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Research Article

Fire Weather Index Implementation in the Alpine Area

Daniele Cane,[1] Nadia Ciccarelli,[2] and Renata Pelosini[1]

[1] *Regional Agency for Environmental Protection, Arpa Piemonte, Via Pio VII 9, 10135 Torino, Italy*
[2] *Forestry Environment Institute, IPLA S.p.A., Corso Casale 476, 10132 Torino, Italy*

Correspondence should be addressed to Daniele Cane, daniele.cane@arpa.piemonte.it

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Piedmont region is located in North-Western Italy and is surrounded by the alpine chain and by the Apennines. The region is covered by a wide extension of forests, mainly in its mountain areas (the forests cover 36% of the regional territory). In the period 1997–2007, Piedmont gained interest by an average of 378 wildfire events per year, covering an average of 1767 ha of forest per year. Meteorological conditions like long periods without precipitation contribute to create favourable conditions to forest fire development, while the fire propagation is made easier by the foehn winds, frequently interesting the region in winter and spring particularly. We applied the Fire Weather Index FWI (Van Wagner, 1987) to the Piedmont region on warning areas previously defined for fire management purposes (Cane et al., 2008). Here we present a new technique for the definition of thresholds in order to obtain alert levels more suited with the local conditions of the forest fire warning areas. We describe also the implementation of the prognostic FWI prediction system, involving the use of good forecasts of weather parameters at the station locations obtained by the Multimodel SuperEnsemble postprocessing technique.

1. Introduction

The Fire Weather Index was originally proposed by Van Wagner [1] for the wildfire prevention in Canadian forests; it is calculated from a set of weather parameters and describes the evolution of the current moisture content of different fuel layers of the forest system, together with the influence of wind in fire propagation. It is widely used by many fire prevention systems in the world. We implemented a version of the FWI in our region Cane et al. [2], based on the data of the very dense non-GTS weather station network managed by Arpa Piemonte. The orography of our mountainous region is very varying, spanning from 150 m asl to more than 4500 m asl. The climatic features vary quite rapidly with the height and with the main weather regime, taking also into account the Alps hindering the perturbations coming from the main zonal flux and the influence of the Mediterranean sea not far from our territory.

The correct implementation of the index requires a very accurate characterisation of these local climatic features; 60 warning areas, usually corresponding to the mountain valleys or of part of them, were individuated, based on the forest fire statistics and on the organisation of the operational forest fire prevention teams (Figure 1). An accurate statistical analysis was carried on the climatological data of the station network, and a set of primary and secondary weather stations was assigned to each warning area in order to minimise the number of lacking data. For each of these selected weather stations the forest fire indices are calculated daily from the data of the previous day, and warning alert maps are produced and distributed to the fire prevention network.

Warning alert levels are automatically assigned with the help of a system of thresholds, calculated according to the indications of Van Wagner [1]. The behaviour of these threshold however was not satisfactory, in particular during the winter season, and we developed a new technique for the threshold calculation (Section 2), taking into consideration the variability of weather characteristics in our region. In Section 3 we present the implementation of our FWI forecasting system, based on very accurate weather parameter forecasts obtained with the Multimodel SuperEnsemble postprocessing method [3].

2. New Threshold Definition

The FWI is a quite rich source of information, and its many subindices describe the fire behaviour and characteristics of the different fuel layers. It is very useful anyway to define

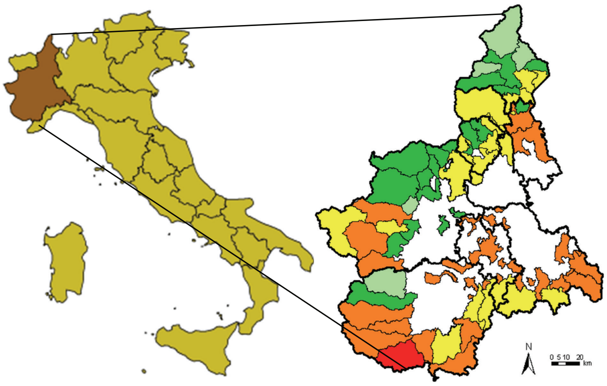


Figure 1: A map of the Piedmont region with an example of the output of the FWI index (July 24, 2007) on the 60 warning areas identified by the regional forest suppression service. Light green: no fire danger, green: low danger, yellow: moderate danger, orange: elevate danger, red: very high danger.

thresholds on the index for the issuing of danger levels, in order to provide a simpler information to the forest suppression operators and to the general public. A five-level alert system was defined, thus requiring the evaluation of four thresholds.

The thresholds were originally evaluated on FWI historical values calculated Within this sequence, the fraction of days that we can consider as extreme danger condition (“very high” danger) was used to detect a discriminating FWI value. This value corresponds to the lower threshold of the extreme danger class. Remaining thresholds, characterized by a decreasing danger level, were defined through a proper scale conversion and a geometric progression. Monthly thresholds were thus defined for each of the 60 warning areas in which Piedmont is divided. A calibration of the defined thresholds was implemented for each warning area according to fire risk level, considering especially fire frequency and the localization of the ignition points.

This technique gives quite good thresholds speaking in general terms, but it has some limitations.

(i) Reproducibility is limited by a certain discretion and empiricism in the definition of the higher level.

(ii) A strong statistics is required to obtain the values of the extreme danger conditions, but with a large number of warning areas, the number of wildfires observed per area and per month is limited, then a certain grouping of warning areas is necessary but brings to errors in the evaluation of the danger levels in warning areas without any observed wildfire.

(iii) In winter and spring the extreme danger conditions often arise from foehn conditions, linked to quite high FWI values with respect to the monthly mean. The thresholds calculated with such high values result relatively high, but they fail in pinpointing the wildfires occurring in nonfoehn conditions.

We then developed a new threshold system, now used operationally for the alert level definition.

We started from the same dataset of 2002–2006 FWI values and wildfire events, and we grouped them on a monthly basis. For each month, we then calculated a set of 19 quantiles (from 5% to 95%) of the distribution of the FWI of the wildfire events in the whole region and for all the considered years, thus obtaining 19 FWI values corresponding to these quantiles. We then calculated the corresponding quantiles of these values in the complete distribution of FWI in the month. We then traced back the latter quantiles to the distribution of each warning area, thus obtaining a set of threshold for each warning area. We finally confronted these threshold with the observed wildfires and calculated again the regional statistics to have a confirmation of having reached the required quantiles of the wildfire distribution. A scheme of our methodology, with an example, is shown in Figure 2.

We now have a set of thresholds among whose the forest suppression service responsible can choose on the basis of a cost-loss criterion; they have a precise picture of their opportunities in terms of expected number of alarms and expected number of hits/misses.

The proposed thresholding system, although sharing with other percentile-based methods (see e.g., [4, 5]) the limitation of a statistics approach, is not based on a fixed percentile choice [6], but for each month different percentile thresholds are chosen based on the hit rates (or, symmetrically, can be chosen on the basis of an expected number of alarms).

The thresholds here presented were chosen with the following criterion: low danger (hit rate >90%), moderate danger (hit rate >80%), elevate danger (hit rate >50%), very high danger (hit rate >20%).

We applied the old and new threshold system on the 2007 data to have an independent verification; Figure 3 shows the confrontation results on a seasonal basis. The new thresholds are very effective in increasing the number of hits during winter and spring seasons, of course paying for a moderate increase in the number of alarms. In particular the winter “moderate danger” (the first level at which the regional service takes prevention measures) increases from 47% hits to a more comforting 80%. The new threshold have a neutral-to-positive impact on the summer and fall seasons, where the results were already satisfying.

We want to stress also the coincidence of the expected and observed hits percentage with the new thresholds; the new thresholds can be associated quite clearly to a precise number of expected hits, then giving a coherent frame of interpretation of the alert level meaning for the end users.

Finally, the new thresholds give a more homogeneous spatial distribution of the danger levels over the region, because each warning area holds a customized set of thresholds, but each of them corresponds to a unique quantile of the whole regional FWI distribution, then if there is any difference among the alert levels of two neighbouring areas, it is possibly due to a really different forest fire potential and not to the use of not well-customized thresholds for the two areas.

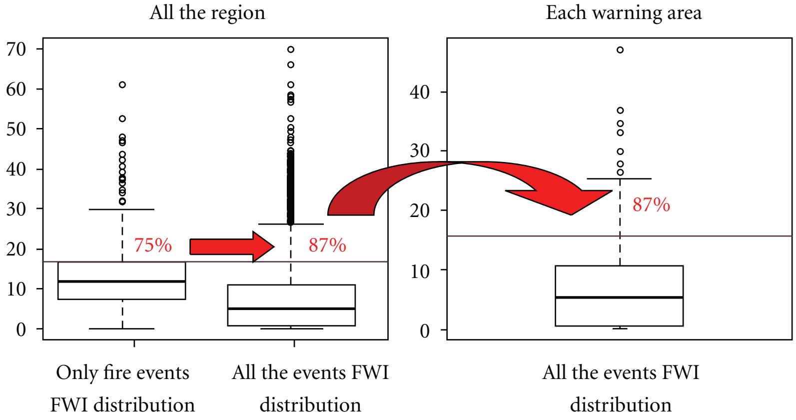


Figure 2: Threshold evaluation scheme. A given quantile (in this example, 75%) is evaluated on the FWI distribution of the fire events on all the region (left). The corresponding FWI value is searched in the general FWI distribution and a new quantile is evaluated (in this example, 87%). The quantile so found is used to define a threshold for each warning area (right).

3. Prognostic FWI Implementation

The forest fire suppression planning requires the knowledge in advance of the wildfire potential, in particular for the management of the helicopter and personnel availability and for the patrolling activities. Two-three days in advance FWI forecasts can be useful for a better planning and significant savings.

We implemented a prognostic FWI alert system based on the forecasts obtained with the Multimodel SuperEnsemble postprocessing method (introduced firstly by [7]). Several global circulation models and nonhydrostatic limited-area models are put together and weighted with weights calculated in a training period to obtain very accurate weather parameter forecasts at station locations. For more details about this method please refer to Cane and Milelli [3].

Temperature and humidity are obtained from Multimodel SuperEnsemble fields, while precipitation and wind are interpolated from the COSMO_I7 limited area model. The latter two parameters are more positively biased in the direct model output than in the postprocessed data, but this characteristic seems to be more effective in the FWI forecast, emphasizing the cases when sudden variation of the danger level can arise. As an example, consider a day with foehn winds: COSMO_I7 model usually overestimates wind speeds, but it is more effective in giving a sudden FWI increase more in accordance with what is happening in reality. After a careful statistics we then chose the above-described configuration.

The prognostic FWI is operational since April, 2008. We show in Figure 4 the confrontation between the alert levels issued from the forecast and analysed from the observed data in the period May 2008–April 2009. Unfortunately (or, more fairly; fortunately) Piedmont experienced very few wildfires in 2008, while the 2009 data are still under validation, then we do not show confrontation with the observed wildfires because of very scarce statistics.

Each panel shows the percentage of cases where the forecast FWI value for a given warning area is higher or equal to the corresponding observed FWI value as a function of the forecast time and of the season. The behaviour is quite satisfying, with 80% or more of the forecasts equal or higher than the observed values, providing a good planning tool for the fire suppression resources. There is a slight decrease of forecast accuracy with the forecasting time, as it can be expected.

Figure 4 shows a small performance lose in winter and a significant decrease in spring. We guess this can be due to problems in precipitation measurement; the larger part of the reference stations for the FWI calculation in the warning areas is set in the mid mountains (around 1500 m asl). Snow melting in the rain gauge can lead to wrong precipitation measurements that can misrepresent the reality.

We are planning to test some technique for data spatialization to leave the use of reference stations and get a more coherent field for the meteorological input parameters, taking into account also the radar fields and a snow mask. We hope that this effort will give improved observed and forecast FWI values for winter and spring.

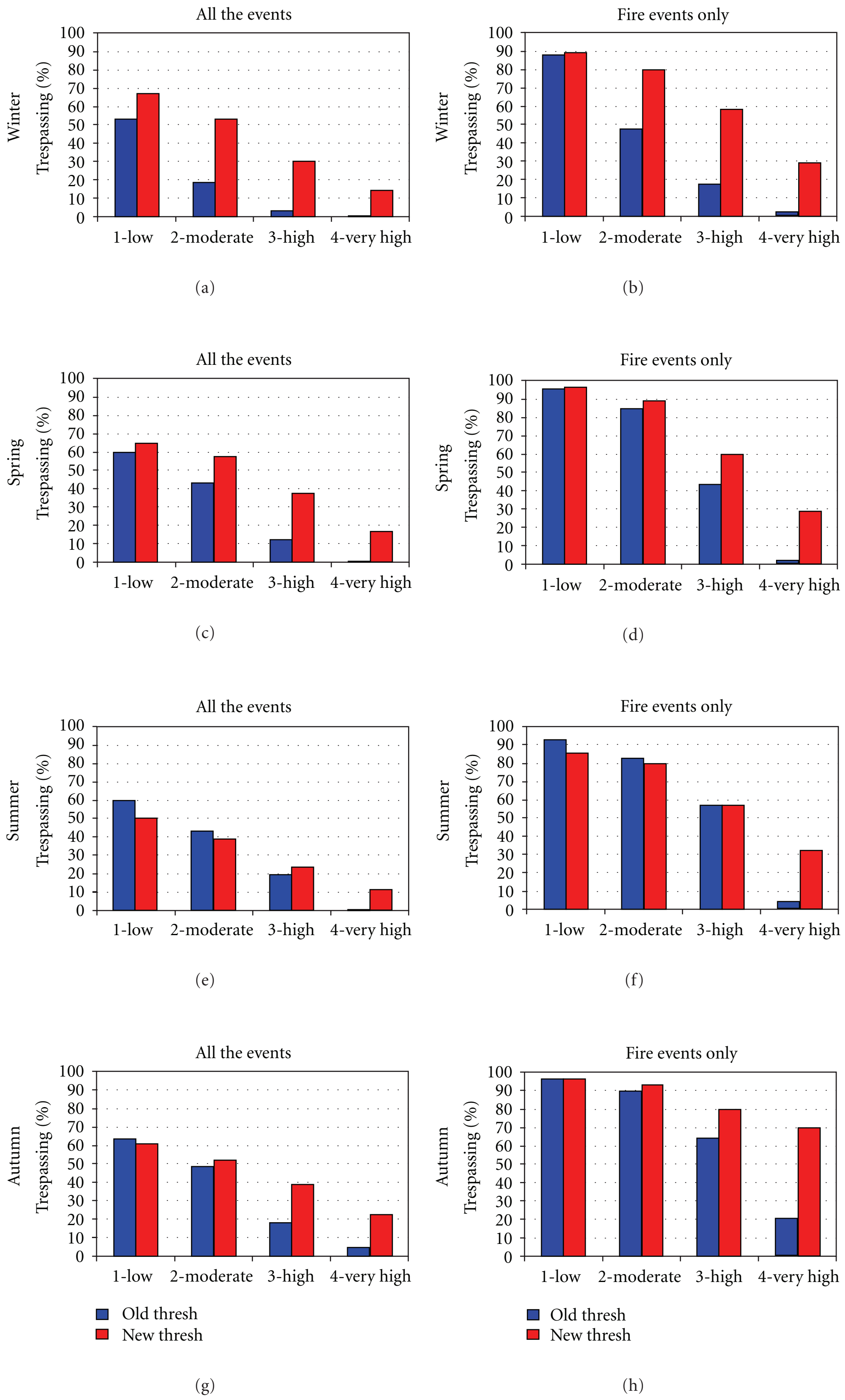
4. Conclusions and Future Developments

The application of the Fire Weather Index to the observed data from our network provides a good diagnostic evaluation of the fire danger situation, compared with the observed fire events. We are planning to improve the quality of this diagnostic evaluation using analysed data with assimilation techniques to get more homogeneous data on the given warning area.

A more extensive tentative effort of adapting the FWI index to the Alpine area will be set out in the framework of the EU INTERREG ALP-FFIRS project.

The new threshold system was obtained with a nonempirical reproducible method and gives correct and stable results all year around, with clear correspondence between the alert level and expected number of hits.

The prognostic FWI evaluation is a very useful tool for the fire suppression planning and gives reliable results with the requested very high resolution of the Piedmontese warning areas. We are planning to improve the quality of



(a) (b) (c) (d) (e) (f) (g) (h)

FIGURE 3: confrontation of the percentage of exceeding the thresholds for FWI on all the events (left panels) and on the fire events only (right panels) for the different seasons.

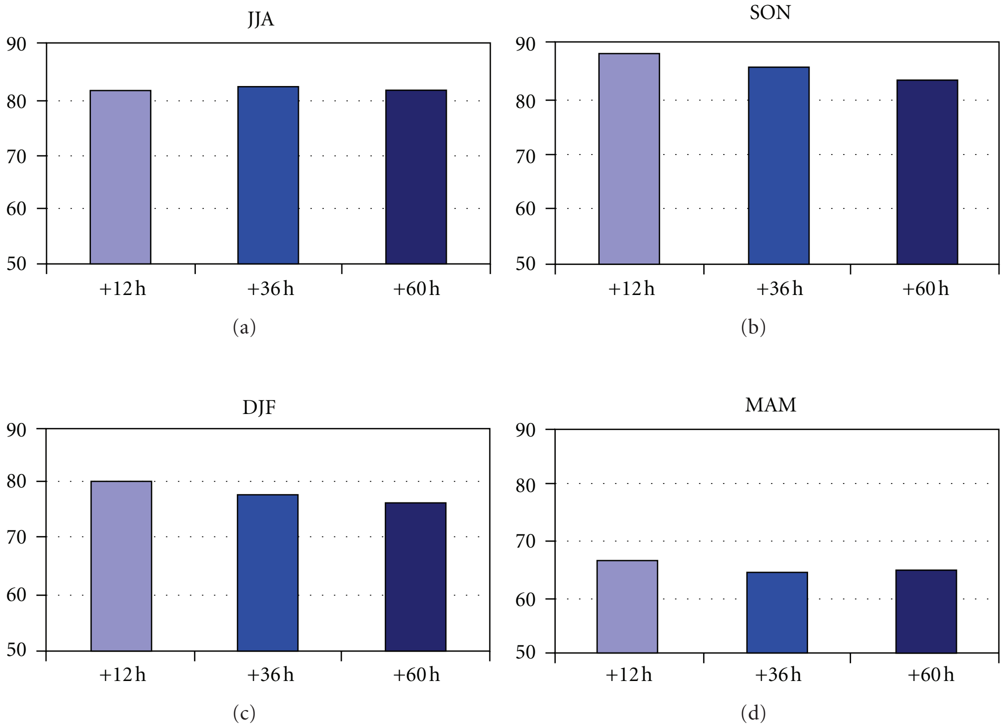


Figure 4: forecast FWI statistics. Percentage of cases where the forecast FWI value for a given warning area is higher or equal to the corresponding observed FWI value as a function of the forecast time (+12 h, +36 h, +60 h) and of the season.

the FWI forecasts by improving the precipitation and wind fields introduced into the FWI calculation.

Acknowledgment

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References

[1] C. E. Van Wagner, "Development and structure of the Canadian forest fire weather index," Tech. Rep. 35, Canadian Forest Service, Ottawa, Canada, 1987.

[2] D. Cane, N. Ciccarelli, F. Gottero, A. Francesetti, F. Pelfini, and R. Pelosini, "Fire Weather Index application in north-western Italy," *Advances in Science and Research*, vol. 2, pp. 77–80, 2008.

[3] D. Cane and M. Milelli, "Weather forecasts obtained with a Multimodel SuperEnsemble technique in a complex orography region," *Meteorologische Zeitschrift*, vol. 15, no. 2, pp. 207–214, 2006.

[4] P. L. Andrews, D. O. Loftsgaarden, and L. S. Bradshaw, "Evaluation of fire danger rating indexes using logistic regression and percentile analysis," *International Journal of Wildland Fire*, vol. 12, no. 2, pp. 213–226, 2003.

[5] R. S. Helfman, R. J. Straub, and J. E. Deeming, "User's guide to AFFIRMS: time-share computerized processing for fire danger rating," Tech. Rep. INT-82, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, Utah, USA, Various pagination, 1980.

[6] F. A. Heinsch, P. L. Andrews, and L. L. Kurth, "Implications of using percentiles to define fire danger levels," in *Proceedings of the 8th Symposium on Fire and Forest Meteorology*, Kalispell, Mont, USA, October 2009.

[7] T. N. Krishnamurti, C. M. Kishtawal, T. E. LaRow et al., "Improved weather and seasonal climate forecasts from multimodel superensemble," *Science*, vol. 285, no. 5433, pp. 1548–1550, 1999.