

INTERPRETING THE CANADIAN FOREST FIRE

WEATHER INDEX (FWI) SYSTEM¹

by

William J. De Groot²

Introduction

Fire danger is defined by the Canadian Committee on Forest Fire Management (Merrill and Alexander 1987) as:

A general term used to express an assessment of both fixed and variable factors of the fire environment which determine the ease of ignition, rate of spread, difficulty of control and fire impact.

The Canadian Forest Fire Danger Rating System (CFFDRS) is the national system for rating fire danger in Canada. The Canadian Forest Fire Weather Index (FWI) System is a sub-system of the CFFDRS and has been in its present form since 1970, with the fourth version of the tables for the FWI System now being used (Canadian Forestry Service 1984; Van Wagner 1987). The purpose of the FWI System is to account for the effects of weather on forest fuels and forest fires. Other factors affecting fire danger (i.e., fuels, topography) are dealt with elsewhere in the CFFDRS.

The FWI System is comprised of six components (see Fig. 1): three fuel moisture codes and three fire behavior indexes. Each component has its own scale of relative values. Even though the scales for the six components are different, all are structured so that a high value indicates more severe burning conditions.

The FWI System uses temperature, relative humidity, wind speed, and 24-hr precipitation values measured at noon Local Standard Time (LST). These values are used to predict the peak burning conditions that will occur during the heat of the day, near 1600 h LST, assuming that the measured weather parameters follow a normal diurnal pattern (Turner and Lawson 1978; Van Wagner 1987).

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²Fire Research Officer, Saskatchewan District Office, Canadian Forestry Service, Western and Northern Region, 101-15 Street East, Prince Albert, Sask., S6V 1G1.

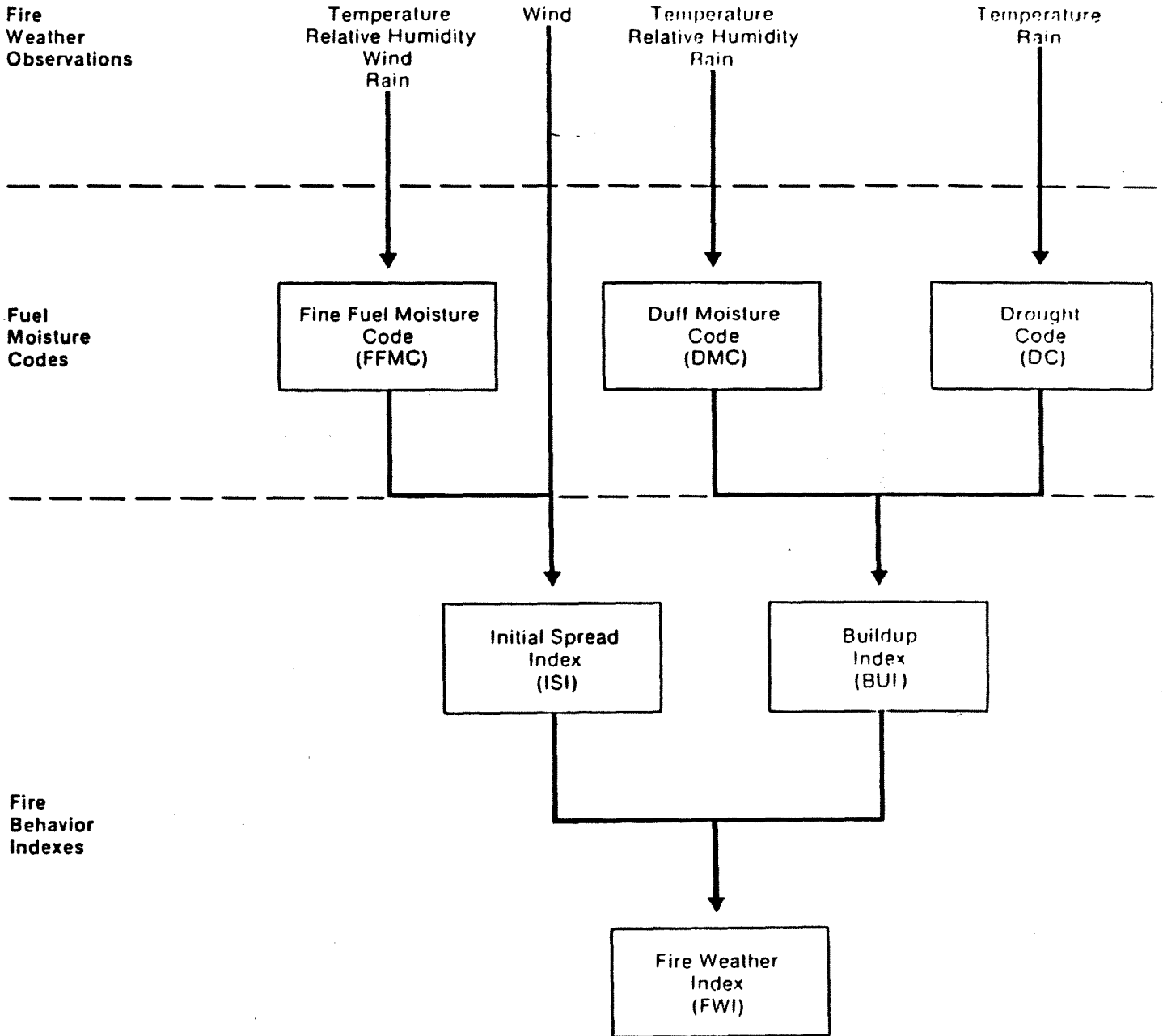


Figure 1. Structure of the Canadian Forest Fire Weather Index (FWI) System.

Fuel Moisture Codes

The FWI System evaluates fuel moisture content and relative fire behavior using the past and present effect of weather on forest floor fuels. The three moisture codes represent the fuel moisture content of three classes of forest floor fuels in the "standard" mature pine stand (Fig. 2). The moisture codes calculate the net effect of a daily drying and wetting phase, similar to a bookkeeping system of moisture losses and additions.

Fine Fuel Moisture Code (FFMC)

The FFMC is a numerical rating of the moisture content of litter and other cured fine fuels (needles, mosses, twigs less than 1 cm in diameter). The FFMC is representative of the top litter layer 1-2 cm deep, and has a typical fuel loading of about 5 tonnes per hectare (t/ha).

FFMC fuels are affected by temperature, wind speed, relative humidity, and rain. However, to account for the interception of rain by the forest canopy, the wetting phase of the FFMC is not initiated if the 24-hr rainfall is 0.5 mm or less.

The rate at which fuels lose moisture is measured in terms of timelag, similar to the 'half-life' decay rate of radioactive material. Timelag is the time required for fuel to lose two-thirds of its free moisture content with a noon temperature reading of 21°C, relative humidity of 45%, and a wind speed of 13 km/h (Lawson 1977). The timelag for FFMC fuels is two-thirds of a day.

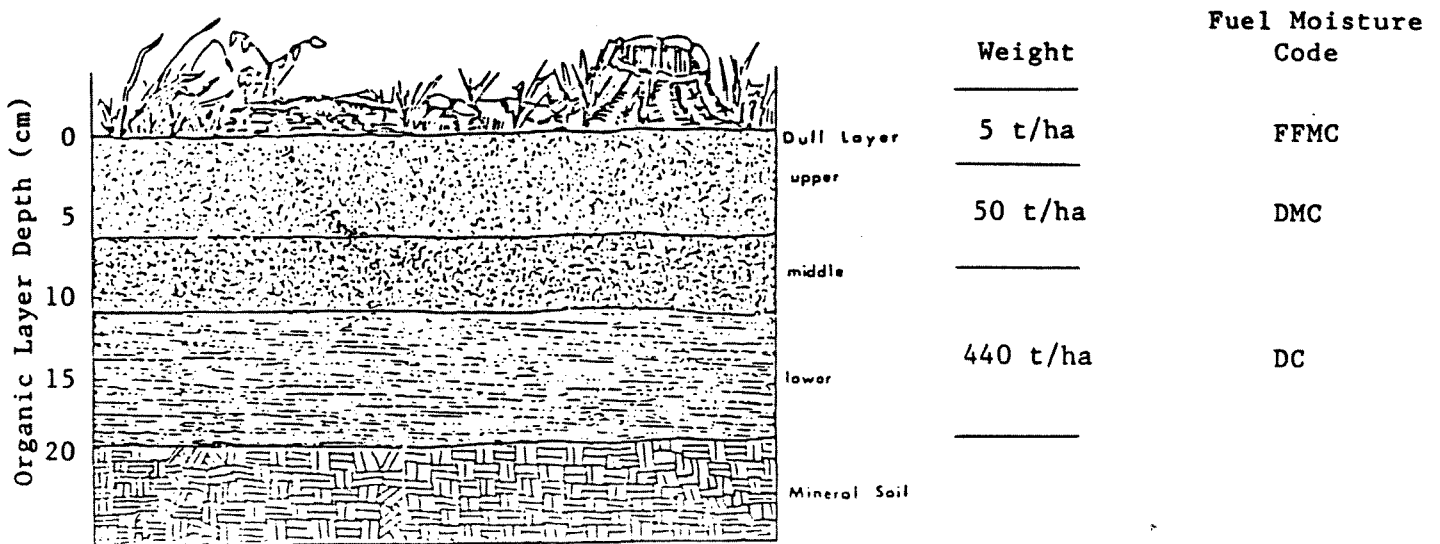


Figure 2. Representation of forest floor fuels by Fuel Moisture Codes of the FWI System.

FFMC values change rapidly because of a high surface area to volume ratio, and direct exposure to changing environmental conditions. This characteristic of rapidly changing moisture content causes the FFMC to have a short-term memory and only reflects the weather conditions that have occurred over the past three days.

The FFMC can be adjusted for times other than 1600 h LST (Van Wagner 1972, 1977; Alexander 1982a; Alexander et al. 1984) to account for changing moisture content of the fine fuels throughout the day or to allow for an irregular diurnal pattern of temperature or humidity.

Because fires usually start and spread in fine fuels, the FFMC is used to indicate ease of ignition, or ignition probability (Fig. 3). The FFMC scale ranges from 0-99 and is the only component of the FWI System which does not have an open-ended scale. Generally, fires begin to ignite at FFMC values near 70, and the maximum probable value that will ever be achieved is 96. At the high end of the scale, a general rule of thumb is that the fuel moisture content is 101 minus the FFMC value. Of importance is the fact that fire starts increase exponentially with an increase in FFMC values at the high end of the scale. In the boreal forest, a high potential for fire starts exists once the FFMC reaches 86-89.

Duff Moisture Code (DMC)

The DMC indicates the moisture content of loosely-compacted organic layers of moderate depth. It is representative of the duff layer that is 5-10 cm deep, and has a fuel loading of about 50 t/ha.

DMC fuels are affected by rain, temperature and relative humidity. Because these fuels are below the forest floor

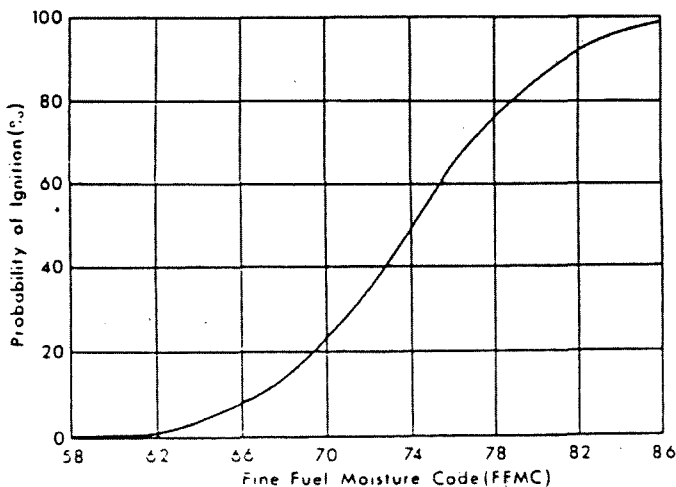


Figure 3. Ignitability of 'shaded' slash pine needle litter under 'no wind' conditions as a function of the Fine Fuel Moisture Code (adapted from Blackmarr 1972 by M.E. Alexander based on Van Wagner 1987).

surface, wind speed does not affect the fuel moisture content. A 24-hr rainfall of less than 1.5 mm has no effect on the DMC because of interception by the forest canopy and the fine fuel layer.

The DMC fuels have a slower drying rate than the FFMC fuels, with a timelag of 12 days. Due to the slower drying rate, the length of daily drying time is important. Therefore, a seasonal day-length factor has been incorporated into the drying phase of the DMC.

Although the DMC has an open-ended scale, the highest probable value is in the range of 150. The DMC is often used to assist in predicting the probability of lightning fire starts (Fig. 4) since lightning strikes usually result in fires smoldering in the duff layer.

Drought Code (DC)

The third moisture code is the DC, and it is an indicator of moisture content in deep, compact organic layers. This code represents the fuel layer approximately 10-20 cm deep, having a fuel loading of about 440 t/ha.

Temperature and rain affect the DC, although wind speed and relative humidity do not because of the depth of this fuel layer. A 24-hr rainfall greater than 2.8 mm is required to affect the moisture content due to interception by upper fuel layers and the forest canopy.

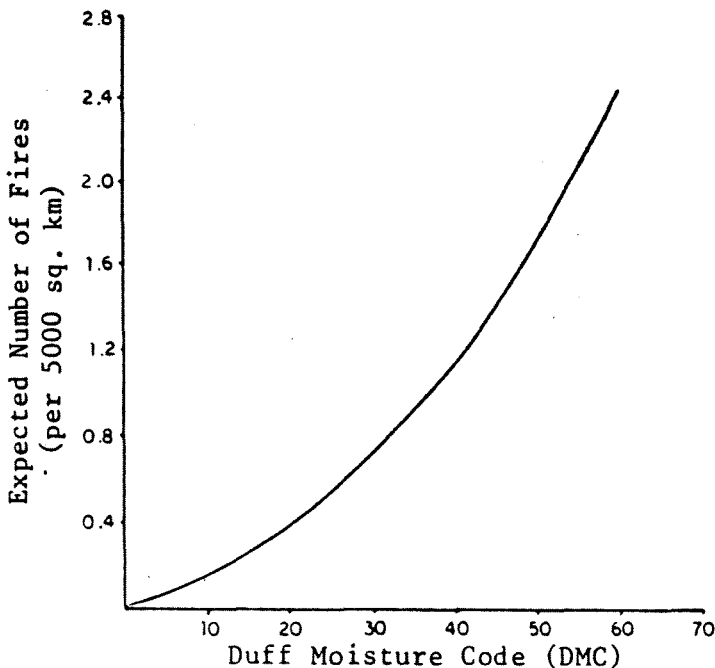


Figure 4. Typical relationship between DMC and lightning fire starts (adapted from Martell 1976).

The DC fuels have a very slow drying rate, with a timelag of 52 days. Therefore, a seasonal day-length factor is also incorporated in the drying phase.

The DC is indicative of long-term moisture conditions and can be used in estimating mop-up difficulty due to deep burning fires (Table 1). The DC scale is open-ended, although the maximum probable value is about 800.

Because of the slow drying rate of DC fuels, the amount of overwinter precipitation is critical to calculating spring starting values. If there has not been sufficient overwinter precipitation to recharge moisture levels in the deep organic layers, then an upward adjustment of the DC in the spring must be done to reflect the drier conditions (Turner and Lawson 1978; Alexander 1982b, 1983).

Table 2 provides a summary of features for all the Fuel Moisture Codes.

Fire Behavior Indices

Initial Spread Index (ISI)

The ISI combines the FFMC and wind speed to indicate the expected rate of fire spread (Fig. 5). Generally, a 13 km/h increase in wind speed will double the ISI value. The ISI is accepted as a good indicator of fire spread in open light-fuel stands with wind speeds up to 40 km/h.

Table 1. Mop-up recommendations as determined by the Drought Code (adapted after Muraro and Lawson 1970; Canadian Forestry Service, 1971).

DC	INTERPRETATION
< 300	Moisture will increase with depth. Usual attention to mop-up and patrol, with closer attention to critical perimeters as a DC value of 300 is approached.
300 - 500	Moisture content may decrease with depth. Extensive mop-up of edges should be initiated as control problems could be posed by critical edges.
> 500	Moisture content will most likely decrease with depth. Extensive mop-up and patrol of all edges is required.

TABLE 2. Summary of Fuel Moisture Code Features.

ITEM	FFMC	DMC	DC
Fuel Association	litter and other cured fine fuels	loosely-compacted organic layers of moderate depth	deep, compact organic layers
Fire Potential Indicator	ease of ignition	probability of lightning fires; fuel consumption in moderate duff	mop-up difficulty; fuel consumption of deep organic material
Depth (cm)	1 - 2	5 - 10	10 - 20
Fuel Loading (t/ha)	5	50	440
Required Weather Inputs:			
Dry-bulb Temperature	X	X	X
Relative Humidity	X	X	
Wind Speed	X		
Rain	X	X	X
24-hour Rainfall Threshold (mm)	0.5	1.4	2.8
Timelag Constant (days)	2/3	12	52
Value Range	0 - 99	0 - 350 ¹	0 - 1200 ¹
Maximum Probable Value	96	150	800
Spring Starting Value	85	6	15 ²

¹An open-end scale; the upper value is shown for convenience of comparing the relative range of scales.

²This value may be adjusted upwards to account for lack of sufficient overwinter precipitation.

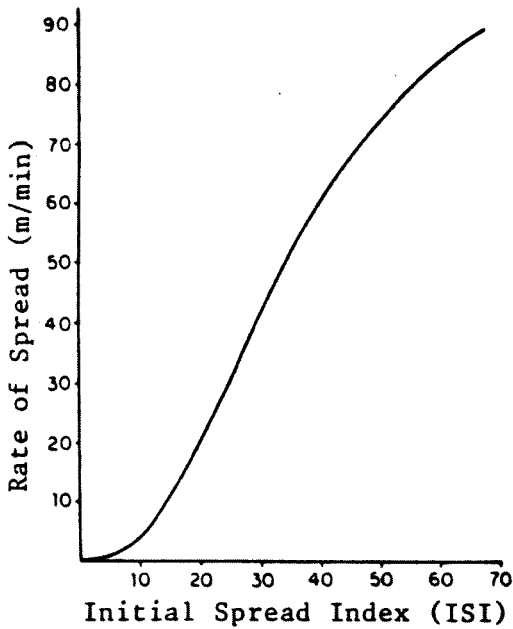


Figure 5. Rate of spread for the mature jack or lodgepole pine fuel type on level terrain as a function of ISI (from Alexander, Lawson, Stocks and Van Wagner 1984).

Buildup Index (BUI)

The BUI is a weighted combination of the DMC and DC to indicate the total amount of fuel available for combustion by a moving flame front (Fig. 6). The DMC has the most influence on the BUI value. For example, a DMC value of zero always results in a BUI value of zero regardless of what the DC value is. The DC has strongest influence on the BUI at high DMC values, and the greatest effect that the DC can have is to make the BUI value equal to twice the DMC value. This weighting procedure makes the BUI an upper organic layer moisture monitor with a deep duff indicator built in. The BUI is often used for presuppression planning purposes.

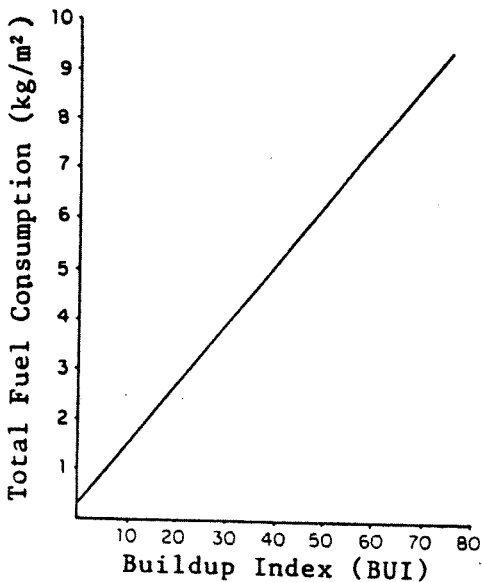


Figure 6. Relationship between total fuel consumption and BUI in jack pine slash (from Stocks and Walker 1972).

Fire Weather Index (FWI)

The FWI is a combination of ISI and BUI, and is a numerical rating of the potential frontal fire intensity (Fig. 7). In effect, it indicates fire intensity by combining the rate of fire spread with the amount of fuel being consumed. Frontal fire intensity is useful for determining fire suppression requirements, as shown in Alexander and De Groot (1988). As well, the FWI is used for general public information about fire danger conditions.

Operational Application

The FWI System provides relative numerical ratings of fire potential over a large area represented by an individual fire weather station site. Understanding the limits of such a system will ensure its proper application. For instance, to account for isolated rainfall at a weather station, the fire manager must also calculate a second set of FWI System values using no-rain to represent areas which did not receive any precipitation (the calculation using the actual rainfall at the weather station is used for the following days calculation). A recalculation of the FWI System would also have to be done if normal diurnal conditions did not occur between noon and the peak burning period. For example, this would typically be done after a frontal passage and would only be valid for that afternoon (but not used for the following days calculation).

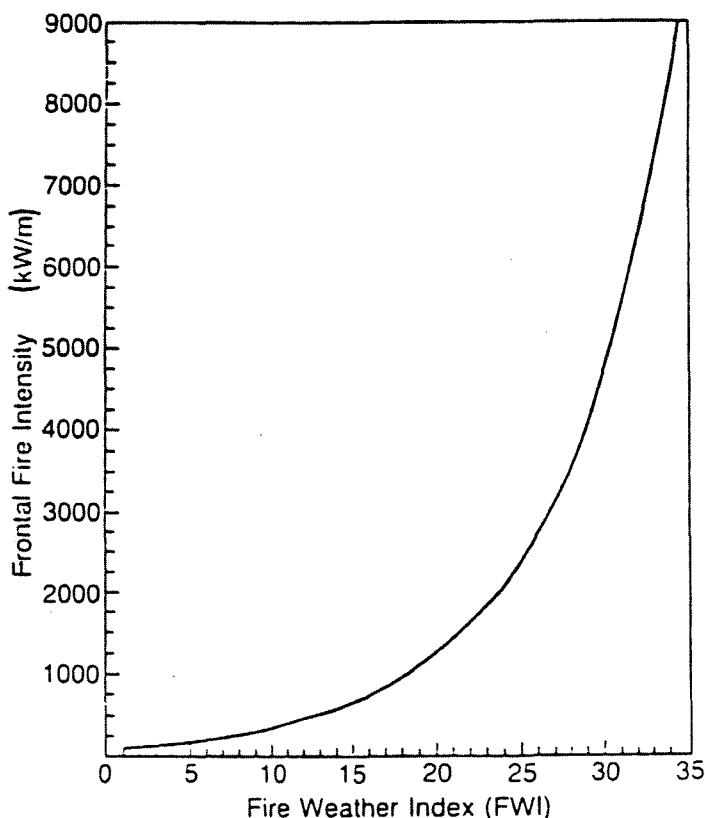


Figure 7. Frontal fire intensity in mature jack pine as a function of the FWI (from Alexander and De Groot 1988).

Concluding Remarks

An understanding of the sensitivity of the FWI System can only be gained by daily observation of the component values and changing weather conditions. By comparing fire activity (fire starts, rate of spread, difficulty of control, etc.) to the values produced by the FWI System, fire managers will gain an expertise in interpreting the FWI System.

ACKNOWLEDGEMENT

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