Each evening from June 30 to September 20, at 5 or 5:30 p. m., when the duff hygrometers had been read and the prevailing conditions plotted on the current chart, a forecast was written down to show the degree of inflammability to be expected on each site 24 hours later. This forecast utilized the zones of inflammability shown in Figure 1, and the U. S. Weather Bureau forecast received that morning covering the following 36 hours. These inflammability forecasts have been rated to determine their dependability. Whenever the point actually fell in the zone predicted, the forecast was rated as 100 per cent accurate. If the point fell in the first zone above or below the one predicted, the forecast was given a rating of 75 per cent. If the point plotted in the second zone, above or below, the forecast was rated at 50 per cent; if in the third zone, 25 per cent; and if in the fourth or fifth zones, zero per cent. The results were as follows:

Dry site	76 forecasts, 82 per cent dependable.
Medium site	55 forecasts, 85 per cent dependable.
Moist site	78 forecasts, 88 per cent dependable.
Total	209 forecasts, 86 per cent dependable.

All of the serious errors, producing zero ratings, occurred when the forecasts for the dry site were framed on the following dates: June 30, July 1, 18, 21, 27, August 13, September 4 and 7. These dates also produced errors, though not all serious, for both the other sites. It is well to point out the conditions which produced the serious errors in forecasting for the dry site, which is the most difficult because it responds most rapidly to changes in the weather.

1. On June 30 the special weather forecast for north Idaho read: "Becoming unsettled. Probably thunderstorms in the mountains tonight and Tuesday * * *." Local conditions substantiated this forecast and a prediction of no inflammability was consequently written for the dry site on the assumption that there would be some rain. The thunderstorms did not materialize, there was no rain, and the inflammability was found to be extreme 24 hours later.

2. On July 1 the weather forecast read: "Hot weather through to-day, will be followed by slightly lower temperatures to-night and Wednesday with thunderstorms in mountains this afternoon * * *." The thunderstorms had not occurred but still seemed probable and a compromise forecast of "High or lower" was written for July 2. It was actually extreme.

3. On July 18 the weather forecast read: "Generally cloudy weather with moderate temperatures through to-night and Saturday with slight possibility of local showers * * *." Local conditions did not seem to favor the "slight possibility of local showers" and a forecast of extreme inflammability was therefore written. A rain of 0.29 inch between 8:30 a. m. and 3:00 p. m. on the 19th resulted in no inflammability.

4. On July 21, contrary to a "fair weather" forecast by the Weather Bureau, but using as a basis the local measurements of pressure, temperature, humidity, and wind direction, a prediction of no inflammability was written. Actually it was extreme.

5. On July 27 the official forecast read: "Cloudy, probably showers to-night and Monday, with thunderstorms in the mountains." No inflammability was forecast; actually it was extreme.

6. On August 13 the weather forecast read: "Showers and cooler to-night and Thursday, probably thunderstorms in mountains." Because of a slightly higher local barometer, a forecast of extreme inflammability was written. Rain amounting to 0.60 inch between 5:30 a. m. and 3:00 p. m. the 14th produced a condition of no inflammability, however.

7. On September 4 the official forecast read: "Fair weather, moderately warm, low humidity * * *." A prediction of extreme inflammability was written, but 0.12 inch of rain between 1:30 a. m. and 1:45 p. m. on the 5th caused no inflammability that evening.

8. On September 7 the weather forecast read: "Fair to-night and Monday, continued warm." Extreme inflammability was predicted, even in the face of a rapidly falling barometer. Rain amounting to 0.29 inch between 5:30 a. m. and 1:30 p. m. on the 8th produced no inflammability.

From these eight cases of absolute failures it is evident that "to rain or not to rain" is the vital question in this region. The chart shows that none of the curves rose to "Very low" or "No inflammability" except when pushed there by precipitation. Changes in other weather elements such as temperature or humidity, while very important, never produced differences in inflammability sufficient to cause serious errors in forecasting fire danger as determined by dryness of fuels. Rain is recognized as the single weather element which can produce a complete cessation of fire danger in this region, and whenever this weather element can be forecast with high dependability large sums of money can be saved in the handling of existing fires.

From these preliminary indications it appears that we are already able to predict the degree of dryness of forest fire fuels with a very satisfactory percentage of dependability. Three features stand out as desirable—first, the official weather forecasts should be strictly adhered to, and local weather conditions should not be given too much weight; second, the period covered by the fire-danger forecast should be lengthened as much as possible; third, predictions of rain or no rain will be more valuable if given with more assurance. An attempt will be made at Priest River Experiment Station to lengthen the period to include 36 instead of 24 hours next year, and it is hoped and expected that the Weather Bureau will name our rainy days even more successfully next year than last. Four additional duff hygrometers will also be installed next season in average sites at four new stations in various parts of western Montana and northern Idaho so that the Weather Bureau forecasts may be utilized more intensively. With increased experience in interpreting the effects of weather on the fuel moisture contents, it is expected that our present percentage of accuracy, which is already satisfactory, can be increased materially.

THE FOREST-FIRE SEASON AT DIFFERENT ELEVATIONS IN IDAHO

By J. A. LARSEN, U. S. Forest Service

[Priest River Forest Experiment Station]

In any fire-ridden forest region, such as north Idaho, there is great need for a tangible basis by which to judge the length and the intensity of the fire season in different forest types and at different elevations. The major and natural forest types, such as the western yellow-pine forests, the western white-pine forests, and the subalpine forests occur in altitudinal zonations one above the other and are the result of differences in air temperature and precipitation which affect not only life, growth, and distribution, but the fire hazard as well. It follows, therefore, that in addition to the local and physical basis of classifying fire hazard, as determined by the quantity and quality of inflammable material in each forest type, we should be in a position to begin the laying of a climatic basis which will set forth and define the length and possibly the intensity of the fire season in various forest types.

With this in view, the writer has examined variations in temperature and precipitation at different elevations in north Idaho, using data collected by the U. S. Forest Service and the U. S. Weather Bureau. These data have been correlated with the major forest types.

On the basis of a very exhaustive investigation,[1] in the course of which over 13,000 fires, which occurred from 1909 to 1919 in different parts of northern Idaho and Montana, were classified by months and correlated with temperature, it became quite clear that a mean air temperature between 45° and 50° F., but nearer 50°, could be used to fix the beginning and the ending of the fire season. Fifty degrees is therefore used to designate the beginning and ending, as well as the duration of the average fire season. It was also shown in the same report that there is practically no fire danger whenever the monthly precipitation averages 2 inches per month and, furthermore, that whenever the rainfall showed less than 2 inches per month the number of fires was directly proportional to this deficit under 2 inches. The danger line in precipitation is therefore fixed at 2 inches per month.

Looking over the air temperature data and curves for indications of the length of the fire season, it is seen that the western yellow-pine stations show a possible fire season of 150 days extending from May 4 to October 2; the western white-pine station of Murray, Idaho, 132 days from May 14 to September 23; and Roosevelt, the station in the subalpine region, 76 days from June 25 to September 9. In the subalpine forests the fire season is only half as long on this basis as in the western yellow-pine forests, these periods existing in full measure during dry seasons and being somewhat curtailed by rainfall during the normal seasons. Not only does the western yellow-pine and the lower white-pine forest type show longer fire seasons than the subalpine areas, but during this season much higher air temperatures prevail over these, and this fact materially increases the intensity of the fire season [2] in the lower as compared to the upper forest types. The other factors of climate bearing on the intensity are taken up later.

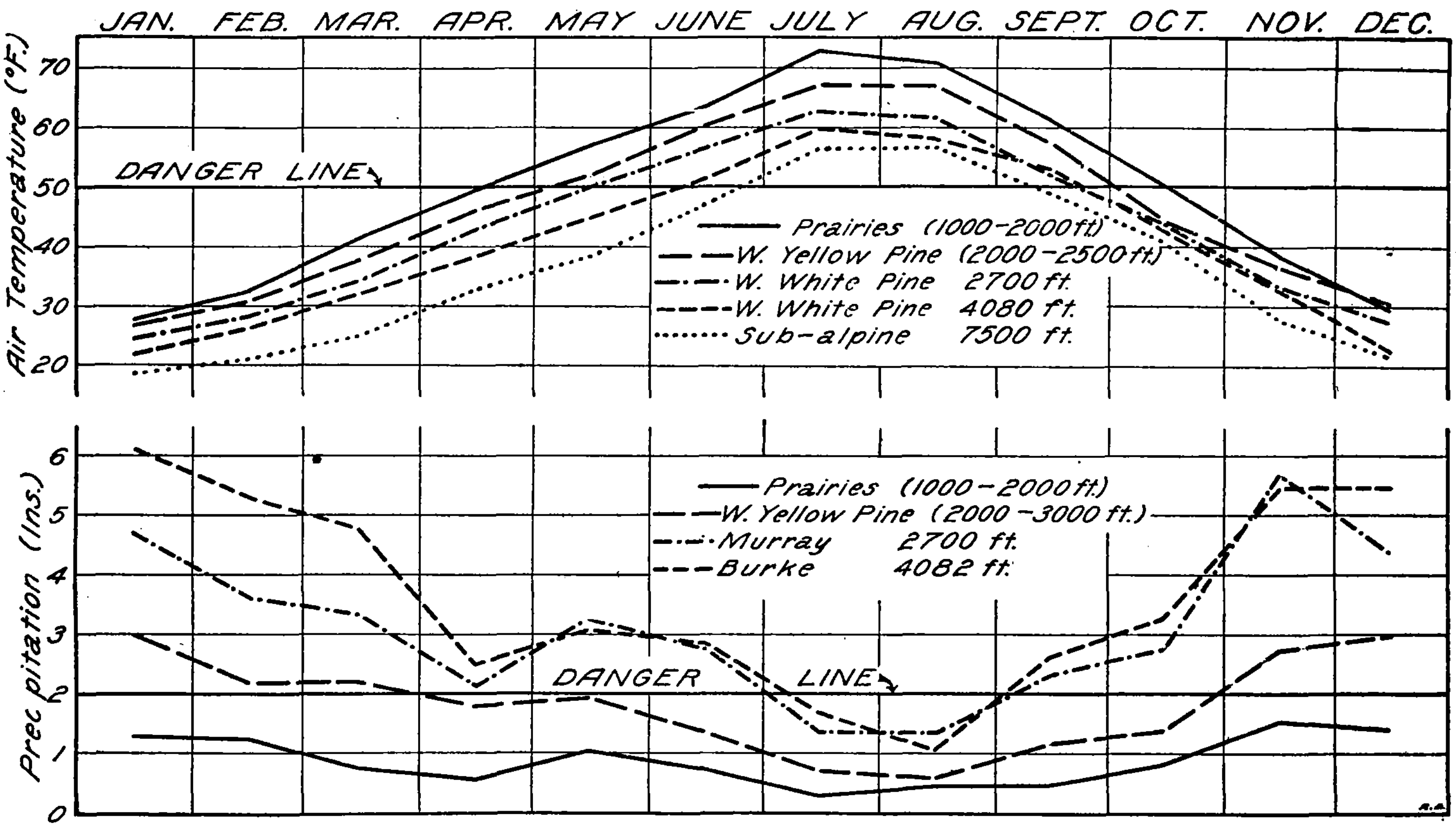

FIG. 1.—Annual march of air temperature and precipitation in relation to the length of the fire season at various altitudes, near Priest River Forest Experiment Station, Idaho

It was stated above that an average rainfall of 2 inches per month during summer holds fires well in check. Since, however, the normal rainfall curves for Idaho go considerably below this point, both in the yellow-pine and the white-pine forests, there is, therefore, a fire season during every summer of normal as well as subnormal precipitation, and a safe season occurs only during the years of abnormal rainfall. The length of the fire season in the western yellow-pine forests, as gaged by the normal rainfall curves, Figure 1, extends from May 15 to October 31, seemingly a period of 168 days, but from this we must deduct 29 days in October in which the temperature is so low that there is really no great danger. This leaves a period of 139 days. We may say, therefore, that under conditions of normal precipitation there is, in the western yellow-pine forests, a fire

[1] "Climate and Forest Fires in Montana and Northern Idaho," by J. A. Larsen and C. C. Delavan, MO. WEATHER REV., Feb. 1922, 50; 55–68.

[2] The phrase *intensity of the fire season* is used in designating whether or not a season is characterized by, for instance, great length and numerous large and destructive fires, or by few fires and relatively small damage, etc.—*J. A. L.*

season of 139 days limited by the rainfall in the spring and the temperature in the fall, and in years of deficient rainfall a fire season of 150 days limited by temperature conditions both in the spring and fall. In the lower station for the western white-pine forest the fire season is similarly limited during seasons of normal rainfall to 67 days from July 1 to September 5, and during summers of subnormal rainfall from May 14 to September 23, a period of 132 days.

Unfortunately, there is no available normal rainfall curve for subalpine forest stations in northern Idaho. Roosevelt, which lies at 7,500 feet, could be compared for temperature but not for rainfall, because it lies too far to the south on a watershed which shows rainfall conditions different from north Idaho.

It should be remarked that in judging the length of the fire season for a given locality, the time of beginning is subject to much more variation than its close, because in the spring the drying out begins at the lower elevations and progresses toward the higher elevations, following melting of the snow and advent of warm weather, whereas the fire season in the fall is often terminated by rains or snow simultaneously for high and low regions alike. Furthermore, because of the variations in weather conditions from year to year and the uncertainty in predicting the kind and character of the season, it is difficult to apply this knowledge. It is, therefore, not claimed that the data for the average season, as here presented, will furnish a safe guide and dependable basis indicating when and where to place the guards each year or how to mass or scatter the protective organization. Nevertheless, the chart is fairly indicative of the average opening and closing of the fire season, and in this way it serves the same purpose as frost data in agricultural pursuits. Again, by comparison of the current May, June, and July records with the normal, the data should aid in the recognition of the approach of abnormal or subnormal conditions so that the cautious administrator would fortify himself for critical conditions.

Going back to a consideration of the relative intensity of the fire season at different elevations, it is necessary to regard the factors of maximum air temperature, atmospheric humidity, and wind movement. (See Table 2). These, aside from the forest cover, influence the rate of drying out, the rate of consumption of material by fire, and the fanning and spreading of the flames. Recent investigations conducted by the Priest River Experiment Station staff and others have shown beyond a doubt that the dryness of the air in summer greatly influences the rate of spread of forest fires.

Although data on these factors are not as complete as could be wished, certain outstanding and significant figures have been obtained. Thus the mean maximum temperatures in August in the yellow-pine forests are about 10° higher than in the western white-pine forests, and nearly 20° higher than at the lookout points above 6,000 feet elevation.

Since the critical conditions for forest fires are as much a result of deficient rainfall as high temperature, it is well to consider the amount of rain which falls during the summer, or, better yet, during the two months, July and August. For the western yellow-pine forests this is only 1.30 inches and in the western white-pine forests 2.71 to 2.75 inches, or 0.65 per month in the yellow-pine type and 1.38 inches per month in the western white-pine type. During years of unusually bad forest fires, such as 1910 and 1919, the total July and August rainfall has been considerably less than 1 inch for these two months, both in the yellow-pine and in the white-pine forests.

The relative humidity also shows much more dangerous conditions in the yellow-pine forest than elsewhere. But while the low lying regions show both a longer and more intense fire season than the higher, the latter are subject to much greater wind movement than low stations and are for this reason not as well off as is indicated by the other factors previously considered. Thus the average wind velocity at Spokane in August is 5.3 miles per hour, at the Experiment Station lookout 8.9 miles, and at Monumental Buttes lookout 15 miles.[3] The figures on wind velocities at the highest lookout points, such as Monumental Buttes, are indicative rather than representative of actual conditions over the high forest area, in that the instruments are maintained on elevated and outstanding points on the topography. Such figures must, therefore, be somewhat reduced

SUMMARY

Comparisons of air temperature and precipitation data obtained in the various forest zonations in northern Idaho, made for the purpose of gaging the length and intensity of the fire season in the various altitudinal belts, show a possible fire season of 150 days for the lower western yellow-pine forest, 107 to 132 days for the forests of western white-pine, and about 76 days for subalpine forests at elevations of 7,500 feet. During these days the mean air temperature averages above 50° F. This length of fire season occurs only during summers of subnormal rainfall. When rainfall is normal the season is cut down to 139 days in western yellow-pine forests and 67 days in the western white-pine forests. Records for the subalpine forests are altogether too meager to permit determination of the length of the normal fire season as limited by rainfall.

As criteria indicating the probable intensity of a fire season, the mean air temperature, maximum air temperature, and amount of precipitation during July and August, as well as the relative humidity, appear to be much more critical in the lower western yellow-pine forests than on the forests which appear at higher elevations. Wind movement is greatest in the subalpine forests and lowest in the western white-pine type, and were it not for the low temperature and high humidity occurring at the higher elevations, the fire hazard would be much greater in the subalpine type than is actually the case.

[3] The relation of air temperature, wind movement, and relative humidity on lookout stations in Idaho and the comparison of these with conditions at valley stations is more completely set forth by the author in the Journal of Forestry, vol. 20, No. 3, Mar., 1922, p. 215-219.

TABLE 1.—*Mean monthly and annual air temperatures, precipitation, and length of fire season (days) for the period 1909–1919, northern Idaho and Montana*

Zonation	Station	Elevation	Mean air temperature (°F.)													Length of fire season		
			Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Beginning	Ending	Days
		Feet																
Prairies of eastern Washington.	(1)	1,000–2,000	27.7	32.6	41.6	49.9	57.1	63.7	72.5	70.9	61.6	50.6	39.0	29.9	49.7	4/15	10/16	184
Western yellow-pine forest	(2)	2,000–2,500	27.2	31.0	37.7	46.1	53.1	60.3	66.8	66.7	57.4	44.5	36.7	30.3	46.4	5/4	10/2	150
Western white-pine forest	Murray	2,700	25.2	28.5	34.4	43.2	50.4	56.4	62.9	61.7	52.2	44.0	33.4	27.4	43.3	5/14	9/23	132
Western white-pine forest	Burke	4,080	22.0	26.4	32.3	38.6	44.8	51.4	59.9	58.2	53.2	43.2	33.0	22.4	40.4	6/8	9/23	107
Subalpine forest	Roosevelt	7,500	19.2	21.4	25.0	32.7	38.3	47.6	56.6	56.6	48.9	41.0	27.8	22.0	36.4	6/25	9/9	76
			Precipitation (inches)													July–Aug.		June–Sept
Prairies of eastern Washington.	(1)	1,000–2,000	1.30	1.25	0.76	0.55	1.04	0.76	0.31	0.45	0.48	0.83	1.54	1.42	10.69	0.76		2.00
Western yellow-pine forest	(2)	2,500	3.01	2.18	2.22	1.82	1.96	1.36	0.73	0.57	1.18	1.49	2.77	2.97	22.39	1.30		3.84
Western white-pine forest	Murray	2,700	4.72	3.62	3.34	2.13	3.27	2.72	1.38	1.37	2.31	2.75	5.71	4.40	37.72	2.75		7.78
Western white-pine forest	Burke	4,080	6.17	5.30	4.78	2.50	3.09	2.84	1.68	1.03	2.62	3.27	5.48	5.48	44.24	2.71		8.17
Subalpine forest	Roosevelt	7,500	2.81	3.01	3.92	1.40	2.03	2.33	1.48	0.82	0.94	1.12	2.46	3.80	26.02	2.30		5.57

[1] Ritzville, Hatton, and Lind, Wash.
[2] Spokane, Coeur d'Alene, and Potlatch, Idaho.

TABLE 2.—*Averages and extremes of weather conditions in August*

Forest zone or type	Place and elevation (feet)	Air temperature (° F.)			Relative humidity (per cent)			Wind movement (miles per hour)	
		Absolute maximum	Mean maximum	Mean minimum	Mean a. m.	Mean p. m.	Lowest monthly	Mean for month	Maximum monthly
Prairies of eastern Washington	Hatton, 1,100	112	88.8	49.2					
Western yellow-pine forest	Spokane, 1,943	105	82.3	53.6	64	25	16	5.3	6.5
Western white-pine forest, low station	Priest River, 2,380	101	81.6	41.8	65	39	24	2.7	6.0
Western white-pine forest, low station	Murray, 2,700	97	80.1	43.3					
Western white-pine forest, high station	Burke, 4,082	92	74.4	42.0					
Subalpine forest	Experiment station lookout, 6,000		68.6	51.0	60	46		8.9	
Subalpine forest	Monumental Buttes, 6,979		72.6	49.1		53	30	15.0	

A PRELIMINARY STUDY OF EFFECTIVE RAINFALL

By J. F. VOORHEES

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SYNOPSIS

Since the water content of the soil does not change appreciably from year to year, each year's rainfall must escape in some manner.

In winter it escapes by evaporation and run-off in streams.

In summer it escapes by evaporation, by run-off, and by transpiration.

Transpiration may be increased at the expense of run-off by increasing the number and vigor of plants.

It appears that the possible effective rainfall for this region will average from 6 to 8 inches per year, which is enough to double the present average yield.

The above title was chosen because this paper is mainly an effort to analyse the problem and indicate the most promising line of attack; and because the data at hand were so general that we could hope to reach only general conclusions. It is believed that a more detailed study, using daily instead of monthly values, would throw much additional light on the subject.

Assuming that in any given region the water content of the soil does not change materially from year to year we are confronted with the fact that each year's rainfall disappears somewhere during the year. This is true whether there are plants present or not, and the object of this study is to learn what part of this water may be diverted for the use of plants. We shall attempt to make this determination by means of a comparison of total rainfall with run-off, supplemented by some data on leaching from the University of Tennessee Experiment Station, and by some data on evaporation from trees, obtained by the author.

It would seem that all of the rainfall can be accounted for in one of the following ways:

a. Evaporation from plant surfaces before reaching the ground.

b. Evaporation from the surface of the soil before penetrating to an appreciable depth.

c. Evaporation in the soil below the surface.

d. Surface drainage.

e. Subsurface drainage or leaching.

f. Transpiration.