dt) of the day
8,1 a 10,0	Abandoning the previous sum and start new calculation, ie, G = (dt) of the day
>10,0	Interrupt the calculation (G=0), starting over the sum in the next day or when rain to cease.

Source: Torres *et al*. (2009)

2.4. P-EVAP

The P-EVAP cumulative index proposed by Sampaio (1991), relates the difference between precipitation (P) and evaporation (EVAP), both daily measured in mm. The restrictions on the calculus are the same of Nesterov index (Table 2).

To normalize the number of classes of indices, the class named as Most High Danger of FMA and Nesterov index was grouped within the class of High Risk. For Index-P EVAP, descriptive classes were determined according to the average of occurrences per day. The descriptive classes of each index are shown in Table 3.

Table 3. Descriptive classes of the indices

Indexes	Hard	Middle	Low	Null
FMA	>8,0	3,1 a 8,0	1,1 a 3,0	≤1,0
Telicyn	> 5,0	3,6 a 5,0	2,1 a 3,5	≤ 2
Nesterov	> 1000	501 a 1000	301 a 500	≤300
P-EVAP	< -44,9	- 17 a - 44,9	- 5 a - 16,9	> -5

Adapted from: Torres *et al*. (2009)

3. Results and Discussion

In the time series, the average was 1.14 events per day. The indices of Nesterov and FMA were those with more days classified as High Risk (Table 4). At Average Risk, FMA and P-EVAP had a greater number of days. Classes of Low and Zero Risk indices with the highest number of days were P-EVAP and Telicyn.

Table 4. Number of days of each index by danger class

Index	Hard	Middle	Low	Null	Total
FMA	1293	495	347	605	2740
Telicyn	990	213	245	1292	2740
Nesterov	1453	295	157	835	2740
P-EVAP	663	487	495	1095	2740

Analyzing the descriptive class of High Risk (Table 5) it is observed that the P-EVAP index showed the highest number of occurrences per day within the period (3.0), and 81% of days classified as High Risk for fires that occurred. On the other side presented the lowest number of occurrences within the period (63%), while Nesterov index record higher percentage of occurrences (88%).

Table 5. Analysis of the descriptive class of High Risk

Index	Events/day	% of days with occurrences	% of occurrences
FMA	2.06	68%	85%
Telicyn	2.42	74%	77%
Nesterov	1.90	64%	88%
P-EVAP	3.00	81%	63%

Regarding the days classified as Medium Risk (Table 6), it was observed that the index of P-EVAP showed the most occurrence per day (1.12), where 54% of days with occurrence and 17% of occurrence on the period. Furthermore, Nesterov and FMA indexes showed less occurrences per day, being classified as Medium Risk (0.56) and percentage of days with events (30% and 31%). However, there was a difference in the percentage of occurrences within the class in relation to the series studied, the FMA had the second highest percentage (9%) while the Nesterov index ranked last (5%).

Table 6. Analysis of the descriptive class of Medium risk

Index	Events/day	% of days with occurrences	% of occurrences
FMA	0.56	31%	9%
Telicyn	0.92	48%	6%
Nesterov	0.56	30%	5%
P-EVAP	1.12	54%	17%

In the days classified as Low Risk (Table 7), the FMA showed the least amount of occurrences per day (0.26), a lower percentage of days with occurrences (14%) and second lowest percentage of occurrences for the period around (3%). The Telicyn index had shown the highest number of occurrences per day (0.82) and percentage of days occurring within the class (42%). The P-EVAP index showed the highest percentage of occurrences in relation to the 2740 days of the series (11%).

Table 7. Analysis of the descriptive class of Low Risk

Index	Events/day	% of days with occurrences	% of occurrences
FMA	0.26	14%	3%
Telicyn	0.82	42%	6%
Nesterov	0.37	25%	2%
P-EVAP	0.68	37%	11%

In the of Null Risk class (Table 8), the FMA and Nesterov index got the best performance in relation to the number of occurrences per day (0.18 and 0.19), percentage of days with no occurrence (92% and 91%) and concentrated the lowest number of occurrences in relation to the whole period (3% and 5%). While the Telicyn index got the highest number of occurrences per day (0.27), a lower percentage of days without incidents (85%) and the highest concentration of occurrences in relation to the whole period (11%).

Table 8. Analysis of the descriptive class of null risk

Index	Events/day	% of days with occurrences	% of occurrences
FMA	0.18	92%	3%
Telicyn	0.27	85%	11%
Nesterov	0.19	91%	5%
P-EVAP	0.23	88%	8%

The results showed some differences and similarities with the studies by Torres *et al*. (2009) They used the Skill Score (SS) method which is the ratio of the difference between the occurrences in the forecast and the expected number of occurrences; and the difference between the observed number of days and number of days with forecast adjustments. It was concluded that the Telicyn logarithmic index achieve the best results for the characteristics of Juiz de Fora territory. However, in an individual analysis of the occurrences predictions and no occurrences of fires, it is observed that the most effective index was the P-EVAP with 77% of correct predictions, while the FMA was the index that best answered forecasts of not fires occurrences with 90% accuracy.

4. Conclusion

The data showed a wide variety in the results of each index . However it can be concluded that for days with high fires risks, the rate of P - EVAP performed better in accuracy of forecasts of occurrences also concentrating the highest average successes per day within the period.
Furthermore, the FMA showed the best results for days classified as Low Risk and No Risk , with higher percentage of success in forecasting of non occurrences and lower value of occurrences per day in class.
Analysing the days classified as Medium Risk , P – EVAP and Telicyn indices were closer to the values from the average of daily occurrences on the whole period studied.
The knowledge of descriptive classes of indices for predicting fire can be very valuable in informing the public, helping the actions of awareness and prevention of more serious accidents.

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