NEW DEVELOPMENTS IN FOREST FIRE DANGER RATING

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<u>New Developments in Forest Fire Danger Rating</u>

For several years a group of federal fire researchers have worked to produce a new system of forest fire danger rating for use across Canada. Some of this work was done at Petawawa, some at Victoria and some at Ottawa. The project was carried out cooperatively, each man contributing experience as well as material work. A great deal of correspondence and several full-scale meetings contributed to the end product. It would be difficult and not very sensible to pick out just the work done at Petawawa - therefore I will instead try to give you a picture of how the whole new system was put together and also what it represents.

Forest fire danger rating is a fascinating but exasperating branch of forest research. The goal is easily stated: Make an index such that any given value will always represent the same fire behaviour, no matter what weather history leads up to it. The trouble is, one quickly outruns the available practical knowledge and theory. A liberal dose of philosophy is therefore required as well. The steps described below are in neat order as if the new system was built up with perfect logic from start to finish. In actual fact there was a great deal of trial and error, backtracking, and revising before the final product emerged. The aim throughout was to retain as much of the present system as possible, building on its best features, and maintaining a link between old and new. As before, the system operates solely from daily weather readings taken at noon.

The new system is based on three classes of fuel of different drying rates, plus the effect of wind on fire behaviour, and the final index is a measure of fire intensity in a standard fuel type. It is no secret that much of the work on which the new system as well as the old is based was done in pine forests: the red and white pine of the Ottawa valley, the jack pine of central Canada, and the lodgepole pine of the West. The combined jack and lodgepole pine type therefore comes closest to our mythical standard.

The three classes of fuel embodied in the new system are:

- First, fine fuel. We are thinking here of finely divided material such as a litter layer of pine needles, about 1/2 inch deep and weighing 1/10 lb/ft^2 or 2 T/ac. Such a material is easily wet by rain and dries readily, but not by any means instantaneously.

- Second, the duff layer. This is a layer of decomposing organic matter about 3 inches deep below the litter and weighing about 1 lb/ft^2 or 22 T/ac.

- Third, we have long-term drought. Exactly what material this represents is not so definite. It could be 1 or 2 feet of organic matter in bogs or swamps, or a layer of mineral soil below the upland duff. In the latter case, drought might have some bearing on the availability of water for suppression, or on the foliar moisture in crown layers. In any case, the concept of drought in the new system is much longer-term and deeper-seated than in the old.

Another way to compare these three fuels is in terms of their drying times from saturation. Since in the new system each fuel dries exponentially (that is, it loses moisture quickly at first and then at a steadily decreasing rate as it gradually approaches an equilibrium level), the proper measure of drying time is the time constant or timelag, the time to accomplish about 2/3 of the change from saturation to equilibrium: The comparison is now easy and the three time constants for average weather are:

Fine fuel - 2/3 day
Duff - 12 days
Drought - 52 days

For each of these fuels a subsidiary index was developed with two phases, one for wetting by rain and one for drying. Each index is in fact a book-keeping system, adding water after rain and subtracting some for each day's drying. We decided to present each in code form with values rising with dryness to produce the best psychological effect. Since the drying times and amounts of rain required for saturation are so different, any one of the three moisture codes may be high or low in opposition to the others. Thus two or three good days' drying after heavy rain will produce a high fine fuel code while the duff code is still very low. Conversely, a light rain after a long dry period will result in a low fine fuel code while the duff code remains high. Finally, the drought code may rise or fall gradually while the other two fluctuate many times.

Actually, the fine fuel moisture code is an adaptation the original tracer index constructed by Wright and Beall. The duff moisture code is based on new field data from Petawawa, and the drought code was designed at Victoria. Once we had the three moisture codes the first and more straight-forward stage of the work was complete. The second stage, relating these moisture codes to fire behaviour, was somewhat more difficult, since it soon became clear that there is as yet no acceptable theory of how fire reacts to fuel moisture and wind over the whole natural range of behaviour.

The final index, called the fire weather index (FWI), is a measure of fire intensity, that is, energy output rate per unit length of front, in the standard fuel type. To calculate the FWI, we needed a function for each fuel moisture code and for wind.

The wind function chosen is a simple exponential that doubles the index for every increase of 12 mph. This is a somewhat stronger wind effect than exists in the present system.

The best available information on the effect of fine fuel moisture, in the absence of theory, is still the mass of test fire data on which the present system is based. An average curve representing fine fuel moisture effect on the present system was therefore adapted for use in the new system.

The wind and fine fuel moisture effects were combined to produce an intermediate called the Initial Spread Index. To obtain the desired intensity rating, duff moisture must then represent the amount of fuel consumed. In other words, as the duff dries, more and more fuel is released to increase fire intensity. The function finally chosen was again drawn from the present system, extended to an indefinite time limit with the help of some theory and experience.

Long-term drought was introduced into the new system by blending the drought code with the duff moisture code before applying the duff function. The weight given to the drought code is small and variable, but it may as much as double the duff moisture code at very high drought. This adjusted duff moisture code thus represents more fuel than the duff moisture code alone.

The final step was to design a scale on which to present the FWI. By plotting the known intensities of some experimental fires of moderate size against the present danger scale, a link was obtained between the new and old systems. A simple intensity scale was ruled out, however, since numbers up to 20,000 or so would be necessary. A percentage-type scale of 0 to 100 also proved impractical, since the problem of an artificial ceiling would still remain. Finally a scale was designed that is open-ended. Normally the level of 100 will occasionally be exceeded, and it is unlikely that 200 will ever be reached. The point is, however, that a higher value will always be possible if the fire weather worsens. A point worth noting is that the entire new system has been reduced to mathematical equations so that computer calculation is readily done.

The first question you may ask is: How is the new system better than the old? Some ways are:

It has a stronger, more realistic wind effect.
It reacts more strongly to temperature.
It reacts to seasonal change in day-length.
It portrays better the effect of heavy fuel moisture.
It has a longer, open-ended scale.
It allows comparison of fire weather all across Canada.
The final index has a more definite physical meaning.

A second question might be: What exactly does the FWI mean? According to how the system was built up, the FWI should be a measure of the intensity of a single fire. Since it contains several effects, obviously a particular index value can be obtained by many different combinations of weather and weather history. The subsidiary moisture codes and initial spread index will yield useful information about what effect is most prominent on a given day. For example, ease of ignition might be best indicated by the fine fuel moisture code. It is not possible to be sure as yet how well the new index will correlate with empirical measures of fire business such as number of fires, area burned, or cost of fire-fighting. Naturally, we expect that the FWI or one of its components will be good indicators of all these matters.

Still another question might be: Where does the new index apply? The ultimate criterion of a fire danger rating is that a given index value should represent the same fire behaviour no matter what weather history leads up to it. This is a very stiff test, and obviously the FWI should apply best in the forest types where the main work was done, namely in pine stands. Nevertheless, it is expected that fair correlation between index and actual fire behaviour can be obtained in many other forest types, so that the FWI can be accepted as a general measure of fire weather. In any event, the whole problem of differences in fire behaviour among fuel types is receiving high priority in the Forestry Service's fire research group.

Finally, the new FWI number scale will take some time to get used to. A division into classes of low, moderate, and high, etc., will be required as before. Here, because the range of weather is so different across Canada, it is expected that a different class breakdown will be designed for each province or region. That is, the same weather will produce the same number but not necessarily the same designation in different regions.