TECHNOLOGY TRANSFER NOTES
Forestry Research Applications Pacific Forestry Centre No.6 October, 1997

Predicting Forest Floor Moisture Contents from Duff Moisture Code Values

B.D. Lawson, G.N. Dalrymple, B.C. Hawkes

Strategic Importance

Wildfires continue to be a dominant force on Canada's landscape, affecting patterns of flora and fauna, forest management activities, resource values, property and even human life. In Canada, approximately $500 million is spent annually on fire management activities. Fire managers are facing increased demands and diminishing budgets. Consequently, the reliability of predictive models is a major concern.

The Canadian Forest Fire Danger Rating System (CFFDRS) has proven to be a reliable tool in directing fire management activities. Initiated by Canadian Forest Service researchers in the late 1960s, the CFFDRS continues to evolve as new information becomes available. Continued research is required to refine and expand the system's ability to predict various aspects of fire behavior, occurrence and effects.

The CFFDRS combines two major systems, the Fire Weather Index (FWI) System and the Fire Behavior Prediction (FBP) System. The FWI system is comprised of three moisture codes and three indexes of fire behavior. The moisture codes track the relative moisture content of three forest floor components. A brief summary of the three moisture codes is provided below.

Moisture content[1] is the main factor controlling a forest fuel's ability to ignite and sustain combustion; a low moisture content means less energy is required to ignite a fuel. The three codes indicate how the moisture content of the different forest floor layers react differently to drying and wetting.

FWI Code	Correlation	Nominal Fuel Depth	Time Lag
Fine Fuel Moisture Code (FFMC)	Litter	1.2 cm	2/3 day
Duff Moisture Code (DMC)	Loosely Compacted Duff	7 cm	15 days
Drought Code (DC)	Deep Compact Organic	18 cm	53 days

Knowledge of duff moisture content is particularly important to:

- Start a weather station late in the fire season;
- Predict smoldering ignition for forest duff types; and,
- Compare the prediction systems for forest floor consumption with those used in other countries.

Duff Moisture Code (DMC)

The DMC is a numerical rating of moderately deep forest floor dryness (basically the soil F layer, also referred to as duff). The flammability of the duff layer is important because duff consumption is one of the main sources of the energy produced in forest fires. The weather factors

[1] Moisture content is defined as the amount of water present in a fuel expressed as a percent of the oven dry weight of the fuel.

involved in the DMC calculation are daily rainfall, temperature and humidity. The amount of drying also varies with day length. Generally, duff fuels dry more slowly and have a longer memory of rainfall events than fine fuels.

The DMC can provide accurate information on duff moisture if weather data collection commences early enough in the spring or appropriate DMC values are used when starting a weather station mid-season. Guidelines and methodology for destructive sampling to determine duff moisture are available (Lawson and Dalrymple 1996a). These techniques require time, some degree of skill and training, and special equipment (laboratory balance, drying oven, sample tins). They are appropriate for determining starting values of DMC and DC (Drought Code), but impractical for daily fire management operations, since it is impractical for fire managers to measure forest floor moisture content directly over broad temporal and spatial scales.

The national standard DMC has been related to the moisture content of duff collected mainly in eastern red pine (*Pinus resinosa*) and jack pine (*P. banksiana*) stands. However, there has been subsequent research to calibrate the equations developed by Van Wagner (1987) for forest floor types in British Columbia and the southern Yukon.

Fire specialists may wish to use the attached equations, tables and graphs to convert DMC values into predicted moisture content for duff layers typical of the Coastal Western Hemlock (CWH) biogeoclimatic zone on the south coast of British Columbia, various biogeoclimatic zones (Interior Douglas-fir (IDF), Montane Spruce (MS), Interior Cedar Hemlock (ICH), Engelmann Spruce/Subalpine Fir (ESSF)) in the southern interior of British Columbia, and the Boreal White and Black Spruce (BWBS) zone of southern Yukon.

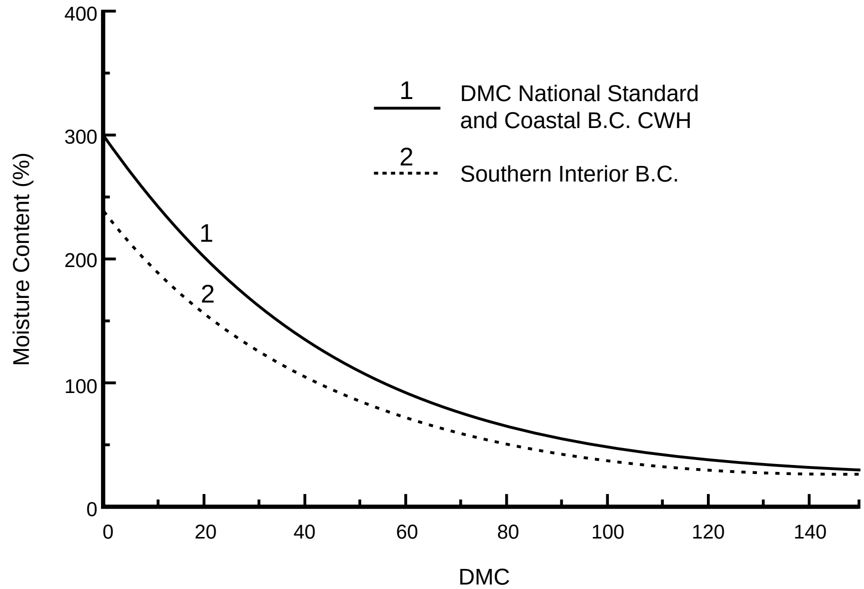


Figure 1: Duff moisture content vs duff moisture code (DMC) for coastal B.C. CWH and southern interior B.C.

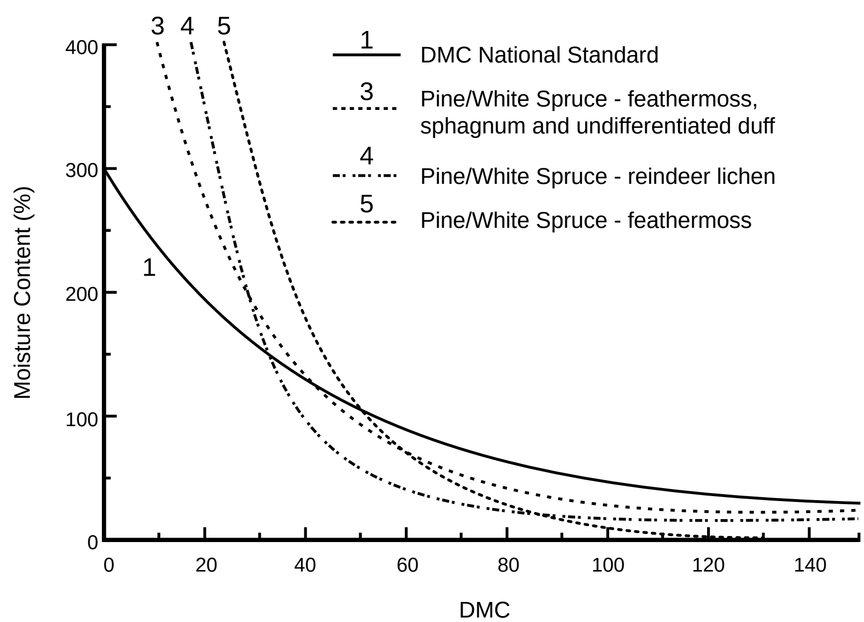


Figure 2: Duff moisture content vs. duff moisture code (DMC) for southern Yukon.

Research Applications

The insert sheet provides mathematical equations (Table 1) and a lookup table (Table 2) that can be used to predict duff moisture content from a DMC value. These equations may be applied in computerized fire management decision support systems, and the lookup table may be used to quickly estimate duff moisture content from a DMC value.

Graphical Relationship

Figures 1 and 2 illustrate how duff moisture content varies with DMC. Different relationships have been established for several different forest floor types in the southern Yukon (Figure 2). It can be seen that the national standard DMC equation is generally applicable to the Coastal Western Hemlock biogeoclimatic zone; this has been proven statistically using non-linear regression techniques.

B.C. CWH

For duff sampled within the CWH biogeoclimatic zone, the duff depth and bulk density values were similar to those listed for the duff type used to develop the national standard DMC equation (7 cm and 0.07 g/cm^3, respectively (Van Wagner 1987)). This accounts for the close match between the moisture content equation developed from coastal B.C. data and the standard DMC equation.

B.C. Southern Interior

The southern interior B.C. equation was developed from the 2-4 cm duff samples of the same data set reported in Lawson and Dalrymple (1996a). Bulk density could not be calculated for the southern interior B.C. sample data, but it is possible that a more shallow total duff depth could account for the equation falling below the standard DMC curve.

Southern Yukon

The southern Yukon duff types exhibit moisture contents that exceed those of the national standard until DMC's surpass values of about 35 - 50. These higher moisture contents are possibly the result of frozen ground restricting drainage in the spring and higher moisture holding capacity of the Yukon duff material (moss and lichen) compared to the national standard (needle litter).
As the season progresses, actual moisture contents of the southern Yukon duff types fall below those of the national standard.

Management Implications

Late Start of a Weather Station

Field sampling procedures and equations for verifying DC starting values are given in Lawson and Dalrymple (1996a). The DMC does not require consideration of overwinter precipitation like the DC. A late-starting fire weather station being set up for a project wildfire or a prescribed burn could be ground-truthed using one of the equations given here to estimate DMC from a sampled duff moisture content.

Predicting Smoldering Ignition

Smoldering ignition probability models, as a function of FWI System component values (DMC and DC), are being published separately (Lawson et al. 1997). The equations in Table 1 have been linked to those developed by Frandsen (1997) to predict ignition probabilities for boreal forest duff types based directly on moisture content of the specified depth of duff.

Comparing Predictive Systems

There is growing demand in Canada and the USA to develop better guidelines for burn prescriptions applicable to treatments such as underburning, stand replacement fire and slashburning. Because different fire danger rating systems are used in the two countries, direct comparison of such prescriptions is difficult unless prescription variables, such as duff moisture content, are comparable.

Additional Reading

Chrosciewicz, Z. 1989a. Prediction of forest floor moisture content on jack pine cutovers. Can. J. For. Res. 19(2): 239-243.

Chrosciewicz, Z. 1989b. Prediction of forest-floor moisture content under diverse jack pine canopy conditions. Can. J. For. Res. 19: 1483-1487.

Frandsen, W.H. 1997. Ignition probability of organic soils. Can. J. For. Res. (in press).

Lawson, B.D. and G.N. Dalrymple. 1996a. Ground-truthing the Drought Code: field verification of overwinter recharge of forest floor moisture. Can.-B.C. Partnership Agreement on Forest Resource Development: FRDA II. FRDA Rep. No. 268. Can. For. Serv., Victoria, B.C.

Lawson, B.D. and G.N. Dalrymple. 1996b. Probabilities of sustained ignition in lodgepole pine, interior Douglas-fir, and white spruce-subalpine fir forest types. Can.-B.C. Partnership Agreement on For. Resource Development: FRDA II Suppl. 1 to: Field guide to the Can. For. Fire Behavior Prediction (FBP) System, FRDA Hdbk. 12, Can. For. Serv., Victoria, B.C.

Lawson, B.D., W.H. Frandsen, B.C. Hawkes and G.N. Dalrymple. 1997. Probability of sustained smoldering ignition for some boreal forest duff types. Can. For. Serv., Nor. For. Centre, Edmonton, AB. Forest Management Note (in press).

Meidinger, D. and J. Pojar. 1991. Ecosystems of British Columbia. B.C. Min. of For., Spec. Rep. Series 6, Res. Br., B.C. MoF, Victoria, B.C.

Russell, R.N. 1975. Organic layer moisture regimes in coastal forests. In Improved fire danger assessment. Proj. PC-17. Can. For. Serv., Pac. For. Centre, Victoria, B.C. Proj. Prog. Rep., pp. 20-39.

Turner, J.A. and B.D. Lawson. 1978. Weather in the Canadian Forest Fire Danger Rating System: A user guide to national standards and practices. Can. For. Serv., Pac. For. Cent., Victoria, B.C., Inf. Rep. BC-X-177, 40p.

Van Wagner, C.E. 1987. Development and structure of the Canadian Forest Fire Weather Index System. Can. For. Serv., Ottawa, Ont., For. Tech. Rep. 35, 37p.

For Additional CFS Information

visit our web site at:
http://www.pfc.cfs.nrcan.gc.ca

Printed on recycled paper

ISSN 1209-6571 Cat. No. Fo29-47/6-1997E
ISBN 0-662-25896-7

Contacts:

Bruce Lawson, R.P.F.
Canadian Forest Service (retired)
Ember Research Services Ltd.
4345 Northridge Cres.
Victoria, B.C. V8Z 4Z4
email: blawson@islandnet.com

George Dalrymple, 250-363-0695;
email: gdalrymple@pfc.cfs.nrcan.gc.ca
Brad Hawkes, R.P.F., PhD. 250-363-0665;
email: bhawkes@pfc.cfs.nrcan.gc.ca
Canadian Forest Service,
Pacific Forestry Centre
Fire Management Network
506 West Burnside Rd
Victoria, B.C. V8Z 1M5

For additional information on site descriptions and equation statistics, contact the individuals listed above.

Acknowledgments

Dr. Mike Curran and Larry Hall,
B.C. Ministry of Forests,
Research and Protection Branch,
Nelson Forest Region.

Keith Kepke, Indian and
Northern Affairs Canada, Yukon Forest Service.

Rolly Kopas, Brad Armitage,
and Karen Sherman, for collection
of the Yukon field data.

Robin Pike, former co-op student,
University of Victoria.

Marty Alexander, CFS, Edmonton.

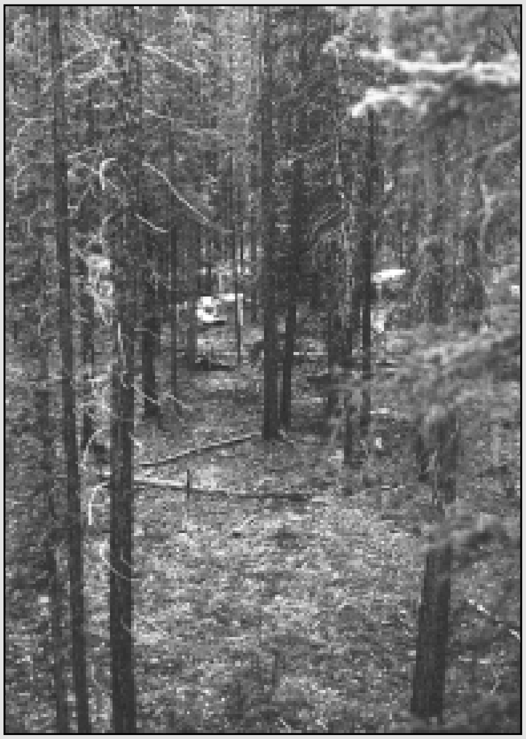
Steve Taylor, CFS, Victoria.

Judi Beck, B.C. Ministry of Forests,
Protection Branch, Victoria.

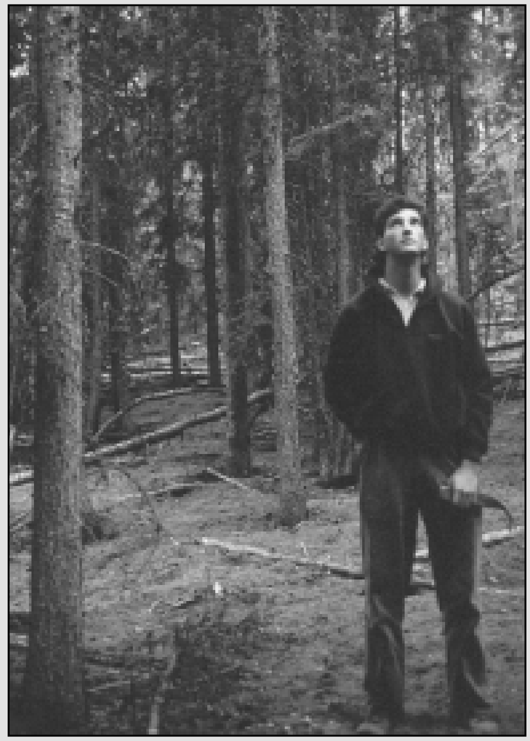
Dean Mills, Editor, CFS, Victoria.

Anne Dickinson,
Technology Transfer, CFS, Victoria.

Cette publication est aussi disponible en français.



Lodgepole pine-white spruce stand with feather moss, sphagnum, undifferentiated and reindeer lichen duff types, Whitehorse, Yukon (nursery site).



White spruce-feather moss duff type, Whitehorse, Yukon (subdivision site).

Table 1: National Standard and Best-fit Non-linear Regression Equations Linking DMC to Forest Floor Moisture Content in Coastal B.C., Southern Interior B.C. and Southern Yukon

Equation 1	**DMC National Standard and Coastal B.C. CWH (2.5-4 cm)[2]** MC=exp[(DMC-244.7)/-43.4]+20
Equation 2	**Southern Interior B.C.[3] (2-4 cm)[2]** MC=exp[(DMC-223.9)/-41.7]+20
Equation 3	**Southern Yukon - Pine/White Spruce** **Feather moss, Sphagnum and Undifferentiated duff (2-4 cm)[2]** MC=exp[(DMC-157.3)/-24.6]+20
Equation 4	**Southern Yukon - Pine/White Spruce** **Reindeer lichen (2-4 cm)[2]** MC=exp[(DMC-106.7)/-14.9]+20
Equation 5	**Southern Yukon - White Spruce** **White spruce/feather moss (2-4 cm)[2]** MC=exp[(DMC-149.6)/-20.9]

Developed by Bruce Lawson and George Dalrymple of the Canadian Forest Service

[2]Sampled depth

[3]Biogeoclimatic zones sampled were IDF, MS, ICH, and ESSF

Table 2: Moisture contents for five duff types estimated from DMC values.

	Duff Type				
			Southern Yukon		
	Standard DMC & Coastal B.C. CWH	Southern Interior B.C.	Pine/white spruce Feather moss / Sphagnum	Pine/white spruce Reindeer lichen	White spruce White spruce/ Feather moss
Equation no.:	1	2	3	4	5
DMC	**Moisture Content (%)**				
0	301	235	400+	400+	400+
5	270	210	400+	400+	400+
10	243	189	400+	400+	400+
15	219	170	345	400+	400+
20	197	153	285	357	400+
25	178	138	237	261	388
30	161	125	197	192	306
35	145	113	164	143	241
40	132	102	138	108	189
45	120	93	116	83	149
50	109	85	98	65	117
55	99	77	84	52	92
60	91	71	72	43	73
65	83	65	63	36	57
70	76	60	55	32	45
75	70	56	48	28	35
80	64	52	43	26	28
85	60	48	39	24	22
90	55	45	35	23	17
95	51	42	33	22	14
100	48	40	30	22	11
105	45	37	28	21	11
110	42	35	27	21	11
115	40	34	26	21	11
120	38	32	25	20	11
125	36	31	24	20	11
130	34	30	23	20	11
135	33	28	22	20	11
140	31	27	22	20	11

Developed by Bruce Lawson and George Dalrymple of the Canadian Forest Service