



# ADVANCES IN FOREST FIRE RESEARCH

DOMINGOS XAVIER VIEGAS

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# Investigation of the weather conditions leading to large forest fires in the area around Athens, Greece

G. Xanthopoulos<sup>a</sup>, A. Roussos<sup>a</sup>, C. Giannakopoulos<sup>b</sup>, A. Karali<sup>b</sup>, M. Hatzaki<sup>b</sup>

<sup>a</sup> *Hellenic Agricultural Organization "Demeter". Institute of Mediterranean Forest Ecosystems and Forest Products Technology. Terma Alkmanos, Ilisia, 11528, Athens, Greece. [gxnrta@fria.gr](mailto:gxnrta@fria.gr)*

<sup>b</sup> *Institute for Environmental Research and Sustainable Development, National Observatory of Athens, Athens, Greece. I. Metaxa and V. Pavlou Street, Palaia Pendeli, 15236, Athens, Greece [cgiannak@meteo.noa.gr](mailto:cgiannak@meteo.noa.gr)*

## Abstract

Large forest fires are of great concern in all fire prone countries. Understanding them and predicting the possibility for their occurrence can be very helpful for forest fire management. They usually occur under very adverse fire weather conditions so any investigation about them is sure to take this into consideration. The Fire Weather Index (FWI) of the Canadian Forest Fire Danger Rating System which enjoys very broad use not only in the vast forests of Canada but also in other parts of the world, is a composite index that represents fire weather conditions quite well. The study presented here is an investigation of the possibility to associate fire weather conditions, as captured by FWI, with the occurrence of large forest fires in the broader area around Athens, the capital of Greece. It is based on forest fire data from the Greek Fire Service for the 2003-2011 period, matched to FWI values for this period, calculated using gridded observation data from the ERA Interim data sets, that were interpolated using the Thin Plate Spline Technique in order to obtain high resolution (1 km) spatial analysis data. Correlations between FWI and burned area per fire proved to be very poor, precluding regression modelling, so an alternative analysis method was used in order to determine, according to the data for the study period, the minimum FWI above which it is possible for fires to exceed certain burned area thresholds.

**Keywords:** *Fire Weather Index (FWI), large forest fires, Athens, Attica, Greece*

## 1. Introduction

In the world of forest fire management the need for understanding and prediction of fire ignition probabilities and difficulty of control is the main reason for collecting fire statistics and for the development and use of fire danger rating systems. A significant number of such systems have been developed around the world, some having more global characteristics and use than others. Among them the Canadian Forest Fire Danger Rating System (CFFDRS) (Stocks *et al.* 1989, Forestry Canada Fire Danger Group, 1992) enjoys very broad use not only in the vast forests of Canada but also in other parts of the world including Europe where the System's Fire Weather Index (FWI) was evaluated favourably, among others, by Viegas *et al.* (1999) in comparison with four other methods of fire danger evaluation, and was adopted since 2007 at the EU level by the European Forest Fire Information System (EFFIS) of the Joint Research Centre of the European Commission (<http://forest.jrc.ec.europa.eu/effis>). The FWI was also evaluated favourably by Dimitrakopoulos *et al.* (2011) and by Karali *et al.* (2014) in Greece. Both these studies proposed FWI value classes for association with fire danger.

Although the FWI, according to most evaluation studies produces good predictions, its use can become much more meaningful for use in operational fire management if it is further investigated and calibrated to the specific fire conditions in the region where it is to be applied (e.g. Fogarty *et al.* 1998, Rainha and Fernandes 2002). Furthermore, it makes sense to examine if its predictions and utility can be improved by introducing additional information to the one already required for FWI calculation.

The study presented here is an investigation of the fire weather conditions leading to large forest fires in the broader area around Athens, the capital of Greece. It was prompted by the operational need to tie the potential for such fires to FWI, in conjunction with the finding of studies like the one by Dimitrakopoulos *et al.* (2011) that the Fire Weather Index (FWI) while highly correlated to fire occurrence is only moderately correlated to burned area.



Figure 1. Map of the study area in Greece.

## 2. Methods

The study area covered the prefectures of East Attica, West Attica, Corinthia and Viotia (Figure 1). For this area forest fire data (dates, number of fires, burned area) for the 2003-2011 period, were obtained from the Greek Fire Service. Meteorological data were obtained from the ERA Interim data set (Dee *et al.* 2011) at a horizontal resolution of  $0.75^\circ$  (approximately 82km). The gridded meteorological data were firstly interpolated from the 82 km grid to a high spatial resolution 1-km grid using the 3D Thin Plate Spline technique (Hutchinson 1998). Subsequently, the interpolated meteorological data were used to calculate FWI values for a particular representative site on Mount Hymettus near Athens. Forest fire data were then matched to the calculated FWI values. Further to this, each fire was associated with representative predawn water potential (WP) measurements for roughly the same day, collected during the 2003-2011 period on the same site on Mount Hymettus (Xanthopoulos *et al.* 2006). These WP measurements were carried out for three representative Mediterranean species: *Pinus halepensis*, *Quercus coccifera* and *Cistus creticus*. This trial aimed to examine if the drought experienced by the living forest plants can play an important role in the occurrence of large fires in addition to the influence of the current weather condition captured by the FWI.

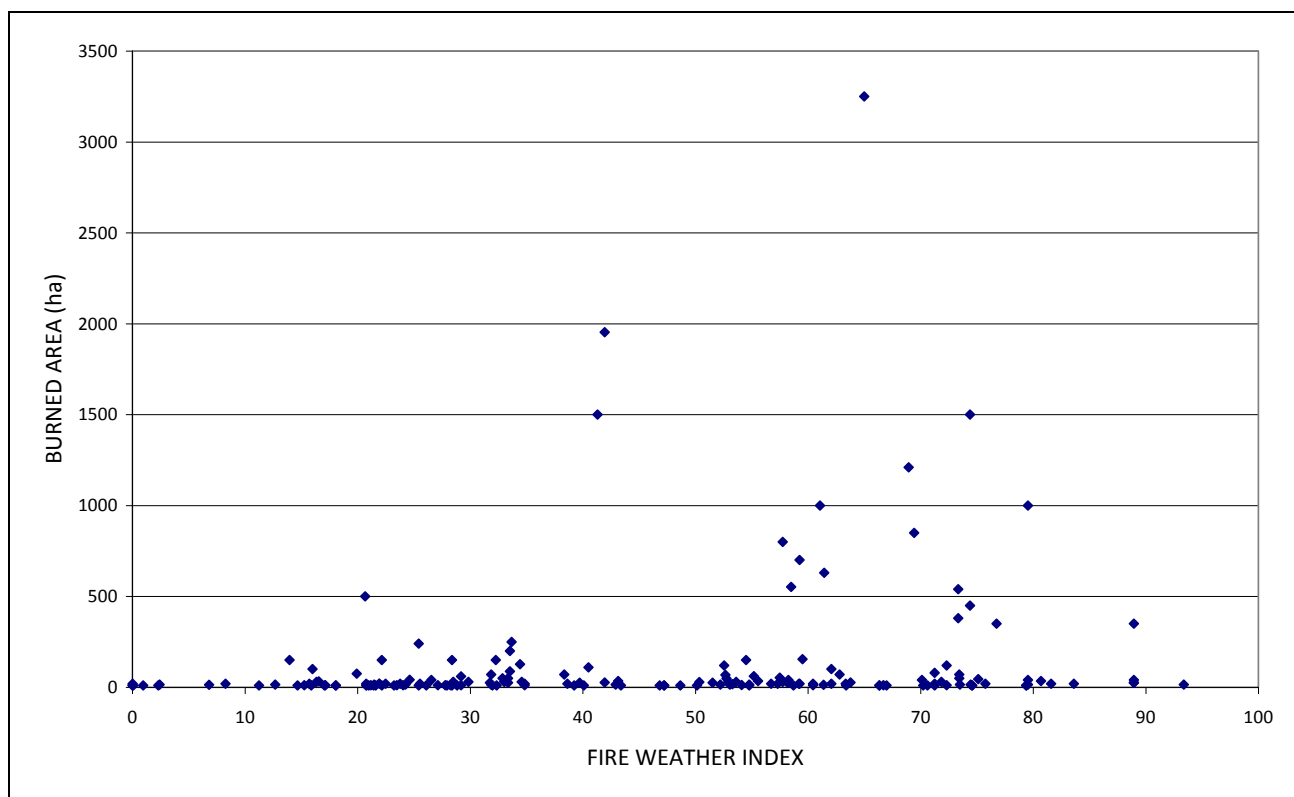
## 3. Analysis and results

The total number of fires reported in the four prefectures in the period of interest reached 6,860. They had burned a total area of 43,569 ha, roughly 5% of the study area. Some of them were identified as

non forest fires (e.g. agricultural residue burning) and were dropped from the database. The rest of the fires were analyzed putting emphasis on the large fires that occurred in this time period.

The FWI for all days with fire, varied between 0.0001 and 102.92. On the day of the highest FWI (August 22, 2010) six fires were reported. Their burned area ranged between 0.05 and 7 ha. The maximum burned area for one fire was 17,500 ha. This historic fire started on August 21, 2009, under an FWI of 71.845.

Focusing on large fires, a sub-sample of the data set was created with all fires having a burned area equal to or larger than 10 ha. The number of observations was 175. This smaller data set was examined in regard to the correlation of burned area with FWI. The Pearson correlation proved to be very low (0.133) and non-significant. The existence of the large 17,500 ha fire of August 2009 in the dataset was considered as a probable reason for this low correlation. However, even when this data point was removed (N=174), the correlation reached only 0.183 and became significant at the 0.05 level (2-tailed). Obviously, these low correlations preclude any effort for predictive regression modelling. Figure 2 is a plot of the 174 point data set, after omission of the 17,500 ha fire.



*Figure 3. Plot of the Fire Weather Index versus the burned area of the 174 largest fires in the study region in the 2003-2011 period, omitting for scaling purposes the largest fire of 17,500 ha that occurred under a FWI of 71.845*

The water potential data for the three species examined also had poor correlation with burned area. The same was true when the product of FWI with water potential was examined for correlation with burned area, so at this stage the WP data were not examined further.

These results illustrated the problem of the potential discrepancies between FWI and burned area and called for a different ad-hoc approach for analysing the data set in regard to large fires. This approach was as follows: selecting sub-samples of the database that included only the fires that burned an area larger than a specific threshold (ha), the minimum FWI and maximum FWI for each sub-sample were entered in a table (Table 1) and were also plotted against that threshold.

*Table 1. Number of fires, Minimum FWI, and Maximum FWI for subsets of the complete dataset that each included only the fires above a selected burned area threshold (ha).*

<b>Burned Area Threshold (ha)</b>	<b>Number of fires</b>	<b>FWI Min</b>	<b>FWI Max</b>
10	175	0,00705	93,37405
20	100	0,01265	88,93933
30	69	13,95373	88,93933
40	56	13,95373	88,93933
50	48	13,95373	88,93933
60	44	13,95373	88,93933
70	41	13,95373	88,93933
80	36	13,95373	88,93933
90	34	13,95373	88,93933
100	34	13,95373	88,93933
110	32	13,95373	88,93933
120	31	13,95373	88,93933
130	28	13,95373	88,93933
150	28	13,95373	88,93933
170	22	20,67158	88,93933
200	22	20,67158	88,93933
250	20	20,67158	88,93933
300	19	20,67158	88,93933
350	19	20,67158	88,93933
400	16	20,67158	79,54018
500	15	20,67158	79,54018
600	12	41,3183	79,54018
700	11	41,3183	79,54018
800	10	41,3183	79,54018
900	8	41,3183	79,54018
1000	8	41,3183	79,54018
1200	6	41,3183	74,38725
1400	5	41,3183	74,38725
1600	3	41,3183	74,38725
1800	3	41,3183	74,38725
2000	2	64,99238	71,84505
3300	1	71,84505	71,84505

As shown in table 1, 175 fires had each burned an area equal to or exceeding 10 ha ( $N_{10}=175$ ). The minimum FWI value among these fires was 0.007 and the maximum FWI was 93.374. This means that a fire may reach or exceed 10 ha even at an FWI=0.007.

When setting the threshold at 20 ha the number of fires dropped to  $N_{20}=100$ , the minimum FWI was 0.012 and the maximum FWI was 88.894. This means that even at this minimum FWI value a fire may exceed 20 ha. The smaller maximum FWI value in this subset means that a fire that occurred with an FWI of 93.374 and was included in the previous subset because it had burned over 10 ha, did not exceed the 20 ha threshold and was left out of this second subset.

The next subset with the threshold burned area set at 30 ha, had a minimum FWI of 13.95 and  $N_{30}=69$ . The same minimum FWI remained for the next subsets until the threshold was set to 170 ha ( $N_{170}=22$ ) and the minimum FWI became 20,672.

Following the same logic, the plot of Figure 3 was created. It shows the minimum FWI thresholds that make it possible for fires to exceed initial attack capabilities and, as long as there is available fuel in their path, to become large or very large.

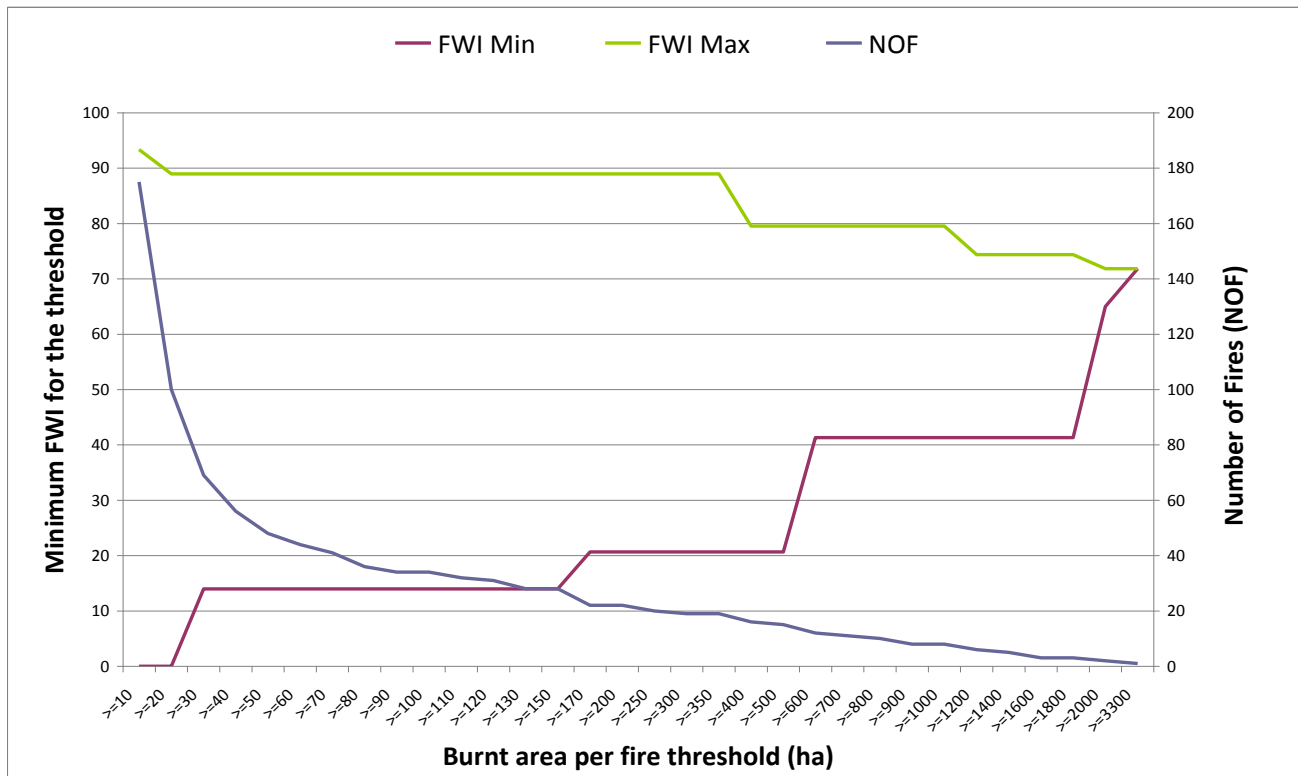


Figure 3. Minimum FWI that may allow forest fires to exceed certain burned area thresholds for the conditions (vegetation, firefighting resources, etc.) in the study area around Athens, in Greece.

#### 4. Discussion and conclusions

The efforts spent looking for a mathematically expressed relation between FWI and burned area did not produce any results. This is in agreement with the conclusions of Dimitrakopoulos *et al.* (2011). It is clear that whereas fire ignition probabilities correlate reasonably well with the weather conditions as captured by FWI, things are quite different in regard to burned area. The varying capability of firefighting resources, temporally and spatially, is a significant factor affecting the evolution of each fire. The existence of fuel in the path of a fire is also another important factor that acts randomly on every fire depending on where it starts and on the direction of its spread. Further to the above, there are various sources of errors in the data set that may have added “noise” reducing correlations further. These sources of error are:

- Inaccuracy of reported burned area per fire by the Fire Service (it is called an estimate, not a measurement)
- Calculation of FWI over broad areas rather than based on the local conditions of each fire.
- Using one value of water potential per species (average of two measurements) from one location in Attica and from the closest available date to the date of the fire.

On the other hand, the alternative method of analysis used here, as shown in Table 1 and Figure 3, provides some thresholds that can be useful for setting mobilization levels according to predicted

weather conditions and FWI, and also for guiding pre-fire positioning of firefighting resources and for supporting dispatching decisions in case of fire eruption. More specifically, it can be concluded that:

- If the FWI exceeds 0,01 fires exceeding 20 ha are possible.
- If the FWI exceeds 13,95 fires exceeding 30 ha are possible.
- If the FWI exceeds 13,95 fires exceeding 30 ha are possible.
- If the FWI exceeds 20,67 fires exceeding 170 ha are possible.
- If the FWI exceeds 41,32 fires exceeding 600 ha are possible.
- If the FWI exceeds 64,99 fires exceeding 2000 ha are possible.
- If the FWI exceeds 71,84 fires exceeding 3300 ha are possible.

## 5. Acknowledgements

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