TABLE 7.—*The number of days with low relative humidity, within the limits indicated, for each year of the period 1894–1927*

Year	For Seattle					For Portland				
	Per cent of relative humidity, 5 p. m.									
	38–31	30–26	25–20	19	Total	38–31	30–26	25–20	19	Total
1894	12	0	0	0	12	24	0	2	1	36
1895	25	8	5	2	40	27	13	8	7	55
1896	30	6	2	0	38	25	15	6	3	49
1897	10	2	2	0	14	24	15	10	5	54
1898	20	5	9	1	35	17	14	12	7	50
1899	19	7	2	1	29	19	3	3	0	25
1900	16	6	1	1	24	17	7	2	2	28
1901	17	2	3	0	22	12	4	3	1	20
1902	27	3	4	1	35	33	5	0	6	44
1903	14	2	1	1	18	19	10	1	1	31
1904	26	1	3	1	31	37	10	11	6	64
1905	4	5	2	0	11	23	7	7	4	41
1906	28	9	1	1	39	30	10	7	2	49
1907	21	8	1	2	32	23	11	8	5	47
1908	6	1	0	0	7	15	8	0	0	23
1909	14	9	2	0	25	12	11	8	2	33
1910	11	1	0	0	12	25	8	4	0	37
1911	25	5	3	0	33	14	5	7	3	29
1912	18	1	3	2	24	8	5	3	0	16
1913	5	0	0	0	5	14	7	2	0	23
1914	15	2	1	0	18	22	12	3	1	38
1915	12	1	0	0	13	19	6	4	0	29
1916	23	6	3	0	32	23	9	4	3	39
1917	25	5	1	1	32	23	11	4	0	38
1918	23	9	8	0	40	25	21	17	6	69
1919	34	8	1	0	43	27	14	10	5	56
1920	21	3	1	1	26	21	14	5	6	46
1921	17	3	3	0	23	33	6	2	2	43
1922	29	5	3	1	38	20	8	7	1	36
1923	22	5	3	0	30	15	12	2	3	32
1924	25	7	7	2	41	24	11	11	2	48
1925	29	5	2	1	37	7	6	1	2	16
1926	49	7	5	4	65	22	9	12	2	45
1927	19	13	3	0	35	27	9	10	0	46

TABLE 7.—*The number of days with low relative humidity, within the limits indicated, for each year of the period 1894–1927*—Con.

Year	For North Head				For Spokane				For Walla Walla			
	Per cent of relative humidity, 5 p. m.											
	50–41	40–31	30	Total	25–20	19–15	14	Total	25–20	19–15	14	Total
1894	2	1	1	4	23	28	22	73	34	13	4	51
1895	3	0	0	3	30	31	38	99	39	23	3	65
1896	5	3	0	8	31	36	19	86	18	4	2	24
1897	2	1	1	4	32	19	5	56	37	11	2	50
1898	2	0	1	3	51	37	16	104	23	2	1	26
1899	1	2	0	3	35	12	7	54	20	13	8	41
1900	1	0	0	1	40	24	11	75	18	9	0	27
1901	2	0	1	3	29	20	8	57	11	2	0	13
1902	2	0	1	3	47	23	1	71	5	1	0	6
1903	1	0	1	2	47	17	5	69	16	5	1	22
1904	2	0	0	2	42	28	24	94	28	4	0	32
1905	3	1	1	5	35	29	11	75	21	11	3	35
1906	2	0	0	2	48	27	11	86	22	12	2	36
1907	0	1	1	2	41	13	1	55	37	13	2	52
1908	0	0	0	0	40	31	19	90	35	27	16	78
1909	1	0	0	1	40	38	13	91	37	34	27	98
1910	1	1	0	2	42	30	20	92	46	30	33	109
1911	1	0	0	1	42	23	8	73	39	26	29	94
1912	0	3	0	3	34	15	2	51	36	27	8	86
1913	0	2	1	3	44	19	4	67	42	34	10	86
1914	1	0	0	1	28	35	17	80	27	33	16	76
1915	0	0	0	0	35	23	8	66	42	26	12	80
1916	0	1	1	2	40	25	5	70	35	15	4	54
1917	1	0	0	1	35	28	27	90	33	29	18	80
1918	3	0	0	3	40	44	15	99	50	31	8	89
1919	4	1	0	5	49	32	23	104	46	29	17	92
1920	0	1	0	1	50	26	8	84	34	28	19	81
1921	1	1	0	2	39	18	11	68	51	24	14	89
1922	1	1	3	5	45	33	17	95	38	21	10	69
1923	0	0	0	0	38	28	5	71	37	29	4	70
1924	0	4	1	5	37	47	29	113	33	46	19	98
1925	3	0	3	6	30	44	16	90	25	35	7	67
1926	2	6	1	9	31	40	24	95	34	33	18	85
1927	1	0	1	2	29	16	5	50	33	22	12	67

FOREST-FIRE WEATHER IN CENTRAL MASSACHUSETTS[1]

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[Northeastern Forest Experiment Station, United States Forest Service, Amherst, Mass., February 29, 1928]

The forest fire hazard in the Northeast is most acute during two distinct periods in the year: (1) In the spring, from the disappearance of the last snow to the complete foliation of the deciduous trees; (2) in the fall, from the beginning of defoliation until the ground is covered with snow. While the trees and shrubs are in a dormant state, the leaf litter—the principal carrier of fire in the Northeast—is fully exposed to the drying-out action of wind and warm dry weather. Between the spring and fall fire seasons the danger is reduced materially by the influence of the tree foliage upon the leaf litter. In other words, the leaves intercept the sun's rays and diminish wind velocity, thereby lessening the rate of evaporation from the duff, which in turn decreases the fire danger.

The above discussion is equally true for open grassland areas. Until the new crop of green vegetation covers the pastures and meadows in the spring and the snow covers the dead plant remains in the fall, conditions are similar to those which are found during hazardous periods on forested lands.

In the present paper the discussion of the correlation between weather and forest fires will be limited to the conditions in central Massachusetts during the spring of 1927. The fire records are for the following counties: Worcester County, the western half of Middlesex County, and the eastern half of Franklin, Hampshire, and Hampden Counties. The total area of the region is approximately 1,750,000 acres, the greater part of which is included in the so-called white pine region. The meteorological data of the Petersham fire-weather station, maintained jointly by the Northeastern Forest Experiment Station and the Harvard Forest, were used for comparing the weather and the occurrence of fires. At Petersham two observation stations were located in the white pine type—one in a clear-cut area and the other in an adjacent mature stand of northern white pine and eastern hemlock. At each station measurements were taken of duff moisture content of the surface layer and at 1 inch depth, and duff temperature, as well as the regular observations of air temperature, relative humidity, evaporation, wind velocity, and rainfall. Atmometers (using the Livingston porous bulbs and Nichols mountings) placed at the level of the leaf litter were employed in securing evaporation data. Special mention should be made of the fact that the three-cup Robinson anemometers were placed only 3½ feet above the ground. Four observations were taken daily: at 8 a. m., 11 a. m., 2 p. m., and 5 p. m. In the tables and graphs which are presented herewith the 2 p. m. records of the station in the clear-cut area are used. These records are chosen (1) because they represent the maximum degree of hazard; (2) because the average daily minimum relative humidity and average daily maxima of air temperature, evaporation, solar radiation, and wind movement occur around 2 p. m. These are all conditions which tend to create a low duff moisture content and consequently a high fire hazard.

Weather conditions during the early part of 1927 were especially favorable for the inception and spread of forest fires. A mild open winter with moderate snowfall was followed by a very dry, warm spring. The transition began early in March and by the end of that month was

[1] The author wishes to thank Mr. A. W. Gottlieb for his assistance in collecting the data at the Petersham, Mass., fire-weather station maintained jointly with the Harvard Forest.

practically complete. Summer heat was recorded on several days during the latter part of March, with the result that what little snow was present disappeared rapidly and early. To sum up, almost six weeks elapsed (March 15 to April 30) from the time when the ground was last covered with snow to the appearance of the green crown cover and the spring rains.

The effect of the dry, warm spring weather upon the leaf litter is reflected directly in the forest fire records. Several fires were reported in March, but the maximum

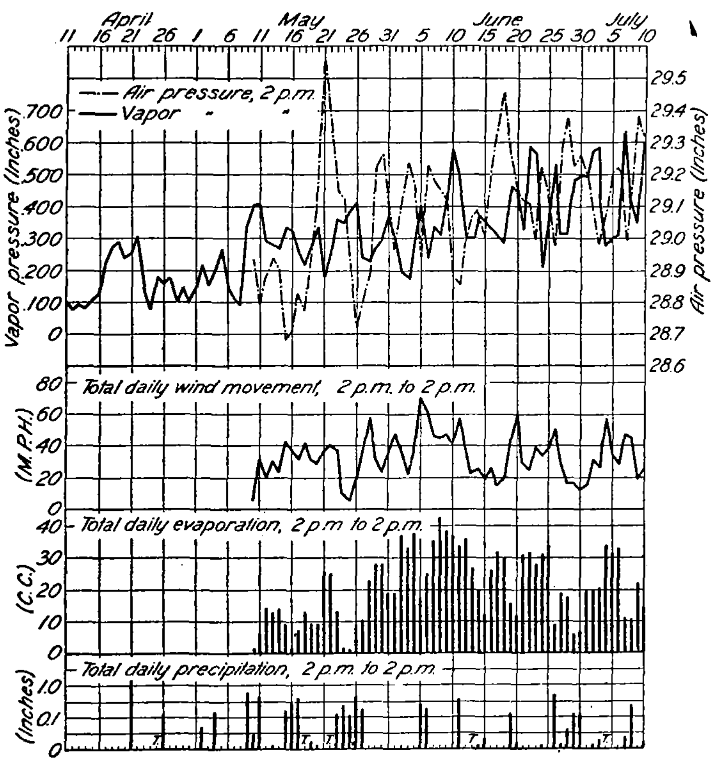

FIG. 1.—Graphs of vapor pressure, air pressure, total daily wind movement, total daily evaporation, and total daily precipitation at Petersham, Mass., April 11–July 10, 1927

number occurred during April. The largest number of and most disastrous fires occurred during the period when fire-weather records were taken. Therefore, while it is true that the entire spring fire season can not be considered, the records taken are representative.

Figures 1 and 2 are graphical presentations of the principal meteorological factors, in addition to duff moisture content of the surface duff layer, duff moisture content at 1 inch depth, and area burned. An inspection of these graphs indicates that of all the climatic factors relative humidity appears to be the best single indication of forest fire hazard, since the peaks of area burned occur with the low records of relative humidity.[1] However, it is the cumulative effect of dry weather—from the end of one rainy period to the beginning of another—which results in the leaf litter becoming dry enough to burn readily. A single reading of relative humidity does not always give a true picture of the hazard. In order to evaluate the probable effect of the moisture content of the air upon that of the duff, we must first know the present duff moisture content. Therefore, the duff hygrometer is indispensable in any system of fire-weather forecasting. A comparison of the curves of relative humidity and duff moisture content indicates that an excellent correlation exists between them, when rainy periods are excluded. This is more readily observed in Table 1, where weather conditions and forest fire records are summarized by relative humidity classes.

Of all the major forest types in the Northeast, the white pine type is inherently the most hazardous. Its leaf litter is highly inflammable because of the resin content. The size and form of pine needles produce a duff with practically no matting but with a great deal of porosity, so that the run-off after rainfall is extremely rapid. The site conditions are of little value in reducing the hazard. White pine in New England is confined generally to the poorer soil types—those composed chiefly of sand. Hence, the rapidity with which the duff dries out is not surprising. Daily rainfalls of one-tenth of an inch or less do not keep the duff above the danger zone. Even with greater amounts of precipitation, the duff moisture content does not remain above 10 per cent for long unless the rains occur at short intervals.

Two additional factors are valuable aids in fire-weather research. The first is the difference between the current air temperature and the dew point temperature, which has been termed the depression of the dew point by Lindgren.[2] The greater the divergence between these

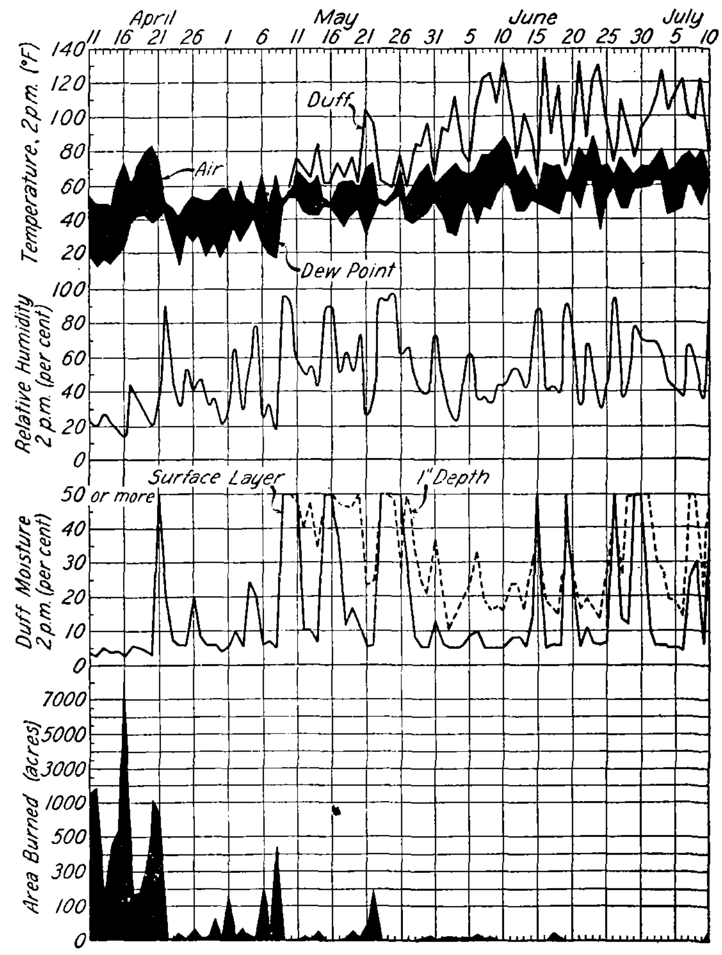

FIG. 2.—Meteorological conditions and forest fires in central Massachusetts, April 11–July 10, 1927. (Weather records taken at Petersham.) Graph 1: 2 p. m. duff, air, and dew-point temperatures. Graph 2: 2 p.m. relative humidities. Graph 3: 2 p.m. duff—moisture percentages at surface layer and at 1 inch depth. Graph 4: Daily area burned

two curves, the lower is the moisture content of both the atmosphere and the duff, and the greater is the fire hazard. When the depression of the dew point exceeds 14° F., hazardous conditions exist. This is similar to the danger point established by Lindgren for the Adirondack Mountain region. Vapor pressure as an aid in forest

[2] Lindgren, G. S. Fire Weather in the Adirondacks. Bul. Amer. Met Soc. vol. 7, No. 2, 1926, pp. 30-32.

fire-weather forecasts has been advocated by McCarthy.[3] In the present investigation also vapor pressure has been found to indicate the trend of fire weather, since the days of greater danger were accompanied by low vapor pressures.

As has been mentioned already, relative humidity seems to be the single meteorological factor which indicates fire hazard most accurately. The data assembled in Figures 3 and 4 demonstrate this point. In Figure 3 the percentage of days in each relative humidity class, the number of fires occurring on these days, the damages, and costs of suppression are plotted on relative humidity. A pronounced difference in hazard exists between the days when the relative humidity was 40 per cent or less and the days when it was greater than 40 per cent. When the relative humidity exceeded 40 per cent, the fires were few and small, and the damages and suppression costs were negligible. Figures on a cumulative basis (Fig. 4), 41.7 per cent of the spring days had relative humidities of between 14 and 40 per cent. On these days 90.7 per cent of the fires occurred, burning over 98.5 per cent of the total area burned, causing 99.1 per cent of the total damages, and amounting to 95.8 per cent of the entire suppression costs. While hazardous conditions do not necessarily produce fires, yet had greater precaution been exercised on these days (less than half the total days in spring) practically all the fires might have been eliminated.

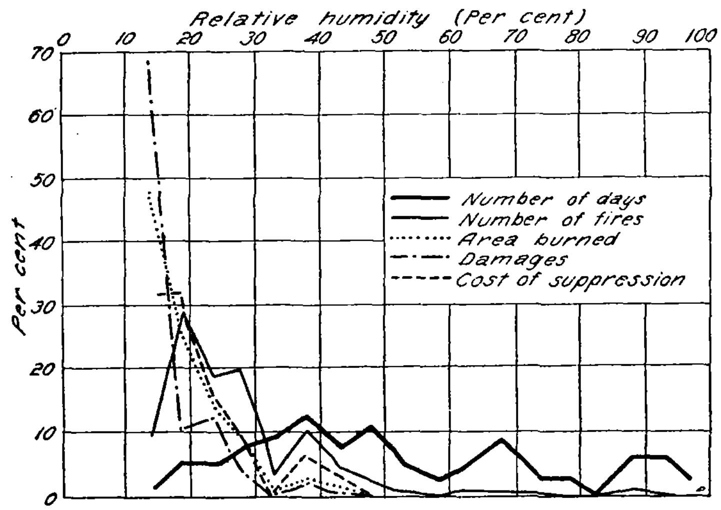

FIG. 3.—Percentages in each relative-humidity class of number of days, number of fires, area burned, damages, and cost of suppression, central Massachusetts, April 11–July 10, 1927

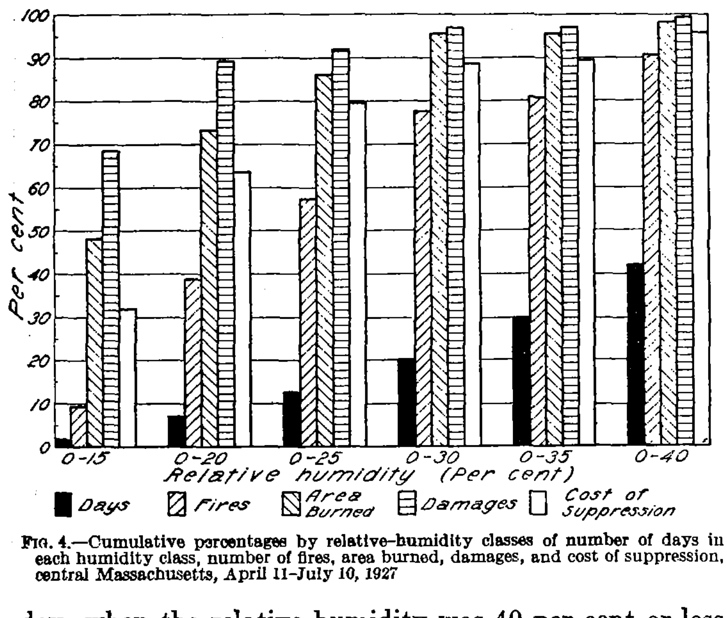

FIG. 4.—Cumulative percentages by relative-humidity classes of number of days in each humidity class, number of fires, area burned, damages, and cost of suppression, central Massachusetts, April 11–July 10, 1927

To summarize briefly, a graphical comparison of the spring forest fire records for central Massachusetts during 1927 and the weather records for the same period indicates that the maximum forest fire hazard exists between rainy periods, when the relative humidity is 40 per cent or less or when the depression of the dew point is greater than 14° F. Under such conditions, the vapor pressure is generally low—less than 0.300 inch, the duff in fully exposed areas contains less than 10 per cent of moisture at the surface and less than 20 per cent of moisture at 1 inch depth.

TABLE 1.—*Summary of weather conditions and forest-fire records, by relative humidity classes, central Massachusetts, April 11 to July 10, 1927*

Relative humidity classes (per cent)	Fires		Area burned		Damages		Suppression costs	
	Number	Per cent	Acres	Per cent	Dollars	Per cent	Dollars	Per cent
11–15	45	9.47	7,643	47.86	125,960	68.70	7,004	31.96
16–20	140	29.47	4,059	25.42	19,890	10.87	7,007	31.98
21–25	90	18.95	2,123	13.29	22,667	12.36	3,477	15.88
26–30	94	19.79	1,395	8.72	8,807	4.80	1,985	9.06
31–35	13	2.74	36	.22	104	.06	176	.80
36–40	49	10.32	473	2.96	4,213	2.30	1,338	6.10
41–45	20	4.21	186	1.16	1,424	.78	697	3.18
46–50	13	2.74	37	.23	229	.12	178	.81
51–55	4	.84	2	.01	1	-------	25	.11
56–60	-------	-------	-------	-------	-------	-------	-------	-------
61–65	2	.42	3	.02	2	-------	8	.04
66–70	1	.21	2	.01	-------	-------	2	.01
71–75	1	.21	1	.01	-------	-------	1	-------
76–80	-------	-------	-------	-------	-------	-------	-------	-------
81–85	-------	-------	-------	-------	-------	-------	-------	-------
86–90	3	.63	13	.08	25	.01	16	.07
91–95	-------	-------	-------	-------	-------	-------	-------	-------
96–100	-------	-------	-------	-------	-------	-------	-------	-------
Total	475	100.00	15,970	100.00	183,372	100.00	21,914	100.00

Relative humidity classes (per cent)	Average 2 p. m. observations within humidity classes									
	Dry bulb	Dew point	Relative humidity	Air pressure	Vapor pressure	Duff moisture		Duff temperature	Evaporation [1]	Wind velocity [2]
						Surface	1" depth			
	° F.	° F.	Per cent	Inches mercury	Inches mercury	Per cent	Per cent	° F.	Cubic centimeters daily	Miles daily
11–15	75	50	14	-------	0.124	3	-------	-------	-------	-------
16–20	64	46	19	-------	.120	4	-------	-------	-------	-------
21–25	62	45	24	29.40	.135	5	19	108	29.6	29.7
26–30	66	49	28	29.17	.185	11	12	110	33.5	34.6
31–35	67	51	33	29.22	.235	7	21	109	28.6	34.6
36–40	68	54	38	29.24	.279	7	19	109	28.8	29.1
41–45	72	58	43	29.12	.345	7	26	100	29.5	33.5
46–50	61	51	48	28.95	.275	13	32	85	19.5	33.6
51–55	64	55	52	28.97	.337	12	38	86	23.2	43.6
56–60	74	65	58	28.88	.408	28	38	102	12.8	16.9
61–65	62	54	62	28.80	.317	30	37	68	12.4	43.0
66–70	68	61	68	29.13	.418	18	36	93	17.2	30.6
71–75	58	54	74	29.09	.354	32	44	61	13.9	26.6
76–80	56	52	78	29.22	.374	35	[2] 50	75	5.8	15.3
81–85	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
86–90	55	52	88	28.92	.382	41	46	66	8.5	27.7
91–95	56	55	94	29.08	.428	[2] 50	48	64	7.5	37.2
96–100	52	51	97	28.89	.361	[2] 50	49	58	.7	5.4

[1] At same level as duff. [2] Atmometers placed 3½ feet above ground.

[3] McCarthy, E. F. Forest Fire Weather in the Southern Appalachians. MONTHLY WEATHER REVIEW, April, 1923, 51: 182–185.