Using the Canadian Fire Weather Index in the Natural Park of Montesinho, NE Portugal: calibration and application to fire management

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Using the Canadian Fire Weather Index (FWI) in the Natural Park of Montesinho, NE Portugal: calibration and application to fire management

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ABSTRACT: Calibration of the Canadian Fire Weather Index (FWI), the current fire danger rating system in Portugal, was undertaken in order to rationalise fire management within the boundaries of the Natural Park of Montesinho. The components of the FWI calculated for the nearby city of Bragança were related with a data base concerning wildfire activity (number of fires and area burned) in the 1994-2001 period. Four fire danger classes (low, moderate, high, very high) and five preparedness levels are defined in terms of the FWI index. Procedures concerning fire detection, activities undertaken by the Park's fire crews, and fire suppression are defined for each preparedness level, and are expected to improve the overall fire management process in the future.

1 INTRODUCTION

Fire danger rating tries to answer the questions of when and where will fires occur, and should classify (or quantify) fire behaviour as objectively as possible (Alexander 1994). Several fire management activities rely on the numerical information given by a fire danger rating system, and consequently the performance of the system affects the efficiency of those activities.

The Canadian Fire Weather Index (FWI) is one of the sub-systems that comprises the Canadian Forest Fire Danger Rating System, and its six components express the combined effects of air temperature, relative humidity, wind speed and precipitation (van Wagner 1987). The Fine Fuel Moisture Code (FFMC), the Duff Moisture Code (DMC) and the Drought Code (DC) are moisture content indexes for three fuel classes, respectively the surface litter, the decomposing litter, and the humus layer. The Initial Spread Index (ISI), Buildup Index (BUI) and Fire Weather Index (FWI) indicate fire behaviour potential and respectively represent rate of fire spread, fuel consumption and fire intensity. The ISI expresses the combined effects of wind and FFMC, the BUI results from the DMC and the DC, and the FWI combines the ISI and the BUI.

Wildfire occurrence and burned area are well correlated with the FWI components in Canada (Kill et al. 1977; Stocks et al. 1989). Analysis carried in Mediterranean Europe recommend its use after calibration or adaptation (Viegas et al. 1994; Bovio & Camia 1998), and the FWI has been adopted by countries such as New Zealand (Pearce 1996) and Portugal (Reis 1998). Among other reasons, calibration is required because the FWI output relates to a standard pine litter fuel type, and hence does not reflect other fuel types.

In spite of the current knowledge, allocation of resources to fire presuppression and suppression activities in Portugal remains guided by rigid criteria, dependent on calendars established by National funding programs. The Natural Park of Montesinho (NPM) is an area located at the extreme NE of Portugal that experiences acute fire problems. Considering that the proper use of a fire danger rating system can contribute to rationalise fire management, it is the purpose of this study to calibrate the FWI sub-system for the NPM and derive related operational guidelines.

2 STUDY AREA AND GENERAL METHODOLOGY

The Natural Park of Montesinho (NPM) covers an area of 73,400 ha in the Northeastern region of Portugal, within the latitudes of 41º44´S to 41º59´N and the longitudes of 6º30´ to 7º10´W. Topography is dominated by uplands (700-1000 m elevation) crossed by deep valleys. Climatic diversity within the Park is high, with a mean annual rainfall of 800 to 1500 mm and an average annual temperature of 8 to 13 ºC; these variation follows continentality and altitudinal gradients. The drought period lasts 4 months. Vegetation is dominated by extensive shrubland areas, with important and flammable pine plantations (*Pinus pinaster*, *P. nigra*, *P. sylvestris*); natural hardwood stands (*Quercus rotundifolia*, *Q. faginea*, *Q. pyrenaica*) occur as residual patches in the landscape. The non-regulated use of fire is common and related to agricultural, pastoral and hunting activities.

A data base was established concerning wildfire activity (number of fires and area burned) within the boundaries of the Park in the 1994-2001 period, and including 770 wildfires that affected an area of 15,036 ha. 180 other wildfires that occurred during the study period were disregarded due to incomplete information. The areas affected by the fires were assessed by the Park's personnel, using ground survey with GPS, false colour aerial photography and 1:25,000 maps. This information was subsequently introduced in a GIS system.

The FWI components were calculated for the nearby city of Bragança, using daily meteorological information measured at 12 UTC by an automatic weather station of the Meteorology Institute. Several statistical methods (correlation analysis, logistic regression, percentile analysis and cluster analysis) were used to relate wildfire activity and the FWI indexes.

3 DATA ANALYSIS AND FWI CALIBRATION

The wildfire regime in the NPM is strongly seasonal (Table 1). The months of September and August concentrate the majority of the fires, with an average of one fire per day and 4 ha of burned area per day. Fire activity is practically non-existent in December, January and May. The months of February, March, April, July, October and November are in an intermediate position. A regression of the form $BA = 2.895 + 1.260 \ln(NF)$, where *BA* is the mean daily burned area per month and *NF* is the mean daily number of fires per month explains 88% of the existing data variation.

Fig. 1 depicts the seasonal trend in the FWI index, which escalates after the month of May and reaches the highest values in July and August, with September still registering a fairly high number of days with high observations. This is in general agreement with Table 1, except that July has lower fire activity than the FWI index indicates, probably because in July, — before harvesting cereal crops — people are careful in the use of fire. Table 2 displays the observed variation in the FWI codes during the study period. It is interesting to note that fires do occur even when the ISI=0 and FWI=0, suggesting that the weather station location is not representative of the fire weather variation within the area of the Park. Also, thresholds for fire propagation should be lower in shrubland (where most fires start) than in pine forest, and, as Fogarty et al. (1998) note, we do not know to what extent the FFMC reflects the actual moisture content of fine dead fuels in open, elevated fuel types that rapidly respond to atmospheric influences.

All FWI indexes are positively and significantly correlated with the number of fires and the burned area, the FWI index and the BUI showing a slight statistical advantage (r=041, $p<0.0001$). The only meaningful relationship between fire activity and the FWI sub-system is given by $BA{>}100 = 144.1 \exp(0.088\ \mathrm{ISI})$, with $R^2=0.65$ and where $BA{>}100$ is the area burned by large fires, i.e., those larger than 100 ha. This suggests that the role of wind speed in fire spread is much more important than the role of fuel moisture content or drought conditions, which is in accordance with most fire behaviour studies conducted in open vegetation types.

Table 1. Mean number of fires and burned area per month in the NPM (1994-2001)

Month	No. fires	Burned area, ha
January	0.4	0.3
February	2.9	0.5
March	8.3	4.6
April	2.8	1.6
May	0.0	0.0
June	1.0	0.5
July	6.8	11.0
August	33.5	114.3
September	34.1	116.2
October	4.6	6.7
November	1.6	5.2
December	0.4	0.8

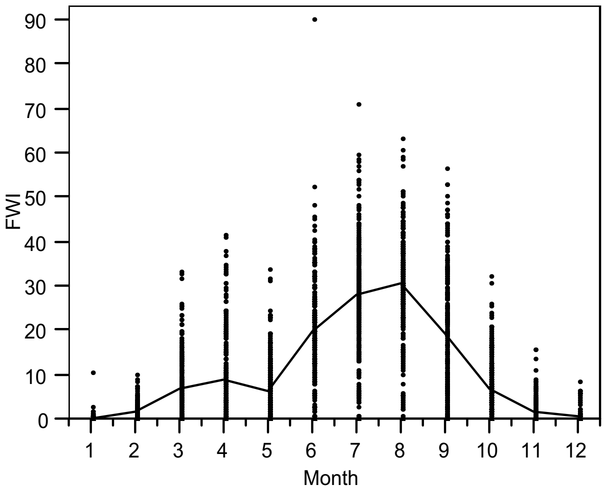

Figure 1. FWI monthly variation (1994-2001) for Bragança. The line connects the mean monthly values.

Logistic regression can be useful to establish thresholds for a fire day or for the occurrence of fires larger than a given size. This approach, however, fails when applied to our data set, and none of the indexes (or combinations of indexes) can be used to build a model with a discriminating ability good enough for operational purposes. Part of the explanation should reside in the nature of our data set, where the number of no-fire days far exceeds the days with fire activity (only 14% of the total). It is thus likely that a probability modelling approach should only be attempted at larger spatial scales.

Table 2. Observed ranges (1994-2001) in the FWI components for Bragança.

Index	Range	Fire days range
FFMC	1-97	33-96
DMC	0-251	0-240
DC	0-828	32-812
ISI	0-56	0-29
BUI	0-272	0-272
FWI	0-90	0-72

The ability to predict the occurrence of large fires is what really matters concerning the minimisation of fire damage, especially considering the ecological role of fire in the shrublands that dominate the Park's area. Table 3 displays the minimum FWI values in days with fires larger than 100 ha. According to the thresholds in Table 3, large fires can take place only in the months of August (68% of the days reach the threshold), September (41% of the days), and, less likely, in July (7% of the days) and October (1% of the days). This means that on average only 35 days per year embody the conditions required for the occurrence of large fires.

Table 3. Minimum observed values for the FWI components in days with large (>100 ha) fires.

FFMC	84
DMC	73
DC	496
ISI	3
BUI	115
FWI	15

Table 4. Proposed fire danger classes for the NPM based on the frequency distribution of the FWI index, and corresponding observed fire activity.

Fire danger class and FWI range	No. wildfires, % of the total	Burned area, % of the total	Mean fire size, ha	No. large wildfires, % of the total
LOW (0 – 8.2)	8.4	3.5	8.1	0
MODERATE (8.3–16.4)	15.7	9.6	11.9	9.5
HIGH (16.5 – 32.9)	35.7	21.2	11.6	14.3
VERY HIGH (≥ 33.0)	40.1	65.8	32.0	71.4

The definition of limits between fire danger classes is an important component of the calibration of a fire danger rating system, even if frequently resorts to a preconceived and arbitrary idea of the percentage of days that should be in each class (Alexander 1994). Following Andrews & Bradshaw (1997) we use the 97th and 90th percentiles of the FWI index to define the extreme and very high fire danger classes, respectively; the high and moderate classes are defined by 1/2 and 1/4 of the 90th percentile. Five danger classes are established this way, but a cluster analysis of the data supports a division in four classes only. Joining the two more severe classes we obtain the low, moderate, high and very high classes, whose demarcation values are displayed by Table 4.

The fire danger classification in Table 4 is accompanied by variables that describe the fire activity observed in each class, as a way of testing the accuracy of the proposed calibration. The results are satisfying, with the very high class clearly distinguished from the others in what concerns burned area, mean fire size and large fires. The comparative performance of the regional classification proposed by Viegas (1999) is quite poor, since 25% of the number of fires, 13% of the burned area and 5% of the large wildfires occur when fire danger is considered nil (FWI<17); it seems also that an excessive (six) number of danger classes is proposed, which complicates interpretation and usage.

4 FIRE MANAGEMENT IMPLICATIONS

The results on Table 4 combined with additional informal knowledge and operational experience provide a basis to establish preparedness levels and recommend operational procedures for the study area.

Preparedness level 1 is equated to the low fire danger class. Survey by ground crews and activation of lookout towers to detect fires is not justified at this level. Nevertheless, the Park's personnel should maintain a radio connection with the regional dispatching centre.

Wildfire occurrence in the preparedness level 2 (moderate fire danger) is essentially dependent on the absence of precipitation for a prolonged period, and on the existence of moderate to strong eastern winds. No large fires are expected, unless the thresholds in Table 3 are reached. Mobilisation of fire detection and suppression resources should proceed in the presence of such conditions. If a fire is detected, the Park's fire crews should evaluate the fire environment and behaviour. If no resource damage is foreseen, the fire will be monitored and can be allowed to fulfil management objectives. Intervention with firefighting trucks is not usually necessary, unless well-trained crews with hand tools are unable to contain the fire. The use of prescribed fire should be restricted to the low and moderate fire danger levels, giving privilege respectively to shrubland areas and forest stands.

Preparedness level 3 is triggered by high fire danger. The likelihood of large fires will depend essentially on the strength and direction of wind. Fire detection from lookout towers, ground fire suppression crews and bulldozers should be operational 24 hours a day. Park's personnel should suspend fuel and stand management activities and be involved in ground surveillance, early fire detection and first attack whenever winds are moderate or strong. Under these circumstances, aerial suppression resources should be available for first attack in priority areas not readily accessible by ground forces. Efficient mop-up should be of concern as early as this level is reached, especially in the peat soils that occur at higher elevations.

Preparedness level 4 corresponds to very high fire danger. Time of ignition, local topography and fuel conditions and promptness of firefighting actions will be critical to the development of large fires. Aerial first attack should be immediate in all priority areas, and heavy ground suppression resources should be dispatched to priority areas in order to rapidly contain and completely extinguish fires.

The additional preparedness level 5 is defined for FWI values above 43, matching the extreme fire events (fires larger than 1,000 ha) observed during the study period. Success of fire suppression can only be accomplished if the fire is attacked in its early stage. Both ground and aerial surveillance should be carried in priority areas from 11:00 am to 20:00 pm. Heavy ground forces should be strategically stationed in the vicinity of the most vulnerable areas.

5 CONCLUSION

The proposed FWI sub-system calibration should be operationally relevant in most fire management situations in the NPM. Performance improvements can be attainable in the future through the use of a network of weather stations covering the main climatic situations in the NPM. However, the influence of local factors, including land use and landscape patterns, fuel conditions and interaction between weather and topography should not be overlooked. Social and demographical factors also play a determining role in the NPM fire regime, given the strong links between population and agricultural activities and the common use of fire irrespective of season.

We believe that this study's results will contribute to an increase in operational effectiveness in the NPM, especially if combined with the already existent fuel hazard maps. Nevertheless, they should be regarded as work in progress, since they are based in information collected during a relatively short time span.

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