UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1495

Washington, D. C. July, 1929

COVER TYPE AND FIRE CONTROL IN THE NATIONAL FORESTS OF NORTHERN CALIFORNIA

By

S. B. SHOW, District Forester, California District

and

E. I. KOTOK, Director, California Forest Experiment Station

Forest Service

E. I. Kotok

For sale by the Superintendent of Documents, Washington, D. C. - - - - - Price 10 cents

UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1495

Washington, D. C. ▼ July, 1929

COVER TYPE AND FIRE CONTROL IN THE NATIONAL FORESTS OF NORTHERN CALIFORNIA[1]

By S. B. SHOW, *District Forester, California District*, and E. I. KOTOK, *Director, California Forest Experiment Station, Forest Service*

CONTENTS

INTRODUCTION

In the complex forest-fire problem of the national forests of northern California, the group of factors dealing with man's efforts to control fire has received most attention from all forest agencies, not only in the literature, but in everyday inspection and study by fire executives. The urgent need to learn what type of protection organization is most effective, how much a given scale of protection will reduce fire losses, and how the performance of the organization can be systematically checked and improved has dictated this concentration on means of attack.

Important as such studies are, however, they must be supplemented by analysis of a second group of factors, which include the physical nature of the forest itself, the character of vegetation or cover type, the behavior of fires as influenced by the kinds and volume of fuels peculiar to each type, and the climatic elements which affect alike the cover type and the occurrence and spread of fire.

[1] Northern California as defined includes the east and west slopes of the Sierra Nevada, the Coast Ranges north of San Francisco Bay, the plateaus of northeastern California, and the cross ranges of northwestern California. The national forests included in this area are for the purposes of this discussion divided into four groups, as follows: (1) Northern group, Klamath, Trinity, Shasta, and California; (2) east-side group, Modoc and Lassen; (3) northern Sierra group, Plumas, Tahoe, and Eldorado; (4) southern Sierra group, Stanislaus, Sierra, and Sequoia. These groups represent natural affiliations, geographically and otherwise. The division has been employed in earlier work, and having proved useful, is retained. The four protection forests of southern California represent a special problem and are not included, nor are the Inyo and Mono National Forests, because of the scarcity of fires on these forests.

All these are intimately related, and they must be understood before the protection organization and the actual control of fire can reach a satisfactory level of effectiveness.

Cover type, or the typical tree or brush species or group of species occupying a given area at the present time, is clearly an element of basic importance in fire control. This was brought out in earlier work by the authors,[2] in the course of a study mainly confined to methods and costs of protection. It is demonstrated more pointedly by Sparhawk's pioneer work[3] which employed similar basic data for all of the western national forest districts for the years 1911 to 1915. His contribution has laid down a method of attack which will be increasingly applicable as more complete and accurate information on each fire is systematically collected. His statement that "the only scientific basis for such a study is what has actually happened; that is, the actual fire history of the different forest areas" is clearly sound and is the foundation of this circular. However, the variability of individual fires is so great, and the classification of type and hazard classes so incomplete, that even with records for a 10-year period available, the authors have not felt justified in attempting the complete analysis proposed by Sparhawk.

The present study aims to distinguish the occurrence and behavior of fire in the major cover types as a basis of fire control, by means of average figures derived for each of the major types, showing length of season, prevalence of fires, rapidity of spread, and difficulty of control. These will express in preliminary fashion the relative effectiveness of equal protection effort in each of the types, and will explain previously observed differences in results obtained in different national forests and variations in behavior of fire from different causes.

COVER TYPES OF NORTHERN CALIFORNIA

DEFINITION AND DISTRIBUTION

The region studied is one of varied and roughly broken topography with a great range in elevation varying from 1,000 feet above sea level in the valleys to 14,000 feet at the crest of the Sierras. Cover type consequently varies enormously. The nine major cover types employed in this study are those used in national-forest administration. (Table 1.) They may be summarized briefly, as including (1) the western yellow pine type, of which western yellow pine (*Pinus ponderosa*) is the principal tree (pl. 1, A), and (2) the mixed conifer type, in which western yellow pine grows in mixture with sugar pine (*P. lambertiana*) and in which Douglas fir (*Pseudotsuga taxifolia*), incense cedar (*Libocedrus decurrens*), and white fir (*Abies concolor*) occur as associate trees in varying proportions (pl. 1, B). Douglas fir (3) also occurs as a distinct type. (Pl. 2, A.) The sugar pine-fir type (4) is composed of white and red fir (*A. concolor* and *A. magnifica*) in mixture with sugar pine. In some places the Jeffrey pine (*Pinus jeffreyi*) takes the place of the western yellow pine in the stands or may grow with it in mixture with other species. The pure fir type (5) includes white fir, mixtures of white and red firs, and the red fir alone. (Pl. 2, B.) Within the timber belt a temporary

---

[2] SHOW, S. B., and KOTOK, E. I. FOREST FIRES IN CALIFORNIA, 1911–1920: AN ANALYTICAL STUDY. U. S. Dept. Agr. Circ. 243, 80 p., illus. 1923.

[3] SPARHAWK, W. N. THE USE OF LIABILITY RATINGS IN PLANNING FOREST FIRE PROTECTION. Jour. Agr. Research 30: 693–720, illus. 1925.

association, the brush field (6), has in many places captured the land following the destruction of the forests by fire, logging, or both. (Pl. 3, A.) This type is in general considered separately from (7) the even less promising chaparral type. (Pl. 4.)

TABLE 1.—*Distribution of cover-type areas in national-forest groups*[1] *of northern California*

[Thousands of acres; i. e., 000 omitted]

Cover type	Northern forests	East side forests	North Sierra forests	South Sierra forests	All forests	
					Total	Per cent
Western yellow pine	1,491	1,244	1,049	770	4,554	30.2
Mixed conifer	1,328	138	635	1,026	3,127	20.7
Douglas fir	1,101	6	35	3	1,145	7.6
Sugar pine—fir	91	43	341	----	475	3.1
Fir	341	266	567	470	1,644	10.9
Grass	105	277	76	97	555	3.7
Chaparral	258	38	12	95	403	2.7
Woodland	248	332	39	332	951	6.3
Brush	1,045	213	385	596	2,239	14.8
All types	6,008	2,557	3,139	3,389	15,093	100.0

[1] Northern, Klamath, Trinity, Shasta, and California National Forests; east side, Modoc and Lassen National Forests; north Sierra, Plumas, Tahoe, and Eldorado National Forests; south Sierra, Stanislaus, Sierra, and Sequoia National Forests.

Grouped for the sake of simplicity and because of similarity are several woodland types (8), including the oak (*Quercus douglasii*), (pl. 3, B), oak–digger pine (*Pinus sabiniana*), and digger pine of the western Sierra Nevada slopes, the juniper (*Juniperus occidentalis*) and juniper–mountain mahogany (*Cercocarpus ledifolius*) of the eastern slopes, the California black oak (*Quercus kelloggii*) and madroño (*Arbutus menziesii*) mixtures of the north Coast Ranges. The grassland type (9) includes areas on which sage (*Artemesia tridentata*), bitter brush (*Kuntzia tridentata*) and the rabbit brushes (*Chrysothamus* sp.) occur. The alpine and subalpine types are practically free from fires and are not considered.

In a broad way the major types succeed each other (figs. 1, 2, 3, and 4), from the grass and chaparral of the Sierra foothills eastward through the oak and digger pine woodland, the commercial forests of western yellow pine, mixed conifer, sugar pine-fir, and pure fir, then across the summit in the scattered alpine protection forests, descending the east slope through the pure fir, the commercial mixed conifer, the pure western yellow and Jeffrey pine forests and the juniper woodland to the sage and grassland of the eastern plateau. An exception is the Douglas fir type, which is largely confined to the northern group of forests. Locally the types follow no simple successive altitudinal arrangement, but, because of minor variations in topography, aspect, or soil, are intermingled. The normal zonation is further upset and in places obscured by the presence of brush fields.

It is found advisable to classify the types more generally by a natural grouping, to bring out more clearly certain trends in the behavior of fire. The natural affiliations as recognized in these groups are:

Chaparral and brush fields.
Woodland and grassland.
Western yellow pine and mixed conifer.
Douglas fir.
Sugar pine-fir and fir.

DIFFERENCES BETWEEN TYPES

To serve as a background for the later analysis of fires, a sketch of the important differences between cover types in climatic factors, fuels, and behavior of fires is needed. These physical differences,

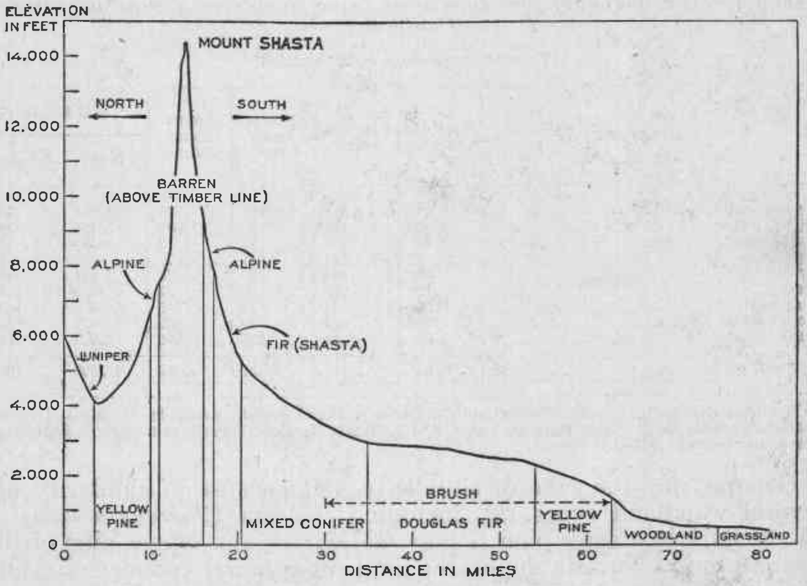


FIGURE 1.—Typical cover-type distribution in the northern group of forests, Shasta National Forest

particularly the composition of the commercial timber stands and forage types, have already played an important part in the formulation of timber and range management plans in the national forests,

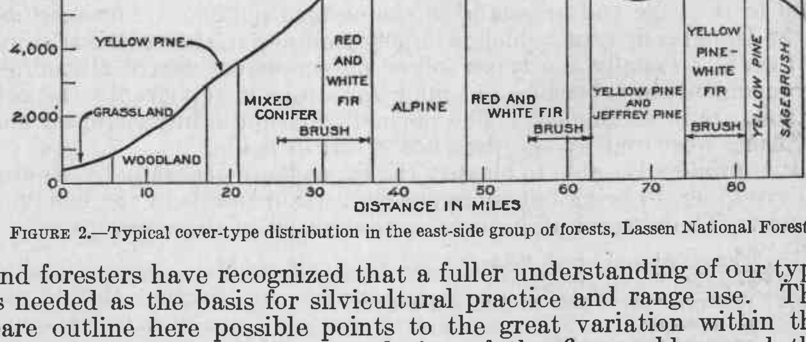


FIGURE 2.—Typical cover-type distribution in the east-side group of forests, Lassen National Forest

and foresters have recognized that a fuller understanding of our type is needed as the basis for silvicultural practice and range use. The bare outline here possible points to the great variation within the region, and indicates the complexity of the fire problem and the extreme flexibility necessary in a control organization designed to cope with the problem. Even the individual types, because of site differences and effect of previous fires, vary enormously within themselves. Density, height, and age of the timber; degree and direction

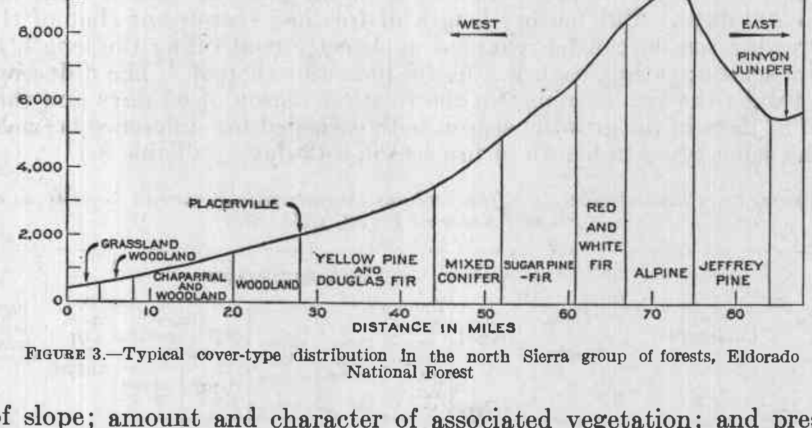


FIGURE 3.—Typical cover-type distribution in the north Sierra group of forests, Eldorado National Forest

of slope; amount and character of associated vegetation; and presence or absence of young growth, all vary at times from acre to acre and hence affect the spread and severity of fires. With given fuel, slope, and soil, the spread of fires also varies greatly from time to

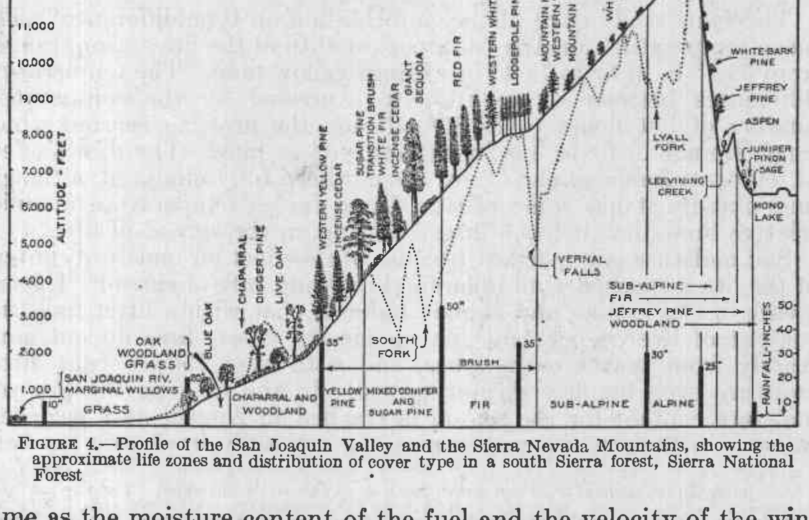


FIGURE 4.—Profile of the San Joaquin Valley and the Sierra Nevada Mountains, showing the approximate life zones and distribution of cover type in a south Sierra forest, Sierra National Forest

time as the moisture content of the fuel and the velocity of the wind vary. The behavior of fire in each type is controlled not only by the amount and kind of fuel, but also directly by the climatic elements of which the type itself is an expression.

TEMPERATURE, SOIL MOISTURE, AND PRECIPITATION

An investigation [4] conducted by the Forest Service, which covered the relation of air temperature and soil moisture to the principal timber types, except Douglas fir, in the central portion of the Sierra region, has brought out the differences between the upper and lower portions of the commercial timber belt. (Table 2.) The frostless season ranged in length from 97 days in the fir types to 162 days in the western yellow pine and length of the growing season from 143 to 200 days. But neither length of frostless season nor that of the growing season can be regarded as directly controlling the length of fire season; rather, each is a useful indicator thereof. The difference between the two extremes in the frostless season of 65 days and that of 57 days in the growing season both exceeded the difference between the same types in length of fire season—42 days. (Table 8.)

TABLE 2.—*Climatological data from stations characteristic of various forest types on Plumas National Forest, 1914–1917*

Cover type	Elevation of station	Aspect	Air-temperature data					Soil temperature, August	Soil moisture, August
			Mean temperature, August	Frostless season	Growing season	Hours during growing season—			
						Above 85° F.	Above 70° F.		
	Feet		*° F.*	*Days*	*Days*	*Number*	*Number*	*° F.*	*Per cent*
Western yellow pine	2,700	South	74.4	162	200	498	1,396	72	3
Mixed conifer	4,000 5,000 4,000	do do North	70.4	158	180	262	1,070	69	5
Sugar pine-fir	5,000	do	66.5	108	155	84	841	66	6
Fir, white	6,000 6,000	South North	66.3	104	150	14	360	63	8
Fir, red	7,000 7,000	South North	51.1	90	135	1	219	------	------

The same study gave further information on type differences. The mean temperature for August, a peak month of the fire season, ranged from 58.7° F. in fir to 74.4° in western yellow pine. The temperature differences between types are also expressed by the comparative number of hot hours (over 85°) during the growing season, which range from 7 in fir to 498 in western yellow pine. The direct effect of temperature on spread of fire has not been fully analyzed, although undoubtedly it has some effect. In so far as temperature modifies relative humidity, it has a direct bearing on the spread of fire.

Soil moisture is important because of its effect on moisture content of the litter and hence on inflammability and rate of spread. Experiments in California [5] and Idaho [6] indicate that with a litter moisture content of over 8 per cent (on an air-dry basis) fires do not start readily from sparks or matches, and with over 25 per cent litter moisture even bonfires do not spread. In the fir type the low soil moisture content for the season is reached in August at 8 per cent; whereas in the western yellow pine the moisture drops to 3 per cent

[4] No comprehensive study of types and climate has been completed for this region. The only published studies are: VARNEY, B. M. MONTHLY VARIATION OF THE PRECIPITATION-ALTITUDE RELATION IN THE CENTRAL SIERRA NEVADA REGION OF CALIFORNIA. Mo. Wea. Rev., 48: 648–650, 1920. SEASONAL PRECIPITATION IN CALIFORNIA AND ITS VARIATION. Mo. Wea. Rev., 53: 148–163; 208–218, 1925.

[5] SHOW, S. B. CLIMATE AND FOREST FIRES IN NORTHERN CALIFORNIA. Jour. Forestry 17: 965–979. 1919.

[6] GISBORNE, H. T. MEASURING FOREST FIRE DANGER IN NORTHERN IDAHO. U. S. Dept. Agr. Misc. Pub. 29, 45 p., illus. 1928.

during the same month. Thus even at the peak of the fire season the high-elevation timber types do not dry out to the degree that the western yellow pine type does. The litter in the fir type becomes dry enough so that fires start readily but do not spread as rapidly as in the western yellow pine and are more readily controlled. Direct measurements of litter moisture are so fragmentary that the differences between types are by no means certain. Those available indicate that for the period from June to October the moisture of the litter in fir and sugar pine-fir types was higher than the danger point (8 per cent) 40 per cent of the time, as compared to 29 per cent of the time in the western yellow pine and mixed conifer types.

TABLE 3.—*Seasonal and annual rainfall and length of rainless season at northern California stations* [1]

Type	Station	Period of record	Annual precipitation	Seasonal precipitation May to October	Duration of dry season
			Inches	*Inches*	*Days*
Grass	Sacramento Valley (2 stations)	1874–1923	29.01	2.65	123
Chaparral	Mokelumne Hill	1882–1922	33.18	3.68	122
	Shingle Springs	1849–1912			
Woodland	Sonora	1887–1922	35.02	4.51	121
Western yellow pine	Placerville	1874–1922			
	Georgetown	1872–1923	51.30	6.43	108
	Grass Valley	1872–1923			
	Nevada City	1863–1923			
Mixed conifer	Cisco	1870–1916	51.56	7.03	105
	Colfax	1870–1923			
	Iowa Hill	1879–1910			
	North Bloomfield	1870–1923			
	Emigrant Gap	1888–1923			
Fir	Summit	1870–1923	59.93	8.26	87
	Bowman's Dam	1871–1916			

[1] From summary of the climatological data for the United States, U. S. Weather Bureau Stations 14 and 15.

The long-period records of the United States Weather Bureau (Table 3) show that total annual precipitation is least in grassland (29.01 inches), followed by that in the chaparral and in the woodland, with a substantial increase of approximately 22.5 inches in the western yellow pine and mixed conifer, and a further increase of over 8 inches in the fir type. Thus the total precipitation at higher elevations (59.93 inches) is over twice as great as in the grasslands of the foothills.

Of even greater importance from the standpoint of fire control is precipitation during the fire season (May to October, inclusive). The quantities received range from 2.65 inches in grassland to 8.26 inches in fir, or over 300 per cent, following the same order of types as for total precipitation.

The length of the fire season, as well as the ease of start and spread of fires during that time, are determined quite as much by the duration of the rainless season as by the total annual precipitation. The average length of rainless season as given in Table 3, ranges from about 122 days for grass, chaparral, and woodland to 87 days for fir. This, when coupled with the temperature differences and the greater total and seasonal precipitation already noted, explains the shorter fire season at the higher elevations.

FUELS AND BEHAVIOR OF FIRE

The nine major types in this region are recognizable as well by the character of associated herbaceous and woody plants as by the principal key tree species. All of this plant life, together with the accumulation of partially decayed vegetable matter in the form of mulch, duff, and humus, determine the amount and character of the fuel.

Within the commercial timber belt the densest stands are found near the upper edge, where precipitation is greatest, in the fir types; and the most open forest is found at the lower edge, where precipitation is least, in the western yellow pine type. In heavy stands, the annual fall of needles and twigs soon becomes compacted into a dense layer of duff, poorly aerated and moisture-retaining. Close stands of timber, moreover, prevent the growth of annual plants, brush, and tree reproduction, so that the duff remains the principal fuel. In the more open western yellow pine stands the duff is less compact, dries out more rapidly, and is better aerated. Because of the general openness of this forest, the subordinate vegetation of annuals and brush is relatively abundant and in late summer, when the plants dry out and burn briskly, becomes an important element in the spread of fire. Young tree growth also may be present to add to the fuel. Hence, whereas fires generally creep slowly in the fir type, where duff is the chief understory fuel, in the pine type they spread rapidly through the considerable understory of vegetation. The form in which the fuel occurs is often more important than total quantity in controlling spread and severity of fire.

The mixed conifer type is usually an all-aged forest, with a considerably heavier volume per acre than is generally found in the western yellow pine type. The forest forms an irregular canopy, pierced by innumerable snags, which are a serious source of trouble in the control of fires. This type is richer in secondary vegetation than the western yellow pine or fir types, and openings are rapidly occupied by brush species, these forming the nuclei of future brush fields. Disintegration of fallen leaves and humus proceeds almost as rapidly as in the western yellow pine type, but on the whole the mixed conifer type has a slightly higher fuel content than has the western yellow pine type. Surface and ground fires are characteristic of this type, and crown fires are uncommon.

The amount and kind of fuel present in the woodland type varies greatly. In the drier situations the oaks, the principal species, occur as isolated trees, with widespreading crowns. This form of woodland type merges with the grassland type throughout its range; the ground is carpeted with grasses and weeds in profusion, and these form the principal fuel. Fires, as in the grassland type, spread with great rapidity over the surface, though rarely running up to the tree crowns. Where precipitation is heavier, the woodland type forms a close canopy of many hardwood species and the ground is heavily covered with a layer of dried and decayed leaves, and lacks any understory of grasses and weeds. Fires in the denser stands eat their way slowly through this semicompacted mass of organic material, flaring up occasionally through the trees under increased wind velocity.

In the brush fields, where fires have been excluded, new coniferous stands are making a start and a heavy layer of humus and duff forms under the closed canopy of the brush. The brush fields have the

F-18225A-48753

A.—Open stands in the western yellow pine type, with a heavy layer of needles and the absence of woody shrubs
B.—A dense stand in the mixed conifer type where considerable reproduction is coming in

F-79927-19332

A.—A typical stand in the Douglas fir type of northern California
B.—Dense, dark, moist forests are characteristic of the pure fir type, with heavy compact layers of humus and duff

highest fuel content of any type and fires sweep through them with great fury. Also, the progress of any given fire is far more uncertain and difficult to check than in the chaparral. In the brush fields the heavy layer of humus retains smouldering embers for long periods, and these flare up at the first wind that may arise and start a new conflagration.

In the chaparral the density and height of stand depend mainly upon the frequency with which past fires have swept the area. Where fires have been absent for a decade or more, there is an uninterrupted, impenetrable cover of multistemmed individual shrubs. The principal species being evergreen and small-leaved, comparatively small quantities of dead material fall to the ground, and the dense shade prevents the establishment of grasses and weeds. Fires race with fury through this unbroken canopy of chaparral when high winds and low humidities prevail. On the other hand, fires subside quickly during calm weather and rising humidities, and finding little fire-holding fuels on the surface, frequently burn themselves out. Thus, a fire in chaparral may at one moment be a raging crown fire and the next almost completely subdued.

The three major kinds of forest fires—those in the branches and tops of forest trees, or crown fires; those confined to the subordinate cover of grass, weeds, and litter, or surface fires; and those that run through the duff, or ground fires—occur at times in all types. Nevertheless, without overgeneralizing, each cover type may be characterized in fire control by the frequent occurrence of one kind of fire, in the following manner:

- Crown fires:
  - Chaparral type.
  - Brush type.
- Surface fires:
  - Grass type.
  - Woodland type.
  - Western yellow pine type.
  - Mixed conifer type.
  - Douglas fir type.
- Ground fires:
  - Sugar pine-fir type.
  - Fir type.

Fires which race through the crowns of dense stands of brush or chaparral have very properly been classified as crown fires in this region, although the term "crown fire" has been almost entirely restricted in other regions to fires which run through the crowns of trees. Crown fires develop where a continuous closed canopy is found, and the chaparral and brush types are distinctly of such character. Only rarely in the daytime, more commonly at night, do fires burn as surface fires in these types, particularly the chaparral, and then only to burst into crown fires with the first considerable decrease in relative humidity or increase in wind velocity. Crown fires sometimes occur in the virgin forest types, but if so they are localized, except in the severest fire years; they are more common in second-growth forest. Crown fires generally spread the most rapidly, surface fires next, and ground fires least; and the degree of damage is ordinarily in the same sequence. The rapidity with which crown fires spread is indicated by the average of 55 acres per hour in the chaparral type, and by 13.79 acres in the brush-field type, in both of which most fires are crown fires.

Surface fires generally develop where an irregular low canopy of flash fuels exists, such as characterizes the grass, woodland, western yellow pine, mixed conifer, and Douglas fir types. In the first two of these, grasses and weeds are the most important fuels, and the average rate of spread is greater than in the commercial timber types, where needles and twigs are the important fuels. This difference in fuels is reflected in the average rates of spread of 17 and 5.3 acres per hour, respectively, for the grass-woodland and timber groups.

Ground fires occur where a compact and poorly aerated layer of humus and duff permits only a small supply of oxygen to reach the fire and where there is a scarcity of flash fuels. Under normal conditions ground fires eat their way slowly. The observed rate of spread for sugar pine-fir is 4.33 acres per hour, and for fir, the lowest in the entire scale, 1.07 acres per hour.

THE FIRE PROBLEM

NEED OF AN INDEX OF FIRE DANGER

Most of the information heretofore available on forest cover types has dealt with climatic or botanical differences and has been of little direct value in attacking the fire problem. That a study of types from the fire-control standpoint is exceedingly difficult is evident from the great differences in age, height, and density of the mature timber, amount of young growth present and other variables, even within what is classed as a single major type. Thus, at first glance it might appear that any attempt to isolate the cover-type factor as it affects the start and spread of fires is foredoomed to failure unless a very large number of subdivisions can be recognized. This would be a theoretically correct approach to the problem, but the results of such a study could find little use until a detailed "fire reconnaissance" of forest areas should recognize and map similar types. No such detailed classification of hazards is now in prospect.

The practical and immediate job of fire control has been the reduction of area burned and in most cases it has been impossible to recognize values demanding special intensive protection. Moreover, it has been necessary to provide much protection in types of generally very low intrinsic value, such as the chaparral and grassland, since these are of great value in preventing erosion, and also are contiguous to or are intermingled with commercial forest or restocking brush fields, with no natural or artificial barrier to prevent fires originating on the low-value lands from spreading on to more valuable properties. It will only be as more funds become available for fire control in the future, and as the whole level of protection effort is greatly raised, that a more detailed classification of risks, hazards, and values will be possible in fire control.

At present not even an approximate expression of the magnitude of differences between types has been worked out, although it is commonly recognized that the fire season is longer and that fires spread more rapidly in cover types of the lower elevations than at higher altitudes. What is needed at once is an index, even though crude, of the difference in fire control between the major cover types.

WHAT CONSTITUTES SUCCESSFUL PROTECTION?

There is no general agreement as to what average annual burned area can be accepted and still make timber management on the national forests a successful venture. Neither the extent nor the value of damage in the different types is known with even approximate accuracy.

A reasonable maximum of acceptable loss might well be based on the acreage that can be burned annually without seriously reducing the ultimate forest crop, although what the protective organization may be expected to attain in the future can not be disregarded entirely. Figures to be given later (Table 12) indicate that, at least in the timber types, 0.2 per cent loss annually is not too low a mark to be reached. Even this low figure would mean a loss of 20 per cent of the possible yield of a 100-year "crop." A loss of 0.2 per cent a year of the area protected can not be completely justified by any of the available data, but neither can it be successfully challenged merely by proving that present efforts have not attained it. For the purposes of discussion, this rate is therefore used as a rough criterion to compare with actual accomplishments. In the future it may even prove to be too high, as timber acquires a higher value and as more forest lands are placed under sustained yield management.

During the decade 1911 to 1920 the degree of protection in effect, averaging good years and bad, resulted in an average annual burned acreage of 0.89 per cent of the total area in the timber-producing types (grassland, chaparral, and woodland excluded) for the national-forest group as a whole. Obviously, this rate of fire loss, which is equivalent to burning over the entire forest area in 110 years, is altogether too great as compared with the timber-growing rotation of 80 to 120 years, even if only part of the destructible value is lost after each fire. This is particularly true since only a relatively small area was reburned. In this study each fire over 40 acres was blocked in on one map, but not over 2 per cent of the areas overlapped as reburned tracts.

Neither has the 0.2 per cent maximum been reached in the chaparral, grass, and woodland types. Radical reduction of burned area in these types is important, however, since fires originating within them will, unless promptly controlled, sweep into adjacent merchantable stands of timber or young growth and destroy in part what has been accomplished in the other types. Although the values at stake here are not represented primarily by the timber and young growth but by the cover as an influence equalizing run-off and minimizing erosion, and by the forage, an annual crop, the preservation of these values requires a far lower percentage of land burned over annually than has thus far been attained.

WHAT CONSTITUTES NEED FOR SPECIAL PROTECTION?

Each spring forest protection organizations face the problem of determining when the protection afforded by the year-round staff becomes inadequate and when special protection measures, such as placing of lookouts, fire guards, and road and trail crews are justified and needed. A similar problem arises each fall in determining when the need is past. A major consideration in the decision, though by no means the only one, is how many fires may be expected.

Obviously, as in setting up a criterion of successful protection measured by area burned, no strict mathematical justification can now be adduced for any figure. In most years of the decade under discussion, when the rate of one fire per 10-day period per 100,000 acres of protected area was exceeded in spring, the need of an auxiliary protection organization was manifest, and when it was not employed a considerable acreage was burned. The same thing was true in the fall whenever special protection was abandoned before fires fell short of this rate. One fire per 10-day period per 100,000 acres has therefore been adopted as a reasonable criterion of need for special protection on a regional and major-type basis. In certain localities and under particular circumstances, placing of the full protection organization before any fires have started may be good management.

METHOD OF STUDY

MATERIAL USED AND METHODS OF HANDLING

The data used in this investigation are derived from reports made by forest officers on 10,476 fires that occurred from 1911 to 1920, inclusive, on and adjacent to 12 timbered national forests of California, as distinguished from the brush-covered protection forests. (Table 4.) It is the Forest Service practice to record as soon as possible after each fire the essential facts of the fire, including its origin, its history, the factors affecting its spread, and its cost. Progressive changes in the recording forms have been made during these years 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 control and who are responsible for the data on these forms, many were unaccustomed to recording notes in the field and to assembling facts on paper. The pressure of work made it impossible for many of the 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 has 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 perfection of data. Data clearly inaccurate have been discarded, and it is probable that ordinary errors are sufficiently compensating so that in the mass the data give approximately true values.

TABLE 4.—*Distribution of fires by cause and cover type, 1911–1920, 12 timbered forests*

Type	General-risk fires					Special-risk fires				Total all causes
	Camper	Incendiary	Lightning	Unknown	Total	Brush burning	Lumbering	Miscellaneous	Railroad	
Western yellow pine	829	460	1,564	237	3,090	87	208	144	125	3,654
Mixed conifer	620	429	1,228	197	2,474	80	272	100	73	2,999
Douglas fir	94	260	263	9	626	17	2	13	1	659
Sugar pine–fir	56	21	117	17	211	14	9	5	3	242
Fir	176	26	512	37	751	17	11	20	12	811
Grass	86	30	53	14	183	9	13	14	5	224
Chaparral	72	95	30	27	224	15	6	22	14	281
Woodland	62	126	93	15	296	12	4	11	7	330
Brush	249	307	449	95	1,100	49	33	58	36	1,276
Total	2,244	1,754	4,309	648	8,955	300	558	387	276	10,476

Many of the original reports did not specify the types in which the fire originated. To determine the type with substantial accuracy, the location of each fire was referred to a type map prepared for the purpose. This map shows the major types and, although probably some errors in determining the type in which particular fires occurred have crept in, these errors again are probably compensatory. It has been necessary to charge the acreage and cost of each fire to the type in which it originated. This is not invariably correct, as for example when a fire starting in chaparral is controlled at the edge of the western yellow pine and burns over a small area in that type. However, with few exceptions, the major run and character of a fire are determined by the type in which it started. A fire starting in chaparral, for example, will ordinarily attain such size and such momentum that it will still be very difficult to combat after it spreads into western yellow pine timber or into woodland areas, and can be classified as characteristically a chaparral fire. The use of the data in this manner probably affects the figures for total area burned by types, but is immaterial in other relationships.

The unusual fire year and the few critical fire days of each year are of extreme importance in measuring ultimate success in protection. However, these extreme days and years affect all types within a general region simultaneously, but with an intensity varying with the type. The quality of data at hand precluded any detailed study of these important facts. They will, however, be isolated and analyzed in subsequent studies.

In the analysis of the 10,476 fires the following data were abstracted for each fire: Date of start, cause, location, acres burned, class of fire, cost of suppression, elements of cost, type of cover, 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 cover types, causes, by size of fires, etc., and studied in groups. In the analysis of the data, cover type was employed as the controlling basis for classification of the major observed and recorded facts. Average relationships have been used throughout.

Meteorological data have been taken from the United States Weather Bureau records and from material collected by J. A. Mitchell and E. N. Munns, of the Forest Service.

OMISSION OF SPECIAL-RISK FIRES

Of the eight recognized causes of fires—railroad, lumbering, brush burning, miscellaneous, lightning, camper, incendiary, and unknown—those resulting from railroads, logging, brush burning, and freak causes (miscellaneous), which may be termed "special-risk" fires, are everywhere localized. Their occurrence depends mainly on the presence within a known restricted area of specific fire-using agencies. They are mainly the result of industrial occupancy. For example, lumbering has caused many forest fires through the use of fire in its operation of wood-burning donkey engines and railroads, and in brush burning, but such fires are possible only during the life of the lumbering operation. Furthermore, protective agencies and the industry have, during this 10-year period, been devising new methods of prevention and control for these classes of fires, making any specific conclusion drawn from observations to date of types and special-risk fires highly questionable. Because cover type is only remotely influential in controlling the occurrence of special-risk fires, it is necessary to omit this category from the present discussion.

The other major causes, lightning, camper, and incendiary, may, on the contrary, be regarded as causes of general-risk fires ("unknown" are also grouped in this classification), because their distribution is widespread and because they may occur practically anywhere within the forest area. These will be the only causes considered in this study, save on particular areas and in the total of the burned area by types.

NUMBER AND SEASONAL DISTRIBUTION OF FIRES BY TYPES

The knowledge that in general the length of fire season decreases progressively from the low-altitude chaparral type to the high-altitude fir, is important in building a protection organization to meet the varied needs of a national forest. But specific information on the average number of days' lag in the opening of the fire season from one major type to the next is far more useful, because the financial structure of the Forest Service requires the use of average dates as a basis for allotment of funds. The usefulness of reliable average opening and closing dates is great, even though variations in length of fire season occur from year to year.

SEASONAL DISTRIBUTION OF FIRES

Over the 10-year period (Table 5) only a few fires have occurred in March, and these have been nearly entirely in the western yellow pine and Douglas fir types, with a very few in the mixed conifer and brush types. Neither in the high altitude fir and sugar pine-fir nor in the foothill types of chaparral and woodland have fires been noted in March. In April substantially the same is true, except that a few fires have occurred in the woodland and grass types. In neither of these months have there been enough fires to justify special measures in addition to the protection afforded by the regular force. In the low elevation grass and woodland types the grass and weeds, the principal fuels, are still green, but in the western yellow pine type the needles are becoming dry.

In no type is the danger point of one fire per 100,000 acres in 10 days reached in the first 10-day period of May. The fir and sugar pine-fir types are still entirely free from fires. In the second 10-day period of May the brush type closely approaches the need for special protection measures, with 0.85 fire per 100,000 acres, and, in the northern group of forests considered alone, past that point. In the western yellow pine and mixed conifer types the number of fires increases markedly, but does not reach the danger point. The fir type has a very few fires. In the third 10-day period western yellow pine, mixed conifer, and Douglas fir exceed the rate of one fire per 100,000 acres. Chaparral reaches a figure of 0.99 fire per 100,000 acres; but in the fir and sugar pine-fir types there still is but a scattered occurrence of fires.

In the first 10-day period of June, there is a general increase but no marked change. The fir and sugar pine-fir are still well below the danger line (0.18 and 0.63); but finally reach that line in the second 10-day period of June.

Table 5.—*Seasonal distribution of general risk fires, 1911–1920, 12 timbered forests*

[Number of fires per 10 days per 100,000 acres of type]

ALL FORESTS

Type	March	April	May			June			July	August	September	October			November	Total for season
			1 to 10	11 to 20	21 to 31	1 to 10	11 to 20	21 to 30				1 to 10	11 to 20	21 to 31		
Western yellow pine	0.42	0.44	0.15	0.55	1.12	1.98	3.65	1.55	18.64	23.91	9.66	1.86	1.71	1.40	0.81	67.85
Mixed conifer	.06	.26	.22	.64	1.73	1.89	4.50	1.73	18.55	27.95	12.50	2.30	2.52	3.24	.83	78.92
Douglas fir	.35	.26	.35	.35	1.59	.87	2.01	.87	12.93	21.05	9.08	1.91	1.84	1.40	.17	55.03
Sugar pine-fir	--------	--------	--------	--------	.63	.63	1.47	1.05	11.16	20.64	5.06	2.10	.42	.63	.63	44.42
Fir	--------	--------	--------	.06	.36	.18	.97	.91	12.11	22.45	6.64	.97	.49	.30	.24	45.68
Grass	--------	.36	.54	.36	.36	.18	1.80	1.98	8.65	10.82	6.30	.54	.18	.54	.36	32.97
Chaparral	--------	--------	.50	.25	.99	1.49	1.74	.99	9.91	18.10	13.37	2.98	1.24	2.73	1.29	55.58
Woodland	--------	.21	.21	--------	.21	.63	1.37	1.26	8.10	11.68	5.36	.31	1.05	.42	.32	31.13
Brush	.05	.27	.09	.85	.45	.90	1.65	.95	10.67	19.28	8.97	1.73	1.92	.90	.45	49.13
Average	.17	.27	.18	.48	.99	1.32	2.79	1.34	14.78	22.16	9.33	1.75	1.65	1.51	.61	59.33

NORTHERN GROUP OF FORESTS

Type	March	April	May 1 to 10	May 11 to 20	May 21 to 31	June 1 to 10	June 11 to 20	June 21 to 30	July	August	September	October 1 to 10	October 11 to 20	October 21 to 31	November	Total for season
Western yellow pine	0.67	0.67	0.20	0.81	1.68	2.75	3.83	1.82	17.76	22.73	8.95	2.29	2.84	2.63	1.09	70.72
Mixed conifer	--------	.23	.30	.83	2.26	2.03	4.96	1.51	19.48	26.95	9.41	2.33	2.78	4.22	.76	78.05
Douglas fir	.36	.27	.36	.36	1.27	.91	2.09	.91	12.62	21.25	8.72	2.00	1.91	1.44	.18	54.65
Fir	--------	--------	--------	--------	.53	.26	1.38	1.07	14.40	28.54	7.20	1.06	.25	.52	--------	55.21
Brush	.01	.48	.10	1.43	1.05	1.15	2.68	.96	15.03	24.11	8.72	2.02	1.83	.87	.68	61.12
Average	.28	.39	.22	.79	1.54	1.71	3.35	1.33	16.37	24.14	8.85	2.10	2.25	2.29	.65	66.26

Up to June 11 the total number of fires is distinctly higher in the western yellow pine and mixed conifer types than in the other timber types, and this continues to be true during the remainder of June and July. In August, however, the rate per 100,000 acres in the Douglas fir, sugar pine-fir, and fir types approaches the average of 25.56 for the combined pine types given in Figure 5. September is marked by a decided falling off in number of fires in all types, though the danger point is exceeded everywhere.

In the first 10-day period of October, as the end of the fire season is approached, the number of fires in all types except grassland is still at or above the danger point. In the second 10-day period, however, the rate for fir and sugar pine-fir drops so low that the season in these types may be considered closed. The third 10-day period of October sees the woodland type down to a similar basis of an occasional fire, but the western yellow pine, mixed conifer, Douglas fir, chaparral, and brush types must still be protected. By November, only the chaparral type continues in the danger zone, and before the end of the month even this is down to a low figure.

When these figures are summarized (Table 6 and fig. 5), the longest fire season is found to be five and two-thirds months, in the chaparral and brush, and the shortest, four months, in the fir and sugar pine-fir types. The principal timber types—the western yellow pine, mixed conifer, and Douglas fir—have a common season of five and one-third months.

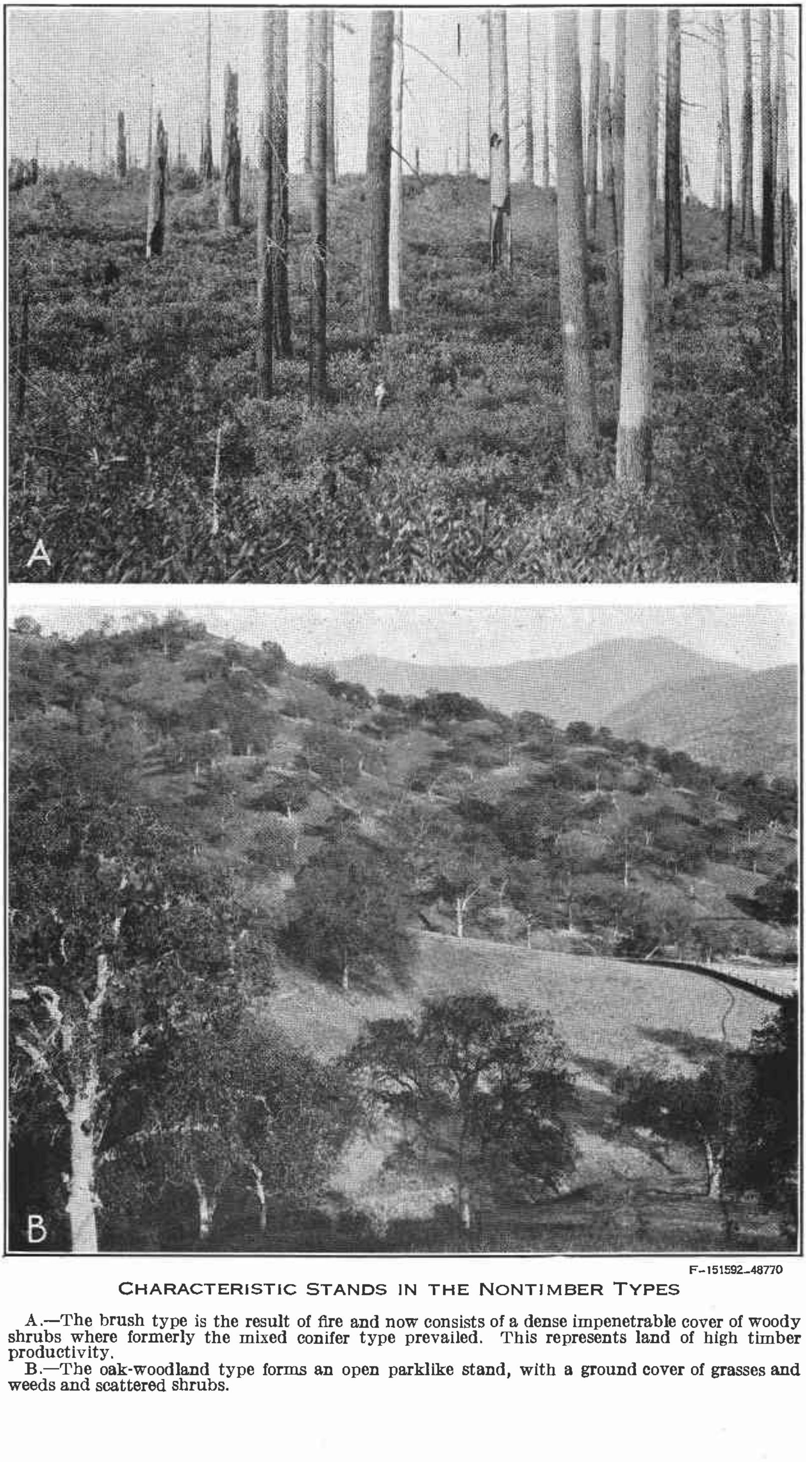
The limitations of these figures should be clearly recognized. They do not mean that in each individual year for each national forest the actual fire season is of the indicated length. Their significance lies rather in what they show of the relationship between the types. For example, they show an average lag of three weeks in opening date between the western yellow pine and fir types, a fact that can be taken into account in placing special-protection men and in making allotments. They show that the fire season lasts three weeks longer in the pine types than in the fir and sugar pine-fir types, a fact that also can be reckoned on. The actual opening and closing dates for a particular year may vary considerably from the dates given in Table 6, depending principally upon the prevalence or absence of rain.

TABLE 6.—*Average length of fire seasons by types* [1]

Type	Opening date	Closing date	Length in months	Type	Opening date	Closing date	Length in months
Western yellow pine	May 20	Oct. 31	5⅓	Grass	June 10	Oct. 20	4⅓
Mixed conifer	do	do	5⅓	Chaparral	May 20	Nov. 10	5⅔
Douglas fir	do	do	5⅓	Woodland	June 10	Oct. 20	4⅓
Sugar pine-fir	June 10	Oct. 10	4	Brush	May 10	Oct. 31	5⅔
Fir	do	do	4				

[1] Basis: Occurrence of fires at rate exceeding one fire to 100,000 acres per 10 days, 12 timbered forests.

A point of considerable significance is that the opening date is the same for all the timber types comprising the bulk of the forest areas—western yellow pine, mixed conifer, and Douglas fir. To provide protection only for the western yellow pine type, as has sometimes been done, thus appears to be an unsound practice, overlooking the possibility of danger to the other types.

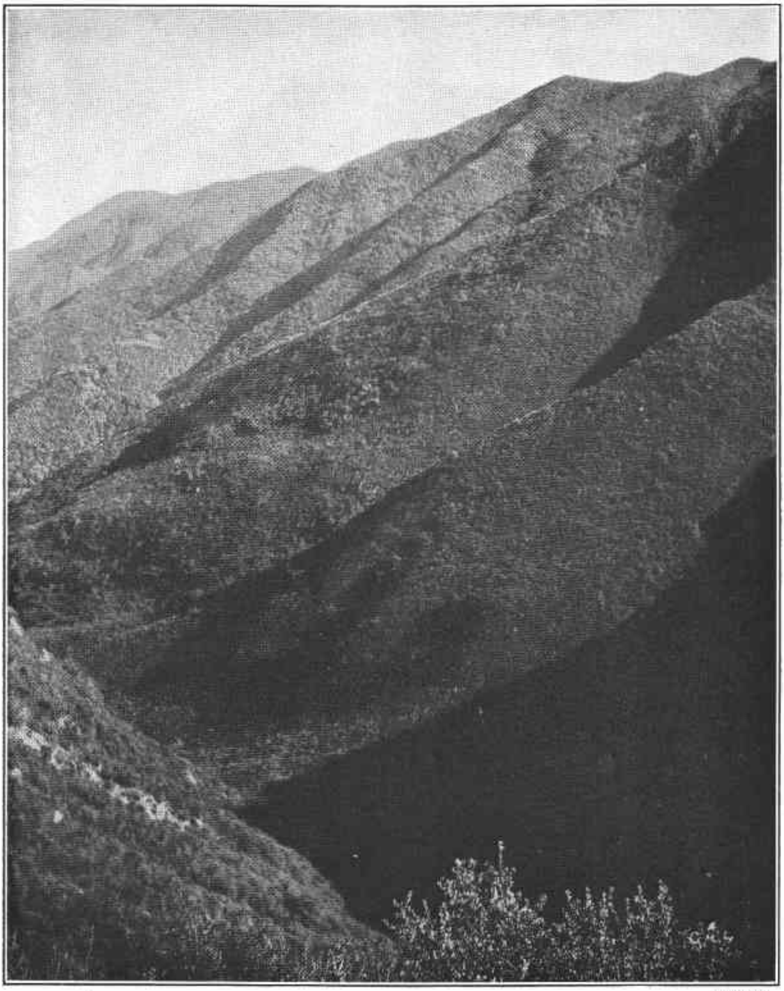


F-151592-48770

CHARACTERISTIC STANDS IN THE NONTIMBER TYPES

A.—The brush type is the result of fire and now consists of a dense impenetrable cover of woody shrubs where formerly the mixed conifer type prevailed. This represents land of high timber productivity.

B.—The oak-woodland type forms an open parklike stand, with a ground cover of grasses and weeds and scattered shrubs.



F-64423

THE CHAPARRAL TYPE

A north slope covered with mature chaparral. Although no fire has gone through this particular stand in over 15 years, this type has been and will continue to be, next to the brush fields, the most hazardous of all the types. Nearly all fires here are crown fires, with a terrific rate of spread, and are certain to involve serious losses in weakened erosion control and considerable damage to any contiguous stands of timber.

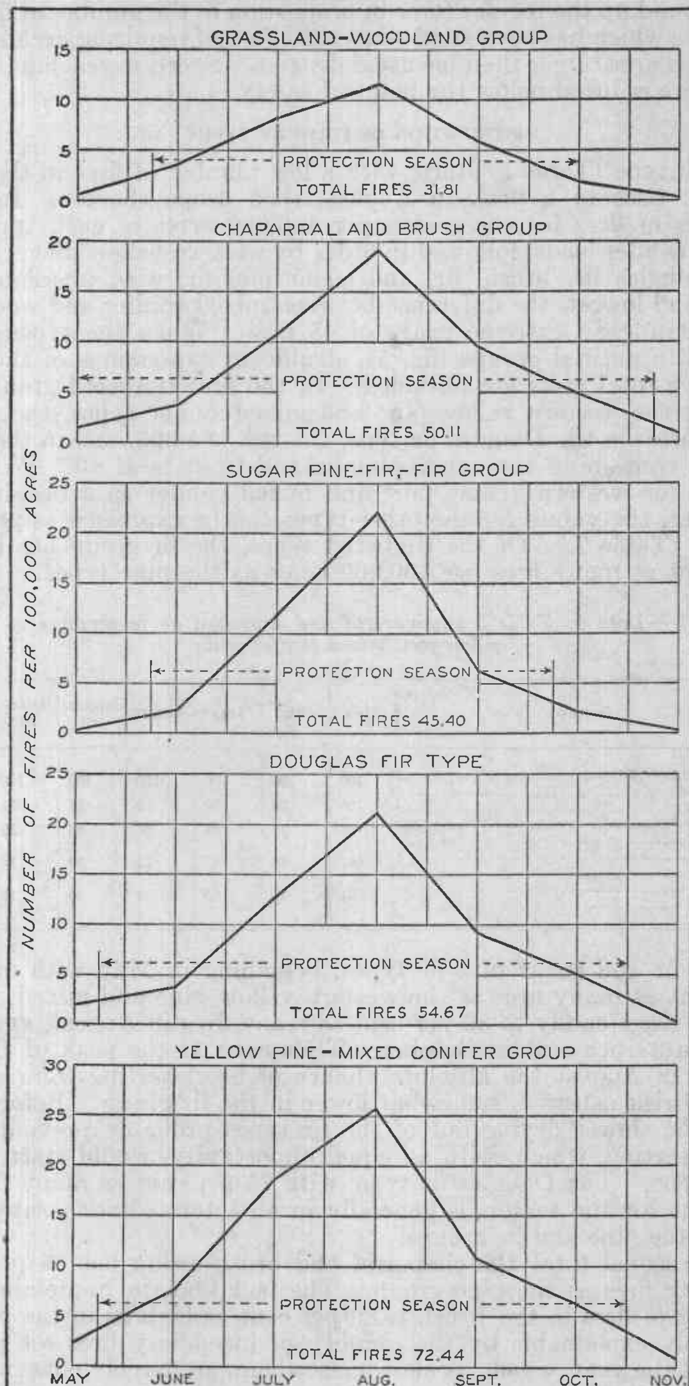


FIGURE 5.—Seasonal distribution of general-risk fires per 100,000 acres, by groups, 1911 to 1920

To build up the regular force in proportion to the number of fires—a practice which has been tried—has the effect of requiring each man to cover an area larger than his usual district. Speed in reaching fires is therefore reduced below the point of safety.

DISTRIBUTION OF FIRES BY TYPES

Each type (Table 5) starts with a low number of fires in the early season, rises to a peak in August, then drops sharply. In total number of fires for the season per 100,000 acres of each type, the mixed conifer leads, followed in order by western yellow pine, chaparral, Douglas fir, brush, fir, and sugar pine-fir, with grassland and woodland lowest, the difference between mixed conifer and woodland representing an extreme range of 48 fires. When the types are arranged in natural groups (fig. 5), significant expressions of the comparative total risks are obtained. In the first timbered group containing the western yellow pine and mixed conifer types, the risk is 72.44 fires; in the Douglas fir type, the risk is 53.03, and in the third group, containing the sugar pine-fir and fir it is 45.40. With the figures for western yellow pine and mixed conifer as a base or 100 per cent, the values for the other types can be expressed as percentages. (Table 7.) Of the timbered types, the fir group has but 63 per cent as many fires per 100,000 acres as the pine types.

TABLE 7.—*Data in Table 5 summarized and expressed as percentages of western yellow pine-mixed conifer group*

Types	May	June	July	August	September	October	Total
Western yellow pine Mixed conifer	100	100	100	100	100	100	100
Douglas fir	90	50	70	82	84	81	75
Sugar pine-fir Fir	22	31	64	86	58	33	63
Chaparral Brush	67	48	57	75	89	78	69
Grass Woodland	34	47	45	44	53	25	44

The fir and sugar pine-fir types, beginning in May with only 22 per cent as many fires as the western yellow pine and mixed conifer group, rise steadily to 86 per cent as many fires in August, and then drop to 33 per cent in October. Thus even at the peak of the fire season in August the absolute chance of fires starting from all the general-risk causes is somewhat lower in the fir group. Before that time the slower drying out of the fir types probably prevents fires from starting, which, with an equal opportunity, would start in the pine type. The Douglas fir type, with 75 per cent as many fires as the pine for the season, is generally in an intermediate position between the pine and fir groups.

In seasonal total the chaparral and brush group has 69 per cent as many fires as the pine group. The fact that, in September, the number of fires in the brush is 89 per cent as high as in the pine, is probably explainable by the number of incendiary fires set at this time of the year, which, as shown elsewhere, are largely concentrated in the brush types.

The northern group of forests, Klamath, Trinity, Shasta, and California, have 6.93 more fires than the total group average for the season. (Table 5.)[7] In two types only are there any appreciable differences in the number of fires per 100,000 acres; fir in the northern forests exceeds the general average by 9.53 fires, and brush by 11.99.

Although for all the forests considered the Douglas fir type is intermediate between the pine types and the true firs in total seasonal fire rate, in the northern group the seasonal rate for Douglas fir is practically identical with that in the true fir type. The length of fire season, however, is the same as for the western yellow pine and mixed conifer types.

The monthly distribution and total number of fires per 100,000 acres for the four most important major types found in the northern group of forests agree in most particulars with the averages for the 12 timbered forests. (Table 5.) In the north the season opens three weeks earlier in the brush type than elsewhere, and for the second 10-day period of May the rate of fires is greater in the mixed conifer and western yellow pine types than elsewhere.

The data for the northern group substantiate also the previous statement that in August all types are about equally susceptible to fires starting.

NUMBER OF LIGHTNING FIRES

Obviously the relative number of fires in different types may be affected not only by inherent differences in the types but also by the relative proportion of lightning and man caused fires. Lightning fires form the most homogeneous group of fires, and analysis of this group should more exactly express the inherent risk between the types than an average of all general-risk fires. The fact that lightning storms are very much more prevalent in the timber belt than in the chaparral and woodland types raises some difficulty, but so far as known the commercial timber types can properly be compared with each other on the assumption that equivalent opportunities exist for lightning fires in all. If there is a higher number of lightning bolts per 100,000 acres per year in one type than in another, it is certainly in the fir rather than in the pine belt.

The lightning-fire data in Table 8 give the western yellow pine and mixed conifer types the highest number of fires. These two types together average 36.35 fires per 100,000 acres, whereas the sugar pine-fir and fir types together average but 29.68 or 82 per cent as many as in the pine group. The indications are that the slower drying out of the upper-elevation types plus the generally heavier precipitation known to occur there with lightning storms tend to prevent many more bolts from starting fires in the fir than in the pine. This is no doubt true for the season as a whole, and particularly in June, when lightning fires in the fir group are but 32 per cent as numerous as in the pine group. In July the percentage is raised to 75. In August, the month in which all types are most nearly alike in susceptibility to fires starting, the number of fires in the two type groups is very similar, the fir group exceeding the pines by 1.21 fires per 100,000 acres. Thus, as with all general-risk fires, the relatively slow drying out of

---

[7] The northern group of forests were selected for special study because as a group they present particularly difficult problems in fire control; also this selection furnishes an opportunity for comparisons between the general averages obtained and a single group.

the upper timber belts is undoubtedly a factor of prime importance in preventing the start of fires during the spring and early summer.

The number of lightning fires is but 55 per cent as high in the brush-field type as in the western yellow pine and mixed conifer group. Since the brush type cuts across the entire timber belt and thus is subjected to the same lightning risk, the difference in rate is attributable to scarcity of trees in the brush fields. Tall trees are the objects commonly struck by lightning. The relative number of lightning fires from month to month in the timber types and in brush is fairly constant.

TABLE 8.—*Average seasonal distribution of lightning fires by types, 1911–1920, all forests*

[Number of fires per 100,000 acres]

Type	May	June	July	August	September	October	Total	Ratio
Western yellow	0.90	4.48	12.59	13.35	2.62	0.40	34.34	--------
Mixed conifer	1.19	5.21	11.83	17.33	3.20	.51	39.27	--------
Douglas fir	.96	2.97	8.91	9.43	.70	--------	22.97	63
Sugar pine-fir	.42	1.90	6.74	13.89	1.47	.21	24.63	--------
Fir	.24	1.40	9.67	16.85	2.68	.30	31.14	--------
Grass	.36	1.62	2.16	4.51	.90	--------	9.55	--------
Chaparral	.50	1.24	1.49	1.98	2.23	--------	7.44	--------
Woodland	--------	1.47	4.10	3.89	.21	.11	9.78	--------
Brush	.45	2.14	6.61	9.38	1.38	.09	20.05	55
Average	.72	3.37	9.55	12.47	2.15	.29	28.55	--------

SUMMARY OF TYPE GROUPS

Type	May	June	July	August	September	October	Total	Ratio
Western yellow pine mixed conifer group	1.02	4.78	12.28	14.98	2.85	0.44	36.35	100
Sugar pine-fir, fir group	.28	1.51	9.01	16.19	2.41	.28	29.68	82
Woodland, grass, chaparral group	.21	1.47	2.98	3.67	.84	.05	9.22	25

In the woodland, grass, and chaparral groups the total number of lightning fires is but 25 per cent as great as in the western yellow pine and mixed conifer group, and but 46 per cent as great as in the brush fields, indicating a relative scarcity of lightning storms. The fact is that most of these storms originate above the upper timber belts and do not generally extend over the untimbered foothill region.

NUMBER OF MAN-CAUSED FIRES

The seasonal total of man-caused fires (Table 9 and fig. 6) is highest in the chaparral, followed in order by mixed conifer, western yellow pine, Douglas fir, brush, grass, woodland, sugar pine-fir, and fir. An interesting contrast is found in the fact that the figures for man-caused fires in western yellow pine (33.53) and mixed conifer (39.85) are practically identical with the lightning figures in the same types (34.34 and 39.27), whereas in the chaparral the 48.14 man-caused fires per 100,000 acres is the highest and the 7.44 lightning fires per 100,000 acres, is the lowest of all.

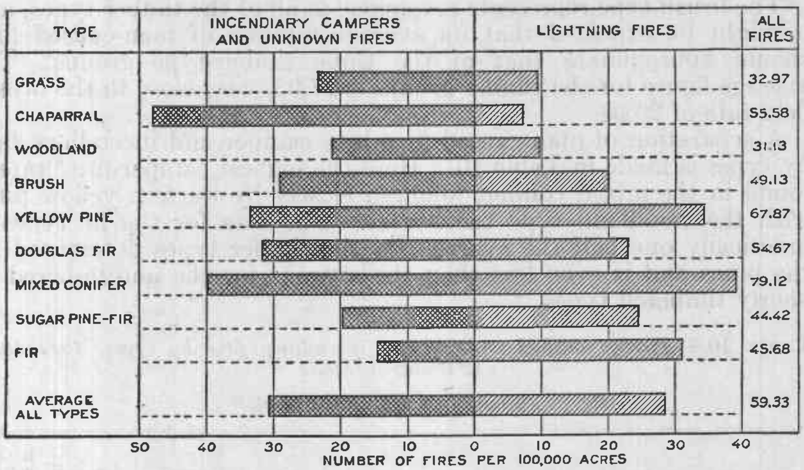


FIGURE 6.—Number of general-risk fires per 100,000 acres annually, by types, 1911-1920

Among the principal timber-type groups, Douglas fir has 88 per cent as many man-caused fires as the western yellow pine and mixed conifer group, and the sugar pine-fir and fir group but 44 per cent as many. Given equal opportunities for fires to start from human causes, a ratio, similar to that for the lightning fires, of 81 per cent between the pine and fir groups would be expected. Evidently, since this is not the fact, the total human use within the fir is distinctly lower than in the pine belt. This view is confirmed by the fact that in August, when the susceptibility of all types to starting of fires most nearly approaches equality, only 55 per cent as many man-caused fires start in the fir as in the pine. No detailed comparison of seasonal distribution of lightning and man-caused fires is required, since the two groups have such different seasonal histories.

TABLE 9.—*Average seasonal distribution of man-caused general risk fires (incendiary, camper, unknown), by types, 1911-1920, 12 timbered forests*

[Number of fires per 100,000 acres]

Type	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Total	Ratio
Western yellow pine	0.42	0.44	0.92	2.70	6.06	10.56	7.05	4.59	0.79	33.53	------
Mixed conifer	.06	.26	1.41	2.91	6.71	10.62	9.31	7.74	.83	39.85	------
Douglas fir	.35	.26	.96	.79	4.02	11.62	8.38	5.15	.17	31.70	88
Sugar pine-fir	------	------	.21	1.26	4.42	6.74	3.58	2.95	.63	19.79	------
Fir	------	------	.19	.67	2.43	5.60	3.95	1.46	.24	14.54	------
Grass	------	.36	.90	2.34	6.49	6.31	5.40	1.26	.36	23.42	------
Chaparral	------	------	1.24	2.98	8.44	16.13	11.16	6.95	1.24	48.14	------
Woodland	------	.21	.42	1.79	4.00	7.78	5.15	1.68	.32	21.35	------
Brush	.05	.27	.94	1.35	4.07	9.92	7.60	4.48	.45	29.13	81
Average	.17	.27	.90	2.07	5.25	9.72	7.18	4.63	.60	30.79	------
SUMMARY OF TYPE GROUPS											
Western yellow pine, mixed conifer group	0.24	0.35	1.12	2.78	6.33	10.60	7.97	5.88	0.81	36.08	100
Sugar pine-fir, fir group	------	------	.19	.80	2.86	5.83	3.86	1.79	.43	15.76	44
Grass, woodland, chaparral group	------	.19	.52	2.05	5.32	7.68	4.87	1.54	.66	22.83	63

The brush type represents reversions in all of the timber types, and it might be expected that its average number of man-caused fires should approximate that of the three timber-type groups. The average figure for the timber groups is 27.95, very close to the brush-field rate of 29.08.

A separation of man-caused fires into camper and incendiary fires by types is made in Table 10. Here the highest camper-fire [8] rate is found in the mixed conifer, followed closely by western yellow pine, with the woodland type the lowest. The rate for the fir types is practically one half the average for the timber types dominated by the pines and is even less than the average for the nontimbered or poorly timbered types.

TABLE 10.—*Average annual camper and incendiary fires by types, 1911–1920, 12 timbered forests*

[Number of fires per 100,000 acres]

Type	Camper fires	Incendiary fires	Ratio, incendiary to camper fires
	Number	*Number*	*Per cent*
Western yellow pine	18.20	10.10	55
Mixed conifer	19.83	13.72	69
Douglas fir	8.21	22.71	277
Sugar pine-fir	11.79	4.42	37
Fir	10.71	1.58	15
Grass	15.50	5.41	35
Chaparral	17.87	23.57	132
Woodland	6.52	13.25	203
Brush	11.12	13.71	123
Average	14.87	11.62	78

SUMMARY BY TYPE GROUPS

Type group	Camper fires	Incendiary fires	Ratio, incendiary to camper fires
Western yellow pine, mixed conifer	18.86	11.57	61
Sugar pine-fir, Douglas fir, fir	9.99	9.41	94
Brush, chaparral, woodland, grass	11.31	13.45	119
All timber	16.22	10.93	67

In a broad way these figures for camper fires indicate the relative recreational use of the different major type groups. The surprisingly high rate in the chaparral and brush is probably caused by the popularity of these types for deer and quail hunting. That there is a real difference in the amount of recreational use between the pine and fir types is indicated by the fact that the fir types, even in August, the peak of the fire season, have but 65 per cent as many camper fires per 100,000 acres as the pines.

Incendiary fires in the chaparral type attain a still higher rate, in striking contrast to that for the western yellow pine and fir types. This indicates that the setting of incendiary fires is induced primarily by the presence of brush, which is burned on the theory that it will increase forage. Further, 47 per cent of the incendiary fires in the chaparral type occur in September and October, the months during which the severest burns may be obtained, a fact well appreciated by

[8] For this period camper fires include what are now segregated as smoker fires.

incendiaries. The high rate of incendiarism in the Douglas fir type is exceptional and is explained by the point of view of the local population in the northern group of forests—a condition not duplicated elsewhere. In the fir and sugar pine-fir types the incendiary problem is insignificant.

RELATIVE EASE OF HANDLING LIGHTNING FIRES AND MAN-CAUSED FIRES

In the earlier analysis of these 10-year data it was found that of the three major general risk causes—lightning, camper, and incendiary—lightning fires were the most easily handled, except where very large numbers occurred at one time. A partial explanation for this is that some rain ordinarily accompanies lightning storms, thus checking the initial spread and giving the organization a chance to suppress the fires. An additional reason now appears to be the relative scarcity of lightning fires in the chaparral and brush types, where fires are most difficult to control. The lightning fires are thus generally timber fires in character, rather than crown brush fires.

The most difficult fires to handle were found to be those caused by incendiaries. The outstanding reasons are evidently that incendiary fires are typically brush and chaparral fires and that they are purposely set under the most difficult circumstances.

Camper fires are more abundant in timber than in brush and chaparral (though by no means absent in the latter types) and so are intermediate in difficulty of control between lighting and incendiary fires.

Man-caused fires as a group form a very much higher part of the total fires of the low elevation types—chaparral, grass, and woodland—than of the higher elevation types of Douglas fir, sugar pine-fir, and fir.

The relative proportion of the different types found in a forest is of tremendous importance in the fire problem, affecting the kind of fires that start and consequently their behavior after start and difficulty of control. This explains to a considerable degree the inherent differences in fire control between adjacent forests and forest groups.

CONCENTRATION OF RISK

So far the numbers of fires starting have been discussed as though they were uniformly distributed within the total area of each type. This is a useful concept in comparing the fire problem in the several types, but it is more accurate to recognize that everywhere fires, both lightning and man-caused, start in well-defined zones, which cover but a portion of the total forest area.

Concentration of risk is well illustrated in the northern group of forests, for which the percentage of each type in actual risk areas was planimetered from type and fire occurrence maps. (Table 11.) The grass and woodland group has the largest part of its total area subjected to risk, followed by the brush-chaparral group, the western yellow pine-mixed conifer group, the Douglas fir group, and sugar pine-fir and fir group. Comparable figures for the other national forest groups indicate similar conclusions and are therefore not included.

In this particular, as in many of the other elements of the fire problem, the nontimbered and, except for the brush fields, relatively low-value types, have a higher rating than the timber types, averaging 46.6 per cent, as compared to 41.9 per cent. This difference, however, is not so striking as that for some of the other elements of the problem, and does not affect materially the reliability of the figures based on total type areas.

TABLE 11.—*Risk areas, by types, northern group of forests, all causes, 1911–1920*

Type	Total area	Area of risk	Ratio of risk
	1,000 acres	*1,000 acres*	*Per cent*
Pine group	2,819	1,205	43
Douglas fir	1,101	453	41
Fir group	671	265	39
Total timbered	4,591	1,923	41.9
Brush, chaparral	1,303	598	46
Grass, woodland	353	174	49
Total nontimbered	1,656	772	46.6
All types	6,247	2,695	43.1

CONTROL OF FIRE AS AFFECTED BY TYPES

The effectiveness of control over a period of years is gauged indirectly by the percentage of fires over 10 acres in extent, or C fires, and more directly by the size of the average fire and the percentage of area burned annually. (Table 12 and fig. 7.) Of the general-risk fires only, the proportion of C fires averages highest (57.1 per cent) in the chaparral type, considerably lower in the brush, grass, and woodland types, and so in descending order through the Douglas fir, western yellow pine, mixed conifer, and sugar pine-fir, down to 9.9 per cent in pure fir. The size of the average fire, ranging from 539 acres in chaparral to 29 acres in the fir type, decreases in almost the same order. The largest average C fire is found, as might be expected, in the chaparral type and the smallest in the fir type.

RESULTS OF PROTECTION

The success of protection as measured by average annual percentage of the type burned in general-risk fires (Table 12, last column) has been least in the chaparral and brush types, or those with the greatest amount of inflammable fuel and with the most critical climatic conditions. Within the commercial timber types the least success has been attained in the western yellow pine and Douglas fir types and the greatest success in the pure fir. As the highest present exploitable timber values per acre are in the pine types, particularly in the western yellow pine, and the lowest in the fir type, even if the objective of fire control is considered to be merely preservation of existing values, the effort made during the decade has by no means accomplished its purpose. The heaviest losses have been sustained in the forest types of highest present values.

The situation in the restocking brush fields is particularly grave, because the annual rate of loss of 1.24 per cent means that the process of restocking the brush fields themselves is retarded through burning of newly established reproduction and by reduction of site quality; also because all fires originating in the brush tend to wipe out a part of the adjacent timber belt. The annual loss rate of 3 per cent in chaparral likewise is to be regarded as serious, for as has already

TABLE 12.—*Acreage burned and size of fires by types, 1911–1920, 12 timbered forests*

Type	Total area	Area burned	Total fires	C fires		Size average fire	Size average C fire	Area burned annually
	1,000 acres	*Acres*	*Number*	*Number*	*Per cent*	*Acres*	*Acres*	*Per cent*
GENERAL-RISK FIRES								
Western yellow pine	4, 554	395, 747	3, 090	642	20. 8	128	616	0. 87
Mixed conifer	3, 127	172, 725	2, 474	521	21. 1	70	332	. 55
Douglas fir	1, 145	89, 332	626	182	29. 1	143	491	. 78
Sugar pine-fir	475	19, 472	211	42	19. 9	92	464	. 41
Fir	1, 644	22, 074	751	74	9. 9	29	298	. 13
Grass	555	32, 338	183	64	35. 0	177	505	. 58
Chaparral	403	120, 792	224	128	57. 1	539	944	3. 00
Woodland	951	79, 224	296	99	33. 4	268	800	. 83
Brush	2, 239	278, 007	1, 100	383	34. 8	253	726	1. 24
Total or average	15, 093	1, 209, 711	8, 955	2, 135	23. 8	135	567	. 80
ALL FIRES								
Western yellow pine	4, 554	502, 552	3, 654	784	21. 5	157	641	1. 10
Mixed conifer	3, 127	200, 444	2, 999	650	21. 7	67	308	. 64
Douglas fir	1, 145	92, 403	659	192	29. 1	140	481	. 81
Sugar pine-fir	475	20, 717	242	51	21. 1	86	406	. 44
Fir	1, 644	38, 726	811	89	11. 0	48	435	. 24
Grass	555	37, 306	224	80	35. 7	167	466	. 67
Chaparral	403	153, 475	281	161	57. 3	546	953	3. 81
Woodland	951	83, 113	330	115	34. 8	252	723	. 87
Brush	2, 239	324, 475	1, 276	447	35. 0	254	726	1. 45
Total or average	15, 093	1, 453, 211	10, 476	2, 569	24. 5	139	566	. 96
SUMMARY OF ALL FIRES BY TYPE GROUPS								
Western yellow pine, mixed conifer group	7, 681	702, 996	6, 653	1, 434	21. 6	106	490	0. 91
Sugar pine-fir, Douglas fir, fir group	3, 264	151, 846	1, 712	332	19. 4	89	457	. 47
All timber	10, 945	854, 842	8, 365	1, 766	21. 1	102	484	. 78
Chaparral, grass, woodland group	1, 909	273, 894	835	356	42. 6	328	769	1. 43

been seen, such frequent burning reduces, at least temporarily, the watershed value of these lands, and the fires frequently encroach on adjacent timber stands.

The combined loss rate due to both general and special risk fires (Table 12 and fig. 7) varies in the same order between types as the loss from general-risk fires alone. In the western yellow pine type, where fire-using agencies are numerous, especially logging, the average annual loss is raised to 1.1 per cent. This is nearly five times as great as in the fir type, the easiest of all the timber types to protect and with the lowest present values at stake. Here the annual loss rate has been held near to the 0.2 per cent of maximum allowable burned area. In the restocking brush fields the loss is six times as great as in fir and over three times as great as for all timber types.

These figures for the entire pine region obviously are a very general expression of the success of protection and the relative spread of fire in different types. Natural groups of forests or individual forests may show considerable difference in the degree of success attained. In the northern group (Table 13) the loss rate in the western yellow pine type (1.38 per cent) approaches that in the restocking brush fields (1.53 per cent). But here, as for the region as a whole, the fir type is the only one in which the annual rate of loss has been kept near 0.2 per cent. The other main forest groups average a lower rate of loss than the northern group, though the relation between types is substantially the same.

TABLE 13.—*Acreage burned and size of fire by types and forest groups, 1911–1920, general-risk fires*

NORTHERN GROUP OF FORESTS

Type	Area of type	Total acreage burned	All fires	C fires		Size of average fire	Area burned annually
	1,000 acres	*Acres*	*Number*	*Number*	*Per cent*	*Acres*	*Per cent*
Western yellow pine	1,491	205,026	1,051	243	23.1	195	1.38
Mixed conifer	1,328	78,515	1,037	231	22.3	76	.59
Douglas fir	1,101	88,958	602	176	29.2	148	.81
Fir	341	6,168	207	30	14.5	30	.18
Brush	1,045	159,981	639	196	30.7	251	1.53
EAST SIDE AND NORTHERN AND SOUTHERN SIERRA GROUPS							
Western yellow pine	3,063	190,721	2,039	399	19.6	94	0.62
Mixed conifer	1,799	94,210	1,437	290	20.2	66	.52
Douglas fir	44	374	24	6	25.0	16	.08
Fir	1,303	15,906	544	44	8.1	29	.12
Brush	1,194	118,026	461	187	40.6	256	.99

CONCENTRATION OF HAZARD AREAS

These losses in percentage of area burned, like occurrence of fires, are not uniformly distributed over the entire area of each type but are concentrated in well-defined zones. For the decade under review in many localities in the northern group of forests, over 40 per cent of all fires became class C, and the burned acreage was correspondingly high. The protection problem is particularly critical on such areas, and this is characteristic of the whole northern group of forests. In Table 14 are given the results of planimetering these areas of concentration of high hazard on type and hazard maps of the Klamath, Trinity, Shasta, and California National Forests. Of the brush and chaparral area, 22.9 per cent had over 40 per cent C fires. This is the lowest degree of success in protection of any type. It is followed

TABLE 14.—*Concentration of hazard: Areas on which 40 per cent of C fires occurred in northern group of forests, 1911–1920*

Types	Total area in type	Area with 40 per cent C fires	
	1,000 acres	*1,000 acres*	*Per cent*
Mixed conifer and western yellow pine	2,819	373	13.2
Douglas fir	1,101	101	9.2
Fir, sugar pine-fir, and alpine	671	63	9.4
Total timbered	4,591	537	11.7
Brush, chaparral	1,303	299	22.9
Grass, woodland	353	48	13.6
Total nontimbered	1,656	347	20.9
All types	6,247	884	14.1

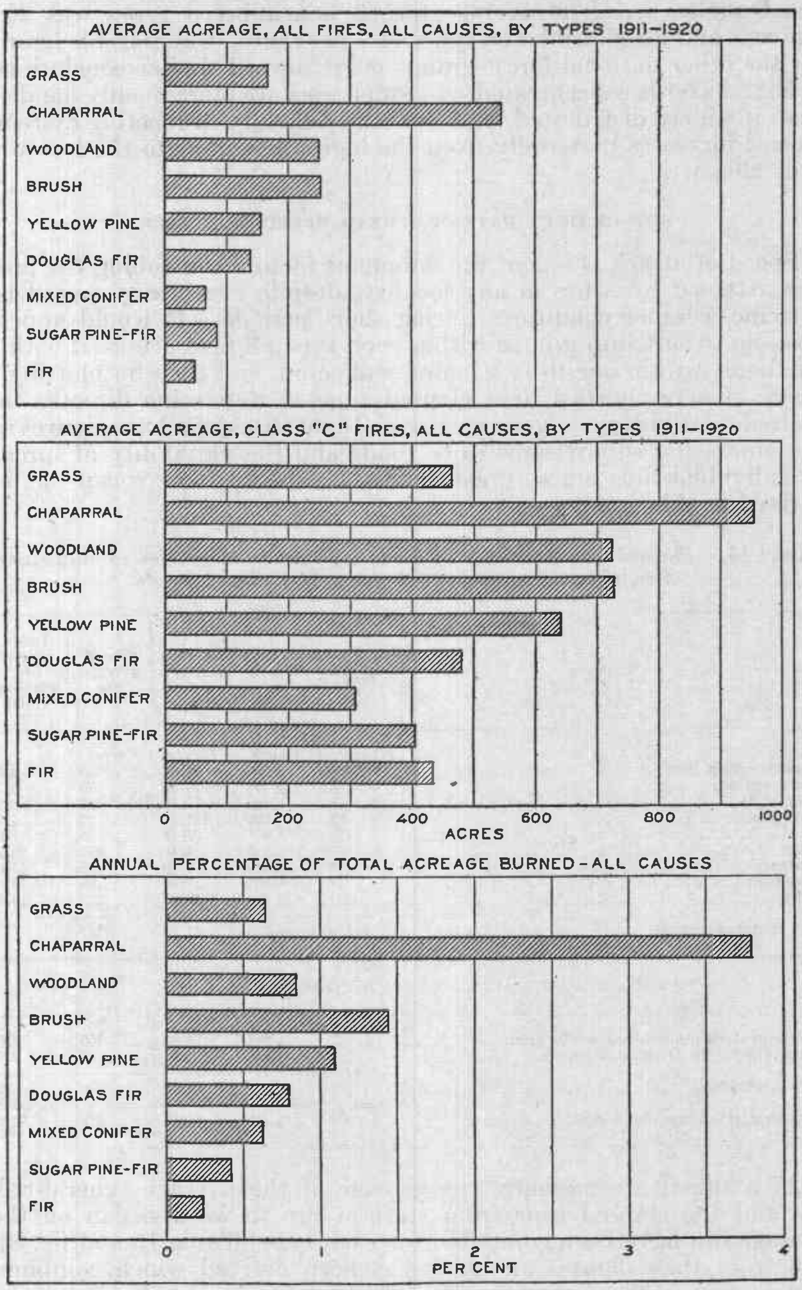


FIGURE 7.—Acreage burned, all causes, by types, 1911–1920

in order but with much lower figures by the grass and woodland group, the western yellow pine-mixed conifer, the sugar pine-fir and fir, and the Douglas fir. The average for all nontimbered types was 20.9 per cent and for all timbered types 11.7 per cent. Comparable figures for the other national-forest groups point toward similar conclusions.

High hazards concentrated on a small area are more readily handled than if widely distributed, and thus the difficulty of meeting extreme hazard increases materially from the high-altitude fir to the low-altitude chaparral.

SIZE OF FIRES, RATE OF SPREAD, SPEED OF ATTACK

Speed of attack is one of the dominant factors controlling the final size attained by a fire in any locality, despite exceptions caused by extreme weather conditions during short periods. It would appear possible to sort into groups within each type all fires attacked within one hour, within one to two hours, and so on, and then by plotting a curve of acres burned over elapsed time to determine directly the desired relationship. Even with over 10,000 fires as a basis, however, the number of subdivisions to be made and the variability of spread in individual fires are so great that a satisfactory curve can not be derived in this manner.

TABLE 15.—*Elapsed time from start of fire to work begun in relation to final size of fires, general-risk fires, 1911–1920, 12 timbered forests*

Type	Total fires	Total elapsed time	Average elapsed time	Size of average fire	Index (size of fire, elapsed time)
	Number	*Hours*	*Hours*	*Acres*	
Western yellow pine	825	12,900	15.64	128	8.18
Mixed conifer	658	12,141	18.45	70	3.79
Douglas fir	76	1,325	17.43	143	8.20
Sugar pine-fir	33	702	21.27	92	4.33
Fir	178	4,831	27.14	29	1.07
Grass	57	425	7.46	177	23.73
Chaparral	104	1,019	9.80	539	55.00
Woodland	47	1,001	21.30	268	12.58
Brush	201	3,689	18.35	253	13.79
Total or average	2,179	38,033	17.45	135	7.74

SUMMARY BY TYPE GROUPS

Type	Total fires	Total elapsed time	Average elapsed time	Size of average fire	Index (size of fire, elapsed time)
Western yellow pine, mixed conifer group	1,483	25,041	16.89	102	6.04
Sugar pine-fir, fir, Douglas fir group	287	6,858	23.90	66	2.76
All timber	1,770	31,899	18.02	96	5.33
Chaparral, grass, woodland group	208	2,445	11.75	379	32.26

As a substitute measure, the acreage of the average general-risk fire and the elapsed time from start of fire to work begun on the average fire have been computed for each type (Table 15 and fig. 8), and from these figures an index has been derived which combines two factors, rate of spread and difficulty of control. For example, suppose two fires, one in grassland and one in chaparral, are attacked by equal crews, each fire being 10 acres in extent at the end of one hour. Obviously the rate of spread is the same for both, but the final acreage of the chaparral fire is likely to be much the larger of the two, for the reason that line construction is easier in the grassland than in the chaparral and the race between line construction and creation of new perimeter by the fire will be most rapidly won in grassland. A factor in difficulty of control which directly affects final acreage is the intensity of heat, which depends upon quantity and inflammability of fuel present, irrespective of other topographic or climatic conditions. On the grass fire the crew will be able to work close to the edge of the flames, thereby holding the amount of line to the minimum. On the chaparral fire, however, the heat of the flames will force the crew to drop back some distance from the burning edge, and thus the length of line to be constructed and the final acreage will be increased.

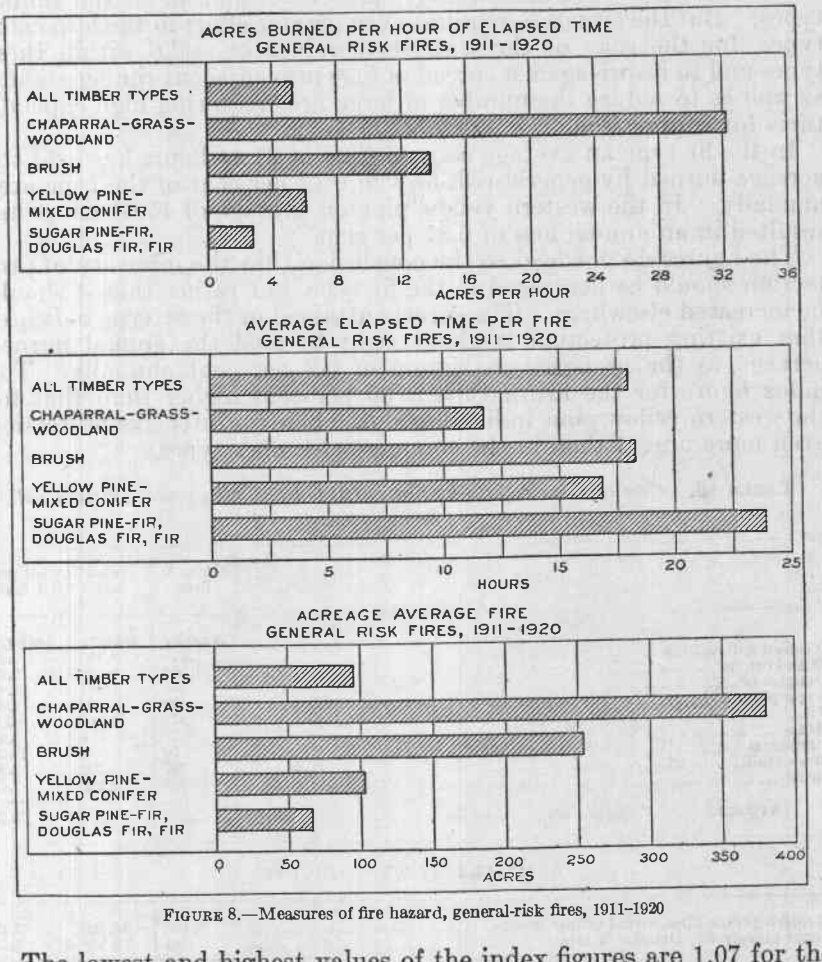


FIGURE 8.—Measures of fire hazard, general-risk fires, 1911-1920

The lowest and highest values of the index figures are 1.07 for the fir type and 55 for the chaparral. In a broad way these figures mean in terms of fire control that with equal speed of attack (i. e., intensity of protection or hour-control) fifty times as many acres per hour will be burned over in the chaparral as in the fir type. Put in another way, it means that if 1-hour control is correct for the fir type, 1-minute control would be required in the chaparral to maintain the same average size of fire. The rate in chaparral is nearly seven times as high as in western yellow pine, the most hazardous of the timber types. The Douglas fir type has almost exactly the same rate of spread as the western yellow pine.

The ratio between the index figures for the western yellow pine and fir type is about 7½ to 1. In the existing protection organization the difference between the two types is recognized only to the extent that on the average in the fir type one protection man covers three or four times as much territory as in the pine type. The average for the low-value chaparral, grass, and woodland types is six times as great as for all timber types. Any theory of basing protection effort on timber values at stake would place the emphasis on the timber types. But the situation requires even greater effort in the low-value types, for the sake of the watershed values at stake within these types and to insure against spread of fires into adjacent timber stands, as well as to reduce the number of large fires requiring high expenditures for suppression.

In the fir type an average elapsed time of 27.14 hours has held the acreage burned by general-risk fires to 0.13 per cent of the type area annually. In the western yellow pine an average of 15.64 hours has resulted in an annual loss of 0.87 per cent.

The figures do not lead to the conclusion that the intensity of protection should be decreased in the fir type, but rather that it should be increased elsewhere. The success attained in the fir type indicates that existing protection is about right to hold the annual burned acreage to the proposed maximum of 0.2 per cent annually. The index figure for the brush type is 69 per cent higher than that for the western yellow pine, indicating a need here for intensive protection even more urgent than in the commercial-timber types.

TABLE 16.—*Cost of class A fires by types, 1911–1920, all causes, 12 timbered forests*

Type	Class A fires	Total cost	Cost per A fire
	Number	*Dollars*	*Dollars*
Western yellow pine	1,627	8,185	5.03
Mixed conifer	1,263	6,404	5.07
Douglas fir	251	1,481	5.90
Sugar pine-fir	109	501	4.60
Fir	474	1,966	4.15
Grass	77	278	3.61
Chaparral	56	582	10.39
Woodland	107	302	2.82
Brush	388	2,926	7.54
Average			5.20

SUMMARY BY TYPE GROUPS

Type	Class A fires	Total cost	Cost per A fire
Western yellow pine, mixed conifer group	2,890	14,589	5.05
Sugar pine-fir, fir, Douglas fir group	834	3,948	4.73
All timber	3,724	18,537	4.98
Brush, chaparral group	444	3,508	7.90
Grass, woodland group	184	580	3.15

MEASURE OF DIFFICULTY OF CONTROL IN FIRE SUPPRESSION

The authors' earlier work [9] with the California fire data brought out as perhaps the best available index of control difficulty the average cost of the fires under one-fourth of an acre in extent, or class A fires. The cost of these small fires represents with substantial accuracy how much work must be done in each type to construct a given length of fire line. (Table 16 and fig. 9.) The highest

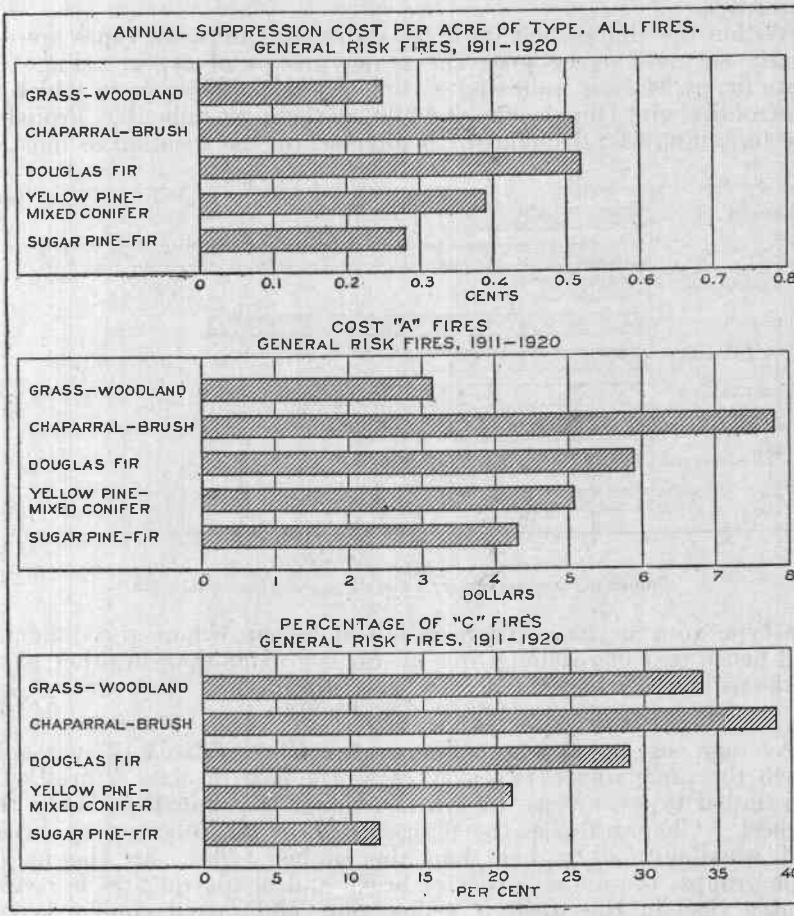


FIGURE 9.—Measures of difficulty of control, general-risk fires, 1911–1920

average cost per fire is in the chaparral and the lowest in the woodland type. The average ($3.15) for the grass and woodland group, where fire-line construction is least difficult, is the lowest of all. In the group of nontimbered types (chaparral and brush), where fires are most difficult to control, the cost averages two and one-half times as much. For all the timber types as a group the cost is 58 per cent higher than for the grass and woodland. These figures over a period

[9] SHOW, S. B., and KOTOK, E. I. Op. cit.

of years, besides expressing the average differences in labor required to suppress fire of a given size, indicate also the relative size of crew required to construct a given length of line in a given time. Thus for brush and chaparral fires, a crew two and one-half times as large is required as for woodland and grass fires. Moreover, since the cost measures the amount of fuel to be removed in line construction and the amount of fuel present is an indication of the severity of the fire, these costs have a further significance as indicating the inherent hazards.

Within the timber belt itself the differences between types are not nearly so great as between the major groups of types. (Fig. 10.) Pure fir, at $4.15 is indicated as the easiest timber type in which to control fire, and Douglas fir, at $5.90, as the most difficult. Probably the high figure for Douglas fir is affected by the location of most of

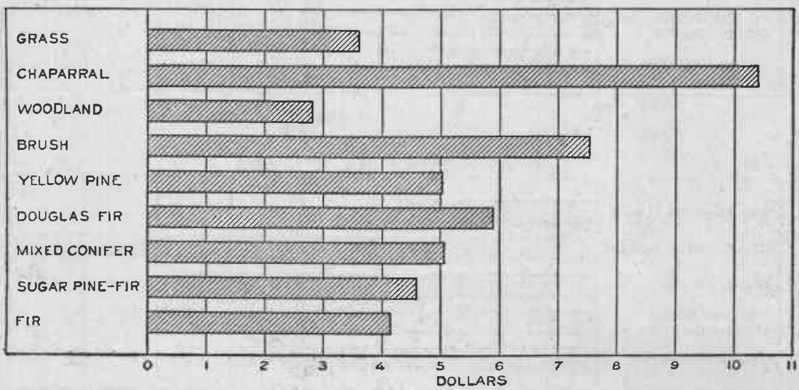


FIGURE 10.—Average cost per A fire, by types, all causes, 1911–1920

the type area in the northern group of forests, where the difficulty and hence cost of reaching fires averages greater than in other parts of the region.

COST OF SUPPRESSION

Average cost per fire for all general-risk fires (Table 17) varies in much the same way between types as the cost of class A fires. Of the timber types, fir has the lowest average cost and Douglas fir the highest. Chaparral has the highest cost of all, followed by brush and woodland, all higher than the timber types. In the major type groups, the average cost of brush and chaparral fires is nearly double that in the western yellow pine and mixed conifer types. The cost in the grass and woodland types is intermediate between all timber and the brush values.

The total cost of suppressing all fires in a type is of course measured both by the cost of the average fire and by the number of fires per 100,000 acres in the group. Combining the two as "Cost per acre per year" produces an expression of suppression cost by types. Within the timber types, the cost is lowest in pure fir and highest in Douglas fir, while costs in western yellow pine and mixed conifer are identical. The highest cost of all is in the chaparral and the lowest in the grass type.

TABLE 17.—*Cost of suppressing general-risk fires in different forest types, in relation to difficulty of control, cost of fires, and degree of accomplishment (percentage of C's), and percentage of area burned annually, 1911–1920, 12 timbered forests*

Type	Cost of average fire	Fires per 100,000 acres	Total cost, 100,000 acres	Cost per acre per year	Class C fires	Cost of A fires	Area burned annually
	Dollars	*Number*	*Dollars*	*Dollars*	*Per cent*	*Dollars*	*Per cent*
Western yellow pine	57.80	67.9	3,920	0.0039	20.8	5.03	0.87
Mixed conifer	49.80	79.1	3,940	.0039	21.1	5.07	.55
Douglas fir	94.20	54.7	5,150	.0052	29.1	5.90	.78
Sugar pine-fir	68.10	44.4	3,020	.0030	19.9	4.60	.41
Fir	46.00	45.7	2,100	.0021	9.9	4.15	.13
Grass	54.70	33.0	1,800	.0018	35.0	3.61	.58
Chaparral	117.60	55.6	6,540	.0065	57.1	10.39	3.00
Woodland	94.20	31.1	2,930	.0029	33.4	2.82	.83
Brush	97.00	49.1	4,760	.0048	34.8	7.54	1.24
Average	64.60	59.3	3,830	.0038	23.8	5.20	0.80
SUMMARY BY TYPE GROUPS							
Western yellow pine, mixed conifer	54.20	72.4	3,920	0.0039	20.9	5.05	0.74
Sugar pine-fir, Douglas fir, fir	67.60	48.7	3,290	.0033	18.7	4.73	.40
All timber	57.00	65.3	3,720	.0037	20.2	4.98	.64
Brush, chaparral	101.00	50.1	5,060	.0051	38.6	7.90	1.52
Grass, woodland	78.21	31.8	2,490	.0025	34.0	3.15	.67

Data on presuppression costs for the different types are not available, though in a broad way probably the average elapsed time (Table 15) measures approximately the intensity of protection in the various types. A comparison of the timber types on this basis indicates that western yellow pine has had the closest protection and fir the least.

CONCLUSIONS

Study of the nine major cover types of the California pine region reveals distinct and characteristic differences between them, many of which have a direct bearing upon fire danger, in their influence upon risk of fire starting, available fuel, type of fire, rate of spread of fire, ease of control, accessibility of fire, and so on. Thus type differences, which are in turn the reflection of differences in climatic conditions throughout the region, are an important key to further refinements of the methods of fire control.

Examples of the close relation of type differences to specific problems in the prevention and suppression of fires are very evident in the data presented. For one thing, the discussion has emphasized the large number of incendiary fires in chaparral and brush, a consideration that may well be of value in promoting specific fire-prevention and law-enforcement measures. The differences in the length of fire season in the different types, varying from five and two-thirds months in chaparral to four months in fir, is a valuable indication in placing fire guards. The rate of spread and difficulty of control, indicated chiefly by index figures, vary in the ratio of more than 50 to 1 between the most difficult and the easiest types to protect. The study of the difficulty of control alone, as measured by the cost of class A fires, brings out valuable indicators for the placing of fire guards and determining the size of suppression crews.

One of the salient indications of the data studied has been the necessity for far greater development of the present protection organizations, and other protection effort. This has appeared in the figures estimating the percentage of type area burned annually, when compared with the proposed acceptable maximum of 0.2 per cent of area per year. (Fig. 11.) In the fir type alone has fire been kept below this maximum. The most valuable timber type, the western yellow pine, stands an annual loss from fires of all sorts of more than five times this figure, a loss that need occur successively for only about 90 years to burn over the entire area of the type. Restocking brush fields, where young growth if protected will develop profitable timber stands of pine and fir, are being burned over at a still higher annual rate. At this rate only 70 years would be required to destroy utterly this promise of future timber forests.

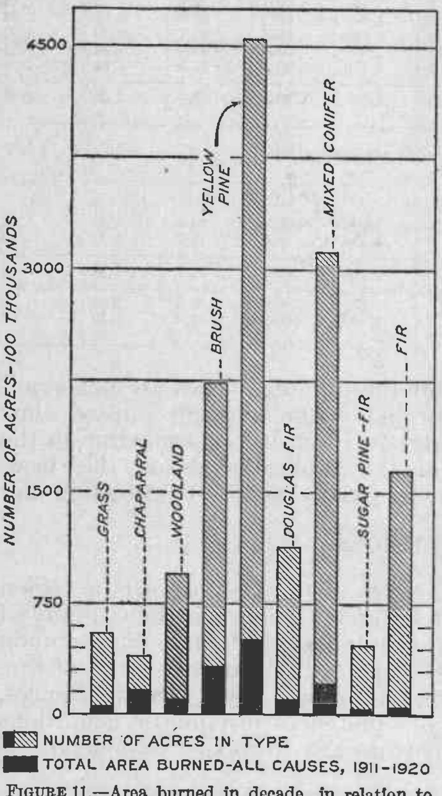


FIGURE 11.—Area burned in decade, in relation to total area of type, all causes, 1911–1920

If this study of forest cover as related to fire control did no more than point out these dangerous shortcomings in the present protection organization, the work would probably be fully justified. It is true that the investigations discussed here lead to no final mathematical expression of the differences between types nor of the corresponding changes needed in fire control. They do, however, yield indications that are vital in the perfecting of the protection organization. They point unmistakably to the types in which protective work must be immediately increased if forest values are to be preserved, and fairly definitely to certain means by which this end may be attained.

Type has been shown to be a factor in the number of man-caused fires and can well be taken into account in the application of any restrictive measures which are designed to prevent fires from starting, and which are directed against campers in general or against smoking in the woods. Where it appears desirable to close certain forest areas to all forms of use, a knowledge of type differences may be of considerable assistance in defining these areas. This knowledge may also be of value as a guide in the extension of such measures as that of removing fuels from along roads, trails, and railroads, or of building fire lines in areas of high hazard, breaking up brush area into blocks, or separating low-value chaparral from brush or commercial yellow pine.

The organization of forest-fire control on the national forests has reached a high level of effectiveness, considering the resources available for the task. But just as this particular analysis shows unmistakably that the needed minimum burned area was not attained, so a similar analysis of even the most recent years would lead to a similar conclusion. During the decade here reviewed, and thereafter, the conception of protection needs has expanded to include large systems of roads, trails, and ways in addition to lookouts, fire guards, patrolmen, and communication systems. The most economical and results-producing use of all these measures can be made only if the question "What hour control is needed in each area?" can be answered explicitly. This question can not be answered now.

In the current extension of the road and trail building programs to improve hour control where fire danger is greatest, existing knowledge of type differences is indispensable, but more exact measures of the magnitude of differences in terms of hour control are urgently needed. In the same way, the replacement of foot travel by horse travel, and of horse travel by motor, will be most economically effected when a full understanding of the actual hour control needs for various areas and types is available.

That this information can not be obtained easily and simply is shown by the results of this preliminary study. It is equally clear that the correct hour-control needs can not be set by judgment alone. A major conclusion of the investigation is that similar analyses should be prosecuted actively in the future. As more complete information on fires is obtained and analyzed, far broader and more specific recommendations for effective fire-control measures can be made than this initial study justifies. Future research should aim to relate cover type, not only to silvicultural systems and range use, but also to forest-protection needs, as a logical basis for allotment of funds, for regulating the intensity of protection, and for correct timing and location of special prevention and suppression measures.

ORGANIZATION OF THE
UNITED STATES DEPARTMENT OF AGRICULTURE

July 12, 1929

Secretary of Agriculture	ARTHUR M. HYDE.
Assistant Secretary	R. W. DUNLAP.
Director of Scientific Work	A. F. WOODS.
Director of Regulatory Work	WALTER G. CAMPBELL.
Director of Extension Work	C. W. WARBURTON.
Director of Personnel and Business Administration.	W. W. STOCKBERGER.
Director of Information	M. S. EISENHOWER.
Solicitor	R. W. WILLIAMS.
Weather Bureau	CHARLES F. MARVIN, *Chief.*
Bureau of Animal Industry	JOHN R. MOHLER, *Chief.*
Bureau of Dairy Industry	O. E. REED, *Chief.*
Bureau of Plant Industry	WILLIAM A. TAYLOR, *Chief.*
Forest Service	R. Y. STUART, *Chief.*
Bureau of Chemistry and Soils	H. G. KNIGHT. *Chief.*
Bureau of Entomology	C. L. MARLATT, *Chief.*
Bureau of Biological Survey	PAUL G. REDINGTON, *Chief.*
Bureau of Public Roads	THOMAS H. MACDONALD, *Chief.*
Bureau of Agricultural Economics	NILS A. OLSEN, *Chief.*
Bureau of Home Economics	LOUISE STANLEY, *Chief.*
Plant Quarantine and Control Administration	C. L. MARLATT, *Chief.*
Grain Futures Administration	J. W. T. DUVEL, *Chief.*
Food, Drug, and Insecticide Administration	WALTER G. CAMPBELL, *Director of Regulatory Work, in Charge.*
Office of Experiment Stations	E. W. ALLEN, *Chief.*
Office of Cooperative Extension Work	C. B. SMITH, *Chief.*
Library	CLARIBEL R. BARNETT, *Librarian.*

This bulletin is a contribution from

Forest Service	R. Y. STUART, *Chief.*
Branch of Research	EARLE H. CLAPP, *Assistant Forester, in Charge.*
Office of Forest Experiment Stations	E. N. MUNNS, *in Charge.*
California Forest Experiment Station.	E. I. KOTOK, *in Charge.*

U. S. GOVERNMENT PRINTING OFFICE: 1929