# APPENDIX 3

## LATITUDE CONSIDERATIONS IN ADAPTING THE CANADIAN FOREST FIRE WEATHER INDEX SYSTEM FOR USE IN OTHER COUNTRIES

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## Introduction

Latitude, along with season or time of year, influences the effective day length (Fig. A3.1) and thereby the amount of drying that occurs on any given day. For example, a day in June in British Columbia at 54° latitude has almost twice the drying power as a day in September with the same weather conditions (Lawson 1977).

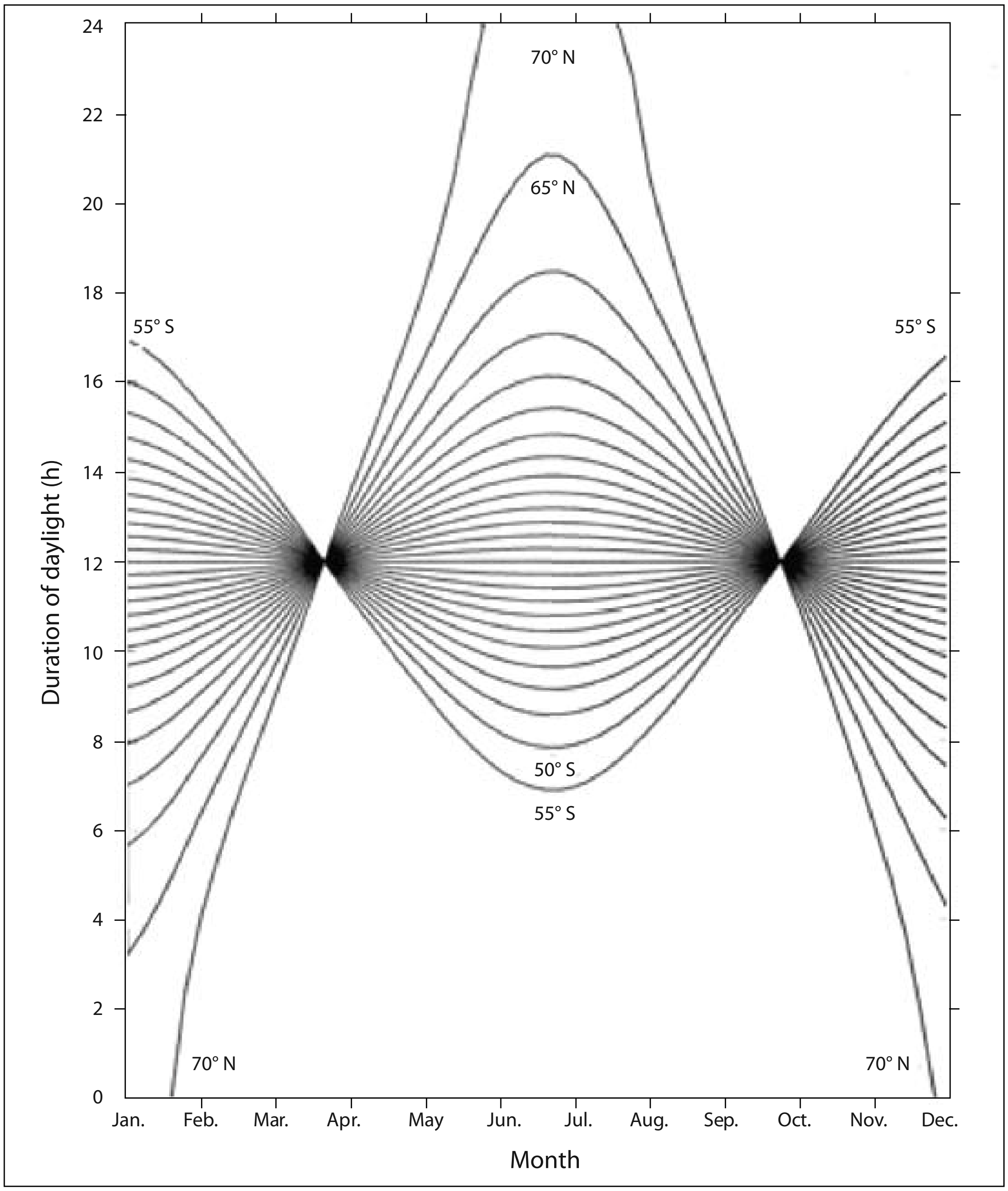


**Figure A3.1 Duration of daylight as a function of time of year and latitude for the wildland fire-prone regions of the world, based on equations given in Whiteman and Allwine (1986).**

In the development of the Canadian Forest Fire Weather Index (FWI) System, these seasonal effects were accounted for in the Duff Moisture Code (DMC) by an effective day length factor ($L_e$) and in the Drought Code (DC) by a seasonal day length adjustment factor ($L_f$). Details regarding the derivation of $L_e$ and $L_f$ were presented by Van Wagner (1970) and Turner (1972), respectively, and will not be covered here, except to say that the derivation of both factors was largely empirical, although for the DMC, "The daylength, varying with season, has an effect roughly proportional to three less than the number of hours between sunrise and sunset" (Van Wagner 1987).

The FWI System was originally designed for the range of fuel and weather conditions found in Canada. However, increasing foreign use of the FWI System and the Canadian Forest Fire Danger Rating System (CFFDRS) has dictated that certain international standards be established. The purpose of this appendix is to discuss how day length considerations in the calculation of the DMC and the DC should be handled for locations outside of Canada.

## Canadian Standards and Latitude Effects

The effective range of latitude for lands prone to wildfire within Canada is over 25° (i.e., from about 42° N to about 68° N). As presented by Van Wagner and Pickett (1985) and Van Wagner (1987), a single set of monthly values for $L_e$ and $L_f$ have been assigned for Canada as a whole (see first row of Table A3.1 and Table A3.2, respectively). These quantities are referred to collectively as the "Canadian standard" (Van Wagner 1987) and are, strictly speaking, valid for only one latitude. This has generally come to be considered as 46° N because the fieldwork associated with the development of the DMC and in turn the $L_e$ values was undertaken at the Petawawa Forest Experiment Station in eastern Ontario, (Van Wagner 1970), although Valentine (1978) considered the reference latitude to be 45° N. However, the $L_f$ values associated with the DC were based on data from 32 climatic stations in British Columbia (Turner 1972), which effectively cover a latitude range from about 49° N to about 60° N.

**Table A3.1 Monthly day length adjustment factors for Duff Moisture Code ($L_e$) in relation to reference latitudes, exclusive of the equatorial region[a]**

| Reference latitude | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ~46° N[b] | 6.5 | 7.5 | 9.0 | 12.8 | 13.9 | 13.9 | 12.4 | 10.9 | 9.4 | 8.0 | 7.0 | 6.0 |
| 20° N | 7.9 | 8.4 | 8.9 | 9.5 | 9.9 | 10.2 | 10.1 | 9.7 | 9.1 | 8.6 | 8.1 | 7.8 |
| 20° S | 10.1 | 9.6 | 9.1 | 8.5 | 8.1 | 7.8 | 7.9 | 8.3 | 8.9 | 9.4 | 9.9 | 10.2 |
| 40° S | 11.5 | 10.5 | 9.2 | 7.9 | 6.8 | 6.2 | 6.5 | 7.4 | 8.7 | 10.0 | 11.2 | 11.8 |

[a] $L_e$ = 9.0 for all months for areas lying between 10° N and 10° S latitude.
[b] Canadian standard (Van Wagner and Pickett 1985; Van Wagner 1987).

**Table A3.2 Monthly day length adjustment factors for Drought Code ($L_f$) for northern and southern hemispheres, exclusive of the equatorial region[a]**

| Reference hemisphere | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Northern[b] | −1.6 | −1.6 | −1.6 | 0.9 | 3.8 | 5.8 | 6.4 | 5.0 | 2.4 | 0.4 | −1.6 | −1.6 |
| Southern | 6.4 | 5.0 | 2.4 | 0.4 | −1.6 | −1.6 | −1.6 | −1.6 | −1.6 | 0.9 | 3.8 | 5.8 |

[a] $L_f$ = 1.4 for all months for areas lying between 10° N and 10° S latitude.
[b] Canadian standard (Van Wagner and Pickett 1985; Van Wagner 1987).

Van Wagner (1970) initially addressed the issue of latitude effects on the DMC in his publication documenting the development of the DMC. He concluded that no correction for latitude was necessary given what is known about the total dose of solar energy varying with latitude and date, although he acknowledged that "some tests … would be desirable." His reasoning went as follows:

> Consider, for example, the difference in this quantity between latitudes 45 and 55. On June 22, the longest day of the year, the respective energy doses are within 1% of one another, since the longer day length at 55° just compensates for the lower angle of the sun. By September 22, when all latitudes have a 12-hour day, the energy received at 55° is still 80% of that received at 45°. The difference by then becomes unimportant, since the daily drying factors are much diminished by lower temperatures.

Later on, Van Wagner (1987) examined latitudinal effects on the DMC and DC at 45° N, 55° N, and 65° N using theoretical day lengths and daily weather data. He found that the effect of latitude was fairly gradual, and the resultant differences in season average and maximum values (Table A3.3) were not judged serious or great enough to warrant special DMCs or DCs for different latitudes.

**Table A3.3 Results of latitude testing of modified Duff Moisture Code (DMC) and Drought Code (DC) values based on theoretical day lengths for three different locations versus the standard values for a single season of fire weather data (April–October 1967, Lac La Biche, Alberta) (adapted from Van Wagner 1987)**

| Statistic | 45° N | 55° N | 65° N | Canadian standard |
|---|---|---|---|---|
| DMC season average | 34.5 | 32.4 | 30.0 | 31.9 |
| DMC maximum value | 85 | 83 | 78 | 88 |
| DC season average | 312 | 302 | 274 | 293 |
| DC maximum value | 523 | 497 | 436 | 495 |

## DMC Effective Day Length Factors and DC Seasonal Adjustments for More Southerly Latitudes

Valentine (1978) was the first to derive a specific set of DMC $L_e$ values for a geographic location quite different from Canada, namely New Zealand. Using Nelson as the central point in the country (at about 41° S), Valentine (1978) computed monthly $L_e$ values by subtracting 3 h from the number of hours of sunshine reported in the New Zealand almanac. These values were in turn used in computer and manual calculations of the DMC. Later on, New Zealand adopted a set of $L_e$ values proposed by Alexander (1993) for 40° S latitude (Table A3.1), on the basis of the theoretical mean day length for each month (less 3 h), as computed from formulas presented by Whiteman and Allwine (1986). These were used to produce the DMC and DC drying factor tables found in the FWI System tables now used in New Zealand (NRFA and NZFRI 1993).

In 1992, the author of this appendix, as a member of the Forestry Canada Fire Danger Group, made a proposal (subsequently accepted by the group as a whole) that the $L_e$ and $L_f$ values for latitudes other than Canada be standardized. On the basis of an earlier suggestion by Van Wagner (1988) and the fact that Canada uses a single set of $L_e$ values over a range of latitude of about 25°, reference latitudes of 20° N and 20° S were selected as representing the ranges from 10° N to 30° N and from 10° S to 30° S, respectively. Latitude 40° S, as originally selected by the author for New Zealand (Alexander 1993), was adopted as the other reference point in the southern hemisphere, on the grounds that the need to apply the associated $L_e$ values to any land mass of interest would not extend beyond 55° S. $L_e$ values were computed as per Whiteman and Allwine (1986), using the theoretical mean day length for each month less 3 h (Table A3.1). de Groot and Field (2004) reproduced these values in their documentation of the Southeast Asia Fire Danger Rating System.

Thus, the reference values for $L_e$ (Table A3.1) would be used as follows:

- For areas at the same latitude as Canada and further north, use the Canadian standard values.
- For areas south of Canada to latitude 30° N, use the Canadian standard values.
- For areas between 10° N and 30° N, use the values for 20° N.
- For areas between latitude 10° S and 30° S, use the values for 20° S.
- For areas between latitude 30° S and 55° S, use the values for 40° S.

To give a few practical examples, countries in Europe, including Turkey and all of Russia, as well as the state of Alaska in the United States, would use the Canadian standard values. Honduras, Fiji, and New Zealand would use the values for reference latitudes 20° N, 20° S, and 40° S, respectively.

Inherent in the 1992 proposal but not explicitly stated was the intention that for areas near the equator (i.e., 10° N to 10° S), which experience nearly equal hours of daylight and night, $L_e$ would be simply 9.0 (i.e., 12 h – 3 h [Van Wagner 1970, 1987]). Indeed, de Groot et al. (2007) set $L_e$ = 9.0 in their adaptation of the FWI System for Indonesia and Malaysia by taking the average of the mean $L_e$ values for reference latitudes 20° N and 20° S (de Groot and Field 2004).

The author's 1992 proposal included a very simplistic approach with regard to the $L_f$ values for the DC. Because of their highly empirical nature, the decision was made to simply reverse the standard values used in Canada for seasons in the southern hemisphere (cf. List 1951, p. 506), the sole exception being the equatorial region. In other words, the $L_f$ used in Canada in July was deemed applicable for January in the southern hemisphere, Canada's August values would be used for February in the southern hemisphere, and so forth (Table A3.2). There was no consideration for any intermediate reference latitudes as there was for the $L_e$ values for DMC. For areas near the equator (i.e., from 10° N to 10° S), the simplest solution was deemed to be using the mean DC day length adjustment value (i.e., $L_f$ = 1.4) year-round, similar to what de Groot et al. (2007) did in their adaptation of the FWI System for Indonesia and Malaysia; the value of 1.4 was based on the annual average value for the northern and southern hemispheres (de Groot and Field 2004).

## Discussion and Conclusions

The concepts outlined here have been implemented in the global FWI System calculator contained in the CD-ROM-based training course "Understanding the Fire Weather Index System" (Alexander et al. 2002; St. John and Alexander 2004).

The following question naturally arises: Why retain a tabular approach, as suggested here, when in fact it is quite possible in this modern digital world to make point-based calculations for $L_e$ (as frequently as daily)? There are at least three reasons for continuing to do so:

- In Canada, one set of values has been used over a relatively large range in latitude for nearly 40 years. Furthermore, Van Wagner's (1987) analyses suggest that the latitude effect is quite gradual.
- Should a change be made in the way day length is entered in calculations of DMC and DC, any past calibrations between fire danger ratings and fire activity (e.g., Viegas et al. 1999; Dymond et al. 2005) would be rendered invalid. This would be especially significant in Canada, given the number of calibration studies of various sorts that have been undertaken. It would also negate the validity of any fire management guidelines (e.g., preparedness system levels), decision aids and guides, or heuristic rules of thumb.
- The difference in the DMC values between tabular and point-based calculations of $L_e$ (using either daily or mean monthly day lengths) are, in all likelihood, small.

Although there may be an overriding desire to present fire danger rating information on a broad regional or global basis, in the form of the FWI System components (Camia et al. 2006; de Groot et al. 2006), and even though it would be feasible to display the information spatially, the fact of the matter is that in a good many instances it would not be desirable or even relevant to do so (e.g., in an extremely arid country with limited accumulation of organic matter). This is because many regions of the globe simply do not have a forest floor layer or the forest floor layer that is present does not necessarily warrant assessment by the DMC, let alone the DC.

At the outset, it seems conceivable that the tabular approach recommended here could lead to discontinuities in countries that span an area north and south of latitudes 30° N, 10° N, 10° S, or 30° S. However, a close look at a world map indicates that, with a bit of common sense, there should be very few problems in implementing the recommendations outlined here. For example, the $L_e$ values for 20° N should be used for all of Mexico, even though the very northern parts of the country extend just above 30° N latitude. Conversely, Florida and southern Texas lie below 30° N but would be best served by the Canadian standard values used in the remainder of the continental United States. The very northern portion of South America, which extends to about 12° N should use the equatorial values of $L_e$. Similarly, all of South Africa would use the 20° S values of $L_e$, even though the most southerly portion of the country extends to 35° S. Argentina extends from about 22° S to about 55° S, but since the bulk of the country lies below 30° S, it makes sense to use the reference $L_e$ values for 40° S latitude throughout the country.

Australia, which spans a latitudinal range from about 10° S to about 43° S, effectively straddles both the 20° S and 40° S reference latitudes. The simplest solution is to apply the 40° S $L_e$ values to Tasmania and the forested regions of Western Australia, South Australia, Victoria, the Australian Capital Territory, New South Wales, including its northeastern coastal region (which lies north of latitude 30° S), and southeastern Queensland (which also lies north of 30° S). For the remainder of country, the 20° S $L_e$ values would apply.

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