FOREST FIRES IN CALIFORNIA 1911–1920

AN ANALYTICAL STUDY

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CONTENTS.

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By S. B. Show and E. I. Kotok, *Forest Examiners, Forest Service.*

INTRODUCTION.

The fires that spring up each year in the national forests constitute the most difficult task confronting the Forest Service—a task that in some years severely taxes its ability, its energy, and its resources. On the solution of this problem the service has spent much money and thought. Forest fires, like epidemics of disease, leave as a by-product a mass of statistics which are useful in analyzing the nature of forest fires and the measures that must be taken to check their devastation.

Forest fires differ from one another in speed, in destructiveness, in their susceptibility to successful attack, and in many other characteristics. Each fire seems to have its own individuality, to call forth new efforts of intelligence and skill from those who seek to check it. Each fire is a new experience, in which, it seems to the fire fighter, the only invariable elements are thirst, fatigue, and smoke. So it is natural that even seasoned fire fighters might doubt if the methods of scientific investigation can be used in studying phenomena so temperamental, so unpredictable as forest fires.

Nevertheless, enough has already been done in fire studies to show that much can be learned from them. Unless we can determine certain facts about the behavior of fires, and unless we can use those facts to determine the objectives and the scale of fire protection with a fair degree of accuracy, we must fall back on personal judgment, changeable and prone to error.

In the light of the recorded experience of 10 years, are our protection forces too large or not large enough? Are they stationed where they are most needed? What light does the frequency of occurrence of fires throw on the relative hazard of the different forests, on the disposition of the lookout force, on the allotment of funds? What effect does the bunching of fires have on the quality of protection, and at what stage does it cause a breakdown in the protection force? What risks do we run in deliberately cutting down the protection force on a forest or the crew on a fire in order to save money, or to eke out insufficient appropriations?

These are merely samples of the kind of questions that urgently need answering, as every administrative officer of the Forest Service knows; and it is to questions of this sort that this circular attempts to supply at least tentative answers.

OBJECTS OF STUDY.

The objects of the present circular fall into two general groups:

1. *A study of methods.*—An attempt to develop methods of analyzing data in accordance with recognized statistical practice, and to derive from them some of the underlying principles and tendencies of which the recorded facts are merely the visible expression.

2. *The application of the results of the study in practice, particularly in organizing the fire-protection force.*—For example, an attempt will be made to determine the relative need for protection in the different units, and to work out such methods for the allotment of funds as will place all units on an equal footing. In addition, a critical examination of the results of two of the theories of protection is proposed.

From such studies it should be possible to establish standards and to determine the relative quality of performance on different forests.

SOURCE OF DATA.

The data used in this investigation are derived from reports made by forest officers on 10,499 fires [1] that occurred from 1911 to 1920, inclusive, in the 12 timbered national forests of California as distinguished from the brush-covered protection forests. It is sufficient to note here that it has been the practice to record as soon as possible after each fire the essential facts: Its origin, its history, the factors affecting its spread, its cost, etc. The progressive changes in the recording forms have been made so as to improve the quality, to facilitate the use, and to increase the scope of the data recorded. Of the hundreds of individuals who have been connected with fire protection and who are responsible for the data on which this study is based, many were unaccustomed to recording notes in the field and to assembling facts on paper. In many cases the pressure of work has made it impossible for field officers to prepare the reports for some days after a fire; and for the same reason detailed examination and survey of many large fires have been impracticable. It must be recognized, therefore, that in quality, accuracy, and completeness the data are far from perfect. But such a study as this is not contingent on absolute perfection of data. Data clearly inaccurate have been discarded, and it is probable that ordinary errors are compensating, so that masses of data give approximately true values.

METHOD OF HANDLING DATA.

In the analysis of the 10,499 fires in 12 of the national forests of California [2] from 1911 to 1920, certain of the figures from the original individual reports were abstracted, simply as a convenience in handling. For each fire the following were recorded: Date of start, cause, location, acres burned, class of fire, cost of suppression, elements of cost, type of cover, degree and direction of slope, length of time from outbreak of fire to attack on fire, and for the years 1918–1920 the length of time from discovery of fire to attack.

These data were then assembled in various ways—by causes, by size of fires, by types of cover, etc.—and studied in groups. In general, the principle of averages has been used as the best method of expressing the essential facts.

This investigation is therefore based on the analysis by statistical methods of masses of data instead of individual bits, and it attempts a critical interpretation of the past performances of the Forest Service in fire protection in California. Although the study is local in scope, the methods evolved may prove to be of more general application.

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[1] See Appendix B for an early and a recent report.

[2] The Angeles, Cleveland, and Santa Barbara (southern California), and Inyo and Mono (east side) are omitted.

THE TWO MAIN THEORIES OF FIRE PROTECTION.

For the purposes of this paper it is sufficient to assume that fires cause damage to timber and other resources, and, as a corollary, that the object of fire protection is to prevent or reduce these potential losses. But just what ideal is to be sought in preventing damage is a debatable question, two principal theories having been formulated to express the objective. These, briefly stated, are:

1. To prevent damage by fires or to hold it to a reasonable, accepted minimum.
2. To keep the total cost (the sum of the costs of prevention,[3] suppression, and damage) to a minimum. This is the so-called economic theory, and considers the value of the resource only in relation to the cost of preserving it.

Under the first theory, the major emphasis is placed on reducing the area and hence the damage; under the second, greater attention is paid to the cost of prevention and of suppression, and in actual practice this has sometimes led to an undervaluation of potential damage.

DEVELOPMENT OF FOREST SERVICE FIRE PROTECTION.

Up to about 1911, modern protection as we know it was not in existence. The lookout system of detection was in its infancy, and methods of communication were very poorly developed. Coupled with this were the inadequacy of funds for fighting fires, and the incomplete knowledge of the nature of the problem and of the kind of organization necessary to meet it. Broadly speaking, individuals had to rely too much on their own resources—a failure of coordination which inevitably reflected itself in large fires.

From about 1911 to 1913, more and more emphasis was placed on adequate protection, the lookout and the communication systems were developed, and the ideal of reducing damage to a minimum expressed in small acreage was dominant. This was essentially an individualistic period; and as a rule each unit or national forest was encouraged to develop along its own lines, with relatively slight control from the central agency, the district office. It was a period of large-scale experimentation.

Following a critical study by DuBois in 1913 the best features developed by the individual forests were knitted together into a fairly well-standardized type of organization; and in 1914 centralized control was inaugurated.

DuBois's protection manual[4] is the expression and result of this study.

THE ECONOMIC THEORY.

Under centralized control, which continued until 1917, the ideal of minimum damage was at first held and efficiency of organization was largely measured by the acreage burned. Then a critical study of the protection theory led in 1916 to the issuing of Headley's Suppression Manual,[5] which for the first time expressed the economic

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[3] For the definition of this and other terms used in more or less special meanings in this study, as well as for the classification of causes of fires, see Appendix A.

[4] DuBois, Coert. Systematic Fire Protection in the California Forests. U. S. Department of Agriculture, Forest Service. 1914.

[5] Fire Suppression Manual, District 5, 1916. Issued to all forest officers in the California district.

theory in full and insisted that the costs of prevention, suppression, and damage (or on individual fires the costs of suppression and damage) be a minimum sum. It was believed at that time expenditures for prevention and suppression were too high. Because of the lack of knowledge of damage, it was natural that this factor should in practice be appraised at too low a figure. Just as the minimum-damage theory had been tested before by increasing the protection forces, so now from 1916 to 1919 the economic theory was thoroughly tested by progressively reducing these forces as the most easily controlled factor. As a corollary the idea was expressed that where low values were at stake large suppression expenditures were unwarranted and that fires in cover of low value might be allowed to become large if the cost of suppression could be thereby reduced.

In principle the economic theory of protection may seem to be sound. In practice it has three grave weaknesses: (1) The difficulty of appraising the true ultimate damage caused by forest fires; (2) the danger that any fire, unless attacked with the utmost vigor, may become a disaster; and (3) the risk that any relaxation in the speed and vigor of assault on fires may have a bad effect on discipline. Even if the theory were sound the Forest Service could not, on the one hand, urge on the public the utmost care with fire and, on the other, condemn itself for failing to follow its own preaching. It is obvious that the element of damage is not controllable at will and that it does not necessarily increase in a mere arithmetical ratio as protective effort is reduced.

Up to 1918 critical studies had been made of individual fires and of individual protection units, but no general examination of the entire field of protection had been attempted. Such a study, using the great accumulated mass of data, resulted in 1919 in a start back toward the more intensive protection of 1914–1916. The period of 1919–20 has perhaps been characterized by an increase in our knowledge of fire damage and an appreciation of its importance. With this change in the theory of protection has come a study of the various factors affecting the efficiency of protection.

Essentially the past decade of fire protection in California has been an experiment on a tremendous scale to determine the relative importance of the various factors affecting sound practice in protection. Progress has been made, but continuous study is necessary to isolate these many factors and to raise the standard of accomplishment.

NATURE OF PROTECTION PROBLEM.

As defined by DuBois, the protection problem is subdivided into:

1. Indirect control—the reduction of fires.
2. Protection finances—the proper distribution of fire-protection resources between units in proportion to the relative fire danger.
3. Direct control—assembling and organizing available resources up to the point of actual fire fighting, so that the minimum time will elapse between start of fire and start of fight.
4. Suppression—putting out every fire that occurs.
5. Determination of need for protection.

This circular will undertake, by a study of past performance, to point out certain of the controlling factors in successful protection.

THE INDEX OF COST AND DAMAGE.

In determining the cost and damage of fires some common unit of measure must be adopted, so that results can be uniformly expressed. The obvious unit is the dollar, as all the factors can finally be expressed in terms of money.

The three main factors of cost are prevention, suppression, and damage. Cost of prevention may be expressed in cents per acre, cost of suppression in terms of fires of given size, and damage either as so much an acre or for total acreage. Further, as will be later shown, the total damage of a group of fires varies with the proportion of class C fires to the total number of fires or according to the size of the average fire.

As criteria of effective protection, the acreage burned, the size of the average fire, and the percentage of class C fires will be used. The reasons for the employment of these standards will appear later.

PERCENTAGE OF C FIRES AS INDEX OF COST.

Throughout this circular, the statement is frequently made that the total burned area, the total damage, and the total cost of suppression vary as the percentage of C fires. An analysis of past performance brings out very clearly the essential facts. (See Fig. 1 and Table 1.) Using each year as a unit, it is found that the 10 years in the record can be conveniently grouped into those with 11–15 per cent C fires, 16–20 per cent, etc., up to 31 per cent or more, each group representing two years. There was then tabulated for each year the number of fires in the A and B classes and in each of the subdivisions of the C class adopted for the study of unit costs; that is, 11–20, 21–40, 41–80, etc.[6]

One feature developed is that the percentage of B fires is nearly constant, ranging only from 32 to 34 per cent, so that in effect a failure to suppress fires while in the A class means C fires. Apparently the same factors which tend to push A fires into the B class in a bad season also push B fires into the C class, decreasing the proportion of A fires while increasing the proportion of C and holding the B fires stationary.

AVERAGE SIZE OF FIRES.

A study of Table 1 shows that in the years with a low percentage of C fires (Group 5), the bulk of the fires are under 300 acres in size, the proportion in the different size-classes falling rapidly as the sizes increase and practically disappearing at the 1,000-acre class. In years with a high proportion of C fires (Group 1), on the other hand, the percentage in different size classes falls very slowly, with a fairly high percentage in the large-size fires (1,000 acres and over). Any of the intermediate groups falls between the two extremes in position and form of curve.

The table and the figure show that in Group 1 (31 per cent C or more) 33.6 per cent of all C fires are over 300 acres, whereas in Group 5 (11–15 per cent C) only 14.4 per cent, or approximately two-fifths as high a proportion, are as large. Considering all fires, in Group 1, 10.7 per cent and in Group 5, 2 per cent are over 300 acres. The intermediate groups again show progressive decreases.

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[6] For classification of fires, see Appendix A.

Any other limiting size can be used with essentially the same results. Comparing Groups 1 and 5, the per cents of all C fires over 1,000 acres are 14 and 2.3, respectively; over 2,000 acres, 8.1 and 1.2; over 5,000 acres, 2.3 and 0.8. Expressed simply, this means that in a year when about one fire in three is allowed to reach the C class,

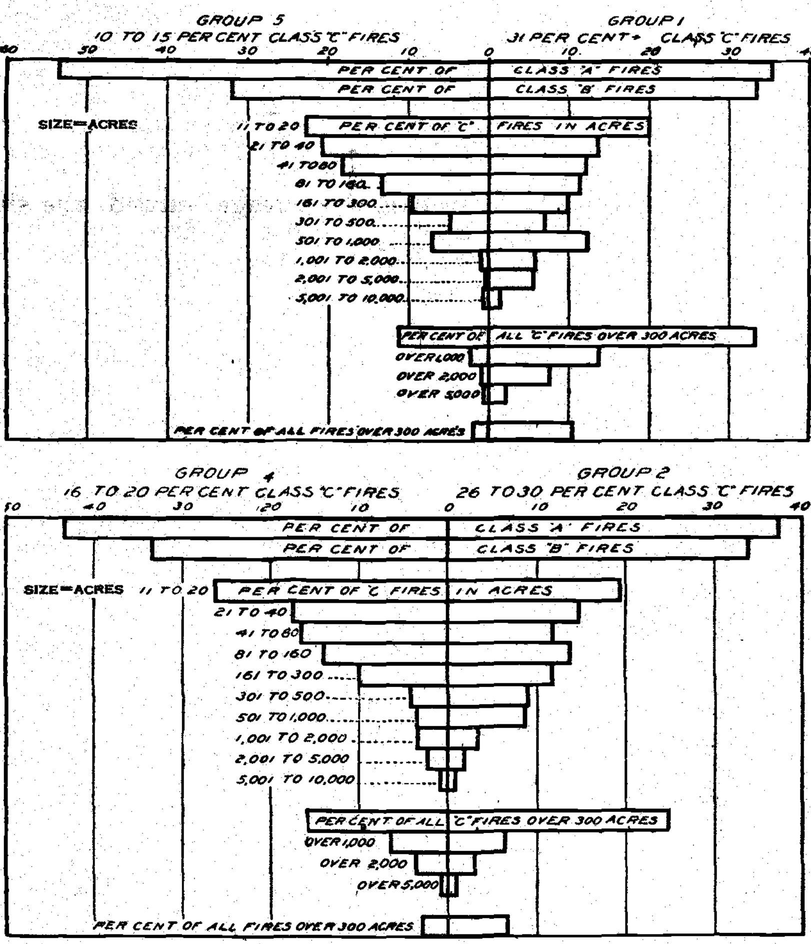


FIG. 1.—Relation of percentage of Class C fires to distribution of fires in different size classes. (Based on Table 1.) Notice that in years with low percentage of Class C fires (Group 5) a high percentage of the fires are stopped in the smaller size groups of 11–20, 21–40, and 41–80 acres, while a very small percentage become large Class C fires of over 1,000 acres. Conversely in years of high percentage of Class C fires (Group 1) a much smaller number are caught as small Class C fires and a much higher percentage become large Class C fires before they are controlled. The percentage of Class B fires remains nearly constant regardless of percentage of Class C fires.

about one-seventh of these C fires (or about one-twentieth of all fires) will exceed 1,000 acres, and about one-twelfth of the C fires will exceed 2,000 acres. If the protection force is so good or climatic conditions are so favorable that only about one fire in eight reaches the C class, then the chance of having big fires is much smaller—only about one fire out of every 43 C fires will reach as much as 1,000 acres and only about one out of 83 as much as 2,000 acres.

In practically all years a few very large fires occur, due either to errors of management or to unfavorable weather, and these occur in years both with low and with high percentage of C fires. No system has yet been developed that will eliminate the possibility of fires of over 5,000 acres in the northern half of the State. Occasional breaks have occurred and probably will occur again if only for the reason that forest fires in their very nature interpose great difficulties in the way of attaining perfection of attack.

The greater the proportion of C fires, not only the more frequent are the very large fires, but the smaller is the number of small C fires. Conversely, as the proportion of C fires decreases, the average size of all fires decreases from a maximum of 285 acres to 32 acres, and the C fires themselves drop from 840 to 215 acres.

After costs of suppression for the various years are reduced to the same basis by eliminating variables, as explained elsewhere (see p. 40), the average cost of all fires is found to be closely related to the proportion of class C fires. From the highest to the lowest the average cost of suppression per fire declines steadily from $91.50 to $29.40 in direct ratio to the percentage of class C fires. From this relation between the percentage of C fires and the cost of suppression, a rule of thumb can be worked out as follows: The cost of suppression of the average fire is equal in dollars to the product of the percentage of C fires multiplied by 2.5.

As Table 2 shows, the average number of fires annually is 1,050, of which 250, or 24 per cent, are C fires. If this can be reduced to 20 per cent, or 210 per year, a difference in cost of suppression per fire of $10 may be expected ($60–$50), according to the above rule—a total saving of $10,500 in suppresion bills.

At least for California, the proportion of C fires is a good criterion of the effectiveness of the protection force. Of course, even with a very low percentage of C fires an occasional large fire is bound to "get away," but the reduction of C fires to a low proportion of the total is an important and practicable objective.

THE FUNDAMENTAL NEED.

In all study and discussion of the protection problem, the fundamental fact revealed by the history of California fires is that successful protection consists not in putting out big fires, but in catching the fires when they are small. If it were possible to get one or two men to each fire in the class A stage, probably C fires would be the exception. Though this objective may be out of reach for the present, owing to the cost compared with the meager scale of appropriations, the experience of a decade shows that, at a reasonable cost in protection, C fires can be held to about 15 per cent of the total number of fires, and that with this standard of performance, considering the district as a whole, the burned area per year will be a very small part of the total forest area. These facts clearly point out the danger of any policy of protection that emphasizes low costs as the main objective, for this policy may not merely lead to a larger proportion of class C fires, and therefore of damage, but may defeat its own purposes by greatly increasing the least controllable element of cost—that of suppression.

CRITERIA OF ORGANIZATION.

It may be stated as an axiom that regardless of what theory of protection is adopted—whether of holding the burned area to an accepted minimum, or keeping the cost of prevention, suppression, and damage to a minimum—success requires consistency of performance. As forest crops require many years to reach maturity, it follows that even an occasional year of large fires may nullify the results of years of adequate protection. A primary aim in building up a protection machine must therefore be to provide adequately for the emergencies which experience shows are certain to occur, either because of the concentration of large numbers of fires at one time or because of very unfavorable weather conditions leading to an unusually rapid spread of fires.

To build such an organization requires, first, a knowledge of what results can be expected from a given organization, and, second, knowledge of how far the organization tends to break down under serious emergencies. An analysis of the various factors affecting the results normally expected of an organization is essential to the main purpose.

It is not the object of this circular to go into the details of the methods of administrative checking of a protection organization. It will be sufficient to examine to what degree actual performance departs from a theoretical standard, and to what extent, therefore, human fallibility must be accepted as one of the factors in the problem.

SUMMARY OF RESULTS, 1911 TO 1920.

Table 2 gives a general summary of results in protection for each year of the decade under consideration. At present only some of the more obvious relationships will be pointed out in order to give a general background for the detailed discussions in succeeding sections.

First, although there are fluctuations in the number of fires from year to year, five of the ten years are very near the average of 1,050 fires and only one year, 1917, was materially higher, with 1,573. The low totals for 1911 and 1912—616 and 565, respectively—are probably due in part to incomplete reporting. Figure 2 shows a great variation in the number of lightning fires throughout the decade, from 181 in 1919 to 794 in 1917; and indicates that lightning fires are chiefly responsible for the marked fluctuations in total fires from year to year. Man-caused fires show a rapid rise up to 886 in 1915, were practically constant through 1916 and 1917, and since then have decreased. The low figure for 1918 (363) is unquestionably due to three causes: First, systematic law enforcement; second, reduced industrial and recreational use of the forests on account of the war; and, third, the fact that much of the incendiary element was employed or left the mountains temporarily. The general downhill trend of man-caused fires in the past three years is probably due mainly to law enforcement. From these figures of fire occurrence it is apparent that the average volume of protection work is fairly well known.

Figure 3 contains a large amount of data and raises several interesting speculations. The various groups of horizontal bars indicate the relation or lack of relation existing between the total number of fires and percentage of C fires, between the total number of fires and area burned over, and between the intensity of protection (expressed in terms of men in the protection force) and the percentage of C fires and the area burned. It will be noted that in the left and right hand groups the bars, representing in one case the percentage of C fires and in the other the burned area, are arranged in order of number of fires per year. The left-hand group indicates apparently that an increasing number of fires does not increase—or perhaps even

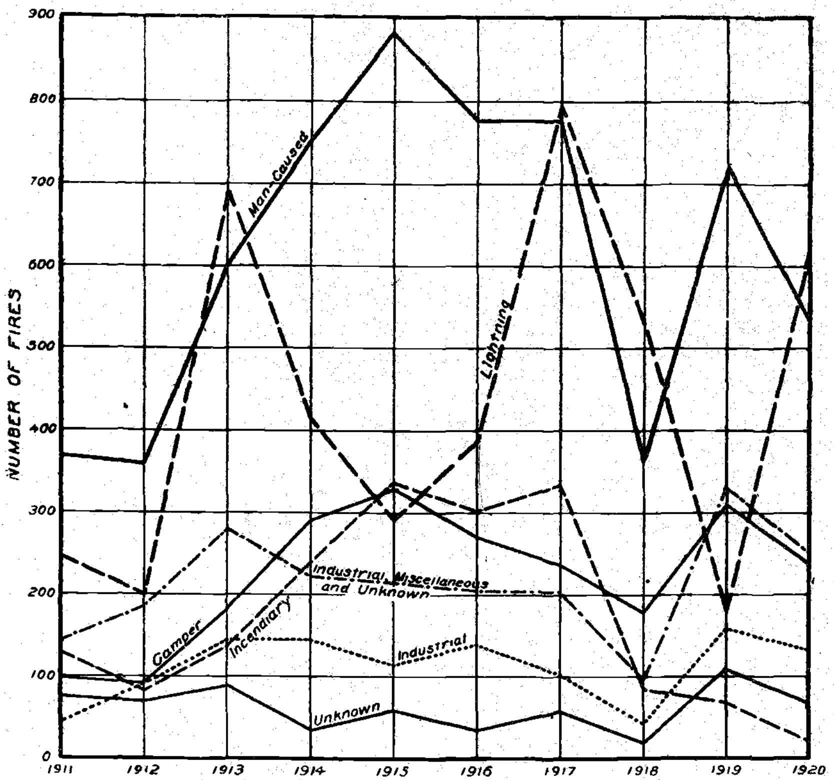


FIG. 2.—Number of fires by years separated into various causes. Notice the rapid drop in camper fires from 1916 to 1918, probably due to education and law enforcement. In 1919 the heavy influx of visitors naturally caused another increase. In incendiary fires there is likewise a heavy drop in 1918, and a lesser drop in 1919 and 1920. If incendiary fires were chiefly attributable to visitors instead of to local residents, this curve would follow the camper fire curve for 1919 and 1920. The curve for "unknown" follows the general course of other man-caused fires rather than of lightning fires, thus indicating their human origin. Industrial fires (logging, railroad, and brush burning) hold a fairly level course, though showing a fairly sharp rise in 1919. (Based on Tables 2, 7, 11, and 14.)

reduces—the percentage of C fires. In other words, the normal organization can absorb a large number of fires and put them out in the A or B stage. Only in exceptional years—as when 1,573 fires occurred—is a point reached where the organization can not handle the bulk of the fires when they are small.

The right-hand group—comparing numbers of fires with total area—indicates no apparent relationship between these two factors, fluctuating widely from one extreme to another, but showing again the disastrous effect of a breakdown in organization, as with the large number of massed fires in the last group.

INTENSITY OF PROTECTION.

In the central group it is apparent that the percentage of C fires and the area burned hold a fairly consistent and definite ratio to the number of men in the protection force. The fluctuations are wide when less than 400 men are employed, but with more than 400 men the area and the percentage of C fires drop rapidly. (See also Fig. 4.)

Obviously, also, a close relation exists between percentage of class C fires and total burned area, as can be seen in the relative proportional sizes of the bars at the right and left sides of Figure 3. Where the percentage of C's increases the area increases, and vice versa.

One further qualifying factor not shown in Table 2 may be mentioned. The variation in climatic factors from year to year is an important element, but discussion of this is reserved until later.

Likewise, between area burned and cost of suppresion the correlation is close, particularly if the latter be corrected to eliminate the

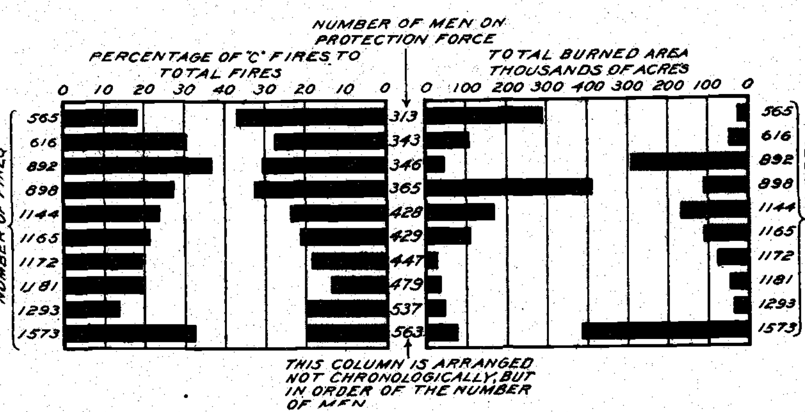


FIG. 3.—Relation between total number of fires and percentage of Class C fires by seasons, between the number of fires and area burned by seasons, and between number of men in the fire protection organization and the percentage of Class C fires and area burned, 1911-1920. (Based on Table 2.) Notice that there appears to be no consistent relation between number of fires and either percentage of Class C fires or area burned. Some of the very best records were made with high numbers of fires in one year and some of the inferior records with relatively low numbers. Between number of protection men and percentage of Class C fires and area burned there appears to be a fairly consistent relation. Both percentage of Class C fires and area burned decrease as intensity of protection measured by men employed increases.

increased commodity and labor prices, as will be done further on in this paper. The relation between the percentage of C fires and the size of the average fire (Fig. 5) is also worthy of note.

Without attempting to prove that intensity of protection has been the basic influence, it may be pointed out that during the period up to 1916, during which it has been shown that relatively intensive protection was given, the percentage of C, area burned, and costs, was strikingly lower than the average. Conversely, at the low ebb of protection forces in 1917 and 1918, the largest proportion of C and acreage burned are found. (See Fig. 4.) In 1920, with increase in protection, reductions in percentage of C and acreage occur. The high cost of labor for fire fighting throws these out of line, especially for the past three years.

Whether or not intensity of protection has been the cause of the progressive changes in the results of protection, there is undeniably a close correspondence between the two sets of factors. Leaving prevention out of the question, the correlation between the percentage of C's and acreage burned, and hence also suppression costs and damage, can not be overlooked. At present damage must be assumed to vary as acreage burned; more detailed discussion of the subject is postponed.

With this general summary in mind it is proposed, first, to study the behavior of fires grouped according to cause[7] and as affected by climatic conditions; second, to analyze the costs of fires; and third, to analyze the results of protection as revealed by the fires of 10 years.

The first question to be answered is: Do fires from different causes behave differently; and if so, how do these differences affect the scheme of protection? As will be shown in the next three sections, the various groups differ markedly and profoundly affect the problem of protection, so that a clear understanding of these differences is vital.

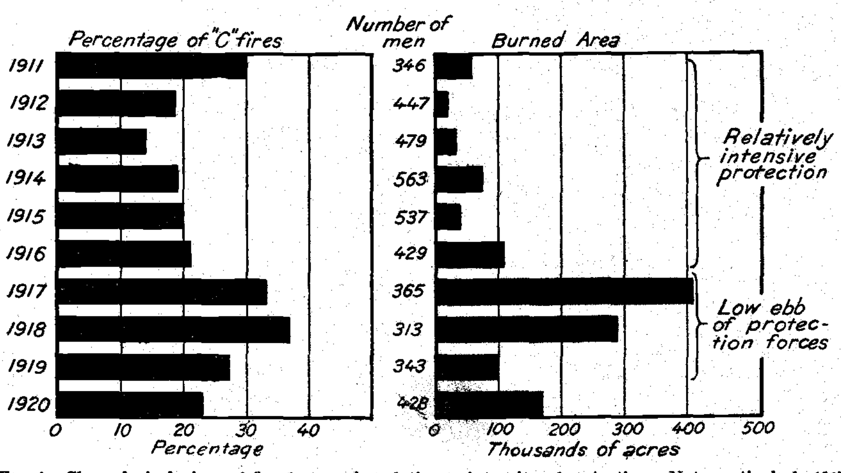


FIG. 4.—Chronological view of fire damage in relation to intensity of protection. Note particularly 1917 and 1918 when the "economic theory" was in full sway. (Based on Table 2.)

LIGHTNING FIRES.

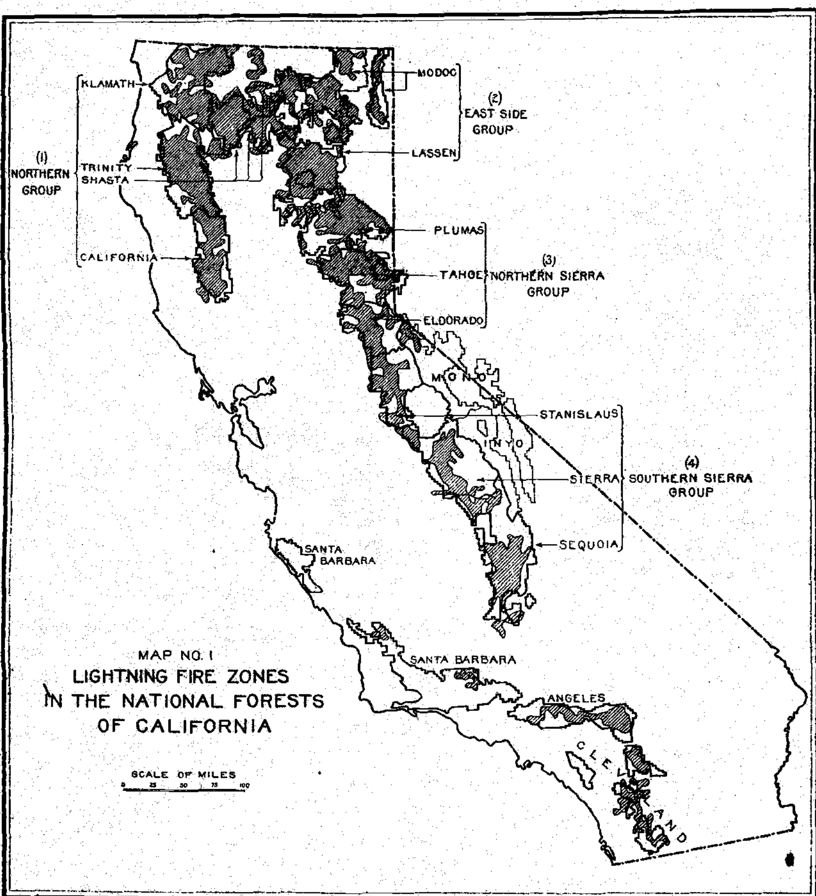
It has already been shown that lightning is the most important single cause of fires, being responsible for 4,362 out of 10,499, or 41.5 per cent, of all fires for the decade.

The zones of lightning fire shown on Map 1 were determined by plotting on a large-scale map the starting point of every lightning fire. We are not concerned with lightning zones in the meteorological sense, but only with those areas in which fires start from lightning and require action by the Forest Service. Much of the high Sierra country is in a heavy lightning belt; but the occasional fires resulting from lightning are not handled by the Forest Service, as they do not spread, because of the character of the ground cover and the heavy precipitation accompanying storms. Consequently, such a region is not included in the lightning fire zone.

Well-marked zones of occurrence and of concentration appear on the map; and considering for the present only the main zones, Table 3 gives the pertinent data. For comparison, total forest areas

[7] For the classification of causes of fire, see Appendix A.

and total areas of hazard (defined as total area in and adjacent to national forests in which fires from all causes occur and require action) are shown. In some cases it will be noted that the total hazard area is larger than the total forest area. Considering groups of forests, it is seen that in the northern group (1) 67.8 per cent of the total hazard area is in the lightning zone; in the north Sierra (3), 66.3 per cent; in the east side (2), 79.2 per cent; and in the south Sierra (4), 86.3 per cent. In other words, the lightning zone increases in relative area from north to south.



CONCENTRATION.

In concentration, which may be defined as fires per 100,000 acres of lightning zone, the reverse is true, concentration decreasing from north to south. (The California National Forest is out of line as compared to other forests in Group 1, but is placed there for geographical reasons.) In addition, lightning fires per 100,000 acres of total hazard area were computed and were found to decrease from north to south. In other words, the farther south one goes, the larger relatively becomes the zone of outbreak of lightning fires; but, on the other hand, these fires are spread out much thinner on these larger areas. The object of this analysis is to determine the demand made on protection forces by lightning fires; and as the protection organization handles fires from all causes, the total hazard areas must be considered.

Taking Group 4 (southern Sierra)—the group with the lowest number of fires per 100,000 acres of total hazard zone—as 100, the relative concentration, and hence demands, are:

Group 4—100.0.
Group 3—101.5.
Group 2—105.2.
Group 1—118.5, or, excluding the California Forest, 125.2.

In other words, for lightning fires alone, the demands on the protection force average 18 per cent greater in Group 1 (northern) than in Group 4 (south Sierra), with the other groups intermediate.

INTENSITY.

These, however, are average demands, and it is common experience that it is the emergency demand, when very heavy lightning storms occur, that tests the organization most severely. To determine the

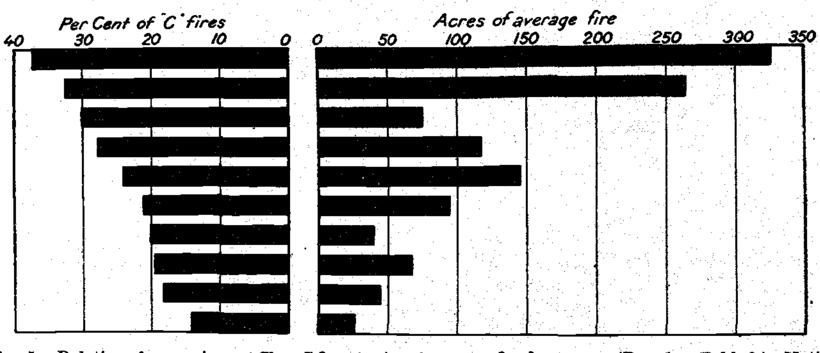


FIG. 5.—Relation of percentage of Class C fires to size of average fire by years. (Based on Table 2.) Notice that size of average fire varies rather uniformly with percentage of Class C fires.

effect of these emergencies, or what may be called intensity, or number of fires per storm, the data given in Table 4 have been worked out. (See also Fig. 6.) The number of fires set by the three heaviest storms in the past decade have been added by forests to secure figures representing maximum intensity. Here again it is found that the decrease is from north to south, with the east side group (2) somewhat out of line, and the northern group (1) averaging 54 per cent higher than the south Sierra group (4). In average demand Group 1 is 18 per cent above Group 4; in highest demand, 54 per cent.

These two lines of study raise the question of whether to organize for average or for maximum demands.

One further expression of the effect of maximum intensity in lightning fires may be mentioned. Table 5 shows average acreage burned for storms of different intensities, expressed as fires per storm. (See also Fig. 7.) Up to 250 fires per storm, the percentage of C, average C, and average fire are practically the same. With from 251 to 350 fires per storm (based on storms of July 16, 1917; June 12, 1918; and August 4, 1920), the percentage of C's more than doubles, the average size C nearly trebles in area, and the average fire is seven times greater.

Of the total area burned by lightning fires during 10 years, 66 per cent was due to the three heaviest storms and 80 per cent to the 19 general storms (that is, those affecting more than one forest). Occasional intense local storms in the 0–50 fires class cause some trouble, but the most severe demands the organization has to meet—the demands that are most likely to strain it to the breaking point—come only from very severe general storms.

The unusual damage resulting from these big storms occurred almost entirely in the northern California and northern Sierra groups (1 and 3); slightly in the east side group (2); and not at all in the southern Sierra group (4). In other words, the intensity data shown previously (Table 4) indicate clearly what may be expected.

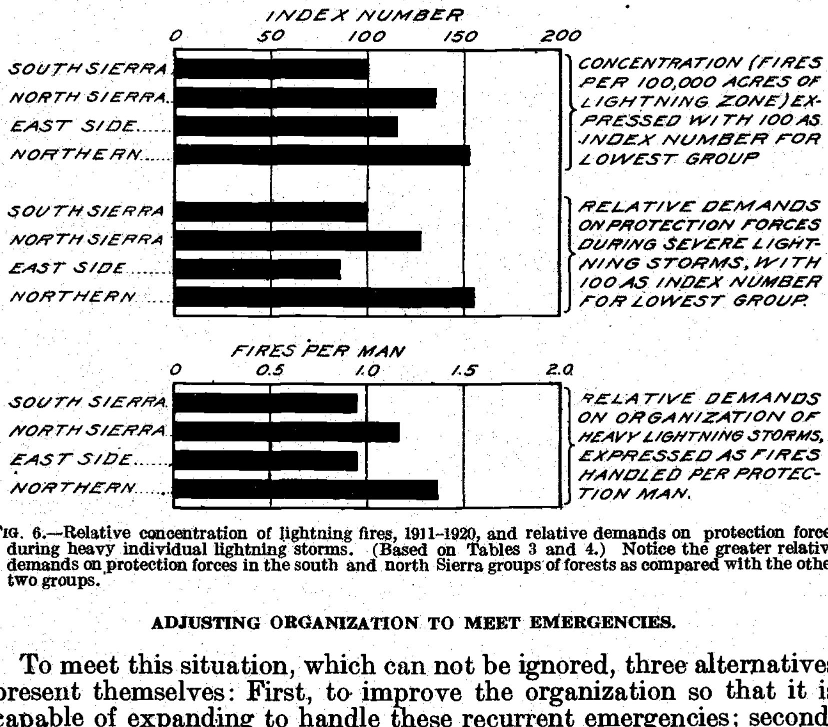


FIG. 6.—Relative concentration of lightning fires, 1911–1920, and relative demands on protection forces during heavy individual lightning storms. (Based on Tables 3 and 4.) Notice the greater relative demands on protection forces in the south and north Sierra groups of forests as compared with the other two groups.

ADJUSTING ORGANIZATION TO MEET EMERGENCIES.

To meet this situation, which can not be ignored, three alternatives present themselves: First, to improve the organization so that it is capable of expanding to handle these recurrent emergencies; second, to increase protection forces to the point that fires per man for the anticipated emergency will be reduced to the known safety factor, with present effectiveness; third, to fully organize potential cooperation, so that a second line of defense may be counted on.

Obviously, progress in improving the organization and in organizing cooperation may be expected to take up some of the slack; but unquestionably in places additional protection must be depended on.

A point likely to be overlooked is the necessity for continuity of protection. In so far as timber crops are concerned, consistency is perhaps the major goal to be attained. To put the matter most simply, protection fails if in even 1 out of 10 years large fires destroy the timber grown during 9 years of successful protection.

Viewed in this way, the extreme importance of meeting emergencies is apparent. Considering only California, the occurrence of 3 emergencies in 10 years is certainly deserving of careful study. It must be recognized that organizing on a scale adequate to meet emergencies, compared with the organization needed for normal years, will be a seeming waste of money, whereas organization for only the normal volume of fires under the same conditions will appear to be a temporary saving. In the long run, it is at least an open question whether the extra cost of carrying additional protection to meet emergencies will not be more than offset by the losses that occur if organization is only for normal seasons.

EFFECT OF INTENSITY ON PROTECTION FORCES.

It has already been shown that in lightning storms of an intensity up to about 250 fires per storm for a group of forests, the organization satisfactorily meets the demand, whereas beyond that point a very large acreage is burned. It may next be profitable to study the influence on the protection forces of specific emergencies on individual forests.

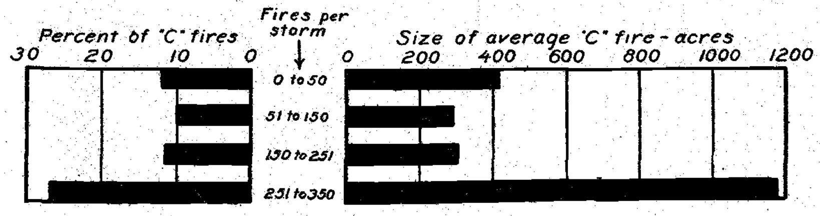


FIG. 7.—The effect of concentrated outbreaks of fires during heavy lightning storms. Note sharp increase in the percentage of Class C fires and in the size of average fire after the number of fires per storm passes 250. (Based on Table 5.) For the present type of organization and present intensity of protection about 250 fires per storm represent the maximum number that can be effectively handled.

For each of the 12 forests the three heaviest lightning storms were selected for study, and the number of fires set by such storms divided by the number of protection men on duty at the height of the season, giving for specific forests and storms the average fires handled by one man.

Table 6 gives a summary of results. (See also Figs. 7 and 8.) Up to an average of one fire per protection man (which includes lookouts, stationary guards, patrolmen, and district and assistant rangers), the individual storms are handled successfully, only 1 case out of 17 showing a percentage of C fires and size of the average fire anywhere near those for the higher intensities. Beyond one fire per man the percentage of C and the size of the average fire increases rapidly, showing clearly that on the average the size of the burned-over area is proportional to the number of fires handled per man.

Lightning storms are peculiarly suited to this form of analysis for two reasons: (1) They exhibit the intensity factor more than do fires from any other cause; (2) lightning storms are usually accompanied by rain, so that for a period of several hours the rate of spread of fire is slow, and different storms on the various forests can safely be compared because the factors influencing the fires set by these storms are very similar. Only one dry lightning storm of consequence is known in California during the 10 years; this has seven values in the table, of which three exceeded the one-fire-per-man figure, and one fell in the 0.5 to 1 group with higher than normal acreage.

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HANDLING LIGHTNING FIRES.

In handling large numbers of lightning fires, those that are reached by the morning of the day after the storm can usually be controlled while small and at low expense. It is the fires that can not be reached for one or two days, because the entire force is already busy, that become large before any work is done. In California, lightning fires are often inaccessible, and it is difficult and costly to

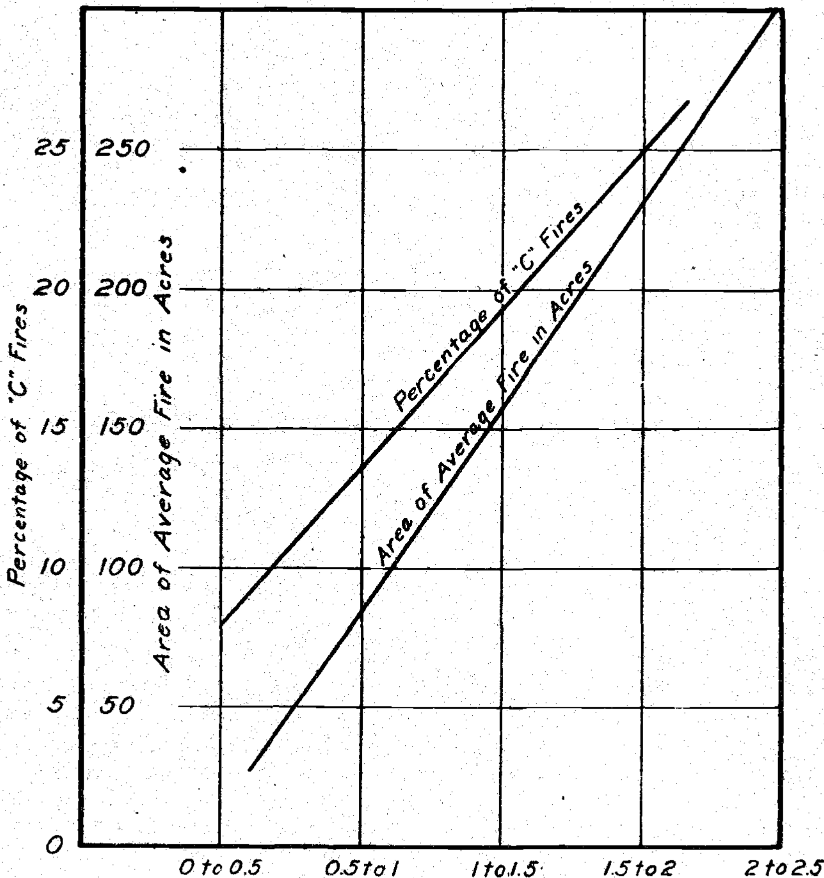


FIG. 8.—The rapid increase in percentage of Class C fires and in size of average fire as the number of fires handled per man increases during any one lightning storm. (Based on Table 6.)

mobilize crews for their suppression. During emergencies it has been the practice to send out all available cooperative forces; but experience shows that without supervision by forest officers, such volunteer crews often fail to make the fires safe. Local residents often have other business to attend to, or through lack of supervision and organization may fail to do a thorough job of suppression. For that reason, in handling emergencies, experience indicates that forest officers must reach all fires with reasonable promptness.

A study of the data shows that a higher percentage of lightning fires gets away after work has been done than in the case of fires from any other cause, particularly during emergencies. This is probably due in part to unsupervised work by cooperators; in part to the fact that protection men had to handle several fires and hence were unable to do a safe job on the earlier ones, being compelled to take a chance and go on to the next.

It is undoubtedly feasible to increase the number of lightning fires that can be handled per man by the better placing of men, and perhaps by a more general use of special tools for felling snags. It seems probable that in time the figure could be raised 50 per cent, but beyond that point special provision must be made.

There is no accurate correspondence between the total number of fires on a given forest in a given year and the number of protection men—in other words, the size of the protection force is not determined merely by the number of fires, for it appears to be true that within the range of the volume of protection work so far en-

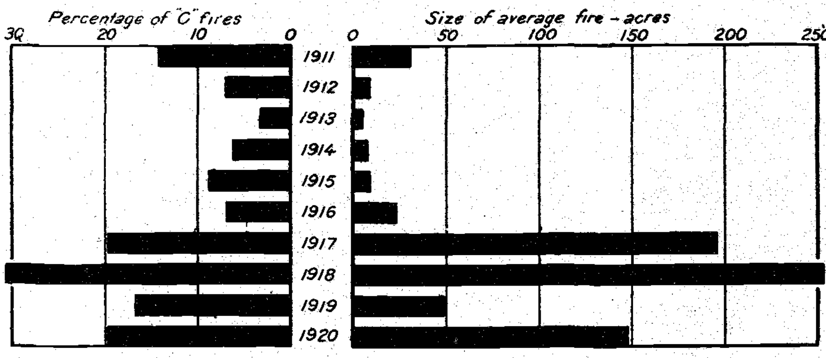


FIG. 9.—Relation of percentage of Class C lightning fires to size of average fires. A chronological view. (Based on Table 7.)

countered the total number of fires is of less importance than their concentration in time. So long as fires occur evenly distributed in time, good protection can be expected. The breaks come with large numbers of fires occurring at one time; and, to attain a high standard of performance, provision must be made to meet these recurring crises.

ANNUAL VARIATION.

Considering annual variations in lightning fires (Fig. 2 and Table 7), the first noticeable fact is the great fluctuation from year to year. The extremes are 794 fires in 1917 and 181 fires in 1919. The percentage of C fires is roughly proportioned, not to the total number of fires, but to intensity as measured by the maximum number of fires per storm for given years. Again, it is to be noted that acreage burned, and hence cost and damage, is a function within limits of the percentage of C fires, modified, of course, by the number of such fires (See Fig. 9.) The size of the average C fire, except in 1913, and of the average fire varies also as the per cent of C. (See Fig. 10.)

From 1911 to 1916 there is an excellent record even in years in which the danger point of 250 fires per storm was approached.

Probably this must be considered in connection with the number of protection men, and possibly with efficiency of organization. The 1919 record of 16.6 per cent C fires, with only 70 fires in the worst storm, probably reflects a defective organization. (See also Fig. 11.)

The figures in Table 7, showing the percentage of the total lightning fires of the season occurring in the worst single storms, are eloquent proof of the extreme intensity of this class of suppression work. On the average, 42 per cent of the total lightning fires results from a single storm.

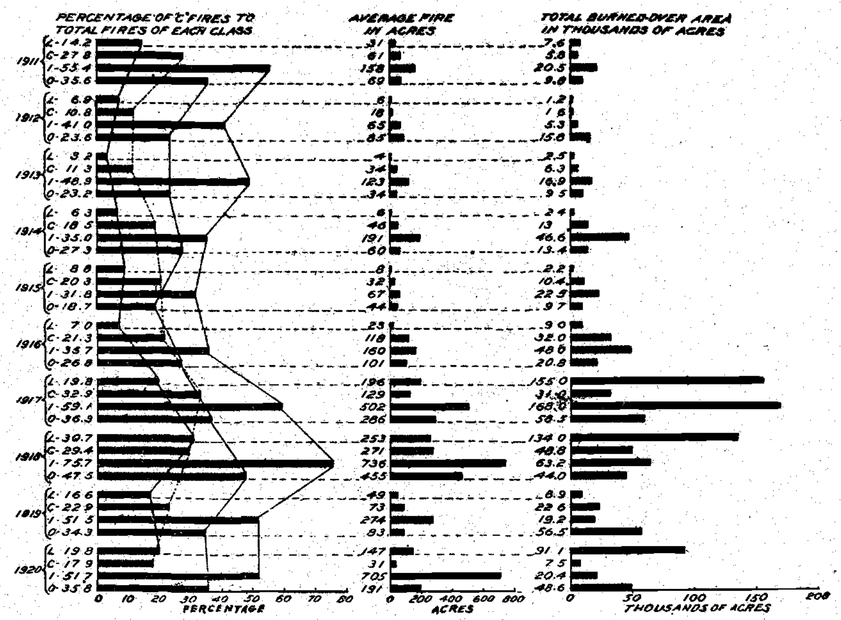


FIG. 10.—Percentage of Class C fires, average fires, and total area burned, separately by years for lightning, camper, incendiary, and other fires. Note how each group retains its own characteristic throughout. These incendiary fires invariably lead in percentage of Class C fires. This parallelism of different groups is brought out more clearly by the lines joining the bars representing percentage of Class C fires from the different causes. The parallelism holds good also in average fires and total area burned, and indicates underlying factors each season (probably climate and intensity of protection) that give a similarity of behavior to all fires of whatever origin. (Based on Tables 7, 11, 14, 16, and 19.)

SEASONAL DISTRIBUTION.

In studying fires from individual causes, seasonal distribution is an exceedingly important factor. The essential data for lightning fires are given in Table 8. (See also Figs. 12 and 13.) On the average only 3.6 per cent of all lightning fires occur in May and October, and 7.6 per cent in September, leaving 88.7 per cent in June, July, and August, with 77.3 per cent in the two latter months. Thus a tremendous concentration of lightning fires comes in the most dangerous part of the season when the forests are dry and inflammable. Fires from all causes, it will be shown, reach their climax in August. In the percentage of C fires the high figures for June reflect partly one heavy storm and partly the occurrence of lightning storms in some years before the protection force was mobilized.

The total acreage burned, and the size of the average C fire and of the average fire, especially during the unfavorable months of June, July, and August, point to the fact that as yet the handling of emergencies has not been successfully solved. The May and October figures are also high, but the relatively small number of fires makes special provision for protection on account of lightning fires unnecessary. Either an increase in the number of men employed or a greater effectiveness of organization, or both, may meet the issue.

SUMMARY OF LIGHTNING FIRES.

They are extremely concentrated both in place and in time. Both the zones of occurrence and the time of greatest danger are clearly defined by a study of the data. With the present strength of the protection force the danger point is reached when 250 or more fires are started by one storm.

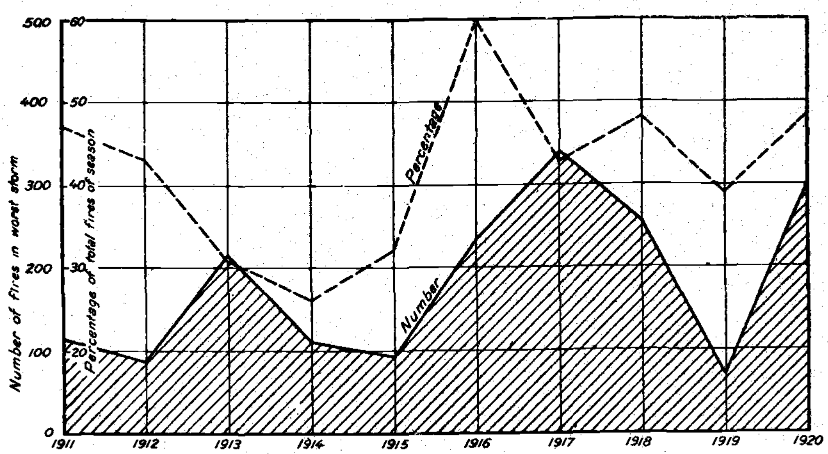


FIG. 11.—The number of fires in worst single lightning storm each year. The extreme gravity of these concentrated outbreaks is shown by the dashed curve, giving the percentage of the total fires of the season caused by these single general storms. (Based on Table 7.)

Because of their slow spread at first and since they occur chiefly in timber, lightning fires are more easily controlled than fires from any other cause. The danger from them comes chiefly from the massing of large numbers at one time.

Accessibility is more difficult than for fires from any other cause because many fires occur on high ridges.

Successful protection must be built on the following principles:

Study of maps so as to correlate placing of men with heaviest concentration of fires.

Proper season of employment of guards.

Either an adequate first line of defense must be organized to meet emergencies which experience shows will occur, or a supplementary second line must be provided.

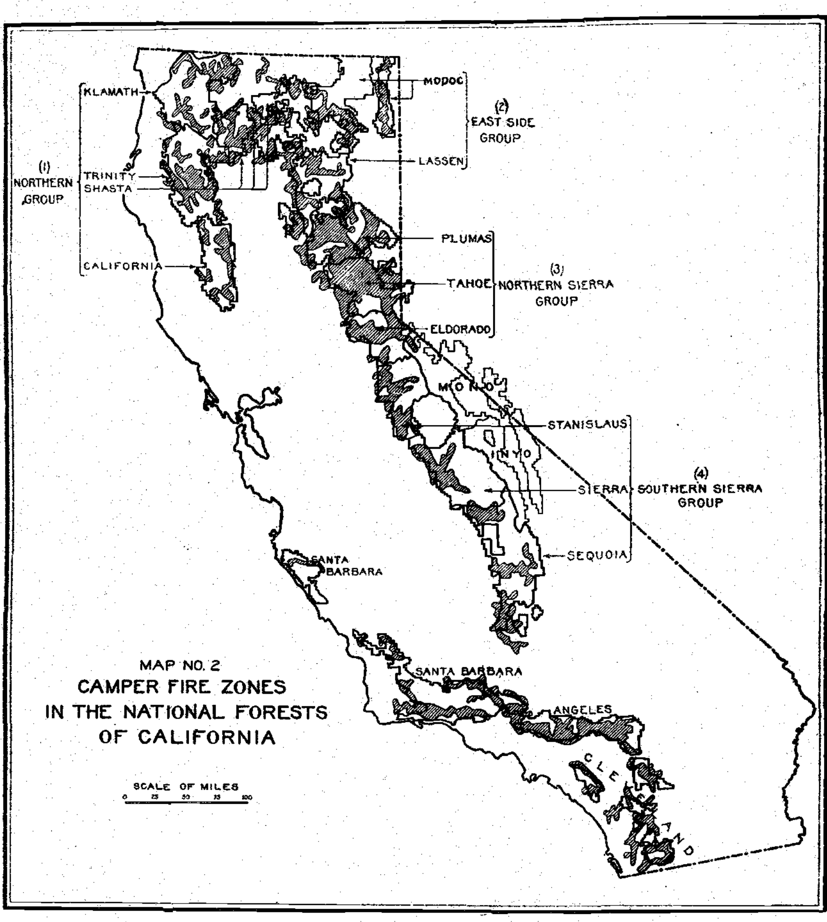
In handling lightning emergencies, extra rapid attack is not so essential as for man-caused fires. The important thing is to get one or two men to each fire with reasonable promptness.

A study of the data for the past indicates that if C fires do not exceed 15 per cent of the total, lightning fires may be regarded as having been successfully handled.

CAMPER FIRES.

During the decade camper fires have totaled 2,239 out of 10,499, or 21.2 per cent of the total number. This cause, therefore, ranks second to lightning in numerical importance.

The accompanying map (No. 2) is reduced from a map showing the starting points of all camper fires, these points being inclosed, with a boundary line of the zone in which such fires may be expected.



Well-marked zones of occurrence and of concentration appear on the map, and considering only the main zones, Table 9 gives the pertinent data. For comparison, total hazard areas are also given. Considering groups of Forests, it is seen that Group 1 (northern) averages 43.5 per cent and Group 1 (east side) 48.2 per cent of total hazard area within the zone of camper fires, or below the general average, whereas Groups 3 and 4 average 76.6 per cent and 60.8 per cent, respectively, or above the general level. In other words, the relative importance of the camper zone increases from north to south.

CONCENTRATION.

In concentration, or fires for each 100,000 acres of hazard area, Group 1 (northern) and Group 3 (north Sierra) are above average; the others below. Certain Forests, notably the Shasta, Plumas, and Tahoe, show strikingly high concentration. This, as Map 2 shows clearly, is due to a combination of main-line railroads and main automobile highways. The Eldorado and Stanislaus have main-line roads, but no railroads.

In general, as is indicated on the map, camper fires are concentrated along routes of travel and on recreation areas, with scattered fires in belts adjacent to these centers. This fact points to special protection for the areas of chief danger. The concentration of this

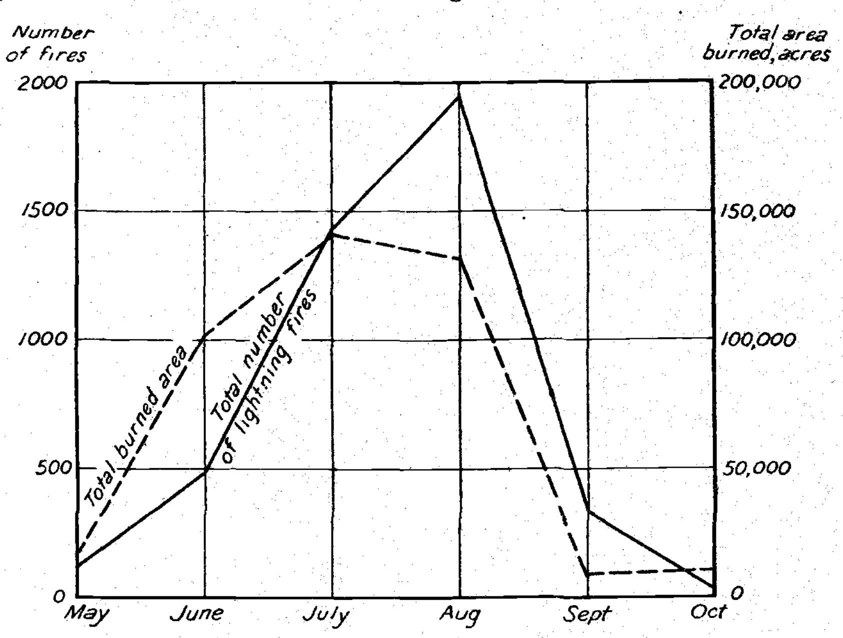


FIG. 12.—Number of lightning fires and the area burned by months. (Based on Table 8.)

class of fires in accessible places makes them easier to attack than scattered fires. A mobile road patrol has proved to be an effective method of handling camper fires.

INTENSITY.

In contrast to lightning fires, camper fires show a very low factor of intensity; that is, there is little tendency for fires to occur in large numbers in a single day. More than fires from any other cause, they occur regularly distributed throughout the season, merely showing a seasonal rise and fall. (See Fig. 13.) This feature, of course, makes for ease of control, as only extreme concentration of fires, or adverse climatic conditions, cause a break in the protection organization.

Contrasting the forest with highest concentration, the Tahoe with 28.2 per cent, and the lowest, the Modoc with 8.9 per cent, there is evidently a considerable difference. Where a relatively high concentration occurs with a high percentage of total hazard area in the camper zone, as on the Tahoe, even with lack of intensity or bunching of fires special provision must clearly be made in protection plans for handling these fires.

ANNUAL VARIATION.

In studying annual variation in camper fires (Table 11 and Fig. 2), the first noticeable fact is the rise in total number from 1911 to 1915, the fall until 1918, then the rise in 1919 and fall in 1920. This must

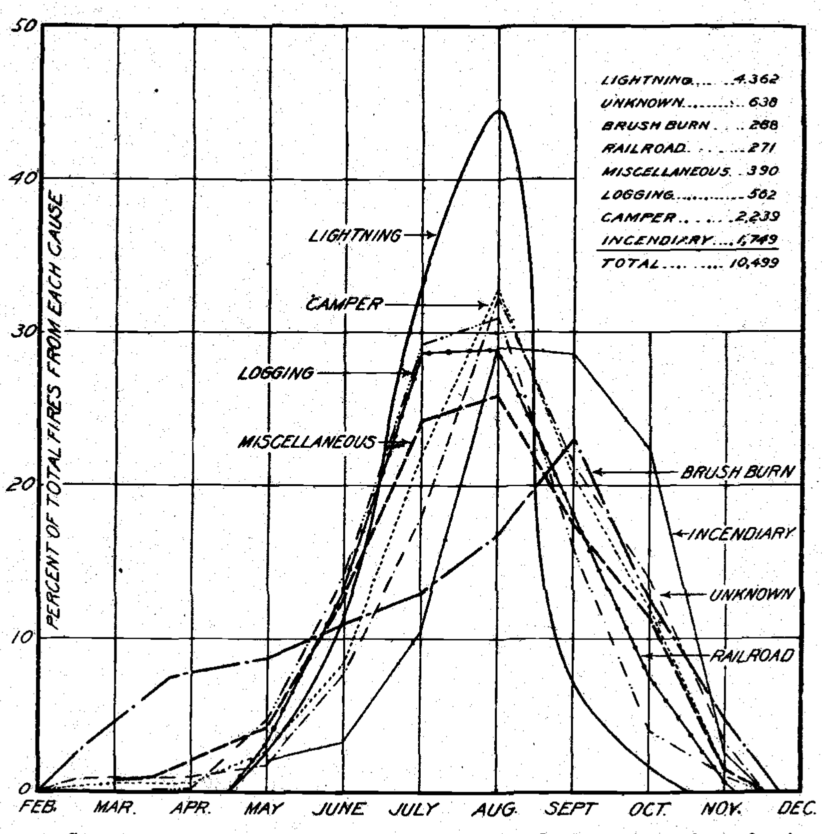


FIG. 13.—Seasonal occurrences of fires grouped according to causes. On the vertical scale the fires in any one group are considered as 100 per cent, and the number occurring in any one month is a fraction of this total percentage. (Based on Tables 8, 12, and 15.) Notice the wide differences in seasonal distribution of fires from different causes. Lightning fires stand at one extreme and brush burning at the other. The prominence of incendiary fires in the late fall is particularly noteworthy.

be considered in connection with such factors as increased volume of travel, educational propaganda, development of camping places, and enforcement of fire laws. Considering first the volume of travel, Table 10 shows the number of visitors to the Yosemite National Park [8] for each year from 1916–1920, inclusive. The tremendous increase in the use of the park, which is a fair index of a corresponding increase in the use of the national forests, shows 2.06 times as many people in 1920 as in 1916. During 1917 and 1918, the war years, the

[8] Data furnished through the courtesy of the Superintendent of the Yosemite National Park.

increases were very slight, but during the past two years the volume has grown immensely. In 1916 approximately 33,000 people visited the park and practically the same number in 1917 and 1918. In 1919 and 1920 the number of visitors rose to approximately 58,000 and 69,000, respectively.

Up to 1915, broadly speaking, the number of camper fires probably increased in about the same ratio as travel. Beginning in 1916 the number of fires decreased, while travel continued upward. The cumulative effect of prevention measures is clearly indicated in Table 10 and Figure 14. The risk figure—that is, the number of fires that are likely to occur for a given number of people—is being gradually but steadily reduced, from 8.16 fires per 1,000 people in 1916 to 3.49

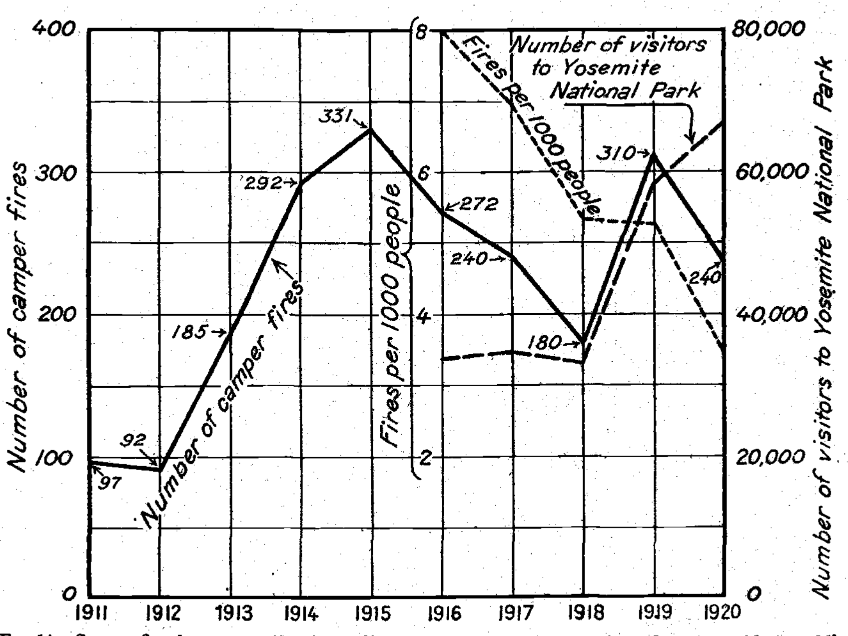


FIG. 14.—Camper fires by seasons, 1911–1920. From 1915 to 1918 there was a sharp drop, traceable to public education and law enforcement. The rise in 1919 was at least partly due to the enormous increase in travel after the war. The dashed curve shows the increase in number of visitors to the Yosemite National Park. Assuming that a proportional increase held good in the national forests, it is apparent that decided headway was made in 1920 in offsetting this new risk. (Based on Tables 10 and 11.)

per 1,000 in 1920, a drop of 57.2 per cent. (See note to Table 10.) The cumulative effect of public education, the preparation by the Forest Service of safe camping grounds, and systematic law enforcement have clearly borne fruit in this reaction. The number of camper fires per 1,000 travelers expresses the success of the various measures to induce the public to be careful with fires.

IMPROVEMENT IN RECORD OF CAMPER FIRES.

The next important feature (Table 11 and Fig. 15) is the very consistent and creditable record in acreage burned, in the size of the average C and of the average fire, and in cost of suppression. The foregoing discussion of camper fires indicates that continuous study of the camper fire problem has been made, both in prevention or indirect control and in the placing of protection forces with reference to areas of concentration. The excellent records of the past two years appear to be at least in part a corollary of law enforcement. As every effort has been made to apprehend persons guilty of allowing fires to escape, the resulting promptness in reaching fires has naturally resulted in keeping them to small size, cost, and damage.

A study of Table 11 indicates that so long as C fires are held below 20 per cent, no serious situation is to be anticipated. With a rise in the proportion of C's, the area burned, costs, etc., rise also, as for fires from other causes (Fig. 10). An occasional bad fire is sure to

FIG. 15.—Camper fires 1911-1920. Total area burned and average size of fire. (Based on Table 11.)

result even with a low percentage of C's, but the cumulative experience of 10 years shows clearly that, for the district as a whole, nothing serious is likely to happen as long as C fires are kept down to a small proportion of the total.

The correlation between percentage of C fires and man power is perhaps worthy of note, as in the case of other causes. (See Fig. 16.)

From the standpoint of protection, the important fact shown in the table is that continuous attention to this difficult problem, both in prevention and in suppression, has gone a long way toward a satisfactory solution.

SEASONAL DISTRIBUTION.

The seasonal distribution of camper fires (Table 12 and Fig. 13) is strikingly different from that of lightning, as is clearly shown in the figure. Both classes of fires assume importance in June, and both reach their peak in August; but while lightning fires then drop to a very low figure, camper fires are important in September and even in October, or up to the end of the hunting season. The concentration, as well as the intensity of camper fires, is thus materially lower than for lightning, and dangerous emergencies from camper fires alone are not likely to occur.

Except for the month of June, reasonably low average C and average-sized fires are found, with a tendency toward a decrease in average size of camper fires toward the end of the season. The high June figures are due to late placing of protection forces in a number of the years in the record.

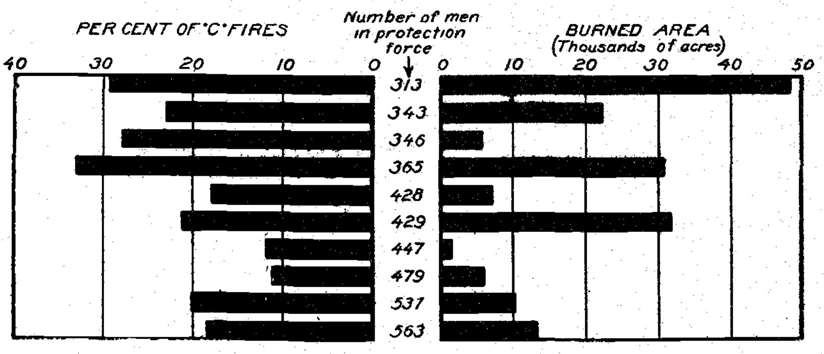


FIG. 16.—Camper fires 1911–1920. Relation between intensity of protection expressed in number of men on protection force and the percentage of Class C fires (compared with total camper fires) and the total area burned by camper fires. (Based on Table 11.) Notice as in the case of all fires the relation of the intensity of protection to the percentage of Class C fires and the area burned.

SUMMARY OF CAMPER FIRES.

Camper fires tend toward a regularity of distribution in time. Zones of occurrence are well marked, and a large proportion of these fires, occurring as they do along routes of travel, are the most accessible of all fires.

Vigorous law enforcement, naturally leading to effective suppression, is apparently on the way to solving this particular problem. In addition, education and the development of public camp grounds should be able to hold camper fires at least to the present annual number, in spite of the anticipated great increase in travel in the Forests.

Special protection for areas of unusual danger must be more and more depended on as the volume of travel increases in the national forests. Special restrictions such as closing of hunting season, prohibiting smoking, or building of fires may also be necessary at times in regions of particular danger.

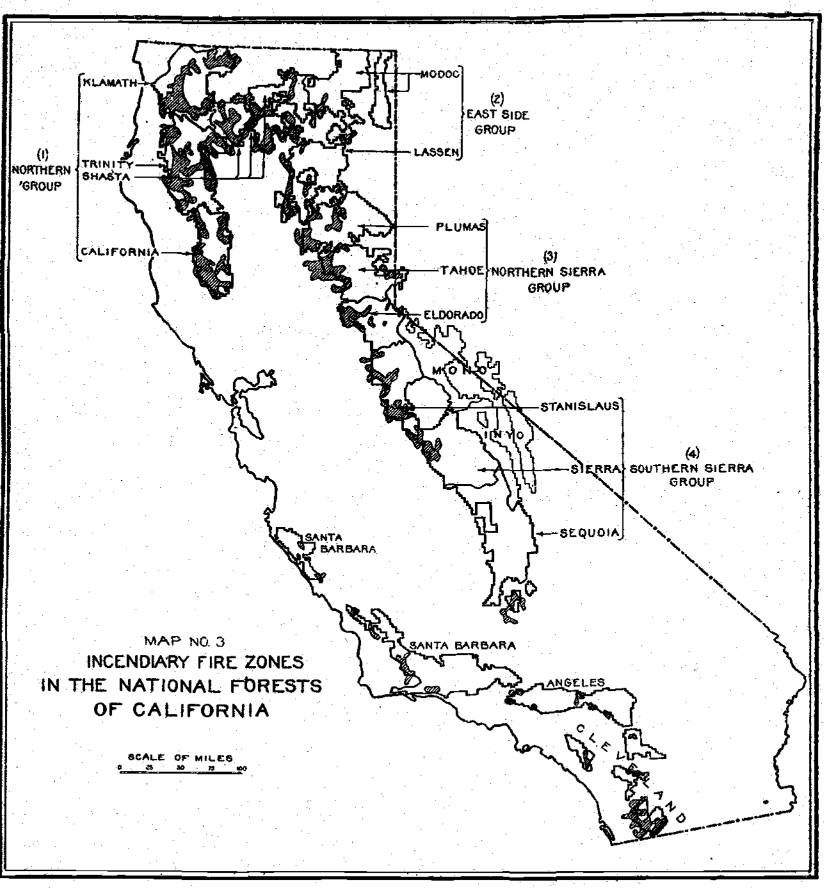
INCENDIARY FIRES.

Incendiary fires rank third in numerical importance for the decade, with 1,749 fires out of 10,499, or 16.7 per cent; but, as will be shown later, incendiarism is the most dangerous individual cause of fires.

The zones of incendiary fires shown on Map 3 were determined by a careful plotting of all incendiary fires in the decade. Some instructive relations appear.

CONCENTRATION.

Several very strongly marked areas of concentration occur. The main zone follows in general the lower or foothill edge of the forests, with occasional interior centers of incendiarism. Broadly speaking, incendiarism is most common in large brush areas, such as are found



MAP NO. 3
INCENDIARY FIRE ZONES IN THE NATIONAL FORESTS OF CALIFORNIA

along the western edges of most of the forests; that is, the principal motive for incendiarism appears to be the desire to burn off the brush, probably in the hope of securing easier grazing conditions. At times, of course, other motives actuate the "fire bug"; but probably the irreconcilable grazier has been the greatest offender, both by direct action and by preaching fire propaganda. The proportion of total hazard area included in the incendiary zone (Table 13) is much less than for either lightning or camper fires; but average concentration in the zone, or fires per 100,000 acres, is even greater than for lightning fires—43.7, compared to 40.3 for lightning and 27.1 for camper. The forest groups rank, in concentration, 1, 3, 4, 2, with Group 1 far in the lead.

The high concentration of fires from this cause has worked in two ways for a control of the situation: First, the actual handling of the fires has been much easier than if they were widely scattered; secondly, the bunching has usually narrowed down the law-enforcement problem to a small community or group of mountain dwellers or even to an individual. It will be seen later that the placing of men for law enforcement with reference to the centers of incendiarism has resulted in conspicuous success in reducing such fires.

INTENSITY.

Incendiary fires, like lightning fires, show a marked tendency to occur in considerable numbers at a given time. For example, on the Klamath as many as 46 and on the Trinity as many as 32 have been set in a day on one ranger district. This feature, together with the fact that incendiary fires are usually set during dangerous fire weather and in heavy brush, makes them either as groups or as individuals the most difficult of any fires to handle. They are started frequently when the protection force is engaged on other fires.

The demands on the protection organization by incendiary fires, indicated by the number of fires per total hazard area (Table 13), vary greatly with individual forests. The Klamath, for example, shows 2.4 times the demand that the Shasta does within its own general group, and 16.9 times as much as the Modoc, a unit in which the incendiary problem is almost lacking.

ANNUAL VARIATION.

In studying annual variation in number of incendiary fires (Table 14 and Fig. 2) the first noticeable feature is the sharp rise from 1911-1915, the practically constant figure for 1915–1917, and the very rapid decline during the past three years. In analyzing camper fires it was found that the peak was passed in 1915, education and construction of public camp grounds having started the downward trend, which was merely accelerated by the initiation of systematic law enforcement in 1918. Evidently only law enforcement can meet incendiarism; and though one must be cautious in attributing the entire decrease since 1917 to this activity, it seems certain that much of the success in meeting the problem has been due to it. Although in the long run education will probably assist in preventing incendiarism, the strong arm of the law must be depended on in the main.

As in the case of camper fires, a systematic study of the problem and the concentration of measures for prevention where they were needed have resulted in conspicuous progress toward its solution.

HIGH PROPORTION OF LARGE FIRES.

The per cent of incendiary C fires averages over twice as high as for camper fires and over three times as high as for lightning fires. In other words, the incendiary fire is intrinsically the most difficult suppression problem we have. The reasons for this are found in the general practice of incendiaries of setting fires in the most dangerous part of the season, on the hottest days, and in brush areas of highest hazard, and often with a knowledge of the position and movements of the protection force. Except for the very heavy lightning storms, no element of our suppression work approaches this in difficulty. The average area of incendiary fires is two and one-half times as large as the area of lightning fires and three times as large as that of camper fires. The total number of acres burned during the last decade is practically the same as for lightning, with about 40 per cent as many fires. (See Fig. 17.) The acreage burned during the past two years has declined to a fairly satisfactory total. One large fire mars the 1920 record. The percentage of C fires has been high throughout, with a fairly close relation between this figure and the size of the average fire. (See Fig. 10.)

The average cost per incendiary fire is about 60 per cent greater than for camper or for lightning fires, which is another way of saying that this is the most difficult and hence costly part of fire protection.

The major effort of systematic law enforcement has been directed against incendiarism, and from any point of view both the policy and the results appear justified.

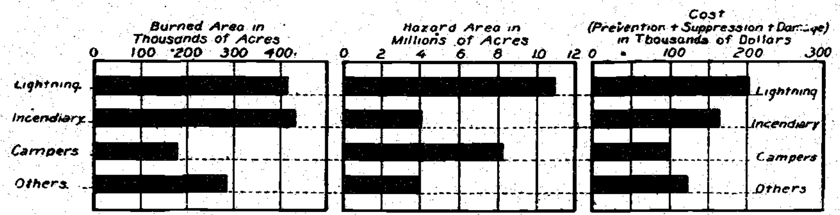


Fig. 17.—Total hazard area, total burned area, and total estimated cost of the various classes of fires from 1911 to 1920. (Based on Table 18.)

SEASONAL DISTRIBUTION.

The seasonal distribution of incendiary fires (Table 15 and Fig. 18) is strikingly different from that of lightning or camper fires. The very strong concentration in August, September, and October is unique among the fires from the various causes. Only 7 per cent of all incendiary fires occur before the end of June, so that the need for adequate protection late in the season is clearly indicated. The large number of fires in the fall is indirect evidence of the responsibility of stockmen, as their practice in pre-Forest Service days was to burn the range after the stock had been driven out. Fires during the summer months are set by prospectors, by men who want to make money as fire fighters, and by various persons actuated by motives of revenge, or the desire to see the country burned. With an active incendiary element, late season protection appears essential

The proportion of C fires is above the average during the months of heaviest concentration. With dry open weather in October, fires burn almost as readily as during August, and this, coupled with the premature disbanding of protection forces in some of the years of the record, accounts for a large part of the October acreage (Fig. 18).

SUMMARY OF INCENDIARY FIRES.

Incendiary fires have the greatest concentration of fires from any cause, and rank next to lightning in intensity. Well-marked zones occur, determined in the main by the presence of brush. The localities of danger and the class of people responsible are pretty thoroughly understood.

Incendiarism is the most dangerous individual cause of fires.

A vigorous campaign of law enforcement as explained above offers the best chance of meeting dangerous incendiarism.

Extra protection late in the season is needed if incendiary elements are active.

Because of the rapid spread of the fires and their usual occurrence in brush, quick discovery of and attack on incendiary fires are essential.

OTHER MAN-CAUSED FIRES.

Included in this group are fires from lumbering, sawmills, railroads, and brush burning, and fires of miscellaneous and unknown origins. It seems certain that the great majority of unknown fires are man-caused, as the curve of seasonal distribution corresponds exactly

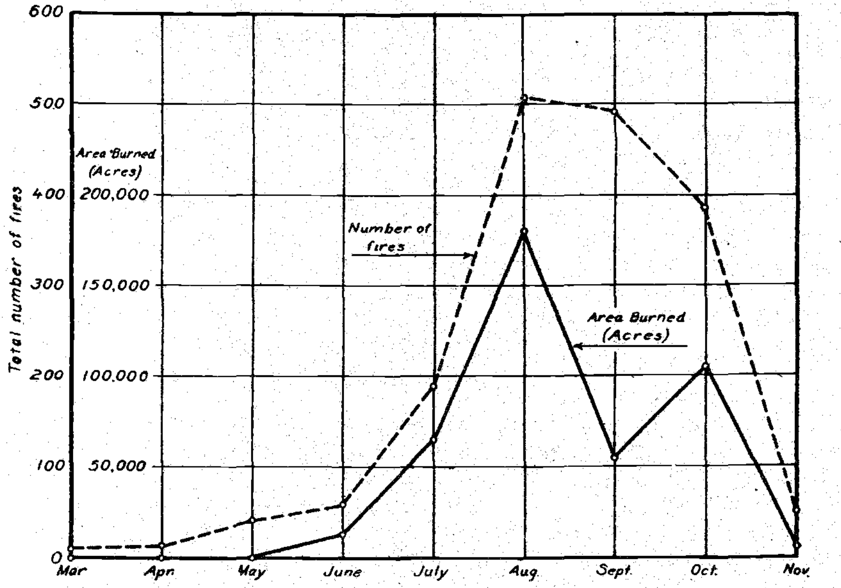


FIG. 18.—Number of incendiary fires and the area burned, by months. (Based on Table 15.) Notice especially the large number of fires in September and October after most of the danger of fires from other causes is past.

to that for man-caused fires, and differs decidedly from the lightning curve. (See Fig. 13.) Likewise, in Figure 2, giving fires by years, the curve from unknown fires follows in general the curve of man-caused fires rather than the curve of lightning fires. Unknown fires are therefore considered as of human origin.

LOCALIZATION OF INDUSTRIAL FIRES.

It has appeared unnecessary to work out hazard areas for fires from any of these minor causes, as all except "unknown" are of relatively slight importance, and arise from industrial activities the location of which is well known in advance.

Lumbering fires, for example, occur only when logging operations are in progress or along logging railroads. True railroad fires occur only along rights of way of operating railroads. Brush-burning fires occur only in clearing lands. Miscellaneous fires originate from what may be classed as freak causes and are fairly widely distributed, but only a few occur each year.

Generally speaking, where logging and railroad fires are of importance, special protection men must be assigned to cover the hazard areas which are always localized. A patrol along railroad rights of way, or a stationary guard (often a scaler) on lumbering-operations, can usually handle the situation. To secure air-tight protection special prevention measures, such as prepared fire lines and disposal of débris, are necessary.

ANNUAL VARIATION.

Table 16 gives the data for these minor causes, showing the number of fires by years. Altogether these fires number a little less than camper fires and only about 20 per cent more than incendiary fires. The railroad and brush-burning fires for 10 years are less than the number of fires set by a single lightning storm. Brush-burning and miscellaneous fires are relatively constant in number from year to year, whereas logging and railroad fires combined show a tendency to increase. It seems probable that railroad fires at times are reported as caused by logging or logging fires by railroads, so that the two should be considered together. Unknown fires are higher than usual in 1919 and 1920, but average only 6 per cent of the total. This increase is probably due to the increased travel in those years, thus throwing these fires not only into the class of man-caused fires, but probably into camper fires rather than incendiary. (See Fig. 2.) The total fires from all minor causes were lower in 1918 than in any other year, partly because of the low stage of industrial activity, partly perhaps because of law enforcement.

SIZE AND DAMAGE.

In percentage of C fires, the class of minor causes as a group is higher than camper and lower than incendiary fires. (See Fig. 10.) The high percentage of C in "unknown" is probably due to the fact that fires that are large when fire fighters arrive are difficult to classify as to origin. The low figure for logging fires probably reflects the fact that men accustomed to fire suppression are usually near by, whereas brush-burning fires show a high per cent, due frequently to the carelessness of ranchers or construction foremen in starting fires in unfavorable weather and to their lack of knowledge of fire fighting tactics.

Of acres burned (Table 17 and Fig. 17) the minor causes have been responsible for 287,350 acres, or over 100,000 acres more than camper, and 140,000 less than incendiary fires. The average fire of 134 acres and the average C fire of 446 are obviously very high, ranking between camper and incendiary fires, as does average percentage of C fires—22.9.

The annual changes in percentage of C, acres burned, and average fires are essentially the same as for other causes already studied—low figures for 1911–1916, a sharp rise in 1917 and 1918, and a decrease in 1919 and 1920. It may be pointed out once more that some factor or factors have operated alike on all fires, whatever their origin, from year to year. (See Fig. 10.) Though each of the minor causes in itself is of relatively slight importance, together they make up an average of 20.5 per cent of all fires and 22 per cent of the acreage burned. Hence as a group they are distinctly worthy of study. Camper and incendiary fires, as has been shown, can be decreased by such means as enforcing the law and educating the public. But it seems clear, from a study of fires from minor causes, that relatively little progress has been made in reducing their frequency. Fires from industrial causes have generally increased, and careless brush burners still are responsible for about as many fires as ever. A decrease in one year is generally lost the next.

SPECIAL PROTECTION NEEDED.

From the standpoint of organization the proportion of C fires from such special causes as railroads, logging, and brush burning must mean that protection men have not always been located with reference to the particular class of fires they must handle. As a rule, where fires from special causes are important, special protection must be given. One of the values of fire studies is to determine accurately the location and importance of these special causes in relation to the protection program.

Because of the great damage caused by fires in slash, logging fires are particularly dangerous, and perhaps require attention ahead of any other special class.

The tendency to shift responsibility for fire fighting to owners on whose land fires originate has often led to delayed action in attack and consequently to fires of large average size. The present fire laws probably need revision and enlargement for the State as a whole; but, nevertheless, even in their present form their vigorous enforcement would do much to reduce man-caused fires.

ALL FIRES.

The preceding four sections have attempted to isolate the chief characteristics of fires grouped by causes, and to indicate the most effective methods of handling each group. These might be called problems of tactics. But above and overshadowing these differences between groups and the resulting differences in the tactics of protection are certain broad questions, affecting all fires, that might be compared to strategy. What, after all, are the aims of fire protection, and how nearly in the light of 10 years' recorded experience have those aims been approached? A brief review of all the data will throw some light on these questions. The data so far presented show an average of 131,292 acres burned each year, or 0.9 per cent of the total hazard area. Part of this is in brush, part suffers only slight damage; but studies in fire damage show that an average loss of at least $3 per acre is a conservative estimate. Fires in the pine belt of California rarely destroy the forest over any considerable area; but just as rarely do they fail to cause considerable, though often inconspicuous, damage. It is the absence of spectacular damage that has tended to an undervaluation of damage. (Map. 4.)

COST AND DAMAGE.

It is clear that at the estimated rate of $3 per acre, damage averages about $390,000 a year. Suppression averages $68,000 (Table 2), and prevention, as nearly as can be determined, $150,000 per year.

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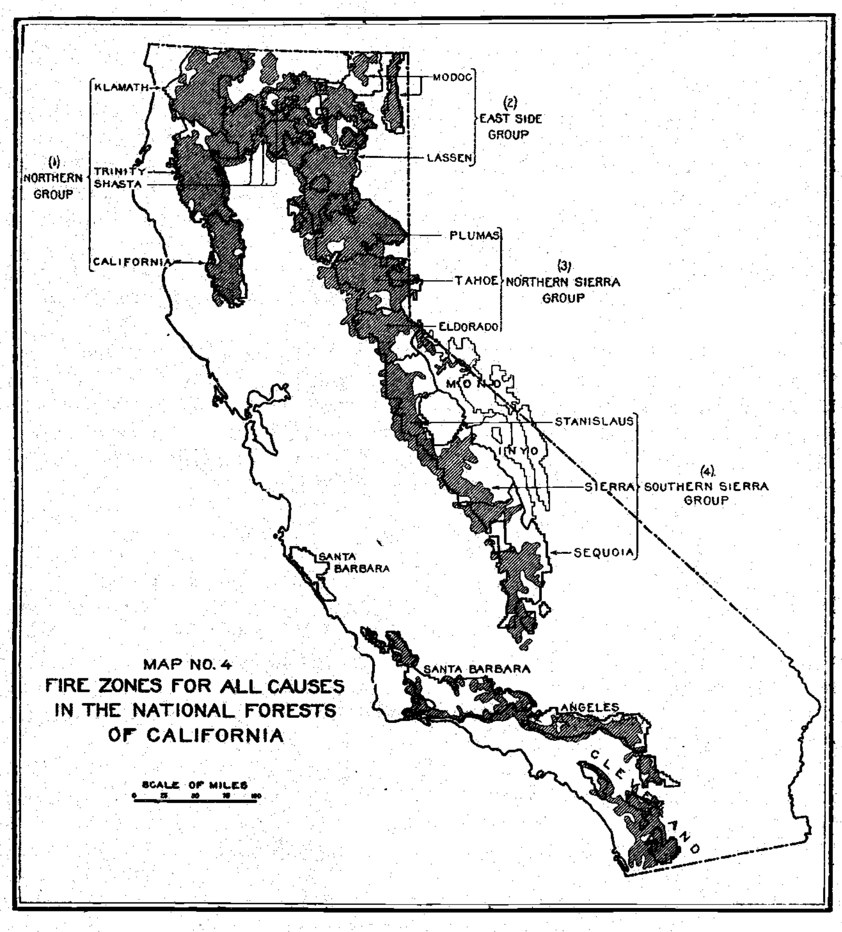
Of the $680,000 spent on suppression in 10 years, $86,500, or 12.7 per cent, has consisted of the wages of forest officers. Thus it is necessary to deduct an annual average of $8,700 of prevention to offset an equal amount contributed to suppression, leaving a net amount of about $140,000. If the principle is accepted that the sum of the costs of prevention, suppression, and damage should be a minimum, it is at once evident that the first and most important problem is to reduce acreage and hence damage. Reduction in the



cost of suppression will naturally follow a reduction in acreage, for it has already been shown that the cost of suppression varies as to area burned; moreover, as the cost of suppression averages only 17.4 per cent of damage, the emphasis must be placed on the factor of damage, although this in no way removes the obligation to handle suppression economically.

FIRE ROTATION AND TIMBER ROTATION.

The need for reducing acreage, and hence damage, is great, but of greater importance is the difficulty of even the crudest form of forest management if the average fire rotation is practically equal to the average forest rotation. Whatever standards may have been advisable in the past, as some form of management is introduced, the necessity for more intensive protection increases.

It has been shown that the burned area, both by causes, by years, and by forests varies as the percentage of C fires; therefore a reduction in acreage will come with a reduction in the ratio of C fires

HIGH PROPORTION OF MAN-CAUSED FIRES.

Man-caused fires as a major group are far too high. The most dangerous single cause—incendiarism—has been measurably met by law enforcement, and considerable progress has been made with camper fires. Probably more vigor in enforcing the law would also greatly cut down the fires from minor causes.

There is evident need for improvement in the suppression of man-caused fires, and how this may be accomplished will be considered later in the present circular.

LIGHTNING THE MOST SERIOUS PROBLEM.

Lightning fires, however, form probably the biggest problem that must be met. As individuals or in small groups, such fires are very easily handled; but in large groups they result in high acreage, cost, and damage. Even with the very best success in preventing man-caused fires, a serious lightning problem must still be met, and an area of nearly 11,000,000 acres, or 74 per cent of the total hazard area, must still be protected.

Table 18 shows that in total cost (prevention, suppression, and damage) lightning is far and away the most important individual cause. (See also Figs. 17 and 20.) Next comes incendiarism, of which it has been shown that a grasp of its danger coupled with aggressive attack has led to some success in stamping it out.

The present emphasis in law enforcement is on camper fires, but the minor causes as a group are evidently of somewhat greater importance than camper fires.

SEASONAL DISTRIBUTION BY CAUSES.

The great difference in seasonal distribution of fires from different causes is shown in Figure 13. In this, fires from each cause are considered as 100 per cent, and the percentage of these occurring in each month are computed. From the forms of these seasonal curves it is evident that there are five groups, as indicated in the upper corner of the chart.

FACTORS OF CLIMATE.

It is now proposed to treat of weather conditions as affecting the methods and results of protection.

The first important question to be answered is the length of the season of fire danger, or, in other words, the average opening and closing dates. In deriving these data, which are given in Table 21, the dates of the first and of the last fire have been taken for each forest and year. It is recognized that the date of the first fire is not necessarily the dates when special protection forces become necessary, and the same is true of the closing date.

OPENING AND CLOSING DATES OF FIRE SEASON.

Considering first the individual forests and groups as previously defined, it is found that the opening date is earliest in Group 1, 6 days later in Group 3, 16 days later in Group 4, and 21 days later in Group 2. This doubtless is an expression of the fact that in the first group the forest boundaries generally go well down into the foot-hills where heat and drought cause early fires; in Groups 3 and 4 the boundaries are progressively farther back; and in Group 2 the low west slope is lacking, giving this group a larger proportion of area at high altitude and consequently a lower fire danger.

The average closing dates are practically indentical for Groups 1, 3, and 4, and even for the individual forests, though Group 2 has a closing date 13 days earlier than the others, again because of its lack of low country. Usually seasons are simultaneously ended by state-wide storms, regardless of geographical position. The average length of the season thus decreases by groups in the order 1, 3, 4, 2. For the allotment of protection funds, the relative positions of the forests and groups can be accepted as indicative of the comparative length of the season to be expected. Different forests and groups will have different opening dates, but about the same closing dates.

The time of putting the special protection forces on duty is largely determined by the occurrence of considerable numbers of fires. Table 20 shows only a few scattered fires in March and April, less than 3 per cent of the season's total in May, but over 10 per cent of the total in June. The bulk of the May fires are in Forest Groups 1 and 3, with opening dates earlier than the average. In these groups, some protection is needed late in May, but for the other groups the average opening date is about June 1.

The considerable number of fires in October clearly indicates the need for protection late in the season. The mistake is sometimes made of taking off protection forces after the first rain (usually in September), with the risk of serious fires if a period of warm dry weather follows the rain. The earliest closing date of the 10 years has been October 1, and it is safe to say that the average of October 23 is not far wrong.

The length of season, as shown in Table 21, has an extreme range of 44 days, 1918 having had the shortest and 1919 the longest season. No formula can be given by which the judgment of local officers on the opening and the closing dates can be replaced. In allotting protection funds, however, the differences between forests are apparently worthy of consideration.

EFFECTS OF ANNUAL VARIATIONS IN WEATHER.

It is well known that differences in weather, and hence in the difficulty of controlling fires, occur from year to year, but giving the proper weight to these seasonal differences has proved to be an exceedingly complex problem. Using large numbers of fires as a basis, it seems probable, on the one hand, that the percentage of fires attacked within a given elapsed time—say, 0–4 hours after start—that become class C will be constant from year to year, provided physical and weather conditions remain constant, and that, on the other hand, the percentage of C fires will vary as these conditions vary; that is, if in 1914, 20 per cent of all fires attacked in less than four hours became C, and if in 1919 again 20 per cent is the figure, it seems safe to say that there was no significant difference in seasons in these two years so far as rate of spread is concerned.

Conceivably, considering all man-caused fires as a group, there are at least three factors that may influence and tend to nullify the assumption that, other factors being equal, the percentage of C fires will vary with weather and physical conditions. The first is the undoubted increase of inflammable material on the ground, which would tend to make suppression more difficult from year to year. The second factor is the possibility that the technique of suppression may have changed during the period, so that if it has improved, a certain percentage of fires will be caught as class B which formerly became class C. The third factor is the variation in the behavior of fires from different causes and consequently the important effect of the relative proportion of fires from the various causes from year to year.

The effect of the second factor, that of human efficiency, can be minimized by using the percentage of class A fires instead of class C, because an A fire is so small that its remaining an A fire is much more likely to be due to weather and other natural factors than to improved technique of suppression. Figure 19, based on about 2,000 fires on four forests, represents the seasonal differences in the rate of spread of fires. It does so indirectly by giving the percentage of fires that spread to the C class in different seasons in the same elapsed time from start of fire to attack. For instance in 1914 only 24 per cent of all fires attacked within four hours after start reached the C stage. In 1917 this rose to 39 per cent, thus showing that the latter year was more favorable to large fires than the former. But, as shown above, improvement or deterioration in fire protection from year to year may seriously affect the validity of the figures by decreasing or increasing the proportion of B fires that become C fires. Therefore class A fires are used, because they are so small (one-fourth acre or less) that climatic factors and consequently the ease or difficulty with which fire spreads are much more likely to influence the proportion of A fires than is the speed of attack by the protection force.

It will be noticed that the seasonal difficulty increased from 1914 to 1917, then dropped, and increased again in 1920. If this method is a correct one, it must be evident that seasonal differences are one of the major factors in determining the results of protection. The values for 1915, 1916, and 1917, already discussed, may conceivably have been raised by the great preponderance of incendiary fires in the man-caused group, and these have been shown, of all fires, to have the highest coefficient of danger. The values for 1919 and 1920 may have been correspondingly reduced by the small number of incendiary fires.

Taking the same Forests used before, Figure 19 shows also the seasonal factor derived from camper fires alone. The C curve shows that, the problem being thus narrowed down, the course from year to year has been essentially the same as for all man-caused fires, and that the seasonal factor is responsible for a maximum of 10 per cent of class C fires, provided the technique of suppression has remained the same from year to year. This maximum is determined by the difference between the highest and lowest points on the curve.

PREDICTION OF EMERGENCIES.

Up to the present time, studies of individual climatic factors as affecting fires have not gone far enough to permit discussion of this important subject. Studies now under way give promise of developing methods of predicting impending fire emergencies a short time in advance, so that the necessary expansion of the protection force may be made before, rather than after the emergency has occurred.

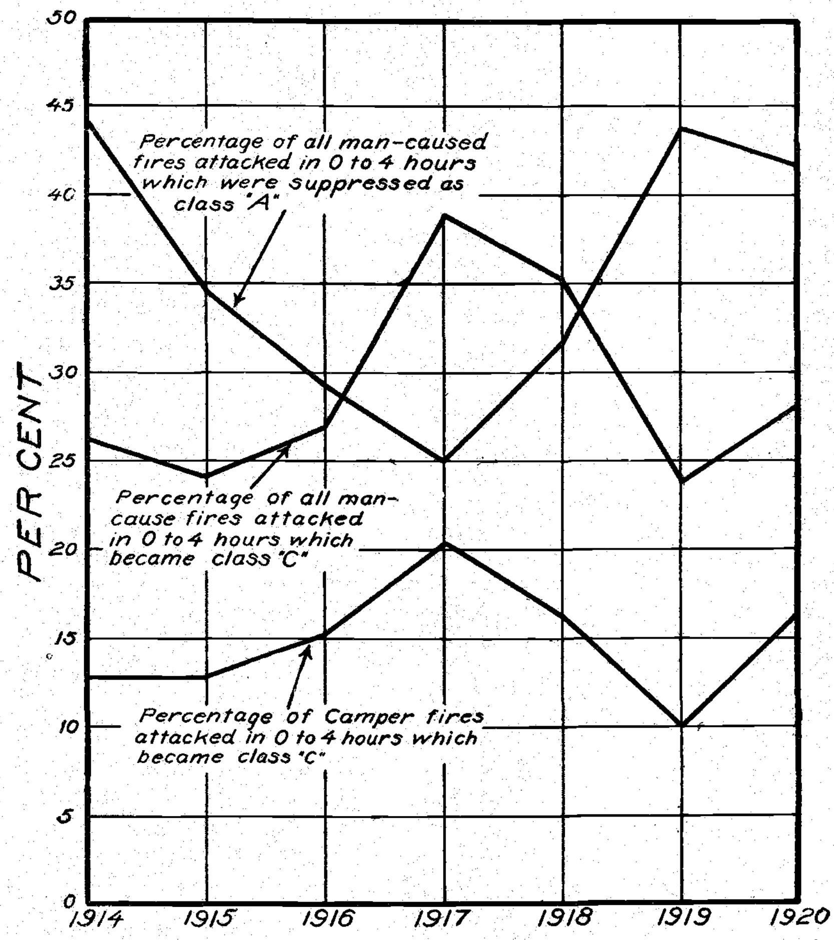


FIG. 19.—Seasonal factor. Based on study of elapsed time of man-caused fire on Klamath, Shasta, Tahoe, and California National Forests. In a bad season, such as 1917, the fires spread more rapidly. Consequently a higher percentage of those attacked within a given length of time became Class C fires than in a relatively good year, such as 1914. For the same reason a smaller percentage of fires are fought as Class A fires. The relative position of these index figures for the different years may measure seasonal difference.

ORGANIZING FOR EMERGENCIES.

At this point the question may be raised as to whether organization should be for average intensity or for maximum. So far as can be seen, a successful record in an extremely bad season, such as 1917 or 1920, must be made, other things being equal, by a quicker attack on fires, in order to overcome the effect of climatic or seasonal factors on the rate of spread of fires. Average performance will serve in an approximately normal year, but in a bad year quicker work must be done or a greater acreage will burn. Perhaps the situation can best be met by combining the improvement of the existing protection force with an increase in the scale of protection. It seems an unsound practice to build an organization capable of handling the normal situation, with the probability that one bad season may vitiate the results of years of successful protection.

Although it is important to determine after a season is over that it was better or worse than average, the most pressing need is for some method of foreseeing periods of exceptional danger and for an organization large enough and flexible enough to meet critical seasons. When crises can be foreseen, it will be possible to organize for them within the critical period without the need of constantly maintaining emergency forces.

DAMAGE.

The preceding sections have dealt with the inherent characteristics of fires of various origins and with variations in climatic factors as affecting fires from year to year. These are the ultimate physical factors that determine the nature of the fire problem. The following two chapters will deal with certain important financial aspects of fire—first, the element of damage, and, second, the cost of suppression.

The reports on individual fires give estimates of damage separately for timber, reproduction, and range. These figures are known to be inaccurate, as most estimates are of necessity made immediately after a fire, when the extent of damage is difficult to determine.

For 12 forests in 10 years the average damage to timber, as returned in fire reports, was 525 board feet per acre burned, a figure certainly much too low. Intensive studies of direct fire damage to timber have been made on 7 large fires on 3 forests, with results shown in Table 19. The average damage on these areas is about 2,000 board feet per acre, or four times the average damage originally returned. With an average stumpage rate of $1.50 per thousand board feet, the average damage is thus about $3 per acre burned, a figure sufficiently conservative for general use. The use of a flat rate is recognized as an unsatisfactory expedient, but until more accurate figures on damage in different forest types are available no other course is open.

No one doubts the fact of damage to reproduction and merchantable timber, but the tremendous loss to brush fields in California is perhaps a more serious blow to economic welfare than the loss even of merchantable timber. Differences of opinion on the exact method of valuing the damage from brush fires do not alter the fact of damage. Such loss is analogous to the complete wiping out of timber stands with no reproduction following, as in the Pacific Northwest. Again, as an expedient an average value of $3 per acre—certainly a conservative figure—is used in expressing this loss.

DAMAGE THE MOST IMPORTANT FACTOR.

Excluding entirely the indirect damage to watersheds and the destruction of forage, and using only minimum figures for damage to timber and reproduction, the point to be remembered is that damage is the most important factor to be considered in any study of the fire-protection problem. On the present scale of protection, damage is over 50 per cent of the total cost of fires in the formula prevention, suppression, and damage, and is the final criterion to be used in determining intensity of protection.

COST OF SUPPRESSION.

Although damage is the largest factor in the total cost of fires, the cost of suppression is of great interest and importance, both intrinsically and because it offers one of the few tangible standards for judging the difficulties of fire fighting and the quality of performance in the different Forests and regional groups. The cost of suppressing class A fires may be taken as an index of these difficulties.

First, unit costs of suppressing class A lightning fires and class A fires from other causes are given separately in Table 22 (see also Figs. 20 and 21), based on an eight-year average. The cost per A fire is of high significance. Beginning with the highest, the Forests rank: Klamath, Trinity, Shasta, California (northern group) with an average of $5.77; Plumas, Tahoe, Eldorado (north Sierra group) with an

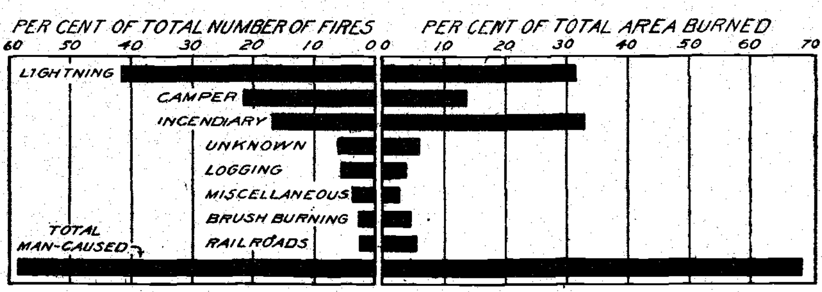


FIG. 20.—Relation between number of fires from various causes and total area burned and between lightning and man-caused fires as major groups. (Based on Tables 16, 17, and 18.) The intrinsic danger of incendiary fires, shown by large area burned relative to number of fires, points to extreme need for control of this cause.

average of $4.44; Stanislaus, Sierra, Sequoia (south Sierra group) with an average of $2.61; Modoc and Lassen (east side group) with an average of $2.35. The average for all is $4.38, which is the same as for the Tahoe.

What does this striking and consistent grouping mean? It seems to indicate clearly that the figures represent inherent differences between the forests in ease of transport and travel, the average distance of travel, and the influence of cover on the amount of work needed to corral a small fire. Efficiency enters into the figures only to a very slight extent. To be sure, the percentages of A fires on two forests give a comparison of the relative efficiency of suppression, but cost per A is not influenced by the element of efficiency. If one man or group of men persistently took crews to small fires, it would be reflected in costs; but an examination of the range of costs indicates that all forests have had A fires costing over $50 as well as fires costing very little. A small fraction of the differences may be due to this cause; nevertheless, it appears to be true that A costs really reflect the relative difficulty of suppression on the several forests. The gradation from north to south is too regular to be accounted for on the ground of coincidence.

EFFECT OF BRUSH FIRES ON AVERAGE COST.

Table 23 shows for the three years 1916–1918 the percentage of fires in various forest groups classed as brush fires. (See also Fig. 21.) Fires in brush under timber are included because they are essentially like pure brush fires in difficulty of suppression. In the northern groups 55 per cent were brush fires, in the north Sierra 59 per cent, in the south Sierra 35 per cent, and in the east side 40 per cent. Evidently the character of the cover is an important factor in determining the cost of A fires, though other factors, such as ease of travel, also enter into the problem.

This table also gives the cost per fire of timber and brush fires. (See also Fig. 22.) The much higher percentage of C fires in brush and the greater amount of work in building fire lines are both reflected in the greater average cost per fire. Of all fires in brush 42.4 per

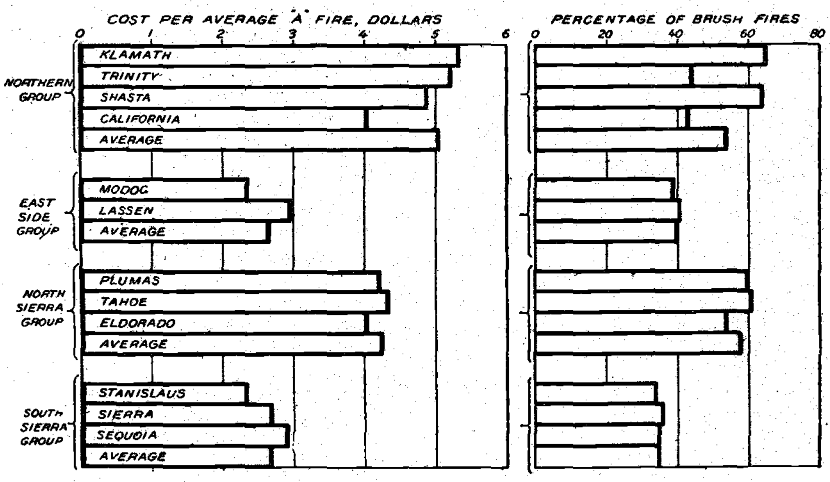


FIG. 21.—Cost of suppression of all Class A fires, 1911, 1918. (Based on Tables 22 and 23.) These figures indicate inherent differences in the difficulty of suppressing fires in these various groups. Bars to right show percentage of brush fires as compared with timber fires and indicate a general relation between this percentage and the cost of Class A fires.

cent became class C, whereas in timber only 18.3 per cent were C's. (See Table 23.) In cost of suppression, the contrast is even greater—$98 as against $24 a fire.

Studies of unit costs on camper, incendiary, and all fires, show the same relative gradation from north to south with an occasional value out of line if only a few fires are represented. There appears to be no need of presenting the data in detail for each separate cause.

COST OF C FIRES.

The costs of class A fires are more important as indicating the individual characteristics of the various forests than on their own account. The great bulk of suppression money goes for the C fires. In studying these it is at once necessary to subdivide into size groups, as a C fire is any fire over 10 acres. This has been done by forming a rough geometrical progression: 10–20 acres, 20–40, 40–80, 80–160, 160–300, 300–500, 500–1,000, 1,000–2,000, 2,000–5,000, 5,000–10,000, 10,000–20,000, 20,000–50,000 or more. Costs were grouped according to this plan for each forest and year, and finally combined in Tables 24 and 25, giving 10-year averages for each forest and each group.

VARIATIONS IN C COSTS IN DIFFERENT GROUPS.

An examination of the table shows at once that both for the individual forests and for groups certain values are either high or low with reference to adjacent values. It is also evident that costs increase more slowly than areas from one size group to the next.

In order to determine whether any general tendency exists, the assumption is tested that on the average cost of suppression should vary as the square root of the acreage. That is, it seems probable that a relation analogous to that between the perimeter and the area should exist. In actually testing this assumption with a large number of class C fires, the assumed law holds strikingly true up to a size of 300 acres. (See Table 24 and Fig. 23.) From that point costs mount more rapidly than they should according to this rule. One of two explanations for this is possible: Either the rule does not

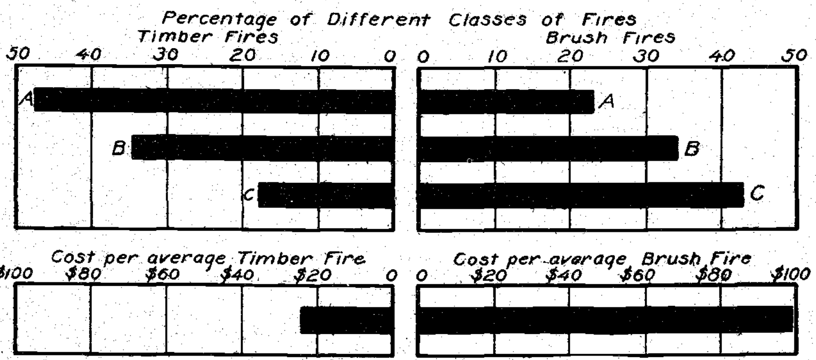


FIG. 22.—Influence of cover type on percentage of fires in various classes and on suppression costs. (Based partly on Table 23.)

apply because of the increasingly irregular shape of large fires, or the standard of performance for large fires is not so well worked out as for smaller C fires.

Up to fires of about 300 acres, the increase in unit cost is fairly regular, but above that it fluctuates widely. It seems probable that on fires of 300 acres or less the matching of resources to the job is on the average pretty thoroughly standardized, whereas beyond that point the difficulty of handling a more complex organization becomes increasingly apparent. Possibly lost fire line is also a factor.

In order to express differences in costs between forests and groups, the costs of fires for the size classes 10 to 300 acres are averaged. It seems that Group 3 has somewhat the highest cost, $126; Group 1 next, $112; Groups 2 and 4 pretty nearly the same, $80 and $76. On the whole, there is a fairly close relation between the class A costs and the class C costs. (See Fig. 24.)

Further study of the table shows that individual forests within a group (for example, the California and Eldorado) do not correspond as closely as might be expected in the unit costs of C fires. It seems that certain forests have more nearly learned to match resources to the job than have others, and that on many of the forests the general scale of costs could perhaps still be reduced.

Great fluctuations in costs of individual fires as compared to the average for the size class have occurred and certainly will continue to occur. Progress in the matter of unit costs is likely to come through a careful comparison by each man of his own performance with reference to the averages which he himself has helped to create.

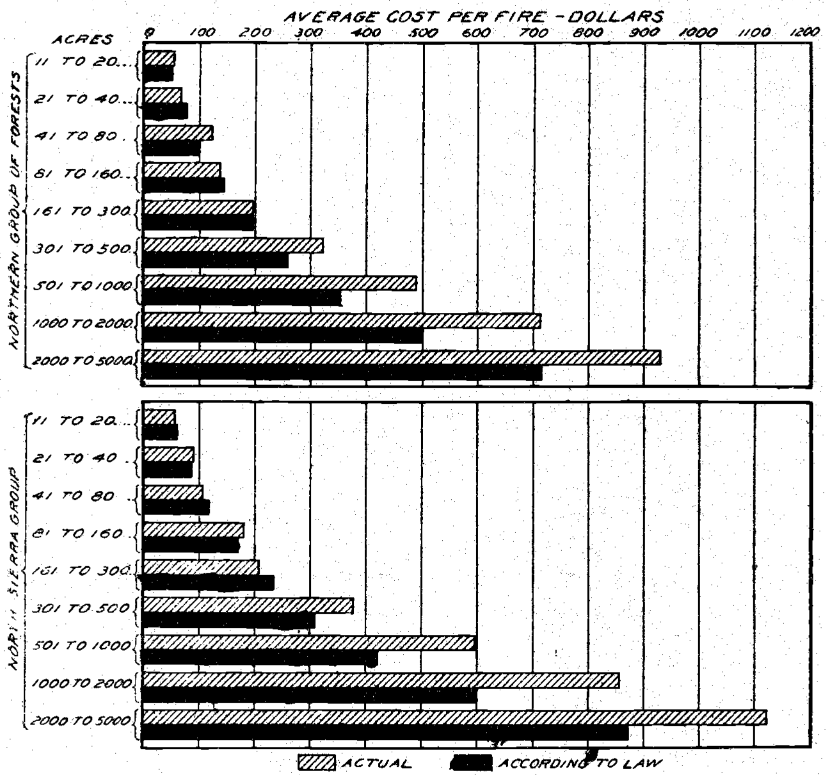


FIG. 23.—Relation of actual suppression costs to costs as computed by general law. (Based on Table 24.)

COST OF SUPPRESSION SUBORDINATE TO DAMAGE.

To establish standards in costs of suppression without reference to more important considerations is likely to be dangerous. Costs of suppression have, on the average, been small compared to damage, and to put the emphasis on low costs of suppression without reference to the areas burned is putting the cart before the horse. High unit costs often reflect a safety factor in taking oversize crews to fires, with the primary object of saving acreage and damage rather than attaining low costs. Considerable latitude should probably be allowed in this respect, the ideal of attainment being not low unit costs of suppression but a low total of suppression cost plus damage.

There is a great opportunity for improvement in the technique of suppression, and continued study may be expected to result in both lower costs and lower damage.

ANNUAL FLUCTUATIONS IN UNIT COSTS.

The Forest Service has suffered from the rise in the prices of commodities and of labor. Table 26 shows for each year in the decade under consideration the average cost of fires of the different size classes up to 300 acres.

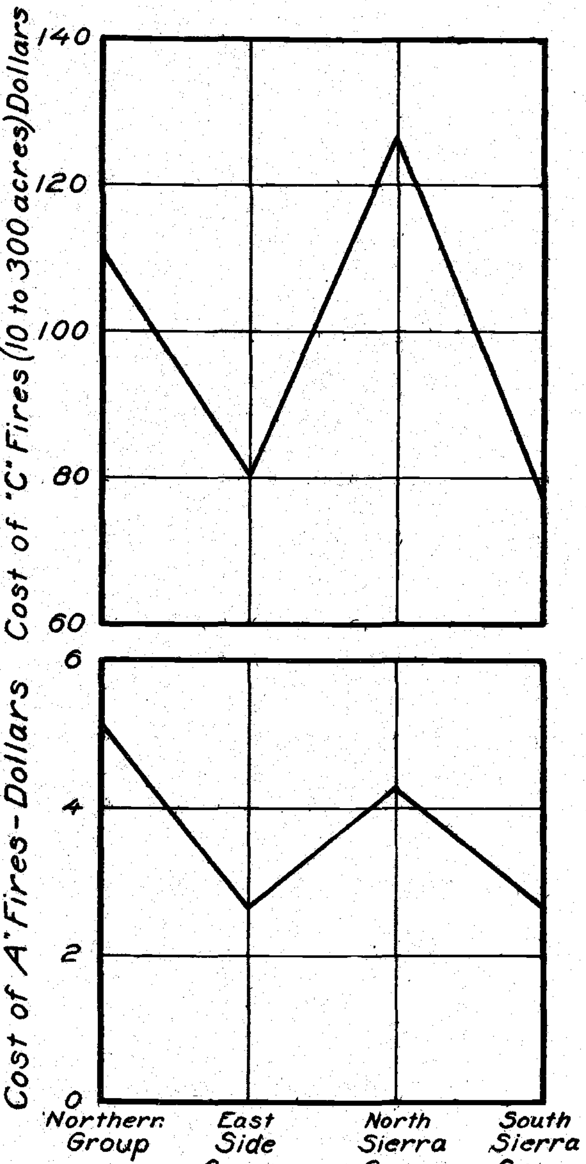


FIG. 24.—The cost of Class A fires compared with the cost of Class C fires in the various groups of forests. The vertical scale for Class A fires is exaggerated in order to bring out the similarity of costs in the two classes. This similarity bears out the contention that the costs of Class A fires are indexes of the differences between the forests in difficulty of suppression. (Based on Tables 23 and 24.)

Considering first only the more obvious features of Table 26 (see also Fig. 25), from 1911 to 1913, unit costs were practically constant with an average of $100. In 1914 unit costs almost doubled, fell somewhat in 1915, and dropped sharply in 1916 nearly to the 1911–1913 values. In the preliminary discussion it was pointed out that the DuBois protection manual issued early in 1914 laid down as the goal aimed at the principle of low acreage as contrasted with low cost of suppression. That this policy resulted in the general practice of taking oversized crews to fires with the object of insuring a large enough factor of safety is clearly reflected in the unit cost of 1914. Conversely, the suppression manual of 1916 insisted that suppression costs were too high and that more emphasis must be placed on reduc-

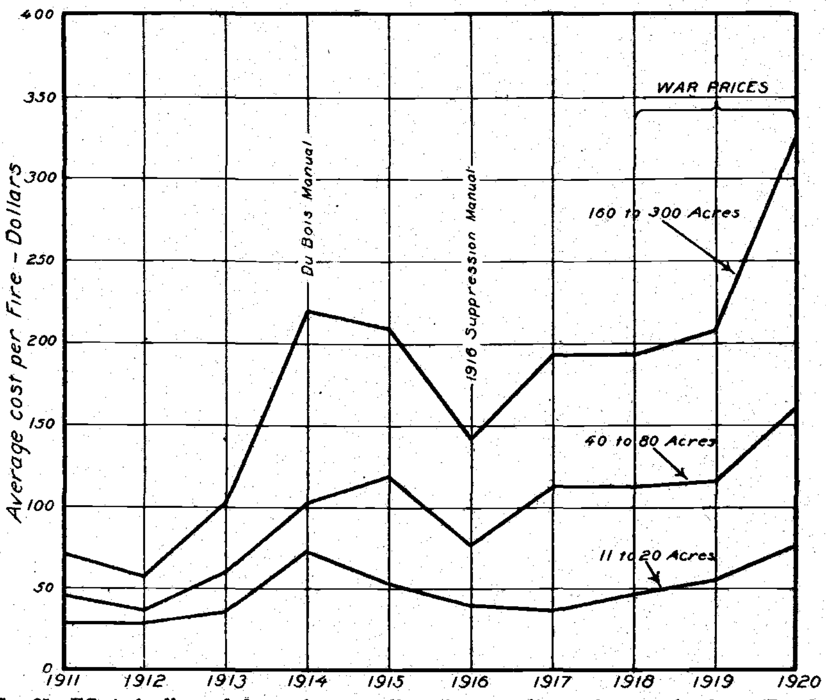


FIG. 25.—Effect of policy and changes in commodity prices on unit cost of suppressing fires. (Based on Table 26.)

ing them. However, as the knowledge of damage was limited, this factor was in practice rated very low in the protection formula, costs of prevention, suppression, and damage. In other words, unit costs are definitely influenced by policy. In 1917, in spite of continued insistence on low costs, they began to rise with the beginning of increased commodity prices.

Since 1918 costs have risen steadily as the prices of commodities and labor have increased, and the figure for 1920 is two and one-half times as high as for 1911. Much of this increase is due to the general rise in prices, although a part of the 1920 rise is probably a reflection of policy.

It is clear that in studying performance from year to year, suppression costs must be reduced to comparable terms. The period averages for 1911–1913, 1914–1917, and 1918–1920 are therefore used in subsequent discussion, with the average for the middle period as the base.

An examination of the table also shows that in the early years of the record the costs fluctuate considerably from size class to size class; but later from year to year the costs show less and less fluctuation, and it seems probable that the practice of fire fighting has become more and more uniform, so that on the average the resources employed on fires are better gauged to the job than in previous years.

ELEMENTS OF COST OF SUPPRESSION.

Table 31 shows for the different years the total cost of suppression subdivided into its component parts. (See also Fig. 26.)

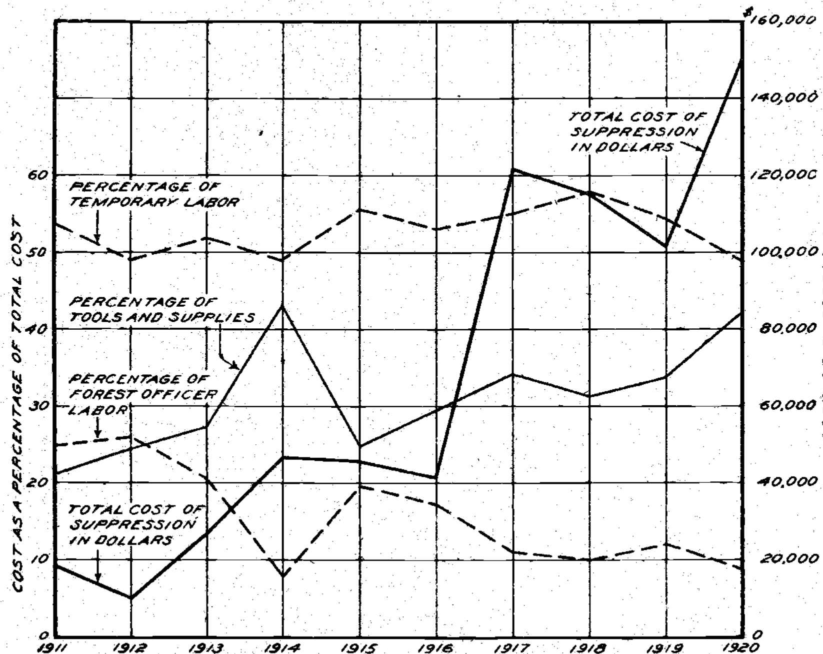


FIG. 26.—In the various elements making up cost of suppression note that temporary labor, as a percentage of the total, has remained fairly constant. Forest officer labor has decreased proportionately, though absolutely it has increased. Tools and supplies have increased rather steadily. (Based on Table 31.)

Temporary labor has been relatively constant, averaging 52.7 per cent of the total, with extreme values of 49 to 58 per cent.

While the proportion of total expenditures made up of forest officer labor has declined steadily, its absolute value has risen. There is every indication that forest officers spend more time on fire suppression now than formerly. It is also clear that on the average only about $1 of forest officer labor for $5 of temporary labor is now applied, compared with a 1 to 2 ratio in the earlier years of the record. This is perhaps merely an indication that supervision of temporary labor is not now so close as formerly, which may be good or bad.

The percentages as well as the amount of expenditure for tools, equipment, food, and transportation have risen rather steadily, the year 1914 being out of line. In general, the decrease in the percentage of forest officer labor has been offset by the higher cost of tools and equipment. The increasing use of the automobile is probably reflected in this item. The 1920 costs for tools and equipment appear relatively somewhat too great, though, as shown before, this is largely due to the high cost of all commodities.

The analysis of these elements of the cost of suppression indicates what, on the average, the proportional cost of the various items has been. Any marked departure of one item from the normal position should be regarded as deserving special study.

CONTINUITY OF PROTECTION.

The analysis so far made of fire statistics indicates that in actual performance there have been considerable changes from year to year in the area burned, consequently in the damage, and less important in the costs of suppression.

Comment has already been made, or will be made later, in this paper on various physical factors in the protection problem—the influence of emergencies, the effect of speed or lack of speed in reaching fires, the effect of individual bad seasons, the characteristics of fires from different causes, the effects of some of the methods of indirect control (such as law enforcement) in reducing fires, the various causes that may be responsible for breaks, and similar factors.

The fact has been insisted on, and is worth repeating, that continuity or consistency of protection is the goal to be aimed at, a goal which can be attained only by reaching fires when they are still small.

ELAPSED TIME.

Granting the difference in behavior of fires from different causes, or in different types of cover, or under varying conditions of weather, there is one element of protection that clearly indicates whether the organization is effective or ineffective. That element is speed of attack as expressed by elapsed time. The question of elapsed time is at the very heart of the fire problem, and no phase of protection is more worthy of careful study.

Elapsed time is defined as the time from the start of the fire to the first attack on it. For more detailed study, the following subdivisions of elapsed time are recognized:

Discovery time.—From outbreak of fire to discovery.
Report time.—From discovery until report is received by attacking force.
Get-away time.—From receipt of report until attacking force leaves for fire.
Travel time.—From time of leaving for fire until work is begun.

The time of outbreak is necessarily an approximation on most fires, whereas the time of discovery is generally definitely known from the lookout record. A comparison of data, using these two points for two important forests, indicated that one point was practically as reliable as the other; that is, errors in reporting the time of outbreak of individual fires compensate when groups are used. As figures for elapsed time from outbreak to attack are more readily available than from discovery on, the former have been employed in this circular.

In the study of elapsed time, only man-caused fires are used, as many lightning fires lie dormant for hours or days and hence are not so susceptible to analysis.

In this study of elapsed time, it is not sufficient to use a single average of elapsed time on all fires, as a few fires with very long periods will distort the average. Therefore, the method used is to regard the total number of man-caused fires in a given Forest in one year as 100 per cent, and to compute the fires attacked in 0–1 hour, 1–2, 2–3, etc., as percentages of the total.

Figure 27 shows, for representative forests, the annual variations in elapsed time (as above defined) for each year from 1914 to 1920. The data were not recorded before 1914. On the same chart is shown the percentage of all man-caused fires becoming class C.

SPEED OF ATTACK AND PERCENTAGE OF C FIRES.

It is clear that a close reciprocal relation exists between the speed of attack and the area of the fire. From 1914 until 1918 the average elapsed time increased with a corresponding increase in the propor-

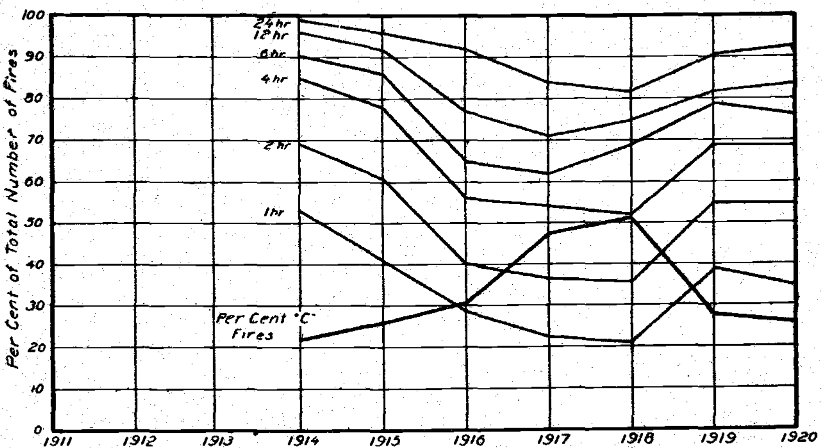


FIG. 27.—The relation of elapsed time to the proportion of Class C fires (man-caused). The total number of man-caused fires in one year is regarded as 100 per cent. The curves show, then, what percentage of these total fires were attacked within 1 hour, 2 hours, 4 hours, etc. Thus in 1914, 99 per cent of man-caused fires were attacked within 24 hours, whereas in 1918 only 82 per cent were so speedily attacked. The lowest curve, percentage of Class C fires, consequently rises from its lowest point (22 per cent in 1914) to 51 per cent in 1918. This shows the close connection between speed in attack and percentage of Class C fires. As has already been demonstrated, there is a close connection between percentage of Class C fires and area, and consequently cost and damage.

tion of C fires. An increase in speed in 1919 resulted in a decrease in the percentage of C fires. In 1920 practically no change in either factor took place.

Figure 27 indicates the trend of events for the past seven years. Figures 28–30 for three individual forests represent the various types of data that are met. Figure 28 shows a forest with a long gradual slowing down of speed, followed by sharp recovery. Figure 29 represents a Forest with relatively slight changes in speed from year to year and with correspondingly slight changes in the percentage of C fires. Figure 30 shows a forest with wide fluctuations from year to year and with no long-continued trend in one direction.

An examination of all these charts indicates that regardless of the efficiency of the fighting force after reaching fires, the speed of attack on the average fire determines whether a protection organization delivers satisfactory or unsatisfactory results. It is obvious, of course, that mere arrival at a fire means nothing unless effective fire fighting is done, but, nevertheless, the first essential is to get there.

Expressing the importance of speed of attack in another way, Figure 31 shows the size of the average fire in relation to the speed of attack on the Shasta National Forest. Again, it is evident that, regardless of everything else, there is a perfectly clear-cut relation between speed and results. The same relation can be demonstrated in other ways: By the percentage of C in relation to speed, or by the cost of the average fire, or damage per fire in relation to speed.

INCREASED SPEED OF ATTACK NEEDED.

Detailed studies of elapsed time indicate in general that efforts should be concentrated on cutting down discovery time by lookouts, and get-away and travel time by the men going to fires. High report

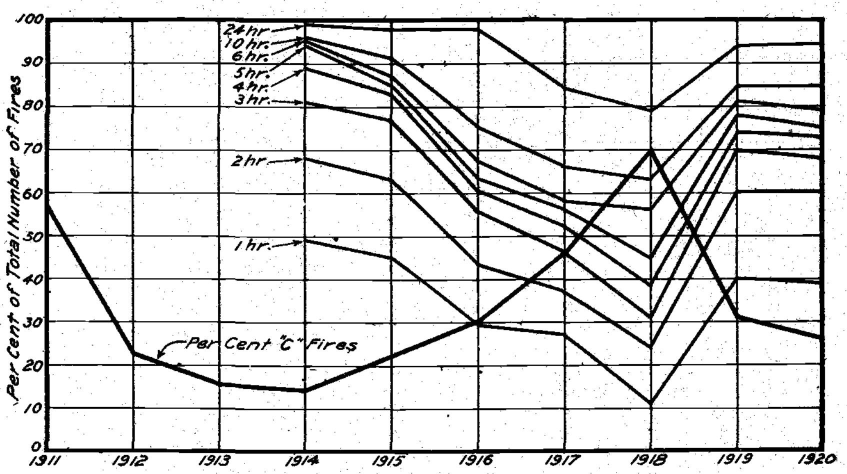


FIG. 28.—The relation of elapsed time to the proportion of Class C fires (man-caused) on the Shasta National Forest. These curves show a gradual decline in speed of attack to the low point in 1918, and then a sharp recovery in 1919 and 1920. Coincident with this abrupt increase in speed there is an equally abrupt and striking drop in percentage of Class C fires. (Basis, 516 fires.) Notice that the speed of attack for the years 1911–1913 could be computed with a fair degree of accuracy. A complete cycle of protection and the start of a new cycle is epitomized on this chart.

time is found where communication facilities are poor. Local studies along these lines are invaluable in isolating the particular factors or men at fault, and should be made currently on every protective unit.

It may be said in general that an adequate study of the data on elapsed time is equivalent to a study of the entire protection organization. Such factors as putting men in the wrong place or in having too few of them to handle fires show up clearly in such a study, and unquestionably have a direct relation to elapsed time.

TWO FACTORS AFFECTING ELAPSED TIME.

Elapsed time is affected in two ways: First, by the action for which individual protection men are responsible, such as slow get-away; and, secondly, by faulty planning over which the individual has no control, such as incorrect position with reference to hazard areas or having more fires than can be handled by one person.

Starting with the final result, damage, expressed in terms of acreage burned, it has been shown that this is a function of the percentage of C fires, and that percentage of C fires is a function of speed of attack, with the character of the individual season and the bunching of fires as factors modifying but not upsetting the broad fundamental relationships. The enormous importance of elapsed time is therefore apparent.

BREAKS.

In studying the performance of a large organization like the Forest Service—widely distributed, working under pioneer conditions, compelled to fight fires under the greatest difficulties of transport and communication, and usually at a distance from a supply of labor—it is natural that the actual execution of a job of fire-fighting does not always measure up to a theoretical standard. Many fires, viewed after the event, could have been handled at a lower cost or

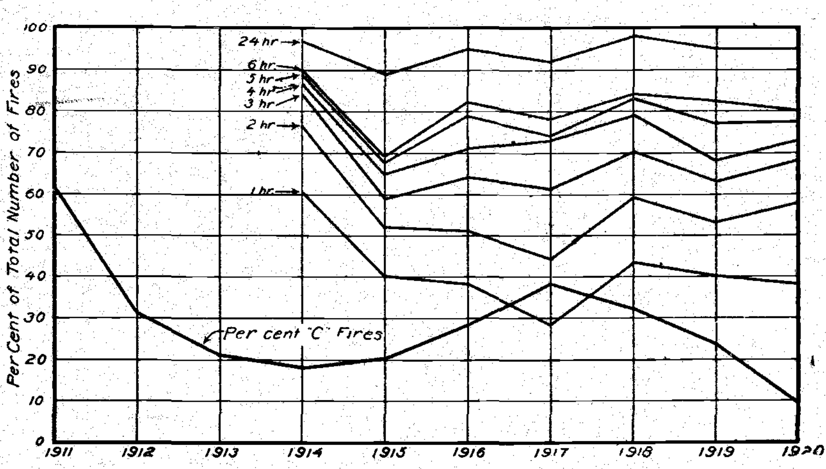


FIG. 29.—The relation of elapsed time to proportion of Class C fires (man-caused), Tahoe National Forest. These curves show only slight changes in speed of attack from year to year and relatively slight changes in proportion of Class C fires.

with less damage than they were handled; but any complete criticism of such a performance must be based on a knowledge of the peculiar difficulties under which the particular attack was handled and carried out; and it is in the light of such allowances that this section must be interpreted.

DEFINITIONS.

A "break" may be defined as the occurrence of a fire or a series or group of fires, which (1) with the resources available at the time could have been handled at a lower total cost (suppression plus damage); (2) with additional resources could have been handled at a lower total; (3) could not have been handled with any possible resources.

The first group may be spoken of as breaks in local organization, or faults of execution; the second as breaks in general organization, or faults of planning and preparation; the third as catastrophes, or faults of circumstances.

CAUSES OF BREAKS.

Group 1, as above defined, may be subdivided as to cause into—

1. Carelessness, poor work in suppression, failure to follow instructions, etc.

2. Doubtful decisions; with two or more possible ways of doing a job, perhaps the wrong way was chosen.

3. Influence of minor emergencies.

Group 2:

1. Emergencies; insufficient men to handle fires.

2. Unfavorable weather, overtaxing an otherwise adequate force organized for average conditions.

3. Incorrect placing of men with reference to occurrence of fires.

4. Indefinite policy; loss of time in determining how to proceed.

5. Leaving to the men on the ground too much latitude of decision, with the result that relatively inexperienced men may make costly errors.

Group 3:

1. Extraordinary climatic conditions.

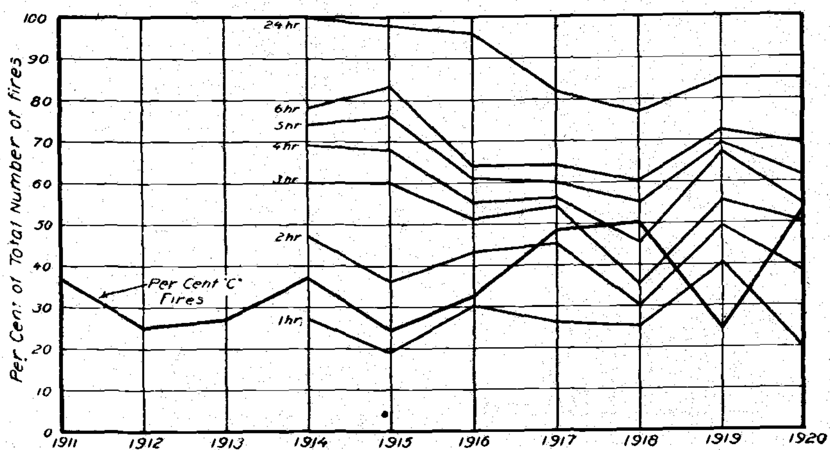


FIG. 30.—The relation of elapsed time to proportion of Class C fires (man-caused), Klamath National Forest. Wide fluctuation in speed of attack and proportion of Class C fires from year to year.

ANALYSIS OF BREAKS.

Within the experience of the Forest Service in northern California it is doubtful if any of the breaks can be charged to Group 3, though it has been shown that climatic factors are an important influence in fire protection. An examination of the limited available data may perhaps help to decide on the relative importance of the other two groups For this purpose there will be used detailed analyses. of all C fires on one forest for two years, in 1917 and 1920. In making the analysis, it has been found that occasionally several factors have contributed in certain fires, but almost without exception one dominant factor can be isolated. Table 27 gives the data for both years combined. (See also Fig. 32.)

Coming under Group 1, as defined above, 11.8 per cent of C fires were due to poor tactics in fire fighting and resulted in 9.8 per cent of the total burned area and 32.7 per cent of the total cost of suppression. To this must be added 7.1 per cent of C fires caused by too slow a get-away, making a total of nearly one-fifth of all C fires for which breaks in the local organization are responsible.

Falling in the second group are the fires, totaling 13.4 per cent, due to the lack of men to send; in other words, to underorganization for emergencies. Slow detection on account of smoke is often prolonged by the failure to organize an emergency patrol, but this failure may frequently be due to the difficulty of securing competent men on short notice. Slow detection is responsible during the two years mentioned for 26 per cent of the C fires on this forest.

The policy of overemphasizing low cost of suppression and underemphasizing the element of damage was responsible for 7.9 per cent

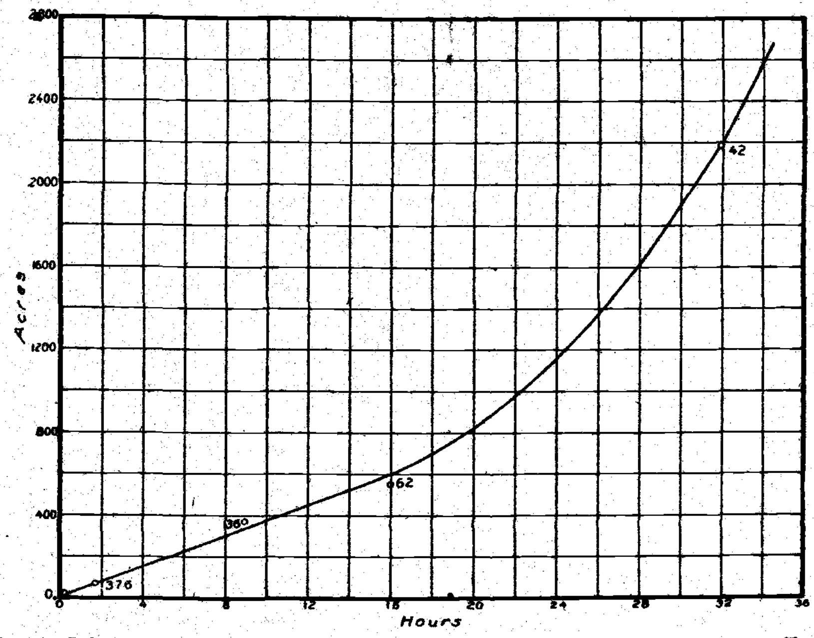


FIG. 31.—Relation of elapsed time to area of average fire (man-caused), based on 516 fires, 1914–1918, Shasta National Forest. This figure, considered in connection with Fig. 23, will give some idea of the value in dollars of every hour saved in beginning work on a fire. Every hour saved at the start means fewer dollars spent, a smaller area burned, and less timber destroyed.

of the fires and the high total of 52 per cent of the area. These figures once more point out the danger of the low cost theory.

Failures due to poor work by cooperators, chiefly employees of lumber companies operating in the national forests, form 8.6 per cent of the total number and 10.6 per cent of the acreage. This in the main is a question of finance—relying on men outside the organization because funds do not permit placing special men at known points of danger.

Finally, 25.2 per cent of these C fires can be classed as satisfactorily handled. Leaving out these 32 fires, and the 10 traceable to the policy of low costs, the balance, numbering 85, are made up of the 15 unsatisfactorily fought, 11 poorly handled by cooperators (making 32 per cent which were reached with reasonable promptness, but on which better tactics could have been employed), and 58 fires (constituting 68 per cent) due essentially to slow attack, either because of slow detection or of insufficient men to go to fires. That is, considering only number of fires, speed in reaching them is of primary importance. Moreover, a clear-cut and definite policy of putting out fires while they are small is essential.

SLOWNESS OF ATTACK.

Using these data as typical—and they undoubtedly are—slowness of attack is reponsible for twice as many poor results as incorrect action after men get there. It should never be forgotten that almost any fire can be handled if it is reached soon enough. As fires become larger, the opportunities for mistakes become progressively more and more numerous. The great majority of the fires classed as poorly fought were reached only after they had attained class C size.

It is a point worthy of note that of the fires employed in this analysis of breaks, those which were attacked in the class B or small class C stages rarely reached a large size.

If fires are large when attacked, it often happens that hasty action is taken and that one mistake leads to another. Particularly when a

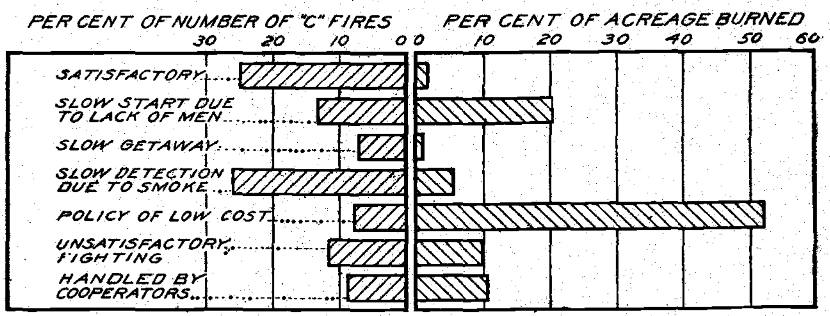


FIG. 32.—Causes of Class C fires. (Based on Table 27.)

fire is so large that several crews must be employed at different points of attack, the organizing ability of the officers in charge is severely tested, so that the organization of the attacking forces may easily be at fault. A lack of competent foremen to supervise the crews has also sometimes resulted in poor jobs of fire fighting.

The major facts to be remembered in studying breaks are:

1. Prompt arrival of the attacking force is of the greatest importance.
2. Unsatisfactory suppression occurs mainly on fires already large when attacked.
3. Human fallibility must always be taken into account as a possible weak spot in the best plans.

Some breaks must, in any event, be anticipated from carelessness or blundering, or other causes. Only by training of personnel can they be reduced to a minimum, though it is doubtful if they can ever be entirely eliminated. Improvement in this respect is an important part of the fire problem.

PROTECTION BALANCE.

The attempt so far has been to separate, weigh, and analyze individual factors in the fire problem. All these factors combine to determine the total cost expressed in terms of prevention, suppression, and damage, subject always, however, to two other factors of major importance whose exact values are hard to determine: First, the climatic factor; second, the bunching of fires. Comparisons of intensity of protection, applied in different units and years over an extended period, require the use of a common denominator. Man power approaches this most nearly and is therefore used. It is granted that differences in character and skill of administration will reflect themselves in the final outcome, but for long periods or for groups of administrative units these differences will not greatly distort the values.

Suppression is expressed directly in terms of money.

Damage, as has been shown, is directly proportional to the area burned, which in turn can be expressed in terms of money.

The next step in weighing intensity of protection is to compare man power with results of protection.

For each of the four groups of forests, a balance sheet has been prepared, showing the total cost of prevention, suppression, and damage for each of the years. Prevention and damage have been figured at the average flat rates for the period, and costs of suppression have been reduced to a uniform basis, as explained under unit suppression costs. These are given in Table 28. For each group (except No. 2) the years are subdivided into three classes, according to the number of men in the regular protection forces: (1) Below average; (2) average; (3) above average.

Considering first group (1), it will be remembered that 1917 and 1920, on the basis of rate of spread of fires, were the worst years in the record. It will be seen that 1917 has the highest total cost within class 1 (below average) and 1920 within class 2 (average). Although it has a total cost much greater than 1920, the year 1918, which falls in class 1 (below average) was a relatively easy year so far as rate of spread is concerned. Likewise, 1916 (class 2) was practically the same in difficulty as 1914 and 1915 (class 3), but the cost in 1916 was about 10 per cent greater than in the other two years. From a study of the balance sheet for this group of Forests it seems probable that the scale of protection should be within the limits of class 3, or around 220 men.

Group 2 has had relatively slight fluctuations in man power, and with the exception of the two bad years, 1917 and 1920, there is only a slight difference in total cost in the two groups. Probably about 50 men is the proper scale for this group.

Group 3 has had considerable fluctuations in man power, 1917 falling in class 1 and 1920 in class 2. Each of these bad years is the highest within its respective class. Here the evidence indicates that satisfactory results have come from the man power of class 2.

In Group 4 there has been considerable change in man power. The balance indicates that good results are obtained with manning as in class 2, say, 115 men.

Summing up, 225 + 50 + 110 + 115 men, or 500 in all, seems to constitute the correct man power for the district.

Taking only the district total (Table 29), it is seen that 300–400 men gives the high average cost of $823,200; 400–500 men gives $415,000; and over 500 men, $393,000. In the upper class, saving in damage and suppression is nearly offset by increase in costs of prevention. (See Fig. 33.)

Clearly, this type of analysis is based finally on the valuation of damage, and it has been frankly recognized that the present data on damage are incomplete and inadequate. There is every reason to believe that further study may result in the change of this factor in the formula for various forests (and finally for forest types), but at present even this very inadequate study is at least better than nothing.

LOCAL STUDIES.

The analysis of fire data so far discussed has aimed primarily at the broader state-wide phases of the problem: The determination of relative needs of different units and groups of units; the isolation and study of fires from individual causes; the relative effects of season, man power, etc., on performance; and the relative hazard areas.

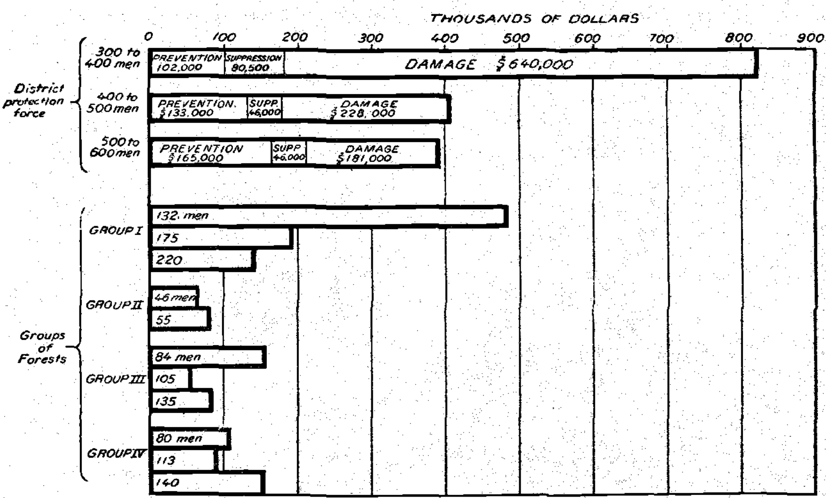


FIG. 33.—The relation between man-power and combined cost of prevention, suppression, and damage. The lower bars are for the four groups of forests and the upper bars are for the whole district. In the district figures, it should be noted that the high costs fall in the years 1911, 1917–18–19, and the low costs fall in 1914–15. In other words, the high total costs coincide with the period when the low cost of suppression theory was dominant and the low costs coincide with the period of intensity of protection. In each set of data, the average cost per year is used. (Based on Tables 28 and 29.)

VALUE OF GENERAL STUDIES.

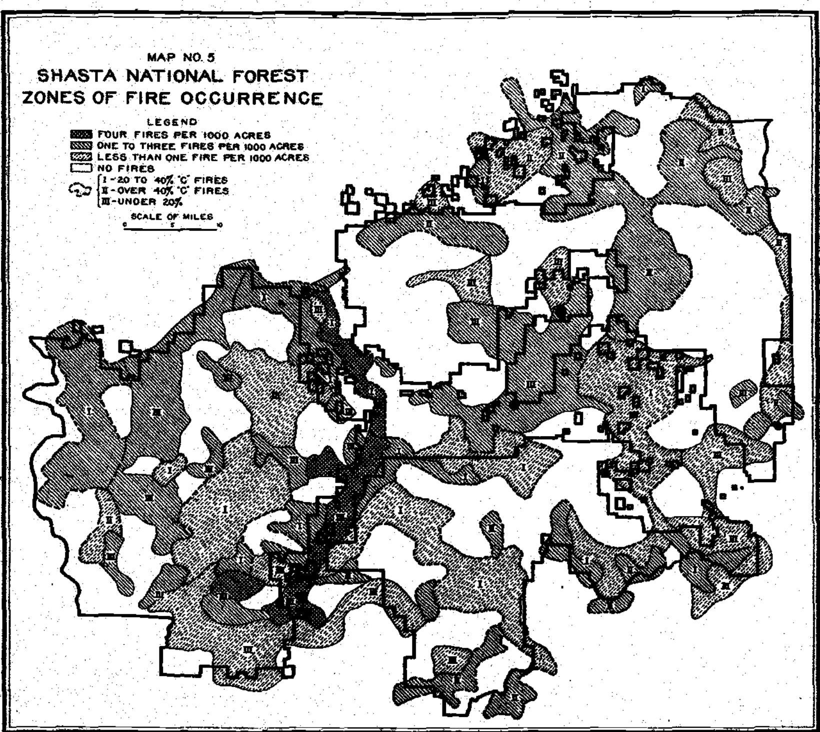
Considered in their broad aspect, such studies make it possible to determine the relative importance of the fire problem on different forests, and therefore to allot money consistently to them; that is, so far as intensity of protection is concerned, to put all on an approximately equal footing. Whether available means are used effectively or ineffectively shows up in studies of elapsed time, in the analysis of unit costs of suppression, in the number of fires successfully handled per man, etc.

Many questions of district policy can finally be answered only by an analysis of these data. For example, the effects of the policy of low cost of suppression, or the question of fighting or not fighting fires adjacent to the forest or on private land inside, are cases in point. Success or failure in the prevention of man-caused fires by means of law enforcement can be determined by such studies. They are, moreover, an administrative necessity. Even the most careful study of an individual forest may fail to isolate the trouble unless there is some way to check it against other forests.

NEED FOR LOCAL STUDIES.

Just as general studies are essential to an understanding of the relative needs and the relative accomplishments of the various forests, so more intensive local studies are necessary to determine the efficiency of the local machinery of protection. It is therefore now proposed to discuss the existing data that can be advantageously studied on individual forests. The results of such a study on one of the forests in California will be used as an example of what is needed and what can be achieved in studies of this kind.

As the allotments to various forests depend largely on relative hazard areas, which are determined by plotting all fires and drawing



zone lines, so the distribution of protection men on an individual forest or ranger district must depend primarily on where the fires occur.

DETERMINING FIRE ZONES.

The first step in the local study is therefore the plotting of the location of the starting point of each fire. Map 5 shows these points after the zone lines have been drawn. In this case four well-defined zones of intensity occur and are segregated on the map.

Zone 1.—Fires at the rate of 4 per 1,000 acres for 10 years.
Zone 2.—Fires at the rate of 1 to 3 per 1,000 acres for 10 years.
Zone 3.—Fires at the rate of less than 1 per 1,000 acres for 10 years.
Zone 4.—No fires.

This should not be confused with a map showing areas burned. Such a map is essential in showing the particular areas in need of most attention, just as in a district study the forests with highest burned areas need most attention. In practice, dots showing the starting points of fires will be the most satisfactory method of showing these data on maps.

RELATIVE HAZARD OF AREAS.

The relative hazard of fires once started can be shown on the maps of occurrence by natural units, based on proportion of class C fires.

Class 1.—Areas with 0–20 per cent C.
Class 2.—Areas with 21–40 per cent C.
Class 3.—Areas with 41 per cent C or over.

Areas of class 1 hazard, experience indicates, have good protection; those in class 3 can at once be isolated as needing immediate attention. It will be found that areas in this class are those that will also show up most conspicuously on the map of burned areas.

ADEQUACY OF DETECTION.

Obviously the first essential for successful protection is that detection shall be adequate, particularly in zones 1 and 2 and classes 2 and 3. The next step in a local study, therefore, is the preparation of lookout visibility maps (Map 6). Here, again, a natural subdivision can and should be made.

Visibility zone A.—Areas directly seen by lookouts in which class A fires can be detected.
Visibility zone B.—Areas in which class B fires can be detected.
Visibility zone C.—Areas in which only C fires can be detected.

Areas covered by regular patrol as well as by stationary lookouts should also be shown. Comparing the fire-occurrence zones and visibility zone maps it is found for the particular forest under discussion that much of the class A visibility falls in areas where, experience shows, no fires occur. Conversely, part of the fire-occurrence zones are not directly seen by any lookout.

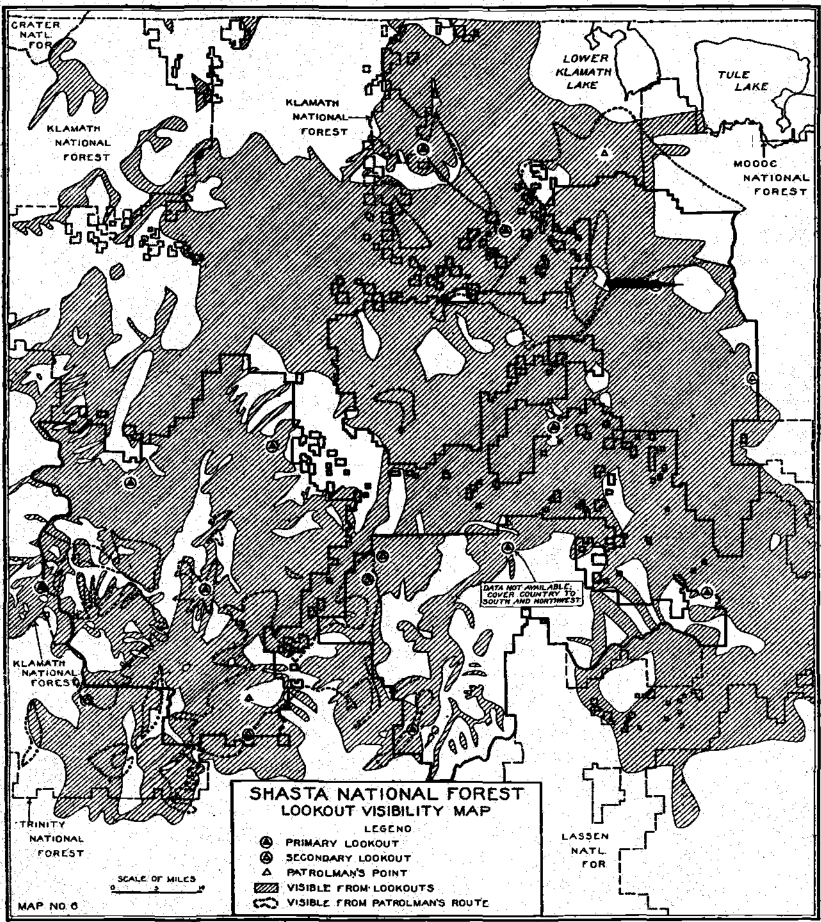
The ideal system would be for all the zones of fire occurrence to be covered by class A visibility from two lookouts, thus permitting quick detection and accurate location by cross shots. Such an ideal probably can not be attained, because mountain peaks available as lookouts are naturally not always situated where they are needed.

In comparing the two maps, areas in which fires occur, particularly zones 1 and 2, but which fall into class B and C visibility, are indicated as needing an immediate study of detection. Particularly if high hazard, as indicated by percentage of C fires, is shown, it will be necessary either (1) to use an additional or a different peak as lookout, (2) to establish a moving patrol to supplement the lookout, or (3) to organize cooperative detection, such as ranchers, stockmen, etc. Which of these is advisable can usually be determined with little difficulty. The main point is that before considering any other phase of the protection problem, adequate detection must be provided.

Analysis of the data shows that the greatest loss in time is in discovery—that is, from the start of the fire until it is detected. The importance of good lookout visibility maps can not be overemphasized.

EFFICIENCY OF LOOKOUT MEN.

The study above outlined measures the effectiveness of lookouts as to position. The personal efficiency of the individual lookout men can easily be determined once the visibility areas are estab-



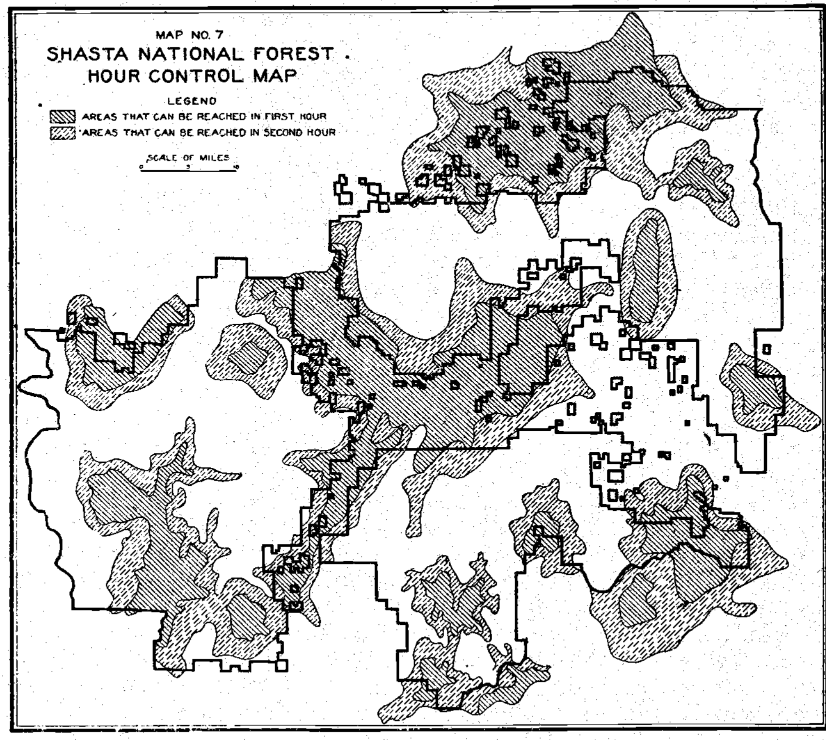
lished by currently checking the fires actually discovered and reported against all those occurring within, for example, the zone of class A visibility. In practice, personal efficiency will be found to vary considerably, and only by a current check can poor lookout men be weeded out of an organization before they are responsible for a break.

Within the fire season, smoky air may put any or all lookouts out of commission for a shorter or longer time, during which the emergency must be met by special patrol. But successful organization demands the development of detection as above outlined.

PLACING THE SUPPRESSION FORCE.

The placing of the men who are to handle suppression is next to be studied. In these days of automobile travel, distance in itself may mean little, as it is possible to go 12 or 15 miles an hour by motor where a few years ago with horses a speed of only 4 miles was possible.

Next, using the data on individual fires, a map is prepared showing the point from which men left to handle each fire (for as many years as can conveniently be shown on the map) and the number of hours travel time. Straight radiating lines from a given station to the individual fires make possible the drawing of "hour contours," or



closed lines surrounding each guard station, showing how far with the best available means of conveyance men can be expected to go in one, two, or more hours.

HOUR CONTOURS.

On any forest certain points, such as district ranger headquarters, are logically the points at which protection men will be placed. Map 7 shows, for the particular forest under discussion, the one and two hour contours from points at which it is certain guards will be placed. The strong influence of the method of travel on the area covered is at once apparent. For example, where only horse travel can be used, a radius of 2 to 3 miles per hour is all that can be counted upon, whereas, by automobile, where roads are passable, as much as 15 miles can be attained.

Comparing this map with that showing zones of occurrence, it is seen that practically all of zone 1 (heaviest concentration) is covered by the one-hour contour; in other words, the protection can be considered adequate. Large areas of zones 2 and 3, however, are found to be beyond the one-hour and even the two-hour contour. Here, again, as in the study of the lookout system, provision must first be made for zone 2 areas of high hazard (20 per cent or more C fires), and later for the other areas.

Considering the east half of the forest in question, it is seen that much of it has a very high hazard (40 per cent or more C fires), whereas the west half has in general a low hazard. The number of additional men that funds can be provided for will be fixed for the Forest by the district forester. No formula can tell just where these men should be placed. The study so far made will show clearly the areas most in need of protection within the one or two hour contours, and if any chances must be taken, they should be in areas of low hazard (less than 20 per cent class C) within zone 3 (few fires).

ZONES OF FIRES, BY CAUSES.

One further set of maps (not reproduced) will be found invaluable in deciding on the position of the men. These maps show separately the zone of lightning fires, the zone of camper fires, and the zone of incendiary fires. It has been shown previously that incendiary fires are the most dangerous group. They occur in well-marked, concentrated zones on this forest, just as they do for the whole district; and once the zones are shown on a map it is generally easy to isolate the type of incendiary and often, by circumstantial evidence, even the individual. Thus in the southeastern part of the forest, stockmen burning the range are obviously the responsible persons. In the western part of the forest, the position of the incendiary zone strongly indicates prospectors as the guilty persons.

In placing protection men, therefore, such special considerations must be weighed. Likewise, the location of the communication system will influence the positions of the men. In fact, the final selection of points must be governed by the balancing of a number of different considerations. Although judgment must always play a part in this or any other system, it is certain that maps of this kind isolate some areas as needing attention and eliminate others as being adequately provided for according to the existing scale of protection.

SUMMARY.

This study has singled out and discussed the main factors—physical and human—in the problem of protection against forest fires. It has examined the various theories of protection; has analyzed variations in fires from divers causes and the effect of these variations on means of control; has traced the great seasonal fluctuations in the intensity of fires due to climatic changes; and, finally, has pointed out certain weaknesses traceable to flaws in organization or to weak spots in the personnel. From this whole discussion certain definite conclusions emerge, which may be formulated as follows:

The development of successful protection depends on a critical study of past performances. For this purpose the importance of accurate and complete records of fires can not be overemphasized.

Such studies as the present one depend absolutely on data secured over a period of years, and though paper records are not the aim of fire protection, they are a by-product which should not be overlooked.

A careful analysis of fires from different causes shows that each group, based on cause, has special characteristics in seasonal distribution, location, and manner of occurrence, as well as in the rate of spread and difficulty of control as expressed in percentage of C's. The measures needed to prevent man-caused fires of different origins or to meet specific local outbreaks usually become fairly clear once such detailed studies are made.

Local studies (that is, studies of individual forests) based on past performance and following the principles discussed in this circular, point the way to the best use of existing means of protection, after isolating the relative needs of the various smaller protection units. A current check of paper records may be expected to prevent at least a part of the breaks which have characterized the record of the past decade.

The determination of relative areas of hazard on different forests and for fires of different causes is an essential step in analyzing fire problems, particularly as it affects the allotment of protection funds.

The problem of man-caused fires is not solved, though measurable progress has been made in their prevention, especially in the case of camper and incendiary fires. The reduction of man-caused fires through education and law enforcement is all the more essential because of the need of freeing the organization for unavoidable emergencies. Cutting down preventable fires is equivalent to increasing the force.

Successful protection is reached at the point where the cost of prevention, suppression, and damage is a minimum. This point is known within a reasonable limit of error for the existing type of organization and for existing physical conditions.

Successful protection demands first of all a clearcut, definite objective. This may be expressed as the reduction of C fires to a low percentage. The area burned, and hence the costs of suppression and damage are expressed indirectly in percentage of C fires. With not over 15 per cent of class C fires, a small area burned may be expected.

The percentage of C fires, other things being equal, depends on the speed with which fires are attacked; in other words, on elapsed time. The character of the individual season modifies this relation to some extent, but does not obscure the principle.

As a practical measure to determine how well the organization is functioning, studies of elapsed time are invaluable. Broadly speaking, speed of attack has varied with intensity of protection—that is, with the number of protection men. This relation has been modified to some extent by occasional weak spots in the organization, or by such physical conditions as a smoky atmosphere, which may put lookouts out of commission at times. However, the basic principle is well established.

As contrasted with poor performances on individual fires, failures in protection (that is, failures due to actual breakdowns of the protection force) have been more frequently due to emergencies than to any other cause. As forestry is a long-term enterprise, so that an occasional bad season may vitiate the results of years of successful protection, the great problem to be solved is consistency of protection. The elasticity of organization needed to meet these occasional extraordinary emergencies has not yet been attained, and just what type and scale of organization will be needed to meet them is open to question.

The analysis of individual questionable class C fires shows that faults of local management are an important factor, but that incorrect or indeterminate policy and slowness in reaching fires are the two major causes of "breaks" in individual fires as contrasted with failures of protection by reason of a breakdown of the force during severe emergencies.

Studies of unit costs, allowing for fluctuation in the value of money, show that the handling of fires up to about 300 acres in size is fairly well standardized, but that in the suppression of big fires there is room for improvement.

Stated in general terms, the major problems in fire protection are:

Holding the costs of prevention, suppression, and damage to the minimum, with full weight to the element of damage.

Consistency of protection—that is, preventing outbreaks in bad seasons from nullifying the results of protection through several preceding years. In practice this means developing an organization capable of handling emergencies under severe conditions.

To develop this elasticity requires also the development of methods of predicting emergencies within the fire season.

Critical local studies to determine the best use of available means of protection.

APPENDIXES.

APPENDIX A.

DEFINITIONS.

Certain terms are used in a more or less technical sense and are here defined.

Prevention.—Preliminary organization, placing of men, allotting of funds, and activities and costs up to the point of beginning work on actual fires. Thus, cost of prevention consists of money spent in hiring lookouts and fire guards (except time on fires), and of a portion of the cost of telephones and trails as well as of administrative overhead.

Suppression.—Extinguishing fires. Cost of suppression includes hiring of men, transportation, tools, supplies on actual fires, and wages of prevention force when on actual fire fighting.

Classes of fires.—A, 0–¼ acre; B, ¼–10 acres; C, over 10 acres. C fires were further subdivided on the basis of damage.

Causes of Fires.

Lightning.

Railroads.

- Sparks from smokestack.
- Sparks from fire box.
- Matches or tobacco thrown from trains.
- Fires escaping in any manner from section gangs, from telegraph or telephone line crews working along the right of way, or from crews engaged in the construction or repair of railroad bridges or other works.
- Fires caused by trackwalkers, whether railroad employees, tramps, or migrating laborers.

Brush burning.

- Fires escaping from clearing land for any agricultural purpose—for cultivation, for fencing, or for beehives, buildings, ditches, or sites for irrigation reservoirs.
- Fires escaping from clearing land for developing power—reservoir sites, transmission lines, power-house sites, or conduit and pipe lines.
- Fires escaping from power-construction crews, at work or in camp.
- Fires escaping from cleaning up and burning litter about small towns and mining camps.
- Fires escaping from smoking out animals, insects, or reptiles.

Campers.

- Fires caused in any accidental manner (unextinguished matches, tobacco, or camp fires) by travelers in the mountains for recreation, hunting, or fishing, whether by foot, horseback, wagon, or automobile.
- Fires caused in any accidental manner by other travelers—stockmen, prospectors, business men, etc.

Lumbering.

- Fires occurring in connection with lumbering, whether from individual members of a crew, or from donkey engines, logging railroads, sawmill engines, woods camps, traction engines, or hoisting engines, or from blasting in connection with logging.
- Fires caused in any accidental manner by wood choppers, shake makers, pole or post cutters, or free use permittees.

Incendiary.

Fires calculated to spread, intentionally set for any motive, good or bad. Under this head would be included light burners, Indians, prospectors (when they intentionally burn off cover), drunks, lunatics, children, or hunters (for the purpose of driving game), as well as the malicious incendiary.

Miscellaneous.

Fires which do not come under any of the foregoing heads—fires from spontaneous combustion, or bottles acting as lenses, fires escaping from burning buildings or automobiles, short-circuited electric wires, etc.

Cover Classes.

Timber.—Mature and immature timber stands with ground cover varying from litter of needles to grass, reproduction, and scattered brush.

Brush.—Ranging from pure brush fields with no timber to heavy stands of brush under open stands of timber.

Cut over.—Logged lands on which slash has not been disposed of.

Sagebrush.—Lands on which sagebrush and similar species form the principal cover.

In the present study no attempt has been made to segregate timber into types.

Elapsed Time.

From start of fire to beginning of suppression, or
From discovery of fire to beginning of suppression.

Hazard Area.

The area on which experience shows fires occur. The term hazard area was formerly defined as an area on which special protection forces are necessary. A further division may be made into zones of intensity according to the average numder of fires per 100,000 acres.

APPENDIX B.

Form of fire report used up to 1913.

Form 874-6.
(Supersedes Form 944.)

Class........
(Supervisor will fill in A, B, or C.)

FIRE REPORT No. ....

...., ...
(Place.) (Date.)

To supervisor .... *National Forest:*

I submit the following report on a fire which was discovered .... the forest and (On or off.) which threatened national forest lands. Location of starting point.................
....
Discovered by .... at ....
(Name.) (Hour.)
on .... reported to me at ....
(Date.) (Hour.)
on .... Work commenced at ....
(Date.) (Hour.)
on ....; finished at..........................
(Date.) (Hour.)
on .... Number of men employed ....
(Date.)
Fire caused by ....
(Outline briefly, with names if possible.)
....
.... action .... recommended.
(Civil or criminal.) (Is or is not.)

	National forest.	Private lands in forest.	Lands outside forest.
Forest officer's labor	$........	$........	$........
Cost of tools, supplies, transportation, etc.	....	....	....
Cost of temporary labor	....	....	....
Total	....	....	....

Assistance without pay was rendered by ....
(Names.)
....
to the amount of ....
(Hours.)

	Acres.
National forest timbered lands burned over	....
Private timbered lands in forest burned over	....
National forest lands not timbered burned over	....
Private lands in forest not timbered burned over	....
Total area burned over	....

Form 874-6—Continued.

	National forest.		Private lands.	
	B. m.	Stumpage value.	B. m.	Stumpage value.
Total stand green timber before fire	....	$........	....	$........
Total stand dead timber before fire	....	....	....	....
Total stand before fire	....	....	....	....
Amount merchantable green timber after fire	....	....	....	....
Amount merchantable dead timber after fire	....	....	....	....
Net loss by fire	....	....	....	....

(To be filled in by supervisor.)
NOTE.—Damaged green timber which will die should be classed as dead.

	Before fire (acres).	After fire (acres).	Average age.
Area of burned tract (national forest land only) satisfactorily stocked with young growth	....	....	....
Amount of scattered young growth on burned tract (national forest land only) expressed in acres of satisfactorily stocked land	....	....	....
Total	....	....	....

Estimated value of young growth destroyed, $.................... (To be filled in by supervisor.) Acreage of range burned over, ... acres. Type of range, ...; carrying capacity, ...; authorized grazing season from .... (Date.) to .... (Date.) Number of days use of range lost, ... days. Estimated value of forage destroyed, $........................ (To be filled in by supervisor.)

Please inform me if you require further information on this fire.

......................................,
Forest Ranger.

Form F 2 a.

[Present form of fire report.]

[United States Department of Agriculture, Forest Service, District 5.]

INDIVIDUAL FIRE REPORT.

Forest ....
Supervisor's number ....
Ranger district .... Date ...., 192
(When report is made.)

Name of fire .... Class ....

CAUSE OF FIRE.... (Check proper one.)
- Lightning ....
- Railroads ....
- Incendiary ....
- Brush burning ....
- Campers ...... Camp fire ....
- Smoking, etc. ....
- Miscellaneous ....
- Unknown ....
(Probable cause.)

Class of persons responsible, as tourists ......, hunters ......, fishermen ......, ranchers ......, stockmen ......, miners ......, other ....
....
(Specify.)
....

Persons responsible—Known ......, suspected ....
Names and addresses:
....
....
....

ELAPSED TIME RECORD.

.... M

Fire started ....M.............. (Date.) Known ...., guess .... Location .... (Subdiv.) Sec. .... T. .... R ....
Fire discovered ....M.............. By .... Title .... Disc. time ....
Fire reported ....M.............. To .... Via .... } Rept. time ....
Report rec'd ....M.............. By .... At ....
Left for fire ....M.............. Who? .... From .... Get away time ....
Arrived at fire ....M.............. Via .... Miles .... Travel time ....
Work started ....M.............. If not a forest officer, who? .... What? ....
(As rancher, miner, cattleman, etc.)
Fire controlled* ....M.............. No. of man-hours .... Control time ....
Fire extinguished ....M.............. No. of man-hours .... Patrol time ....
Totals .... No. of man-hours .... Elapsed time ....

Further details of action, if any, before arrival of forest officer ....
....
Approximate area fire had covered when first man arrived ....

* A fire is controlled when definite-fighting stops; it is extinguished when the last man leaves patrol as a steady job.

Form F 2 a—Continued·

CHARACTER OF AREA BURNED.

(Check as follows: "S"=scattered, "M"=medium, "D"=dense.)

Cover Types: TIMBER—YP........; YP-SP........; YP-F........; fir........; woodland........; reproduction........
BRUSH—Chaparral........; chemise........; sage........; mixed........; grass........
GROUND COVER UNDER TIMBER—Brush........; bear clover........; needles........; grass........; reproduction........
GROUND COVER UNDER BRUSH—Grass........; litter........; reproduction........

Wind: BLOWING FROM—N........; NE........; E........; SE........; S........; SW........; W........; NW........ INTENSITY—Calm........; gentle........; light........; fresh......; brisk........; high........; gale........

Topography: SLOPES—Level........; gentle........; moderate........; steep........; very steep........; mixed........
EXPOSURE—N........; NE........; E........; SE........; S........; SW........; W........; NW........; mixed †........
SURFACE—Smooth........; broken........; outcrop........; loose rock........; various†........

Miles of held line ‡.................... Difficulty of constructing line..
(Only for fires over 100 acres.) (Proportion classified as easy, medium difficult, or very difficult.)

† In case of mixed exposure or various surface check also prevailing one.
‡ Held line is actually constructed line which holds the fire. Natural barriers do not count.

AREA BURNED.

Status of land.	Timbered.	Nontimbered.	Total.	How much of total area is—	
				Reproduction.	Used range.
Inside:					
National forest........					
Cooperators........					
Noncooperators........					
Outside:					
Cooperators........					
Noncooperators........					
Totals........					

DAMAGE.

Timber, $.............................. Reproduction, $.............................. Improvements, $.............................. Total, $..............................
(This report is final where damage is under $25. See note at foot of page.)

Form F 2 a—Continued.

COST OF FIRE.

Items.	Natl. forest land.	Inside boundary.		Outside boundary.		Totals.	Forest officers' time.	
		Coops.	Noncoops.	Coops.	Noncoops.		Names.	Hours.
Temporary labor	$	$	$	$	$	$		
Equipment, supplies, transportation, etc.*								
Total FFF								
Forest off. labor								
Total cost								
Value of cooperation (free service)								

Assistance without pay (as above distributed) was rendered by .... to the amount of .... man-hours.

LAW ENFORCEMENT.

Clues found ....

Gravity of offense ....

(How dangerous where fire was built, what care used to extinguish?)

What investigation started and by whom? ....

What action taken; what more to be done; is any help needed? ....

Additional remarks ....

Supervisor: I will reexamine this area (damage over $25) and submit Form F 2-b not later than ...., 192

Initials ....

Report made by ....

Title ....

Place ....

N. B.—This report must be prepared as soon as possible after each fire.

* Include auto mileage to and from fire as shown under heading "Elapsed time."

APPENDIX C.

TABLE 1.—*Relation of percentage of C fires to distribution of fires in different size classes.*

Group.	Per cent of C fires.	Years.	Total number of fires.	Size of average fire.	Size of average C fire.	Per cent of C fires.				Per cent of total number of fires over 300 acres.	Cost per fire.	Ratio of cost per fire to per cent C fires.	Per cent of B fires.
						Over 300 acres.	Over 1,000 acres.	Over 2,000 acres.	Over 5,000 acres.				
				Acres.	*Acres.*								
1.......	31+	1917, 1918	2,465	285	840	33.6	14.0	8.1	2.3	10.7	$91.50	2.96	33.4
2.......	26-30	1911, 1919	1,514	100	482	24.6	6.8	3.2	1.1	7.2	68.40	2.48	34.0
3.......	21-25	1916, 1920	2,309	120	536	18.2	6.1	3.0	1.8	4.3	52.70	2.32	34.0
4.......	16-20	1914, 1915	2,353	51	258	15.8	7.6	3.7	.9	3.0	36.60	1.96	33.6
5.......	10-15	1912, 1913	1,858	32	215	14.4	2.3	1.2	.8	2.0	29.40	2.12	32.0

TABLE 2.—*General summary (all Forests except Angeles, Cleveland, Santa Barbara, Inyo, and Mono).*

Year.	Number man caused.	Number lightning.	Per cent of lightning.	Total number.	Area burned.	Per cent of A and B.	Per cent of C.	Suppression costs.	Total protection force.	Average acres per fire.
1911...............	370	246	40	616	44,006	70.0	30.0	18,746	346	71
1912...............	361	204	36	565	24,772	81.9	18.1	10,197	447	44
1913...............	602	691	53	1,293	35,152	86.5	13.5	26,782	479	27
1914...............	759	413	35	1,172	75,923	80.8	19.2	46,611	563	65
1915...............	886	295	25	1,181	44,821	79.6	20.4	45,525	537	38
1916...............	777	388	33	1,165	109,986	78.9	21.1	41,498	429	94
1917...............	779	794	50	1,573	413,075	67.8	32.2	121,707	365	263
1918...............	363	529	59	892	290,174	63.5	36.5	114,986	313	326
1919...............	717	181	20	898	107,308	71.9	28.1	101,433	343	120
1920...............	523	621	54	1,144	167,706	76.2	23.8	152,851	428	146
Total........	6,137	4,362	....	10,499	1,312,923	....	....	680,336	4,250	....
Average...........	614	436	42	1,050	131,292	75.8	24.2	68,034	....	125

TABLE 3.—*Lightning zones (areas in thousands of acres).*

Forest.	Total area.	Total hazard area.	Total lightning zone.	Per cent total hazard area.	Number of lightning fires, 1911-1920.	Number of fires per 100,000 acres of lightning zone.	Number of fires per 100,000 acres of total hazard area.
Klamath........................	1,744	1,659	1,110	67.0	684	61.5	....
Trinity........................	1,724	1,493	1,042	69.8	499	47.9	....
Shasta........................	1,585	1,972	1,145	58.0	558	48.8	....
California........................	1,063	838	749	89.4	165	22.1	....
Total northern group (1) .	6,116	5,962	4,046	67.8	1,906	47.2	32.0
Modoc........................	1,905	1,106	895	80.9	334	37.2	....
Lassen........................	1,321	1,438	1,118	77.7	389	34.8	....
Total east side group (2)...	3,226	2,544	2,013	79.2	723	35.9	28.4
Plumas........................	1,433	1,438	922	64.2	483	52.4	....
Tahoe........................	1,222	1,460	1,032	70.8	312	30.2	....
Eldorado........................	836	691	425	61.6	189	44.5	....
Total north Sierra group (3)...............	3,491	3,589	2,379	66.3	984	41.4	27.4
Stanislaus........................	1,104	747	628	84.2	164	26.1	....
Sierra........................	1,663	819	674	82.4	250	37.1	....
Sequoia........................	2,022	1,207	1,090	90.3	335	30.7	....
Total south Sierra group (4)...............	4,789	2,773	2,392	86.3	749	31.3	27.0
Grand total...............	17,622	14,868	10,830	72.8	4,362	40.3	29.4

TABLE 4.—*Intensity of lightning fires per storm.*

Forest.	Number of fires, three heaviest storms.	Total lightning zone, by groups, in 100,000 acres.	Intensity factor.	Relative demand.	Number of men in protection force.	Fires per man.	Relative intensity.
Klamath	174				132	1.32	
Trinity	172				118	1.46	
Shasta	179				111	1.61	
California	87				88	.99	
Total, Group 1	612	4,046	51.1	154	449	1.36	143
Modoc	74				55	1.34	
Lassen	82				109	.75	
Total, Group 2	156	2,013	7.7	79	164	.95	100
Plumas	117				98	1.20	
Tahoe	95				105	.91	
Eldorado	96				61	1.57	
Total, Group 3	308	2,379	12.4	127	264	1.16	122
Stanislaus	55				85	.65	
Sierra	62				68	.91	
Sequoia	117				93	1.26	
Total, Group 4	234	2,392	9.8	100	246	.95	100

TABLE 5.—*Summary of lightning storms.*

Fires per storm.	Number of storms.	Number of fires.				Per cent C.	Total C.[1]	Average C.	Average fire.
		A.	B.	C.	Total.				
							Acres.	*Acres.*	*Acres.*
0–50	(?)	916	571	199	1,686	11.9	83,478	419	49
51–150	13	674	372	118	1,164	10.1	33,988	288	29
151–250	3	366	190	71	627	11.3	21,153	298	34
251–350	3	332	319	234	885	26.5	275,937	1,178	312
Total		2,288	1,452	622	4,362	14.3	414,556	665	95

[1] Area B fires negligible.

TABLE 6.—*Fires per member of protection force during individual lightning storms (three heaviest storms on each of 12 forests).*

Fires per man.	Per cent C.	Area of average fire.
		Acres.
0–0.5	8	31
0.5–1	14	49
1–1.5	21	166
1.5–2	26	275
2–2.5	26	200

TABLE 7.—*Lightning fires, 1911–1920.*

Year.	Number of A and B.	Number of C.	Per cent C.	Total number of fires.	Total area burned by C fires.[1]	Area average C.	Area average fire.	Total costs.	Cost per fire.	Number of fires, worst storm.	Per cent of total fires.	Protection force—number of men.
					Acres.	*Acres.*	*Acres.*					
1911	211	35	14.2	246	7,637	218	31	3,149	13	116	47	346
1912	190	14	6.9	204	1,231	88	6	1,290	6	89	43	447
1913	669	22	3.2	691	2,534	115	4	4,548	7	214	31	479
1914	387	26	6.3	413	2,408	93	6	8,467	21	108	26	563
1915	269	26	8.8	295	2,204	85	8	5,798	20	94	32	537
1916	361	27	7.0	388	9,053	336	23	4,297	11	233	60	429
1917	637	157	19.8	794	155,363	990	196	54,770	69	339	43	365
1918	367	162	30.7	529	134,019	828	253	63,039	119	255	48	313
1919	151	30	16.6	181	8,932	298	49	9,234	51	70	39	343
1920	498	123	19.8	621	91,175	740	147	72,527	117	295	48	428
Total	3,740	622	14.2	4,362	414,556	666	95	227,119	52	1,813	42	4,250

[1] Area B fires negligible.

TABLE 8.—*Lightning fires, 1911–1920 (seasonal distribution).*

Month.	Total number.	Number of C.	Per cent C.	Per cent of total number of fires.	Total area of C fires.[1]	Size of average C fires.	Size of average fire.
					Acres.	*Acres.*	*Acres.*
May	109	20	18.3	2.5	17,048	853	156
June	498	135	27.2	11.4	103,446	761	208
July	1,436	153	10.6	32.9	141,001	922	98
August	1,939	258	13.3	44.4	132,269	512	68
September	331	42	12.7	7.6	9,461	225	29
October	50	13	26.0	1.2	11,331	873	227
Total	4,363	622	....	100.0	414,556	666	95

[1] Area of B fires negligible.

TABLE 9.—*Camper fire zone areas (areas in thousand acres).*

Forest.	Total hazard area.	Total camper zone.	Per cent total hazard area.	Number of fires 1911–1920.	Number of fires per 100,000 acres camper zone.	Number of fires per 100,000 acres, total hazard.
Klamath	1,659	636	38.3	167	26.3	10.1
Trinity	1,493	710	47.5	181	25.5	12.1
Shasta	1,972	857	43.5	334	39.1	16.9
California	838	387	46.2	109	28.2	13.0
Total, Group 1	5,962	2,590	43.5	791	30.5	13.2
Modoc	1,106	590	53.3	98	16.6	8.9
Lassen	1,438	635	44.2	167	26.3	11.6
Total, Group 2	2,544	1,225	48.2	265	21.6	10.4
Plumas	1,438	1,041	72.5	287	27.6	20.0
Tahoe	1,460	1,245	86.3	411	33.0	28.2
Eldorado	691	460	66.6	108	23.5	15.6
Total, Group 3	3,589	2,746	76.6	806	29.4	22.4
Stanislaus	747	480	64.3	125	26.1	16.7
Sierra	819	415	50.7	105	25.3	12.8
Sequoia	1,207	794	65.8	147	18.5	12.2
Total, Group 4	2,773	1,689	60.8	377	22.3	13.6
Grand total	14,868	8,250	55.5	2,239	27.1	15.0

TABLE 10.—*Summary of Yosemite National Park (travel data).*

Year.	Number of cars.	Number of people.	People per car.	Total people.	Per cent increase.	Number of camper fires.[1]	Fires per 1,000 people.
1916	4,043	14,527	3.6	33,390	Base.	272	8.16
1917	6,521	22,456	3.5	34,510	3.3	240	6.95
1918	7,621	26,699	3.5	33,527	.4	180	5.37
1919	12,109	42,900	3.5	58,362	74.8	310	5.32
1920	13,418	46,074	3.4	68,906	106.4	240	3.49

[1] On National Forests.

The column "Fires per 1,000 people" merely attempts to indicate the number of camper fires per 1,000 people, as shown in the last column, assuming that the increase of travel on the National Forests is proportionate to the increase in the Yosemite National Park, an assumption that is probably roughly correct.

This column gives relative numbers of fires per unit of travel and is based on number of people using the park. The actual number of people using the National Forests in California is about twenty times as great as the park figure.

TABLE 11.—*Camper fires, 1911–1920.*

Year.	Number of A and B.	Number of C.	Per cent C.	Total number	Total acreage.[1]	Acreage average C.	Acreage average fire.	Total costs.	Cost per fire.	Number of men in protection force.
1911	70	27	27.8	97	5,896	218	61	$2,694	$28	346
1912	82	10	10.8	92	1,653	165	18	1,207	13	447
1913	164	21	11.3	185	6,282	299	34	5,109	28	479
1914	238	54	18.5	292	13,528	250	46	17,176	59	563
1915	264	67	20.3	331	10,412	156	32	15,183	46	537
1916	214	58	21.3	272	32,136	554	118	15,735	58	429
1917	161	79	32.9	240	31,025	393	129	14,243	59	365
1918	127	53	29.4	180	48,818	922	271	16,760	93	313
1919	239	71	22.9	310	22,616	319	73	18,138	58	343
1920	197	43	17.9	240	7,468	174	31	14,363	60	428
Total or average	1,756	483	21.6	2,239	179,834	372	80	120,608	54	4,250

[1] Area B fires negligible.

TABLE 12.—*Camper fires, 1911–1920 (seasonal distribution).*

Month.	Total number.	Number of C.	Per cent C.	Per cent of total number of fires.	Total acres of B and C.[1]	Average C.	Average fire.
March	8	4	50.0	0.4	255	63	32
April	21	4	19.1	.9	403	101	19
May	80	18	22.5	3.5	2,235	124	28
June	206	37	18.0	9.2	35.907	970	174
July	487	93	19.1	21.9	45,171	487	93
August	750	176	23.5	33.4	61,764	351	82
September	462	81	17.6	20.6	21,304	264	46
October	214	64	29.9	9.6	12,109	189	56
November	11	6	54.5	.5	686	114	62
Total	2,239	483	21.6	100.0	179,834	373	80

[1] Area B fires negligible.

TABLE 13.—*Incendiary fire zones (areas in thousands of acres).*

Forest.	Total hazard.	Total incendiary zone.	Per cent of hazard area.	Number of fires, 1911-1920.	Number of fires per 100,000 acres, incendiary zone.	Number of fires per 100,000 acres, total hazard.
Klamath	1,659	628	37.9	390	62.0	23.6
Trinity	1,493	822	55.0	312	38.0	20.9
Shasta	1,972	619	31.4	197	31.9	10.0
California	838	490	58.5	180	36.8	21.4
Total, group 1	5,962	2,559	43.0	1,079	42.2	18.1
Modoc	1,106	46	4.2	15	32.6	1.4
Lassen	1,438	157	10.9	94	60.0	6.5
Total, group 2	2,544	203	8.0	109	53.8	4.3
Plumas	1,438	274	19.0	124	45.2	8.6
Tahoe	1,460	331	22.7	169	51.1	11.6
Eldorado	691	175	25.4	84	48.0	12.1
Total, group 3	3,589	780	21.8	377	48.3	10.5
Stanislaus	747	211	28.2	76	36.0	10.2
Sierra	819	157	19.2	93	59.2	11.3
Sequoia	1,207	92	7.6	15	16.3	1.2
Total, group 4	2,773	460	16.6	184	40.0	6.6
Grand total	14,868	4,002	27.0	1,749	43.7	11.8

TABLE 14.—*Incendiary fires, 1911-1920.*

Year.	Number of A and B.	Number of C.	Per cent C.	Total number.	Total acreage.[1]	Average C.	Average fire.	Total costs.	Cost per fire.	Number of men in protection force.
1911	58	72	55.4	130	20,587	286	158	$8,955	$69	346
1912	49	34	41.0	83	5,397	159	65	2,236	27	447
1913	70	67	48.9	137	16,872	252	123	11,176	82	479
1914	158	85	35.0	243	46,562	547	191	12,458	51	563
1915	229	107	31.8	336	22,545	211	67	19,723	59	537
1916	193	107	35.7	300	48,040	449	160	9,641	32	429
1917	137	198	59.1	335	168,208	850	502	37,959	113	365
1918	21	65	75.7	86	63,298	974	736	19,235	224	313
1919	34	36	51.5	70	19,221	534	274	10,748	154	343
1920	14	15	51.7	29	20,453	1,363	705	20,963	723	428
Total	963	786	44.9	1,749	431,183	549	246	153,094	88	425

[1] Area B negligible.

TABLE 15.—*Incendiary fires, 1911-1920 (seasonal distribution).*

Month.	Total number.	Number of C.	Per cent C.	Per cent of total number of fires.	Area burned.	Size of average C fire.	Size of average fire.
					Acres.		
March	10	4	40.0	0.6	881	220	88
April	14	4	28.6	.8	349	87	25
May	40	11	27.7	2.3	699	64	17
June	59	24	40.8	3.3	13,144	548	223
July	189	100	52.9	10.7	65,343	653	345
August	507	238	46.9	29.1	180,789	762	357
September	491	206	42.0	28.0	56,662	276	116
October	384	170	44.3	22.0	105,653	621	275
November	55	29	52.7	3.2	7,623	263	139
Total	1,749	786	44.9	100.0	431,143	549	246

TABLE 16.—*Other man-caused fires, 1911–1920.*

Cause.	Numbers, by years.										Total number.	Number of C.	Average per cent C.
	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920			
Logging	23	48	83	74	67	96	61	17	64	29	562	127	22.6
Railroads	4	20	22	34	17	12	11	12	59	80	271	74	27.3
Brush burning	18	15	36	37	33	33	32	17	41	26	288	105	36.4
Miscellaneous	22	31	50	45	38	28	39	28	63	46	390	116	29.7
Unknown	76	72	89	33	64	36	61	23	111	73	638	222	35.0
Total number	143	186	280	223	219	205	204	97	338	254	2,149	644	29.9
Number C	51	44	65	61	41	55	74	46	116	91	......	644	......
Per cent C	35.6	23.6	23.2	27.3	18.7	26.8	36.3	47.5	34.3	35.8	......	......	29.9
Number with unknown excluded	67	114	191	190	155	169	143	74	227	181	1,511	......	......

TABLE 17.—*(Other man-caused fires). Acres burned, by years.*

Cause.	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	Total acreage.
Logging	681	1,088	1,078	5,713	1,961	1,947	25,241	332	9,436	2,560	50,037
Railroads	385	300	1,730	90	300	1,325	4,100	27,260	20,994	11,911	68,395
Brush burning	500	10,793	400	1,181	1,460	9,236	9,348	5,157	7,370	3,713	49,158
Miscellaneous	1,890	640	1,734	4,088	2,934	1,452	15,446	5,765	2,488	5,408	41,845
Unknown	6,430	3,670	4,522	2,353	3,005	6,797	4,344	5,525	16,251	25,018	77,915
Total [1]	9,886	16,491	9,464	13,425	9,660	20,757	58,479	44,039	56,539	48,610	287,350
Average fire	69	89	34	60	44	101	286	455	167	191	134
Average C	193	375	146	220	236	377	790	958	488	534	446

[1] Area B fires negligible.

TABLE 18.—*General summary (total for 10-year period).*

Main causes.	Acres burned.	Per cent of total.	Number of fires.	Per cent of total.	Total suppression costs.	Per cent of total.	Average fire acres.	Per cent C.	Zone hazard areas.	Cost per year—Suppression, damage, prevention.
Lightning	414,556	31.6	4,362	41.5	$227,119	33.4	95	14.2	10,830,000	$22,711 123,365 56,500 202,576
Campers	179,834	13.7	2,239	21.3	120,608	17.6	80	21.6	8,250,000	12,060 53,949 43,000 109,009
Incendiary	431,183	32.8	1,749	16.7	153,094	22.6	246	44.9	4,002,000	15,309 129,354 21,100 165,763
Minor causes	287,350	21.9	2,149	20.5	179,515	26.4	134	29.9	[1] 4,000,000	17,951 86,205 20,500 124,656
Total	1,312,923	100.0	10,499	100.0	680,336	100.0	124	24.2	[2] 14,868,000	[3] 602,004
Annual average	131,292	....	1,049	....	68,033	....	124	....	....	....

[1] Acreage estimated. [2] Areas of separate causes overlap. (See map.) [3] Actual.

TABLE 19.—*Damage based on intensive examinations.*

Forest.	Number of fires.	Acreage covered.	Type.	Damage in M board feet.	Damage per acre, board feet.
Shasta	1	560	Yellow pine	6,100	12,410
Eldorado	5	11,835	Mixed	19,200	1,610
Modoc	1	20,000	Yellow pine	39,600	1,980
Total	7	32,395		64,900	

Average loss, 2,000 board feet; value, $3 per acre.

TABLE 20.—*Seasonal factors.*

Class.	Opening month.	Number of fires.	Per cent C.	Last month.	Number of fires.	Per cent C.
Lightning	May	109	18	October	50	26
Camper	March	8	50	November	11	54
Incendiary	do	10	40	do	55	53
Unknown	do	5	60	do	20	45
Brush burning	do	7	43	do	13	69
Railroad	May	8	25	do	1	0
Miscellaneous	March	1	0	do	7	57
Logging	April	1	0	do	5	80

Month.	Number of fires.
March	32
April	44
May	291
June	1,175
July	2,558
August	3,740
September	1,620
October	820
November	99
Total	10,379

TABLE 21.—*Seasonal and geographic variations in opening and closing dates.*

SEASONAL VARIATION.

Year.	Average opening date.	Average closing date.	Length of season.
			Days.
1911	May 26	Nov. 2	160
1912	May 11	Oct. 17	169
1913	Apr. 27	Oct. 24	179
1914	Apr. 21	Oct. 29	190
1915	May 12	Oct. 17	158
1916	Apr. 30	Oct. 24	178
1917	May 26	Oct. 31	158
1918	May 3	Oct. 1	150
1919	May 6	Nov. 17	194
1920	May 3	Oct. 6	155
Average for decade	May 7	Oct. 23	169
Average of +	May 19	Nov. 1	
Average of −	May 1	Oct. 10	

TABLE 21.—*Seasonal and geographic variations in opening and closing dates*—Contd.

GEOGRAPHIC VARIATION.

Forest.	Average opening date.	Average closing date.	Average length of season.
			Days.
Klamath	Apr. 13	Oct. 21	192
Trinity	Apr. 30	Nov. 1	186
Shasta	Apr. 19	Oct. 23	188
California	May 13	Oct. 28	168
Group 1, average	Apr. 26	Oct. 26	183
Lassen	May 3	Oct. 22	172
Modoc	May 31	Sept. 29	121
Group 2, average	May 17	Oct. 12	147
Plumas	Apr. 21	Oct. 26	189
Tahoe	Apr. 25	Oct. 18	177
Eldorado	May 23	Oct. 26	156
Group 3, average	May 2	Oct. 23	174
Stanislaus	May 21	Oct. 29	160
Sierra	May 8	Oct. 21	166
Sequoia	May 8	Oct. 25	170
Group 4, average	May 12	Oct. 25	165

TABLE 22.—*Index figures of class A fires (average of 1911–1918, inclusive; basis, 3,072 fires).*

Forest.	Cost per acre.	
	Lightning.	All causes.
Klamath	$5.80	$5.34
Trinity	6.80	5.22
Shasta	5.19	4.89
California	4.90	4.06
Group 1, weighted average	5.77	5.05
Modoc	2.23	2.37
Lassen	2.47	2.98
Group 2, weighted average	2.35	2.68
Plumas	4.49	4.23
Tahoe	4.38	4.36
Eldorado	3.36	4.06
Group 3, weighted average	4.44	4.25
Stanislaus	2.76	2.35
Sierra	2.26	2.70
Sequoia	2.82	2.92
Group 4, weighted average	2.61	2.68

TABLE 23.—*Timber and brush fires (1916–1918).*

Forest.	Number of timber fires.	Per cent C.	Number of brush fires.	Per cent C.	Per cent brush fires.	Cost per timber fire.	Cost per brush fire.
Klamath	173	17.3	276	42.0	61.5	$25.75	$165.83
Trinity	251	25.5	202	38.7	44.6	27.75	128.52
Shasta	188	30.3	335	48.1	64.1	35.40	192.62
California	123	21.1	94	63.8	43.3	30.90	114.98
Modoc	95	8.4	60	25.0	38.7	10.45	28.67
Lassen	142	27.5	100	44.0	41.3	32.35	82.15
Plumas	155	10.9	231	35.5	59.8	15.32	130.11
Tahoe	156	10.9	244	37.4	61.0	46.20	115.45
Eldorado	125	14.4	146	32.9	53.9	8.22	36.28
Stanislaus	114	19.3	59	57.6	34.1	10.78	73.17
Sierra	104	15.4	59	61.1	36.2	9.00	104.46
Sequoia	131	7.7	72	43.0	35.5	16.75	108.03
Total	1,757		1,878				
Average		18.3		42.4	51.7	24.00	98.35

TABLE 24.—*C fires—Average unit costs by forests and groups, 1911–1920, inclusive (basis, 2,511 fires).*

Forest.	Size, in acres.												Average, 10–300 acres.
	10–20	20–40	40–80	80–160	160–300	300–500	500–1,000	1,000–2,000	2,000–5,000	5,000–10,000	10,000–20,000	20,000–50,000	
Klamath	$57.10	$85.90	$126.20	$303.00	$137.00	$354.00	$502.00	$1,159.00	$2,010.00	$2,450.00	$1,159.00	....	$141.90
Trinity	65.20	62.00	127.40	112.00	186.00	222.00	507.00	779.00	475.00	1,006.00	....	....	111.00
Shasta	43.10	51.90	137.10	131.00	288.00	669.00	589.00	768.00	655.00	4,120.00	....	$3,895.00	130.20
California	32.40	59.90	71.20	116.00	112.00	150.00	275.00	288.00	351.00	1,324.00	....	....	78.30
Weighted average cost [1]	51.90	64.50	120.70	124.60	197.10	321.00	490.00	712.00	928.00	2,720.00	1,159.00	3,895.00	111.70
Modoc	29.20	37.60	63.00	74.00	200.00	49.00	114.00	338.00	....	1,127.00	....	....	80.80
Lassen	30.40	51.80	53.90	113.00	151.00	250.00	292.00	684.00	766.00	3,629.00	12,340.00	....	80.00
Weighted average cost	28.30	48.20	56.90	96.80	169.00	225.00	238.00	635.00	766.00	3,379.00	12,340.00	....	79.80
Plumas	61.50	112.50	102.20	274.00	217.00	370.00	699.00	707.00	2,120.00	510.00	3,801.00	....	153.40
Tahoe	62.00	91.50	121.50	141.00	209.00	623.00	614.00	2,160.00	678.00	866.00	....	....	125.00
Eldorado	20.20	26.50	44.60	134.00	189.00	105.00	361.00	292.00	50.00	....	....	....	82.90
Weighted average cost	52.80	87.60	104.50	180.00	208.00	378.00	599.00	853.00	1,120.00	777.00	3,801.00	....	126.50
Stanislaus	21.30	37.40	46.50	72.00	241.00	108.00	129.00	60.00	2,377.00	1,339.00	6,298.00	....	83.60
Sierra	39.40	47.40	36.20	102.00	77.50	164.50	202.00	267.00	512.00	1,245.00	....	....	60.50
Sequoia	44.40	78.00	90.50	129.00	118.00	129.00	864.00	231.00	540.00	624.00	....	....	92.00
Weighted average cost	36.20	50.50	53.40	92.40	150.00	136.00	401.00	182.00	954.00	958.00	6,298.00	....	76.50

[1] Weighted average is total cost of fires for group of forests divided by total number of fires. For example, in northern group, 10-20 acres, simple average is $49.40; weighted average, $51.90.

TABLE 25.—*C fires—Unit costs by groups, average of 1911–1920, inclusive (basis of 2,511 fires; weighted average).*

Group.	Size, in acres.												Average 10–300 acres.
	10–20	20–40	40–80	80–160	160–300	300–500	500–1,000	1,000–2,000	2,000–5,000	5,000–10,000	10,000–20,000	20,000–50,000	
Northern	$51.90	$64.50	$120.70	$124.60	$197.00	$321.00	$490.00	$712.00	$928.00	$2,720.00	$1,159.00	$3,895.00	$111.70
East side	28.30	48.20	56.90	96.80	169.00	225.00	238.00	635.00	766.00	3,379.00	12,340.00	....	79.80
North Sierra	52.80	87.60	104.50	180.00	208.00	378.00	599.00	853.00	1,120.00	777.00	3,801.00	....	126.50
South Sierra	36.20	50.50	53.40	92.40	150.00	136.00	401.00	182.00	954.00	958.00	6,298.00	....	76.50
Average cost	47.70	65.80	97.90	129.00	186.00	320.00	483.00	502.00	958.00	2,305.00	5,900.00	3,895.00	....

TABLE 26.—*C fires—Average costs, by years (basis, 2,511 fires).*

Year.	Size, in acres. 10–20	20–40	40–80	80–160	160–300	300–500	500–1,000	Cost per A fire.	Cost per A fire (average)	Cost per B fire.	Cost per B fire (average)	Average factor.[1]	Average 10–300 acres.
1911..	28.3	27.5	43.4	88.8	70	156	189	$3.91		$14.91			7.7
1912..	27.9	35.7	34.2	132.5	52	156	189	3.40	$3.55	11.40	$13.53	8.1	8.4
1913..	35.6	37.3	58.1	120.5	99	198	620	3.33		14.65			8.2
1914..	72.4	106.2	99.0	156.6	217	188	498	4.18		23.85			15.9
1915..	51.5	61.9	118.5	80.0	206	176	493	4.33	4.23	17.25	17.55	12.2	12.2
1916..	38.3	60.8	75.9	106.2	138	192	778	4.14		12.85			9.9
1917..	36.8	9.8	111.5	74.5	191	292	378	4.25		16.25			10.7
1918..	44.6	56.4	109.3	166.5	188	198	436	5.65		18.10			12.7
1919..	55.0	80.0	114.6	128.2	205	336	655	6.75	6.77	18.90	21.65	15.9	13.8
1920..	75.2	127.0	159.6	228.0	324	720	655	6.90		27.95			21.1

[1] Factor $= \frac{\text{Average cost}}{\sqrt{\text{acres}}}$.

TABLE 27.—*Causes of C fires on one forest for the two years 1917 and 1920.*

Cause.	Number of fires.	Acres burned.	Cost of suppression.	Per cent of total number.	Per cent of total acres.	Per cent of suppression cost.
Satisfactory	32	2,978	$4,582	25.2	1.5	11.7
Slow start on account of lack of men	17	38,718	6,404	13.4	20.2	16.4
Slow get-away	9	895	1,255	7.1	.5	3.1
Slow detection on account of smoke	33	10,365	4,863	26.0	5.4	12.4
Policy of low cost	10	99,675	3,747	7.9	52.0	9.6
Errors in fighting	15	18,740	12,778	11.8	9.8	32.7
Handled by cooperators	11	20,597	5,503	8.6	10.6	14.1
Total	127	191,968	39,132	100.0	100.0	100.0

TABLE 28.—*The relation of man power to total cost of prevention, suppression, and damage, by the various groups of forests.*

GROUP 1.—KLAMATH, TRINITY, SHASTA, CALIFORNIA.

Year.	Class 1.—Below average. 100–150 men. Men.	Total cost.	Year.	Class 2.—Average. 150–200 men. Men.	Total cost.	Year.	Class 3.—Above average. 200–250 men. Men.	Total cost.
1911	117	$91,700	1912	184	$61,600	1913	203	$100,900
1917	141	917,300	1916	171	178,400	1914	245	171,900
1918	125	683,300	1920	171	334,000	1915	216	151,300
1919	143	248,000						
Total	526	1,940,300		526	574,000		664	424,100
Average	132	485,100		175	191,300		221	141,400

TABLE 28.—*The relation of man power to total cost of prevention, suppression, and damage, by the various groups of forests*—Continued.

GROUP 2.—MODOC, LASSEN.

Year.	Class 1.—Below average. 40-50 men. Men.	Total cost.	Year.	Class 2.—Average. 50-60 men. Men.	Total cost.
1911	43	$38,600	1914	56	$29,500
1912	45	17,500	1915	55	30,900
1913	45	25,200	1920	55	191,100
1916	47	41,400			
1917	48	168,900			
1918	44	112,800			
1919	48	44,400			
Total	320	448,800		166	251,500
Average	46	64,100		55	83,800

GROUP 3.—PLUMAS, TAHOE, ELDORADO.

Year.	Class 1.—Below average. 80-100 men. Men.	Total cost.	Year.	Class 2.—Average. 100-120 men. Men.	Total cost.	Year.	Class 3.—Above average. 120-140 men. Men.	Total cost.
1911	83	$73,700	1912	104	$42,200	1914	122	$87,800
1917	86	224,900	1913	109	69,200	1915	147	89,400
1918	79	200,000	1916	105	31,500			
1919	89	133,200	1920	104	88,800			
Total	337	631,800		422	231,700		269	177,200
Average	84	158,000		105	58,000		135	88,600

GROUP 4.—STANISLAUS, SIERRA, SEQUOIA.

Year.	75-100 men.		Year.	100-125 men.		Year.	125-150 men.	
1917	83	$159,000	1911	103	$60,400	1914	140	$153,800
1918	65	54,600	1912	114	103,000			
1919	75	82,200	1913	122	90,900			
1920	95	135,900	1915	119	70,700			
			1916	106	143,700			
Total	318	431,700		564	468,700		140	153,800
Average	80	108,000		113	93,700		140	153,800

TABLE 29.—*The relation of man power to total cost of prevention, suppression, and damage.*

SUMMARY FOR DISTRICT.

300-400 MEN.

Year.	Prevention (1).	Damage (2).	Suppression (3).	Total.
1911	$104,000	$132,000	$29,000	$265,000
1917	110,000	1,239,000	128,000	1,477,000
1918	91,000	870,000	88,000	1,049,000
1919	103,000	321,000	77,000	502,000
Total	408,000	2,562,000	322,000	3,293,000
Average	102,000	640,500	80,500	823,200

400-500 MEN.

Year.	Prevention (1).	Damage (2).	Suppression (3).	Total.
1912	$134,000	$75,000	$15,000	$224,000
1913	144,000	105,000	40,000	289,000
1916	128,000	330,000	41,000	499,000
1920	128,000	404,000	88,000	648,000
Total	534,000	914,000	184,000	1,660,000
Average	133,500	228,500	46,000	415,000

500-600 MEN.

Year.	Prevention (1).	Damage (2).	Suppression (3).	Total.
1914	$169,000	$228,000	$47,000	$444,000
1915	161,000	135,000	46,000	342,000
Total	330,000	363,000	93,000	786,000
Average	165,000	181,500	46,500	393,000

TABLE 30.—*Area per number of men in the protection force in the various groups of forests.*

Group.	Number of men.	Acres of hazard.	Acres per man.
1	225	5,960,000	26,500
2	50	2,540,000	50,800
3	110	3,590,000	32,600
4	115	2,770,000	24,100
Total	500	14,860,000	29,700

TABLE 31.—*Elements of suppression costs.*

Year.	Temporary labor.	Forest officer labor.	Tools, etc.	Total cost.	On National forest land.	On private land.	
						Inside forest boundaries.	Outside forest boundaries.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
1911	53.9	24.8	21.3	$18,746	67.5	21.4	11.1
1912	49.4	26.1	24.5	10,197	68.0	20.6	11.4
1913	52.1	20.7	27.2	26,782	62.2	16.7	21.1
1914	49.0	7.7	43.3	46,611	36.8	14.8	48.4
1915	55.4	19.7	24.9	45,525	67.8	20.1	12.1
1916	53.0	17.5	29.5	41,498	66.0	23.8	10.2
1917	55.1	10.7	34.2	121,707	(1)	(1)	(1)
1918	58.0	9.8	32.2	114,986	(1)	(1)	(1)
1919	54.4	12.0	33.6	101,433	(1)	(1)	(1)
1920	49.0	8.8	42.2	152,851	(1)	(1)	(1)
Total				680,336			
Average	52.7	11.9	35.4				

[1] Not available.

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