Computer Calculation of the Keetch-Byram Drought Index—Programmers Beware!

Martin E. Alexander[1]

Ph.D. scholar, Department of Forestry, Australian National University, and visiting fire researcher, National Bushfire Research Unit, CSIRO Division of Forestry and Forest Products, Canberra, Australian Capital Territory

The Keetch-Byram Drought Index or KBDI (Keetch and Byram 1968) has been or is still being used as a guide for estimating the cumulative moisture deficiency in deep duff or upper soil layers. Such information is needed for planning fire management operations in many regions of the world (McArthur 1966, 1967; Cheney 1971; Mount 1972; Valentine 1972; Wade and Ward 1973; Burgan, Fujioka, and Hirata 1974; Just 1978; Noble, Bary, and Gill 1980; Crane 1982; Sirakoff 1985; Swart 1986; Burgan 1988; Melton 1989; Donaldson and Paul 1990; Jordan 1990). As well, the KBDI has been widely utilized in various fire research studies (Burgan 1976; Haines, Johnson, and Main 1976; Dayananda 1977; Miller 1978; Olson 1980; Lorimer and Gough 1982, 1988; Hall and Gwalema 1985; Johansen 1985; Van Wagner 1985; Burrows 1987; Gill, Christian, Moore, and Forrester 1987; Brown, Booth, and Simmerman 1989).

It has come to my attention (Crane 1983) again that there are two significant typographical errors in the original 1968-published USDA Forest Service Research Paper SE–38 dealing with the drought index developed by John J. Keetch and George M. Byram. Crane (1982) determined that the equation used to calculate the daily drought factor was in fact incorrect. The last constant in the numerator of Equation 18 on page 31 of Keetch and Byram's (1968) publication should have been 8.30 and not 0.830 (fig. 1). The end result of this error is a drought factor that is always slightly higher than the correct value (table 1). Crane (1982) also suggested that the last constant in the numerator of Equation 15 on the same page should have been 0.213 instead of 2.113. However, in a review draft of Keetch and Byram (1968) dated October 22, 1966, which was kindly provided by D.R. Packham (Commonwealth of Australia, Bureau of Meteorology, Melbourne, Victoria), it's clear that the errors in Equations 15 and 18 were both typographical in nature, and the constant in the former should have been 0.2113. It's worth noting that the drought factor tables contained in Keetch and Byram's (1968) report, which are based on Equation 18, are correct however.

... there are two significant typographical errors in USDA Forest Service Research Paper SE–38 dealing with the drought index developed by John J. Keetch and George M. Byram ... the misprints in Equations 15 and 18 have been corrected in a 1988-revised reprinting of the publication ....

Just how insignificant are these sources of error in calculating the KBDI? On a day-to-day basis, the error may have only a small effect on the resultant value (table 1). However, a computer-calculated value would eventually depart considerably from the correct value due to the cumulative nature of the KBDI, especially during a rainless period (Fujioka 1991). There will of course always be differences between equation-calculated values and those derived from tables when it comes to fire danger indices (Deeming 1975).

English unit equation [corrected] from Keetch and Byram (1968)

$$dQ = \frac{[800 - Q]\,[0.968 \exp(0.0486T) - 8.30]\,d\tau}{1 + 10.88 \exp(-0.0441R)} \times 10^{-3}$$

S.I. unit equation from Crane (1982)

$$dQ = \frac{[203.2 - Q]\,[0.968 \exp(0.0875T + 1.5552) - 8.30]\,d\tau}{1 + 10.88 \exp(-0.001736R)} \times 10^{-3}$$

Symbol	Quantity	English units	S.I. units
dQ	Drought factor	0.01 in	mm
Q	Moisture deficiency[1]	0.01 in	mm
T	Daily maximum temperature	°F	°C
R	Mean annual precipitation	in	mm
$d\tau$	Time increment	= 1 day	= 1 day

[1] Yesterday's KBDI or value as reduced by the daily net precipitation (i.e., the amount in excess of 0.20 in or 5.1 mm).

Figure 1—*The two versions of the equation used to calculate the daily drought factor in computing the Keetch-Byram Drought Index (KBDI).*

[1] The author, a fire research officer with the Northwest Region of Forestry Canada stationed at the Northern Forestry Centre in Edmonton, AB, is presently on professional development and educational leave in Australia.

Table 1—*Increase in the value of the daily drought factor of the Keetch-Byram Drought Index (KBDI) as a result of the typographical error in Equation 18 of Keetch and Byram (1968). Please note that due to the nature of the error in Equation 18, the increase above the actual value is independent of daily maximum temperature.*

Mean annual precipitation		Yesterday's KBDI[1] or value as reduced by the daily net precipitation							
(in)	(mm)	100	200	300	400	500	600	700	800
10	254	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
20	508	1.0	0.8	0.7	0.5	0.4	0.3	0.1	0
30	762	1.3	1.1	1.0	0.8	0.6	0.4	0.2	0
40	1,016	1.8	1.6	1.3	1.0	0.8	0.5	0.3	0
50	1,270	2.4	2.0	1.7	1.4	1.0	0.7	0.3	0
60	1,524	3.0	2.5	2.1	1.7	1.3	0.8	0.4	0
70	1,778	3.5	3.0	2.5	2.0	1.5	1.0	0.5	0
80	2,032	4.0	3.4	2.8	2.3	1.7	1.1	0.6	0

[1] In the original formulation of the KBDI, 800 represented the maximum possible value. However, the metric or S.I. unit scale of the KBDI technically limits the value to 203.

To my knowledge, an errata to Keetch and Byram (1968), which highlights the aforementioned problems, has never been issued. However, the misprints in Equations 15 and 18 have been corrected in a 1988-revised reprinting of the original publication, although no mention of these corrections is made. This note has been prepared to alert those, who may be calculating the KBDI by computer, to these two errors, since it's not always readily apparent whether they have been detected by other users. The corrected version of Equation 18 and the one rederived by Crane (1982) in terms of the International System (S.I.) of units are presented here (fig. 1) in the interest of completeness. Furthermore, the references compiled here constitute a selected bibliography on the KBDI. ■

Literature Cited

Brown, J.K.; Booth, G.D.; Simmerman, D.G. 1989. Seasonal change in live fuel moisture of understory plants in western U.S. aspen. In: MacIver, D.C.; Auld, H.; Whitewood, R., eds. Proceedings of the 10th conference on fire and forest meteorology; 1989 April 17–21; Ottawa, ON. Ottawa, ON: Forestry Canada and Environment Canada: 406–412.

Burgan, R.E. 1976. Correlation of plant moisture in Hawaii with the Keetch-Byram Drought Index. Res. Note PSW–307. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 6 p.

Burgan, R.E. 1988. 1988 revisions to the 1978 National Fire-Danger Rating System. Res. Pap. SE–273. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 39 p.

Burgan, R.E.; Fujioka, F.M.; Hirata, G.H. 1974. A fire danger rating system for Hawaii. Fire Technology. 10(4): 275–281.

Burrows, N.D. 1987. The Soil Dryness Index for use in fire control in the south-west of Western Australia. Tech. Pap. No. 17. Perth, WA: Western Australian Department of Conservation and Land Management. 37 p.

Cheney, N.P. 1971. Forest industries feasibility study, Zambia. Fire protection of industrial plantations. FO:SF/ZAM 5 Tech. Rep. 4. Rome, ITALY: Food and Agriculture Organization of the United Nations, United Nations Development Programme. 71 p.

Crane, W.J.B. 1982. Computing grassland and forest fire behaviour, relative humidity and drought index by pocket calculator. Australian Forestry. 45(2): 89–97.

Crane, W.J.B. 1983. Fire danger and drought index **warning**. Institute of Foresters of Australia Newsletter. 24(4): 27.

Dayananda, P.W.A. 1977. Stochastic models for forest fires. Ecological Modelling. 3(4): 309–313.

Deeming, J.E. 1975. Calculating fire-danger ratings: computer vs. tables. Fire Management Notes. 36(1): 6–7,9.

Donaldson, B.G.; Paul, J.T. 1990. NFDRSPC: The National Fire-Danger Rating System on a personal computer. Gen. Tech. Rep. SE–61. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 49 p.

Fujioka, F.M. 1991. Starting up the Keetch-Byram Drought Index. In: Proceedings of the 11th conference on fire and forest meteorology; 1991 April 16–19. Missoula, MT. Bethesda, MD: Society of American Foresters [in press].

Gill, A.M.; Christian, K.R.; Moore, P.H.R.; Forrester, R.I. 1987. Bushfire incidence, fire hazard and fuel reduction burning. Australian Journal of Ecology. 12(3): 299–306.

Hall, J.B.; Gwalema, W.N.K. 1985. Drought indices and fire danger indices at Morogoro, Tanzania. Forest Ecology and Management. 10(2): 125–134.

Haines, D.A.; Johnson, V.J.; Main, W.A. 1976. An assessment of three measures of long term moisture deficiency before critical fire periods. Res. Pap. NC–131. St Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 13 p.

Johansen, R.W. 1985. Effect of drought on live fuel moisture content. In: Donoghue, L.R.; Martin, R.E., eds. Proceedings of the eighth conference on fire and forest meteorology; 1985 April 29–May 2; Detroit, MI. SAF Publ. 85–04. Bethesda, MD: Society of American Foresters: 47–51.

Jordan, D.W. 1990. The value of drought index in the Country Fire Authority. In: Proceedings of the third Australian fire weather conference; 1989 May 18–20; Hobart, TAS. Melbourne, VIC: Commonwealth of Australia, Bureau of Meteorology: 133–139.

Just, T.E. 1978. Extreme fire weather in Queensland. Tech. Pap. No. 9. Brisbane,

OLD: Queensland Department of Forestry. 17 p.
Keetch, J.J.; Byram, G.M. 1968. A drought index for forest fire control. Res. Pap. SE-38. Asheville NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 32 p. [Revised November 1988.]
Lorimer, C.G.; Gough, W.R. 1982. Number of days per month of moderate and extreme drought in northeastern Wisconsin, 1864-1979. For. Res. Note 248. Madison, WI: University of Wisconsin-Madison, Department of Forestry. 14 p.
Lorimer, C.G.; Gough, W.R. 1988. Frequency of drought and severe fire weather in northeastern Wisconsin. Journal of Environmental Management. 26(3): 203-219.
McArthur, A.G. 1966. The application of a drought index system to Australian fire control. Canberra, ACT: Commonwealth of Australia, Department of National Development, Forestry and Timber Bureau, Forest Research Institute. 18 p.
McArthur, A.G. 1967. Fire behaviour in eucalypt forests. Leafl. No. 107. Canberra, ACT: Commonwealth of Australia, Department of National Development, Forestry and Timber Bureau. 36 p.
Melton, M. 1989. The Keetch/Byram Drought Index: a guide to fire conditions and suppression problems. Fire Management Notes. 50(4): 30-34.
Miller, R.K. 1978. The Keetch-Byram Drought Index and three fires in upper Michigan, 1976. In: Preprint Volume, 5th national conference on fire and forest meteorology; 1978 March 14-16; Atlantic City, NJ. Boston, MA: American Meteorological Society: 63-67.
Mount, A.B. 1972. The derivation and testing of a soil dryness index using run-off data. Bull. No. 4. Hobart, TAS: Forestry Commission, Tasmania. 31 p.
Noble, I.R.; Bary, G.A.V.; Gill, A.M. 1980. McArthur's fire-danger meters. Australian Journal of Ecology. 5(2): 201-203.
Olson, C.M. 1980. An evaluation of the Keetch-Byram Drought Index as a predictor of foliage moisture content in a chaparral community. In: Martin, R.E.; Edmonds, R.L.; Faulkner, D.A.; and others, eds. Proceedings of the sixth conference on fire and forest meteorology; 1980 April 22-24; Seattle, WA. Washington, DC: Society of American Foresters: 241-245.
Sirakoff, C. 1985. A correction to the equations describing the McArthur forest fire danger meter. Australian Journal of Ecology. 10(4): 481.
Swart, R.K. 1986. Drought index for plantations. Johannesburg, SOUTH AFRICA: First Bowring Protection Consultants (Pty) Limited. 8 p.
Valentine, J.M. 1972. Drought index for fire control—a measure of seasonal severity. For. Establish. Int. Rep. No. 23. Rotorua, NEW ZEALAND: New Zealand Forest Service, Forest Research Institute. 15 p.
Van Wagner, C.E. 1985. Drought, timelag, and fire danger rating. In: Donoghue, L.R.; Martin, R.E., eds. Proceedings of the eighth conference on fire and forest meteorology; 1985 April 29-May 2; Detroit, MI. SAF Publ. 85-04, Bethesda, MD: Society of American Foresters: 178-185.
Wade, D.D.; Ward, D.E. 1973. An analysis of the Air Force Bomb Range Fire. Res. Pap. SE-105. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 38 p.

The 1992 National Wildland Fire Training Conference

The conference sponsored by the National Wildfire Coordinating Group's Training Working Team every other year is scheduled to be held in 1992 in Orlando, FL, on February 20-22, at the Clarion Plaza Hotel Convention Center on International Drive.

The theme of the training conference is "Training, Performance, Technology—Visions of Tomorrow." Many varied training sessions, with speakers and workshops, will highlight this theme. An important topic for all of us will be the new fire suppression curriculum and its development.

Plan now to attend this important conference, and be sure to budget funds in the next fiscal year. For further information, contact Jim Whitson, Florida Division of Forestry, 3125 Conner Boulevard, Tallahassee, FL 32399-1650; telephone 904-488-6111. ■