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RELATION OF NUMBER AND SIZE OF FIRES
TO FIRE-SEASON WEATHER INDEXES

IN WESTERN WASHINGTON AND WESTERN OREGON

by

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"Hard-hitting fire-fighting crews and effective fire prevention held down this year's fire losses despite critical weather." Have you ever read such a statement and wondered how much of the apparently good record was really due to weather conditions?

The role of weather can be determined for areas where the relation between measurable weather conditions and fire occurrence can be reduced to simple equations. In this study, fire-season weather indexes for western Oregon and western Washington^{2/} were found to be reliably correlated with actual fire occurrence. Resulting equations make it possible to compute the fire occurrence that might reasonably have been expected under actual fire-weather conditions. By comparing actual fire occurrence with that reasonably expected, a fire-control officer can assess the effectiveness of prevention and suppression efforts. Equations can also be prepared for individual protection areas.

^{1/} The author is indebted to Mrs. Dorothy E. Martin and Mrs. Edgel C. Skinner for the statistical analysis.

^{2/} Cramer, Owen P. Forest fire weather in western Oregon and western Washington in 1958. U.S. Forest Serv. Pac. NW. Forest and Range Expt. Sta. Res. Note 163, 9 pp. 1958. (Processed.)

DETERMINING THE RELATION BETWEEN FIRE OCCURRENCE AND WEATHER

The basic problem was to determine the particular relation between fire occurrence and measurable weather conditions for given areas. This was done by multiple regression analysis wherein mathematical equations were derived for estimating three indexes of fire occurrence from three indexes of fire-season weather. In this process, strength of the resulting relations was measured by correlation analysis. All possible regression equations were tested, using each weather index singly and in combination with the others. The equations having the strongest relations were selected.

Because of changes in forest practices, land use, and fire-control procedures over the years, it was reasonable to suspect that there may have been related trends in fire occurrence. Consequently all relations between fire-occurrence indexes and weather indexes were checked for trend.

Indexes of Fire Occurrence

A fire season makes its mark in terms of number of fires and acreage burned. The total number of fires--one way of expressing fire occurrence--would certainly vary with weather conditions, as for example between moist and dry summers. In Oregon and Washington, however, lightning accounts for a large and highly variable proportion of the fires. And number of lightning fires depends on lightning storm occurrence, a weather phenomenon not related to the factors tested here. For this reason, the number of man-caused fires was used to indicate frequency of fire occurrence.

Another aspect of fire occurrence is size. A measure of fire size was needed which would not be subject to great fluctuation as a result of chance occurrence of very large fires. Average fire size did not satisfy this requirement, but two other indicators of size did: (1) the percentage of all fires becoming no larger than one-fourth acre, and (2) the percentage of all fires increasing to 10 acres and greater on State and private lands, or to 100 acres and greater on national-forest lands.^{3/} Fires of one-fourth acre and less comprise

^{3/} All fires 10 acres and larger were grouped together in State tabulations, whereas the largest size class in Forest Service tabulations is 100 acres and greater.

the largest group. These fires add little to total acreage burned, but they keep the regular fire-control organization busy. The large fires comprise the smallest group but they represent the fires with which the regular protection force is unable to cope--the fires that do the most damage and cost the most to suppress. Preliminary checking showed that each of these measures of fire occurrence is sensitive to differences in fire-season weather.

Indexes of Fire-Weather Severity

The ease with which a fire will start, the speed with which it will burn, and the length of time it will burn depend greatly upon the weather. Three weather indexes, in use for several years, measure these different qualities:

Burning index. -- Effects of wind speed and fuel moisture on ignition and rate of spread are given by this index. Only the highest 50 percent of the daily burning indexes (BI's) are used in computing the season index since the severity of a fire season is determined by the worst days.

Average number of days since a wetting rain. -- This measure of the length of drying periods between rains indicates dryness of the forest, which is closely related to the time since substantial rain fell. A wetting rain is defined as a minimum of one-fourth inch of precipitation in the 24-hour reporting period. When this amount is recorded at the low-elevation weather stations used, considerably more will usually have fallen upon nearby forested areas, most of which are at higher elevations.

Total number of rainless days. -- The greater the number of rainless days, the more severe the fire season. In a sense, this is a rough measure of the number of days when some degree of fire protection is necessary. It is supplemented by the average number of days between wetting rains to show effect of spacing of rainy periods.

These three indexes are computed for several key stations in the western parts of Oregon and Washington for the April 1-October 31 period, and the results are averaged to arrive at a value for each half-State area.

Statistical Analysis

In the regression analysis, national-forest lands and State and private lands were considered separately for the western part of each State. This was done to separate altitudinal, land-use, and protection agency differences in both weather and fire occurrence. For each half-State ownership area, equations were developed to express the relation between each fire-occurrence index and the weather indexes. Every possible combination and number of the weather indexes were considered.

RESULTS

The most important results of this study are presented as equations (table 1), three for each half-State ownership area, expressing fire occurrence expected for given fire-season weather. Thus for State and privately protected forest lands in western Washington, the most effective combination and number of fire-season weather indexes for computing expected number of man-caused fires were found to be (1) average number of days since a wetting rain and (2) burning index.

Important information about the weather indexes and fire occurrence in western Oregon and western Washington was gained through derivation and checking of these equations:

1. A highly significant correlation exists between each fire-occurrence index and fire-season weather as indicated by one or more of the weather indexes. This was true for both land-ownership groups in both half States.
2. The fire-season weather indexes are significantly correlated with each other in both half-State areas.
3. A definite trend was present in fire occurrence in western Washington in the 1944-56 period (figs. 1 and 2). No such trends were found for western Oregon (figs. 3 and 4).

Fire-Occurrence Trends in Western Washington

Where trends seemed to be present, the occurrence equations were recomputed, including year as an independent variable. By so doing, the trend during the base period was evaluated. These computations showed a very significant annual increase in the number of

Table 1.--Fire occurrence equations for western Washington and western Oregon, based on fire-weather indexes for the April-October fire season

Area and regression equation ^{1/}	Correla- tion co- efficient	Standard devi- ation around regression (±)	Base-period mean		
				<u>Fires</u>	<u>Percent</u>
Western Washington (1944-56):					
State and private lands:					
MC = 97.4B+29.2W-1138.4	0.95**	165	--	871	--
P _{1/4} = 148.6-0.619R	-0.78**	--	6.3	--	61.7
P ₁₀ = 0.216R-24.9	0.70**	--	2.8	--	5.4
National forests:					
MC = 1.394R-142.4	0.65*	21	--	53.5	--
P _{1/4} = 109.6-1.83B	-0.71**	--	5.8	--	79.6
P ₁₀₀ = 0.603B-7.84	0.76**	--	1.6	--	2.0
Western Oregon (1940-56):					
State and private lands:					
MC = 11.64R-1402.8	0.71**	126	--	416	--
P _{1/4} = 94.99-0.966B-0.554W	-0.76**	--	6.1	--	57.8
P ₁₀ = 0.59B+0.288W-11.22	0.82**	--	2.8	--	10.4
National forests:					
MC = 4.92B+2.28W-72.2	0.81**	23.7	--	105	--
P _{1/4} = 123.4-1.80B	-0.80**	--	4.8	--	77.3
P ₁₀₀ = 0.181B+0.112W-5.45	0.71**	--	1.4	--	1.7

^{1/} Where B = Season burning index.

W = Average number of days since a wetting rain.

R = Total rainless days.

MC = Number of man-caused fires.

P_{1/4} = Percentage of all fires 1/4 acre and smaller.

P₁₀ = Percentage of all fires 10 acres and larger.

P₁₀₀ = Percentage of all fires 100 acres and larger.

* Indicates a significant correlation, i.e., the 5 percent or 0.05 level of significance.

** Indicates a highly significant correlation, i.e., the 1 percent or 0.01 level of significance.

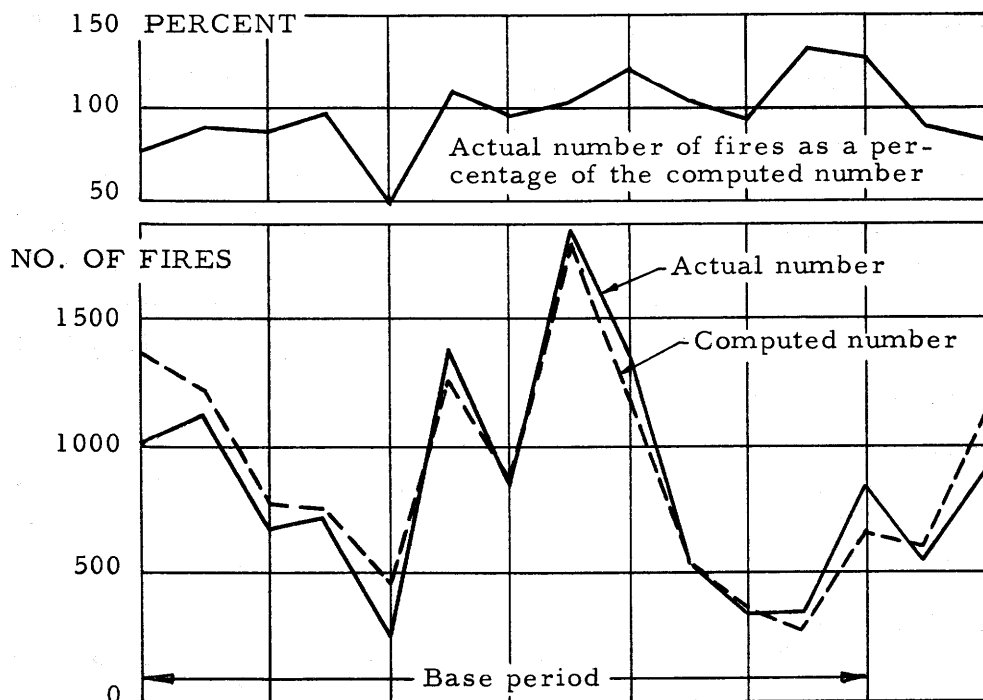


Figure 1.--Actual vs. computed number of man-caused fires--State and private lands, western Washington, 1944-58.

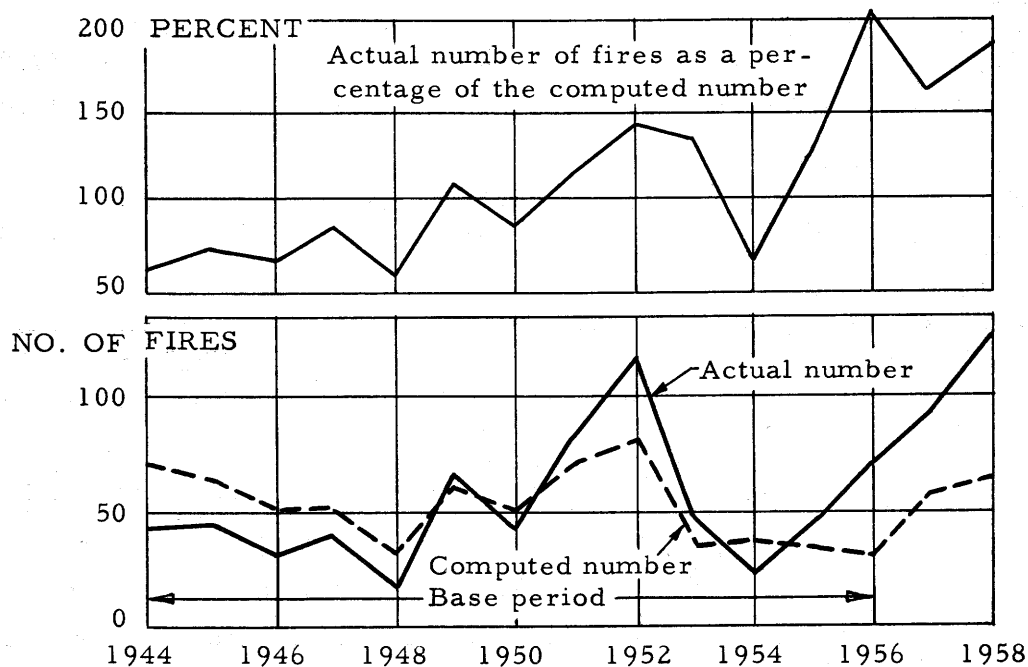


Figure 2.--Actual vs. computed number of man-caused fires--national forests, western Washington, 1944-58.

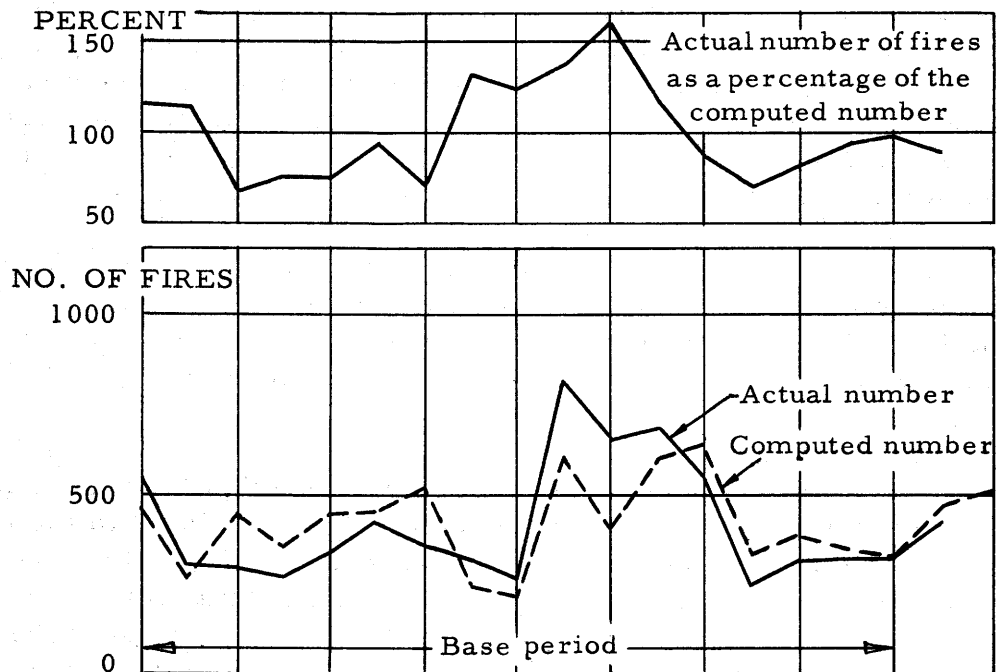


Figure 3.--Actual vs. computed number of man-caused fires--State and private land, western Oregon, 1940-58.

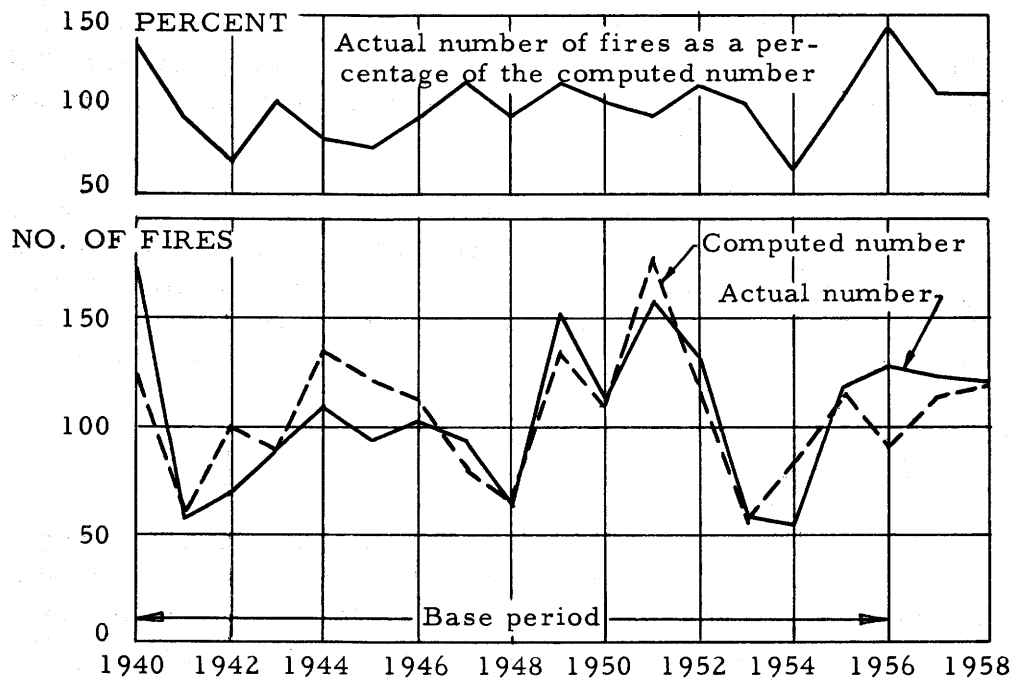


Figure 4.--Actual vs. computed number of man-caused fires--national forests, western Oregon, 1940-58.

man-caused fires in western Washington. On State and private lands, where an average of 871 man-caused fires occurred annually in the 1944-56 period, the average rate of increase during that period was 37 fires once weather variation was taken into account. This trend, however, did not extend into the 1957 and 1958 seasons. The change, apparently, was due to more stringent prevention measures.

A similar trend was noted on national-forest lands of western Washington. The number of man-caused fires, which averaged 53.5 annually in the 1944-56 period, was found to be increasing at an average rate of 5 fires per year. This is nearly 10 percent of the average for the period.

Once this time trend is allowed for statistically, the number of fires on national-forest lands becomes closely related to the total number of rainless days, much more so than is indicated by the equation in table 1 showing fires as a function of total rainless days alone. The closer relationship is indicated by an increase in correlation from 0.65 to 0.91 and a decrease in the standard deviation around the regression from ± 21 fires to ± 12 fires. The recomputed equation is not given, however, since it is useful only in determining the magnitude of the trend during the 1944-56 base period and the close relation of total rainless days to number of fires once trend is taken into account. The basic relation between number of fires and number of rainless days alone is more likely to be meaningful beyond the base period when changing cause and prevention factors may be expected to form new trends.

Another trend during the 1944-56 period indicates that fires on State and private lands of western Washington were becoming less likely to reach 10 acres in size than in previous years. Taking weather variation into account, the average rate of reduction in percentage of all fires reaching 10 acres or greater was 0.6 percent during the 13-year period.

Application of Results

These equations may be used to compute expected fire occurrence for past seasons. Computed and actual fire occurrence are easily compared graphically, either directly or by showing actual occurrence as a percentage of expected occurrence (figs. 1-4). The percentage comparison is more helpful for detecting trends.

In using the equations, however, it must be remembered that they represent a balance between forest use, fire hazard, weather, and fire-control activities during the base period. In following years, changing uses and hazards on forest areas and changing prevention efforts may affect fire occurrence to the extent that the formulas may not be representative of the situation at that time. Nevertheless, they will provide a useful reference base for year-to-year comparison and a basis for detecting occurrence trends.

Interpretation of computed occurrence. -- Reasons for differences between computed and actual fire occurrence will vary from one area to another. Unclassified variation, presumably due to the chance combination of firebrand, fuel, weather, and topography may be greatest for an area with relatively few fires. In contrast, estimates from the equations given here are likely to vary from actual occurrence because of the heterogeneous weather and fire-occurrence conditions in the extremely broad areas encompassed by a single rating. Consider, for example, State and privately protected lands of western Oregon, which vary from the moist Coast Range in the north to the dry Rogue River basin in the south. Separate equations for smaller areas more homogeneous in both weather and fire occurrence would enable sounder interpretation in terms of identifiable fire causes and fire-control activities.

Normal variation is indicated by the standard deviation around the regression^{4/} (table 1). An observed value may be expected to differ from a computed value by more than one standard deviation one season in three. A difference of 2 standard deviations may be expected 1 season in 20. Stated in another way, if a difference of 2 standard deviations occurs, chances are 19 out of 20 that it was due to something other than chance variation. At that point, it is up to the user of the formula to determine the cause of the variation.

Once it has been established that there is a statistically significant difference between expected and actual fire occurrence, it becomes necessary to interpret the difference in light of local

^{4/} The years used are considered a base period and not a sample of a larger population. Therefore we have used the standard deviation, which is a measure of variation within the base period only.

experience during the season. A less-than-expected percentage of fires remaining one-fourth acre or less, for example, might imply decreasing effectiveness in initial attack. A greater-than-expected percentage of fires in the largest size class might indicate a breakdown in followup action after initial attack. The same result might come about as a result of change in fuel type, or change in distribution of risk without adjustment of protection forces. A greater-than-expected number of man-caused fires could mean increasing risk or changing patterns of forest use. The reasons for differences between expected and actual fire occurrence would have to be determined separately for each protection unit.

Equations for individual protection areas. -- Useful equations for computing probable fire occurrence as a function of weather indexes may be derived by standard regression analysis techniques^{5/} for areas that average no fewer than 20 to 25 fires per season, as for a national forest or State district. Such equations are likely to be more satisfactory than half-State equations, which obscure by averaging even the major sectional variations.

CONCLUSIONS

This statistical study of the relation between three indexes of forest-fire occurrence and three indexes of fire-season weather permits the following conclusions:

1. The indexes of fire-season weather used by the Pacific Northwest Station for several years provide evidence of fire-season severity, as demonstrated by their very significant correlations with the indexes of fire occurrence.
2. Expected fire occurrence may be computed for past seasons by means of the equations developed in this study. Similar equations can be prepared for individual protection areas, such as national forests or State districts.
3. Equations of the type developed may be a useful tool in evaluating the effectiveness of fire-prevention and fire-suppression efforts.

^{5/} Croxton, F. E., and Cowden, D. J. Applied general statistics. Chapters 22-24. New York. 1941.

4. The weather index or combination of indexes giving the best fire-occurrence equations for any area can be determined only by trial.

5. In the period 1944-56 the number of man-caused fires was increasing in all ownerships in western Washington.

6. Fire-season fire occurrence--as measured by (1) total number of man-caused fires, (2) percentage of all fires remaining one-fourth acre and less, and (3) percentage of all fires reaching 10 acres and greater on State and private land, and 100 acres and greater on national-forest land--is highly dependent upon average weather conditions during the fire season.