ROCKY MTN. EXPT. STA. LIBRARY
FLAGSTAFF FILE COPY
REFERENCE NO. 431.2

431.2

PACIFIC SOUTHWEST
Forest and Range
Experiment Station

FOREST SERVICE
U.S.DEPARTMENT OF AGRICULTURE
P.O. BOX 245, BERKELEY, CALIFORNIA 94701

FINE FUEL MOISTURE MEASURED AND ESTIMATED in dead Andropogon virginicus in Hawaii

Francis M. Fujioka

USDA Forest Service
Research Note PSW-317
1976

Fujioka, Francis M.
1976. **Fine fuel moisture measured and estimated in dead *Andropogon virginicus* in Hawaii.** USDA Forest Serv. Res. Note PSW-317, 4 p., illus. Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif.

Fuel moisture estimates generated by the National Fire-Danger Rating System procedure were compared with actual fuel moisture measurements determined from laboratory analysis. Meteorological data required for the NFDRS procedure were collected at two heights to assess the effect of temperature and humidity lapse rates. Standard measurements gave the best results, but use of a xeric hygrometer showed promise of giving reliable fuel moisture estimates by a simple linear regression.

Oxford: 431.2:812.211–015.
Retrieval Terms: fuel moisture estimation; National Fire Danger Rating System; hygrometrix; xeric hygrometers; sampling.

The ignition potential of fine fuels—that is, grasses and other herbaceous plants—is critically dependent on fuel moisture. The National Fire-Danger Rating System[1] (NFDRS) provides a method for estimating fine fuel moisture (FFM) in dead vegetation using meteorological data. The relevant weather variables are dry-bulb temperature, relative humidity, and state-of-weather, here considered to mean cloudiness. In the NFDRS computer algorithm,[2] FFM is directly proportional to the equilibrium moisture content,[3] which can be computed from the weather variables. Presently, it is not known how well FFM estimates approximate fuel moisture of dead vegetation in Hawaii.

This study compared moisture content calculated by the NFDRS method with moisture content of fuel samples as determined in the laboratory. Temperature and relative humidity were measured at two different heights, to see what effect the actual vertical variation of these variables had on fuel moisture calculations. A new instrument, the Hygrometrix[4] xeric hygrometer, which employs a cellulosic element that responds to changes in atmospheric humidity, was tested for its ability to estimate FFM. Using a combination of techniques, I generated four estimates for each observation time. Only one of these measurements conforms to NFDRS standard procedure, but I have included the correlations between all estimates and actual fuel moisture. The standard procedure yielded the best estimate, but the results showed potential for using the Hygrometrix hygrometer readings in a simple linear regression.

METHODS

Paired observations were made of weather and fuel moisture of broomsedge (*Andropogon virginicus* L.), a major wildfire fuel in Hawaii. The sampling site overlooked Tripler Military Reservation, on the lee side of the Koolau Range. Mean annual rainfall in this area is about 125 cm (50 inches). The broomsedge grew on a southwest-facing slope, about 300 m (1000 ft) above mean sea level. A portable fan psychrometer and a Hygrometrix xeric hygrometer were placed in weather shelters set at two heights, one 0.25 m (10 inches) above ground, and the other 1.22 m (48 inches), the standard observing height.

At hourly intervals during daylight, the observer collected three samples of dead fuel in airtight round-bottom 500 ml boiling flasks; he read the dry- and wet-bulb temperatures from the psychrometer, and noted the Hygrometrix index at each shelter. He also estimated amount of cloud cover and recorded the appropriate state-of-weather code.

The fuel samples were processed by xylene distillation to determine percent moisture content by dry weight, and the average of the three values for each collection time was taken as *actual fuel moisture* (AFM).

For the computed fuel moisture (CFM), two estimates were made for each height, using two different values for humidity: CFM_1 used the value obtained from the fan psychrometer and CFM_2 used the value observed on the xeric hygrometer scale. Only the CFM_1 estimate from the 1.22 m height legitimately follows the NFDRS procedure. A total of 58 sets of weather measurements, 29 at each shelter height, were used with 29 corresponding actual fuel moisture measurements.

In the analysis phase, I computed the simple linear correlation coefficients between each of the CFM's at each height, and the AFM, and between the direct xeric hygrometer readings and AFM. I also tested for statistical differences between AFM and CFM_1.

RESULTS AND DISCUSSION

The computed fuel moistures generally underestimated actual moisture content. Actual fuel moistures, obtained by the xylene process, gave a pooled standard deviation of 1.02 percent. Examination of the differences between AFM and each of the fuel moisture estimates showed that CFM_1 at 1.22 m was apparently best (*table 1*). It had the lowest absolute mean difference, the lowest root-mean-square difference, and a comparably low standard deviation of difference. This might have been expected, because the data used for the other estimates were not obtained by the legitimate procedure. The next best set of estimates was the CFM_2 set at 0.25m.

Table 1—*Statistical analysis of differences between actual fuel moisture and computer fuel moisture*[1] *(AFM-CFM)*

Shelter height and CFM estimates	Mean difference	Standard deviation of difference	Root-mean-square difference
0.25 m			
CFM_1	−1.6	1.1	1.9
CFM_2	−1.2	1.0	1.6
1.22 m			
CFM_1	−0.7	1.1	1.3
CFM_2	−1.7	1.1	2.0

[1] Humidity estimate for CFM_1 obtained from fan psychrometer; for CFM_2 from xeric hygrometer scale.

Table 2 gives the correlation coefficients computed between each of the CFM's and AFM, and between the direct xeric hygrometer readings and AFM. All the correlations were significant at the 1 percent level. The highest correlations were associated with use of direct xeric hygrometer readings, but the correlation coefficients were not vastly different from each other. A chi-square test of the homogeneity of the coefficients in *table 2,* using Hotelling's z* transform[5], showed no significant difference at the 10 percent level.

Table 2—*Correlation coefficients of values for actual fuel moisture and computed fuel moisture*

Shelter height	CFM_1	CFM_2	Hygrometrix index
0.25 m	0.89	0.92	0.93
1.22 m	.87	.89	.93

The high correlation between AFM and the direct xeric hygrometer reading suggests that a linear regression model may reliably estimate AFM from xeric hygrometer observations (*fig. 1*). The coefficient of determination, r^2, is 0.87.

The plots of fuel moisture over time (*fig. 2*) show, as does *table 1,* that the CFM's generally underestimate AFM. Results for CFM_1 at 1.22 m, which was calculated following the NFDRS procedure, are of greatest interest here. The effect of the "sunny-cloudy" variable on CFM apparently complicates the results. The procedure directs the observer to report cloudy conditions outside the period from 1000 to 1500 LST, even though sunny skies are actually observed. Otherwise the fuel moisture estimates are unduly depressed (the NFDRS algorithm decreases relative humidity by one-fourth of its reported value,

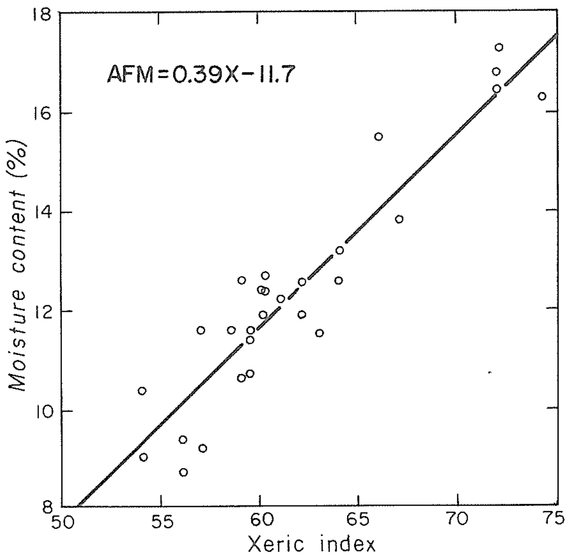

Figure 1—A simple linear regression of actual fuel moisture content (percent of dry weight) on xeric index gives the equation as shown.

when sunny conditions are observed). This rule was initially overlooked, and the calculations produced CFM-AFM differences that were twice as large as they should have been. To see how good CFM_1 would be if we *always* assumed cloudy conditions, I recomputed fuel moistures for all clear sky data points, assuming cloudy conditions for each, and obtained the differences given in figure 3.

Sunny skies were observed 11 times in the sampling period. In 7 of these instances, the CFM's matched closer to the AFM when cloudy conditions were assumed. Significantly, the 4 times when the sunny sky estimates were better than the assumed cloudy estimates were those when AFM was low (<10%). The mean difference between sunny CFM_1 and AFM was −1.9; assuming cloudy conditions, the mean difference between CFM_1 and AFM was reduced in magnitude to 0.6. The first difference is significant at the 5 percent level, the second is not (10 d.f.).

The data suggest that the information on cloudiness does not improve the fuel moisture estimate computed from the algorithm. On the other hand, when sunny skies are ignored, CFM tends to exceed AFM. How significant is the overestimate? At the 5 percent level, the difference between mean CFM_1 (assuming cloudy skies) and mean AFM was not large enough to reject the hypothesis that mean CFM_1 ≤mean AFM. However, the probability of a Type II error (acceptance of a false hypothesis) in this particular test is 0.78. More sampling is needed to reduce this margin of error, and to investigate the seasonal variability (if any) of differences between computed and actual fuel moistures.

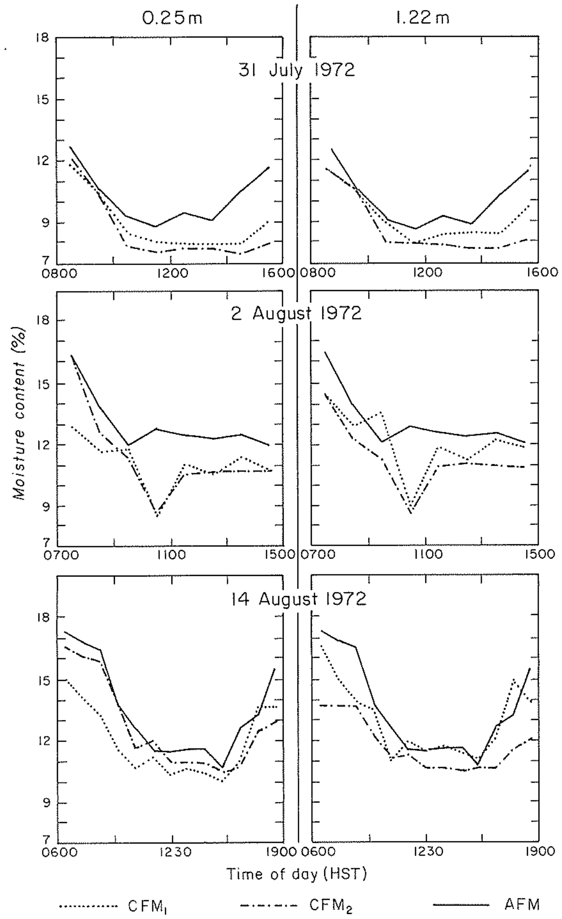

Figure 2—Fuel moisture estimates (CFM's) were compared with actual fuel moisture (AFM) on 3 days. Estimates from lower shelter (0.25 m) are shown at left, from standard shelter height (1.22 m) at right. Local apparent noon (sun at relative zenith) occurs at about 12:35 this time of year. Fuel moisture estimates were obtained from fan psychrometer (CFM_1) and from xeric hygrometer scale (CFM_2).

There is much appeal in obtaining fuel moisture estimates quickly, using the xeric hygrometer readings in a simple linear regression. However, a further study must test the effectiveness of the regression. Continuous sampling should also be considered, to investigate local diurnal variations in fuel moisture.

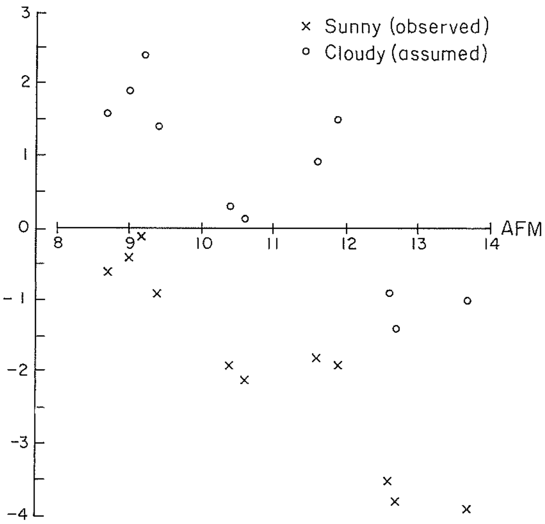

Figure 3—The difference between fuel moisture estimates and actual fuel moistures, assuming cloudy conditions for actually sunny conditions, was determined, with results as shown.

NOTES

[1] Deeming, John E., James W. Lancaster, and Michael A. Fosberg. 1972. *National Fire-Danger Rating System.* USDA Forest Serv. Res. Paper RM-84, 165 p., illus. Rocky Mountain Forest and Range Exp. Stn., Fort Collins, Colo.

[2] Furman, R. William, and Robert S. Helfman. 1973. *A computer program for processing historic fire weather data for the National Fire-Danger Rating System.* USDA Forest Serv. Res. Note RM-234, 12 p., illus. Rocky Mountain Forest and Range Exp. Stn., Fort Collins, Colo.

[3] Fosberg, Michael A., and John E. Deeming. 1971. *Derivation of the 1- and 10-hour timelag fuel moisture calculations for fire-danger rating.* USDA Forest Serv. Res. Note RM-207, 8 p. Rocky Mountain Forest and Range Exp. Stn., Fort Collins, Colo.

[4] Trade names or commercial brands are mentioned solely for information. No endorsement by the U.S. Department of Agriculture is implied.

[5] Sokal, Robert E., and F. James Rohlf. 1969. *Biometry.* W. H. Freeman and Company, San Francisco, Calif. p. 518 ff.

The Author

FRANCIS M. FUJIOKA is a research meteorologist assigned to the Hawaiian forest ecosystems work unit with headquarters in Honolulu, Hawaii. He earned a B.S. degree (1968) and an M.S. degree (1972) in meteorology at the University of Hawaii. He joined the Forest Service and the PSW staff in 1972.

U.S. Forest Service research in Hawaii
is conducted in cooperation with
Division of Forestry
Hawaii Department of Land and Natural Resources