COMPARISON OF PETAWAWA MARK IV AND B. C. MARK II DROUGHT INDEXES

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The severity of a fire season is strongly dependent on the periodicity and amount of precipitation occurring during the summer months. In forests of the north temperate region the proportion of fuel available for combustion is largely dependent on the cumulative drying of the large size, slow drying fuel components. It is not surprising that a parameter of the moisture content of these fuels is an integral component of all Fire Danger Ratings Systems designed for this zone.

As a result of the decision to revise the Canadian Fire Danger Rating System a number of parameters of the moisture content of the slow drying fuel components were proposed. The Petawawa Mark III developed by Van Wagner at Petawawa and the B. C. Mark II developed by Turner, together with members of the B. C. Regional Fire Research Section, were two such indexes discussed at the Calgary meeting in May 1967. As a result of field testing and further work both indexes have been changed, the B. C. Mark II only so far as computation techniques. However, the Petawawa has undergone sufficient changes to justify the new nomer of Petawawa Mark IV.

The B. C. Mark II index was designed to parameter the moisture regime in organic layers having moisture holding properties similar to the samples displayed. These organic layers are common to all areas of the Coast, Subalpine, Columbia and Boreal Forest regions of British Columbia. In the Montane Forest Region they occur on all but the extremely dry lodgepole pine and ponderosa pine sites.

These organic layers are generally composed of an integrated moss and litter layer overlying a dense fermentation and humus layer often consisting largely of rotten wood and nearly always containing a fair proportion of living roots. The depth of these organic layers varies, being generally deeper on wet or poorly drained sites and more shallow on drier sites. The characteristics of the samples are included in Table I.

Table I. Characteristics of organic samples.

Sample	Wt.* Lbs.	Depth Inches	Area $Ft.^2$	Vol. $Ft.^3$	$Lbs/Ft.^2$
1	.35	2.5	.17	.036	2.06
2	.26	2.0	.17	.029	1.53
3	.25	2.2	.17	.032	1.47
4	.53	3.5	.15	.044	3.53

*Air dried only -- 9 months in laboratory where average conditions are 70° F and 30% R.H.

If we presuppose the index is a satisfactory reflection of the general drying trend of the organic layers described and if similarity of surface appearance is any criteria of the general moisture retention characteristics, then it is likely the B. C. Mark II Index would be applicable to the remainder of the Canadian Boreal Region. Applicability to the wetter areas of the Great Lakes and Acadian Regions also seems appropriate. The proportion of Canadian land area where the B. C. Mark II Index is thought to be applicable is shown in Figure I.

FIGURE I

As a result of the discussions concerning the two Indexes at the Calgary meeting in May 1967 it was decided to utilize all possible opportunities of comparing the Indexes during the 1967 fire season. In accord with this decision, all readily available data from field studies and wild fire action was analyzed and related to the two Drought Indexes in question. The data accumulated was from four main sources.

(1) wild fire action in British Columbia during the 1967 fire season

(2) destructive sampling for organic layer moisture content

(3) fire impact studies from B. C. 608 and B. C. 606

(4) observation and experience

The fourth source must be recognized because, regardless of the results of these discussions this factor is most important from the user's point of view.

Wild Fire Action

If the drought index is accepted as being a good relative index of fire season severity then the general fire load should be reflected in the drought index. The Petawa Mark IV Index and the B. C. Mark II Index was plotted for four stations in the Nelson and Kamloops Forest District.

FIGURE 2. COMPARISON OF DROUGHT INDEXES -- SHUSWAP FALLS 1967

Figure 2 shows the Petawawa Mark IV Index and the B. C. Mark II Index with the date and amount of rain for the 1967 fire season. On this figure there are two areas of significances: the first is the striking similarity of the two indexes at the lower values and the very similar drying rates when the B. C. Mark II Index is on the standard drying rate. The second is the pronounced difference in length of period affected by rainfall at the higher drought index numbers. Consider the three rains of July 7, 19 and August 4, the bracketed numbers following the effective period is the mean daily moisture loss in inches.

		Effective Period (Days)	
Date of Rain	Amount	B. C. M. II	Pet. M IV
July 7	.27	3 (.09)	11 (.024)
July 19	.12	2 (.06)	7 (.017)
Aug. 4	.37	4 (.09)	22 (.017)

FIGURE 3. COMPARISON OF DROUGHT INDEXES -- CRANBROOK 1967

Figure 3 which shows the drought indexes for Cranbrook reveals the same characteristics as Figure 2. The essentially similar reaction at the lower levels and a similar rate of drying during the standard rate are apparent. Again, even more striking in this case, is the difference caused by the .13 inches of rain on August 7. The implications of the effect of this small amount of rain are of even greater significance because the seasonal peak is displaced by three weeks, the Petawawa Index never recovering from this rain even after the 23 days shown. The effect of the rainfall of .07 on July 19 is also quite different but does not have the psychological impact of displacing the period of relative severity.

FIGURE 4. DROUGHT INDEXES AND FIRE ACTION -- CHASE 1967

Figure 4 shows the similarity of standard drying rates indicated in the previous two figures. From this figure the effective periods for the rain occurring on the same day as those at Shuswap Falls are compared below; as in Figure 2 the bracketed figures are the daily moisture loss in inches.

		Effective Period (Days)		
Date of Rain	Amount "	B. C. M. II	Pet. M IV	
July 7	.15	2 (.075)	14 (if continued)	.015
July 19	.53	10 (.053)	18 (if continued)	.029
Aug. 4-6	.18 + .08	3 (.086)	14	.018

On this figure Kamloops Forest District fire action in terms of total manpower is shown on a logarithmic scale. Periods of varying degrees of activity which coincide with high periods of both indexes are obvious. The manpower peaks coinciding with the rains mentioned previously are in part at least to the lightning fires associated with the rains. The leveling off in the latter part of August indicates the fire load saturation point rather than a decreasing severity.

FIGURE 5. DROUGHT INDEX AND FIRE ACTION -- CRESTON 1967

The comparison of Drought Indexes and fire action in the Nelson Forest District during 1967 reveals many of the same characteristics as the fire action comparison for Chase. Again the similarities at the lower index levels and the similar drying rates are apparent. The inconsistencies in fire action are due to the same causes as those mentioned for Chase. Note the difference in the Petawawa Index value calculated at Creston and Cranbrook -- the difference being caused by the .13 inches of rain on August 7.

FIGURE 6. REGRESSION OF DROUGHT INDEXES AND BURNED ACREAGE -- CRESTON

The regression of the weekly burned acreage in the Nelson District and the highest drought index for the week calculated at Creston is shown in Figure 6. The equations for the lines are $Y = 1.05 + .015$ and $Y = 1.11 + .02X$ for the B. C. Mark II and Petawawa Mark IV Indexes respectively. The respective correlation coefficients are .80 and .78. The similarity of these correlation coefficients are understandable when the similarity of the indexes from Figure 5 is recalled. In Figure 7 the regression of burned acreage in the Kamloops District and the Drought Indexes calculated at Chase, B. C. are shown.

FIGURE 7. REGRESSION OF DROUGHT INDEXES AND BURNED ACREAGE -- CHASE

In this figure there is a significant difference in the correlation coefficients of the two indexes; for the B. C. Mark II it is .77 and for the Petawawa Mark IV it is .61. This difference is meaningful when the difference in the drought indexes shown in Figure 4 is considered. The figures beside each point in both figures are the chronological order of the weeks commencing in June. The larger acreages burned in the last few weeks verify the reason of fire load saturation for the leveling off of man power on Figures 4 and 5 for the latter part of August.

Destructive Samples of Organic Layers

Project B. C. 608, "Development of a Burning Index and Guidelines for Prescribed Burning in Spruce Balsam Logging Slash" offered an opportunity to test the ability of the two drought indexes to indicate the moisture content of the organic layer. On this area located at an elevation of about 2800 feet near the south end of Macleod, the organic layers are typical of those displayed with the exception of having a less luxuriant growth of moss and were generally more shallow. Two samples are described below.

Sample	Wt. O.D. Gr.	Depth Inches	Area $Ft.^2$	$Lbs./Ft.^2$
1	379.8	1.8	.73	1.14
2	575.4	2.4	.79	1.59

Sample number 1 and 2 included 27 and 144 grams of roots, respectively. These roots were large and easily removed; an unknown proportion of smaller roots remained.

From each of the 46 plots shown on Figure 8 three composite samples of the upper organic layer and three composite samples of the lower organic layer were taken prior to each burn.

FIGURE 8. MAP OF STUDY AREA, MACLEOD LAKE, B. C. 608 - 1967

The Macleod Lake plots were burned from June 19th through to August 24.

The B. C. Mark II Drought Indes and the Petawawa Mark IV for the season, including this period, is shown in Figure 9.

FIGURE 9. COMPARISON OF DROUGHT INDEXES -- MACLEOD LAKE 1967

The regression of the destructive samples of the upper and full organic layer moisture contents and the two drought indexes are shown in Figure 10.

FIGURE 10. REGRESSION OF MEAN TOP ORGANIC AND FULL ORGANIC MOISTURE CONTENT WITH B. C. MARK II AND PETAWAWA MARK IV DROUGHT INDEXES.

These values plotted ~~in chronological order~~ on the auxiliary figures A and B show the variation in moisture content due to location. Although these figures show the general drying trend they also show the wide variation in moisture content due to factors other than weather.

The inconsistencies in moisture content due to location are even more striking when figure 11 is examined. The relation shown in Figure 11 is from

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FIGURE 11. FULL ORGANIC M.C., MEAN OF FOUR SAMPLES FROM SELECTED LOCATIONS

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the mean of four samples of the full organic layer under a seed block adjacent to the study area. Shortage of help prevented this type of sampling for the major part of the summer as was intended and the samples shown were commenced on a daily basis from August 19 and continued to September 2. The sample at the lower right of 157 percent was taken on September 11 after a total of 1.28 inches of rain had fallen since September 1. The point on September 2 at 79 percent M.C. had sustained a rainfall of .26 inches of rain since the previous day's M.C. of 37.7 percent. The equations for these lines are $Y + 188.4 - .75x$ and $Y = 124.0 - 2.46X$ for the B. C. and Petawawa Indexes respectively, their correlation coefficients are -.95 and -.63 respectively. The moisture content of the upper mineral soil on September 11 was 13 percent, relatively dry for these fine textured soils. This relatively low soil moisture content indicates that the 1.28 inches of rainfall that occurred since September 1 had hot penetrated the entire organic layer. This again illustrates the strong stratification of moisture in organic layers similar to those displayed.

Fire Impact Studies

The last means of comparing the two Drought Indexes is perhaps the most meaningful, this is the comparison of the Drought Indexes through analysis of the amount of organic material removed by prescribed fires. An index that can confidently be applied to this purpose becomes an invaluable tool for selecting necessary weather regimes to accomplish a predetermined treatment. Such an index can also be applied to determine damage potential of wild fires to wildland values other than timber. A meaningful index that can be related to fire impact is a necessary priority before relating the fire characteristic of intensity to the fire danger rating system. Figure 12 shows the regression of organic layer depletion in percent and the B. C. Mark II Drought Index. Note the strong correlation coefficient of .80 using the Macleod Lake data. To test this prediction capability, depletion data from the six burns on Mabel Lake were also plotted; with this data the correlation coefficient is strengthened to .95. Only the B. C. Mark I Index and Turner's soil moisture index showed regressions that even approached the Mark II. In this regression, percent depletion rather than absolute depletion was used to avoid the complications of a transition in organic layer depths.

FIGURE 12. REGRESSION OF PERCENT DEPLETION OF ORGANIC LAYER AND B. C. MARK II INDEX

Various other indexes including the Petawawa Mark II and Mark IV, U.S. national buildup, and the Canadian 25 day system are on the subsidiary scattergrams. Regressions for these systems were not calculated because of the bimodal distribution of the sample population.

To conclude this comparison, I can only add my own personal observations during the Macleod Lake project. There is no doubt that conditions were much drier at the end of August than on July 19 where the Petawawa Index shows the most extreme condition. Surface water was still present on July 19 which continued to decrease up to the time of the September rains. A small creek which had to be forded during the early part of the season ceased showing surface water on about July 10. Surface water showed for one day on July 20 never to reappear in 1967 not even after the early September rains. Traversing the area with vehicles was still extremely difficult in mid-July and it was not until mid-August that ease of vehicular traffic was achieved. The rate of drying of surface drainage from puddles coincided roughly with recuperation of the Mark II. The increasing severity of the situation was amply verified by the increasing fire intensity on the test plots.

These observations are verified, in principle at least, by the feelings of the Prince George Protection Personnel who had no doubt of the greater severity during the late August period over that which existed in July.

The evidence offered in this paper shows the B. C. Mark II Index to be a more realistic parameter of moisture content in organic layers similar to those displayed than the Petawawa Mark IV. The Petawawa Mark IV Index is probably more applicable to the relatively uncompacted organic layers in the drier areas of the Great Lakes Forest region, however, the relative scarceness of these organic layers precludes the use of the Petawawa Mark IV Index as a component of the revised fire danger rating system.