Can Southern California Wildland Conflagrations be Stopped?

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In southern California, many fires start and burn under conditions that permit their control with little burned acreage and fire damage. In contrast, under other conditions of weather and topography, on a small group of fires, control effort is relatively ineffective; they become large and destructive. A major reason for these "conflagration fires" is the extreme difficulty of stopping the head of a hot, fast-running fire in dry fuels and strong winds. No radically new concept of suppression can be anticipated. The best prospect for alleviation of the problem is modification of the vegetation to reduce fuel energy output. In a fuel-type mosaic containing large areas of light fuels, where conventional suppression will be effective, potential conflagrations could be brought under control while relatively small. Creation of the fuel-type mosaic will require coordinated area-by-area planning and a variety of techniques.

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The 1970 fire season was one of the worst in California's long history of disastrous fire seasons—certainly the worst in recent years. More than 500,000 acres of watershed and timber were burned, most of them in the short period between September 25 and October 4. The loss of 16 lives can be attributed to the fire activity. More than 700 homes and other structures were burned, and fire damage and suppression costs have been estimated at $233,000,000. The damages will continue to mount, since the threat of flood and erosion will continue until protective vegetative cover returns to the denuded watersheds—in some areas this will take many years.

California does not have an exclusive corner on the large-scale, high-intensity fires often called conflagrations or conflagration fires. In 1970, several such fires in Washington State destroyed extensive areas of timber. The Trapper Peak and Sundance fires burned in Idaho and Montana in 1967. Other regions also have large wildland fires from time to time. But conflagrations in other areas are usually infrequent, with several to many years elapsing between "bad" seasons. In California, large and devastating fires occur nearly every year. Statistics compiled by the U.S. Forest Service indicate that the California region consistently accounts for about 42 percent of the burned area and 55 percent of the reported damage in the National Forests within the contiguous United States. Most of the California conflagrations occur in the southern half of the State, the area south of the Tehachapi Mountains being particularly susceptible.

The gravity of the southern California fire problem has long been recognized. But despite years of effort by control agencies and research, the fires continue to occur with alarming regularity, and damages and suppression costs continue to grow.

This paper describes the causes and characteristics of the conflagration fires in southern California, and evaluates present and proposed efforts to find a solution. A unified program aimed at the one element of conflagration fires that can be practicably modified—the fuel—is outlined.

THE FIRE PROBLEM

Climate, Fuels, Topography, and People Create Fire Problem

Why are there so many fires in southern California? Primarily because the Mediterranean climate and a distinctive complex of topography and fuel create conditions favorable to major fires during every month of the year. The winters are mild, with infrequent short rainy periods. A long period without rain often extends from early spring to late fall or early winter. Steep and rugged mountains, cut by numerous canyons, border most of the major cities. Much of the mountain land is covered with a dense growth of flammable chaparral shrubs, such as chamise, manzanita, ceanothus, and scrub oak. On the lower slopes and foothills, this heavy growth gives way to lighter, but extremely flammable vegetation, such as sage, buckwheat, and various grasses and forbs. Some of the higher ridges are covered with conifers—mostly pine—interspersed with chaparral and grass. During the late winter and early spring growing season, the vegetation usually contains large amounts of moisture—providing there has been enough rain to start growth at all. But with the onset of the long rainless season, the annual plants die, and the shrubs lose much of their moisture. By September, some of the living plants, such as chamise, can be ignited with a match, and the dead and dry annuals can be touched off by a spark. After a fire, many of the plant species sprout prolifically, and others regenerate from seed left in the soil. Within 10 to 20 years, enough standing fuel has developed and dead material accumulated to permit the area to burn hot and fast again.

The great population influx into southern California has vastly complicated the fire hazard created by natural conditions. Residential subdivisions and individual houses have been pushing farther and farther into the mountains. Houses are often perched on ledges bulldozed into the steep slopes, or are crowded on sharp ridges and in narrow canyons. The conifer-covered ridges do not escape this influx—wherever private land is available, homes and resort communities abound. Campgrounds, picnic areas, and organization camps dot the public lands in these areas. The result is a fire control problem probably without parallel elsewhere in the world.

Relatively Few Fires Become Conflagrations

All fires that start in California do not have the potential for becoming large and damaging. Local variations in weather, fuels, topography, and the location of the fire may limit the rate and extent of fire spread, and create wide variations in the difficulty of fire control. And wildland fire control forces are highly effective. As a result, the vast majority of fires are controlled while still small. In the 5-year period ending in 1968, less than 1 percent of the fires on California National Forests became 300 acres or larger, and less than 4 percent larger than 100 acres. Even during the unusually severe conditions between September 25 and October 4, 1970, less than 5 percent of the fires reached 300 acres or more. It is the few fires that escape early control, however, that do most of the damage—80 to 90 percent of the total. And it is these fires that must be stopped if the southern California conflagration problem is to be solved.

Conflagrations Are Most Frequent During Santa Ana Winds

During most of the year, southern California has westerly winds and a marine climate. Hot days can occur almost any time during the year, but are most frequent during the summer and early fall. Because of the marine influence, the air is seldom excessively dry. Overcast days even in summer are not unusual. Relative humidity, and hence fuel moisture also, usually reach fairly high levels at night. Under these conditions, fires can usually be controlled when small—most within a short time after they start. Occasionally, however, when the weather is particularly dry or windy, a fire will escape early control and become large and damaging. Such fires are relatively rare under the marine climate, however.

Most of the large fires in southern California occur when the marine airflow is replaced by the föehn-type Santa Ana winds. Originating as cold, dry air high in the troposphere, these winds sweep down from the Great Basin area, warming by compression and becoming more dry as they come. Reaching the ground near the desert rim, they roar down the mountain slopes and canyons to the sea. Wind speeds may reach 100 miles per hour in exposed areas, and relative humidity frequently approaches the vanishing point. The rough, broken topography and high wind speeds create highly turbulent air flow in the many canyons. Wind direction in these areas may switch 180 degrees and back again in a few seconds.

The Santa Ana "season" ordinarily starts in middle or late September. Santa Ana periods increase in frequency during October and November and begin to taper off in December. A second peak in Santa Ana frequency may occur in March *(table 1)*.

Table 1—*Number of Santa Ana periods by months southern California 1951-60*

Month	Frequency	Average days
September	11	4.4
October	19	4.5
November	26	5.0
December	18	3.7
January	7	1.7
February	10	1.9
March	17	2.5
April	8	1.8
May	7	1.4
June	4	4.5
July	2	2.5
August	0	0

Santa Ana periods that occur in fall and early winter, before the rains begin, generally create the greatest conflagration hazard, as the moisture content of both dead and living fuel is then likely to be at its lowest ebb. Because of the rapid drying of all fuels under Santa Ana conditions, however, major fires can occur later in the year, particularly when winter rainfall is light. For example, three fires starting in the mountains at the edge of Los Angeles during a Santa Ana on March 16, 1964, burned a total of 11,650 acres, destroyed 20 houses, and severely damaged 10 others.

The Santa Ana winds usually follow a typical pattern of development and regression. In their initial phase, the strong winds reach the ground suddenly and follow the terrain configurations. The temperature is often high, and the relative humidity remains low both day and night. With these conditions, living fuels become parched and the dead fuels quickly become tinder dry. Because the dry Santa Ana air is relatively heavier than the more moist marine air, the winds tend to "channel," flowing through the mountain passes and down the main drainages. Between these areas the wind is often light. The initial phase of the Santa Ana can usually be measured in hours, but occasionally may last 2 or 3 days.

When the area on the lee side of the mountains fills with the dry, heavy air, and the offshore pressure gradient begins to weaken, the strong Santa Ana winds begin to lift above the ground, bringing some moderation in the wind speed at the surface. This process begins at low elevations first, and then progresses upward until only the higher slopes and ridges have the strong winds. The high-speed winds may surface again intermittently, particularly at night. Where winds are light, thermal up-slope and up-canyon airflow will develop during this phase of the Santa Ana, as it normally does under the marine climate. The air remains extremely dry, however, and the wind over the ridges is opposite in direction to marine airflow. This phase of the Santa Ana lasts for varying times—usually 2 or 3 days, but sometimes a week or more.

As the offshore gradient continues to weaken, the marine air begins to intrude again, first along the coast, and then pushing further inland as onshore pressure gradient builds. Although burning conditions in this phase of a Santa Ana have been greatly moderated, it is a period of high hazard for firefighters. In the area where the marine and Santa Ana air meet, the wind can be highly variable in speed and direction. The fuels remain extremely dry, and fires can flare up quickly and move rapidly, particularly in rough terrain. Most firefighting accidents in southern California occur during this phase of a Santa Ana. Finally the Santa Ana winds cease, the fuels begin to pick up moisture from the marine air, and normal weather conditions again prevail.

Suppression of Santa Ana Fires is Difficult

Controlling a fire that starts in a wind affected area during the initial phase of a Santa Ana is an enormously difficult task. The dry fuels permit fires to start easily and build up quickly. Within a few minutes spot fires begin to appear. The fire is then so widespread that it is usually beyond hope of control by initial attack forces. Driven by the strong wind, the fire spreads rapidly. It is not unusual for a fully developed fire in chaparral to enlarge at the rate of 4 to 6 square miles per hour during the initial phase of a Santa Ana. Spot fires are numerous, sometimes up to a mile ahead of the main fire and occasionally as much as 4 miles. Because of the spot fires, rough topography, and turbulent wind, the fire front is often extremely ragged—the effective fire front may be very deep, with rapidly enlarging spot fires and moving tongues of fire as much as a mile ahead of the main body of fire. The smoke from the fire is held close to the ground by the wind, cutting visibility to near zero in many areas.

As the fire grows, so does the difficulty of controlling it. Barriers that could have been used by firefighting crews to make a stand against a fire under the marine climate become ineffective as a hail of burning embers is driven into the unburned fuel ahead of the fire—Santa Ana fires have been known to cross freeways without slowing. Long distance spotting becomes more prevalent as the fire enlarges. Dense smoke, and blowing sand, dust, and ashes make control work slow and arduous. Because of the rapid fire spread, numerous spot fires, poor visibility, and the large and deep fire front, the hazard to the firefighting force is extreme. Some of the usual firefighting tools and techniques also become ineffective.

Thus, the fire often continues to spread rapidly with the wind until the fire head runs out of fuel or the initial phase of the Santa Ana ends. But even then, the fire is not over. Control forces are still faced with the monumental task of constructing many miles of fireline to stop the lateral and rearward spread of the flames. If the wind continues, additional rapid fire runs, parallel to the initial run, may occur. Because of the rugged topography, access to the fire edge is nearly impossible in many places, and feasible locations for control lines are few and far between. Also, considerable time is required to construct effective control lines. As a result, the fire may double or even triple in size during the final control operations, even though burning conditions have moderated.

Usually, little can be done to stop the head of a fire during the initial phase of a Santa Ana, but effective work is often possible at the rear and much of the flanks of the fire. Because of the strong wind, large sections of the rear of the fire oftentimes go out, and frequently the flanks are relatively free of many of the problems that plague firefighters at the head of the fire. Thus, it would appear that if firefighting efforts were concentrated on the rear and flanks of the fire, control could be effected soon after the head of the fire stops. And this technique is frequently used in other areas where fires burn under strong winds. Unfortunately, however, the "people" problem often precludes the effective use of this strategy in southern California. In this area it is now unlikely that a fire can become large without homes, communities, and various other improvements being in its path. Because of this threat, it is frequently necessary to divert a large part of the available control force to the evacuation of people and the protection of structures and improvements. Often only token effort can be made toward control of the rear and flanks of the fire until the fire head stops. This problem becomes particularly acute when several major fires are burning at once and fire control forces are thinly spread.

FIRE CONTROL AS A SOLUTION

Much effort has been devoted to the abatement of the conflagration fire problem through improved fire control, and further endeavors in this area are being made or have been proposed. They include fire prevention activities, development of organizational structures and procedures for multifire and multiagency fire suppression, increases in fire control forces and their efficiency, and improvements in firefighting techniques and equipment. Over the years, substantial increases in the effectiveness and efficiency of fire control operations in general have been achieved. No apparent drop in the number of conflagration fires has resulted, however, and the economic and human losses directly attributable to these fires continue to mount. There are several reasons for this condition.

Fire Prevention Has Limited Value

Fire prevention has received considerable attention as a possible means of eliminating or reducing the number of conflagration fires; obviously a fire that does not start will not have to be controlled. During the critical fire weather period of September 25 to October 5, 1970, the fire control agencies greatly intensified their fire prevention efforts. This action undoubtedly prevented many fires that would otherwise have further overloaded the fire control forces. But fire prevention programs appear to have little effect on those indifferent to the consequences of careless use of fire and fire starting agents. Arson fires are not susceptible to fire prevention programs, and neither are accidental fires such as those caused by motorized vehicle and other equipment accidents. Despite intensive fire prevention in 1970, the number of fire starts set a record.

All fires do not have conflagration potential; fires starting in some areas and from some causes are more likely than others to become conflagrations. Although fire prevention programs may reduce the total number of fire starts, even the best of fire prevention is not likely to significantly affect the number of fire starts that can become conflagrations.

In one area, however, fire prevention action could have significant impact. In California during 1970, about 55 percent of the burned area resulted from fires started by powerlines. In southern California, the figure was 68 percent, and included some of the most devastating fires. Although these 1970 figures were probably higher than normal, powerlines are known to be consistently a major cause of conflagration fires. Usually caused by strong winds, most such fires start in extreme fire weather, and often in exposed areas of difficult access. Almost all powerline fires are started by secondary or "feeder" lines, not the major transmission systems. New types of conductors and techniques to put these powerlines underground have been developed. Application of this technology could virtually eliminate powerline fires and would substantially reduce the burned acreage in southern California—perhaps by as much as 50 percent.

Effect of Organizational Problems on Fire Size is Small

In southern California, several fire control agencies often must work together and provide mutual assistance during fire control operations on large fires and during multiple fire situations. The mutual aid between agencies in this area is perhaps the best anywhere in the nation, and it has been effectively used many times. It is probably inevitable, however, that some problems will arise between agencies that differ in organizational structure and power to act—especially during the confusion of multiple fires of major proportions.

Changes in fire control organization and procedures, particularly for critical fire situations, have been considered as a means of reducing the conflagration fire problem. Studies aimed at the development of sophisticated organizational structures and of techniques and procedures for highly centralized control of fire suppression operations have been undertaken. But interagency problems have been largely procedural and administrative. They have had little effect on the number of conflagration fires or the area that they burn. Thus, although more sophisticated organization and operational procedures may possibly effect more economic fire suppression, this line of attack does not appear to hold much promise for abatement of the conflagration fire problem.

Firefighting Techniques and Equipment Are Not Adequate

A fire that starts in an exposed area under a strong wind and dry fuel conditions, and with extensive areas of dense chaparral ahead of it, has a high probability of becoming a major fire unless it is suppressed almost immediately. Most chaparral fuels have nearly ideal characteristics for rapid combustion under dry and windy conditions, and the heat energy produced by a large and rapidly moving fire is tremendous. For example, a fire enlarging at the rate of 4 square miles per hour will produce 400 to 800 *billion* Btu's of heat per hour—about the same as burning 3 to 6 million gallons of gasoline. And the greatest heat production is at the head of the fire. Because of the enormous energy output of an intense chaparral fire, present fire suppression methods and equipment are generally ineffective in stopping the head of a hot, fast-running fire in a strong wind. *This is the primary problem in the control of conflagration fires.*

Fire suppression methods have not changed basically since organized fire control began; equipment and techniques already in use have been improved and modified. Thus, bulldozers and other mechanical equipment are now used for much of the firebreak construction that was formally done manually, but firebreaks still remain the basic fire control method. Fire tankers and portable pumps have replaced the bucket brigade, and these have been supplemented with aerial delivery of water and fire retardants. Chemical retardants have been used in fire suppression since ancient times, but today better formulations and delivery methods have made their use more widespread.

Further improvement in firefighting techniques and equipment has been strongly supported in the search for an answer to conflagration fires. For example, soon after the 1970 fire disaster, the suggestion was made that massive air attack with fire retardants would provide quick control of conflagration fires. Over-all, however, the potential for "victory through air power" does not appear bright. The use of air tankers in the conditions in which conflagration fires burn is beset with difficulties. The hazard of low-level flying in rough terrain and turbulent winds may often preclude the use of aircraft at all. Air tankers do not provide an efficient method of retardant application; a sizable part of the retardant delivered is wasted—even under favorable conditions. And on the many spot fires and deep ragged front of a conflagration fire, delivery of extremely large volumes of fire retardants or water is required for any significant effect on fire behavior.

The effectiveness of fire retardants also decreases rapidly as fire intensity increases. Fire retardants are just that; they can be used to retard or slow a fire, but seldom extinguish it even under moderate burning conditions. It is essential that fire crews and equipment be able to work on the fire edge very soon after the retardant is applied if fire spread is to be stopped and the retardant drop is to be of any value. In conflagration fires, the opportunities to do so are usually limited to the flanks and rear of the fire because of difficult access and the extreme hazard at the head of the fire. Like other fire control techniques, air attack is stymied by the nature of the conflagration fire and the conditions under which it burns.

Quick control of conflagration fires will probably require a radically new concept or technique in fire suppression. Such a breakthrough is not imminent, and it is improbable that one will appear soon. Suppression of conflagration fires does not appear amenable to solution with present technology.

Increased Fire Control Force Is Only a Partial Answer

Public wildland firefighting forces in southern California are probably the best of their kind in the world. Well trained and well led, and with a large amount of generally good equipment, they do an extraordinary job of suppressing fires and protecting property in difficult and hazardous situations. Without a firefighting force of this quality, losses from wildland fires would be vastly greater. But higher wages, greater operating and equipment costs, and appropriations that have not kept pace with these rising costs, are resulting in erosion of the strength and quality of public firefighting forces. Highly trained and experienced initial attack crews are becoming smaller or fewer in number. Some firefighting equipment cannot be fully manned, or cannot be used at all because of lack of manpower. The effect of this shrinking firefighting capability is felt most when critical fire weather and numerous fires occur over wide areas. When this happens there are not enough fire crews and equipment to handle the situation, and some fires become large that otherwise could have been stopped when small.

On the National Forests, the manpower problem has recently been ameliorated to some extent by increased authorization to use emergency firefighting funds during the fire season. But this must be considered a stop-gap measure—it does not provide the cadre of well trained and experienced firemen needed to direct season personnel and to insure safety and efficiency in firefighting.

Since present firefighting techniques are not generally effective in stopping the head of a conflagration fire, most of the effect of strengthened firefighting resources can be expected for non-conflagration situations. And fires under such conditions account for only 10 to 20 percent of the burned acreage. The impact on conflagration fires is not likely to be great. Many of the fires that start during Santa Ana and other severe fire weather are beyond hope of early control before firefighting forces can reach them—some before they are discovered—because of rapid spread, difficult access, or both. Under these conditions, it simply is not economically feasible to have enough crews and equipment to stop all fires immediately after they start; the protected area is too large, the access too difficult, and the number of days during the fire season they are really needed in large numbers too few. While augmented fire control resources can ease the strain on firefighting agencies, reduce the number of fires and burned area for nonconflagration situations, and possible effect earlier control of some conflagrations, the final answer to the conflagration fire problem is not likely to be found in more men and equipment alone.

A SOLUTION THROUGH FUEL MODIFICATION

If conflagration fires cannot be prevented from starting, and cannot be controlled before becoming large, must such fires be accepted as inevitable in southern California? I think not. The behavior of wildland fire is determined primarily by the weather, the topography, and the fuel. Little can be done about weather or topography. But wildland fuels, which supply the energy that makes some fires uncontrollable, are subject to modification and management. Limited fuel modification is, in fact, the basic principle of most control methods now in use. Depriving a fire of continued energy by removing all of the fuel in a band or firebreak around the fire, or putting water and chemicals on the fuel so that it will burn slowly or not at all, is fuel modification.

People have been changing the characteristics of vegetation as a fuel, intentionally and unintentionally, since prehistoric times. World-wide, vast areas have been cleared of native vegetation to provide farming and grazing lands, and sites for cities. Today, road construction, timber harvesting, silvicultural practices, grazing use, watershed development, recreational use, wildlife management practices—all result in modification of wildland fuels. In some areas, man-made air pollution has altered the vegetation and added to the amount of high flammable dead material. Man-caused fires quickly change the vegetation, and repeated fires may effect long-term changes in the fuel characteristics. Fire prevention and quick control of fire in areas where fires have occurred naturally in the past can result in the build-up of flammable vegetation that makes fires more intense and damaging when they do occur.

What kind of fuel modification is needed to stop southern California conflagration fires? The crux of the problem is the high energy output of chaparral fuels in extreme burning conditions. When a fire reaches an extensive area of low fuel loading, or slow-burning fuel, or where the chaparral is interspersed with such fuel, the energy output drops over the fire front or at least many segments of it. Fire suppression methods then again become effective along much of the fire front, and firefighting forces can safely concentrate effort on the few relatively high-intensity sections and can take quick advantage of lulls in burning conditions. *What is needed then, is to create a fuel complex whose energy output even in the worst burning conditions is low enough to permit firefighting forces to contain the fire.*

Fuel modification is an accepted practice to reduce fire hazard and to aid in fire control. In timber areas, debris left from logging and silvicultural treatments is often reduced by burning or mechanical treatment. Prescribed fire is used in forest stands in the southern United States and some parts of the West to reduce the amount of fuel. In some regions, extensive areas of brush have been converted to grass or timber.

Although some fire control experts have long recognized the extensive areas of heavy chaparral as the primary cause of southern California's conflagration problem, no comprehensive plan has been put forth to reduce the hazard through extensive fuel modification and management. The disastrous 1970 fire season, however, and the growing realization that further large increases in fire control and fire prevention may not be helpful, have focused attention on fuel modification and management as a solution. Several approaches have been proposed or undertaken.

Rotational Burning Creates a Mosaic of Age Classes

Rotational burning is one method of fuel modification that has recently been strongly recommended for southern California. After a wildfire, chaparral does not burn easily again until the shrubs have regrown and dead fuel has accumulated. This regrowth may require 10 to 20 years or more, depending on the weather, soils, and intensity of the wildfire. In an area that has been subject to numerous fires over a period of years, the chaparral tends to appear in a mosaic of age classes, some parts of the mosaic not having sufficient fuel to support an intensive fire. If the mosaic contains enough areas of young chaparral and these areas are favorably distributed, conflagration fires are unlikely, as the large expanses of heavy fuels needed for such fires are lacking. Under the rotational burning concept, the mosaic of age classes would be artificially created by intentionally burning portions of the area each year under conditions in which a fire can be controlled and confined to a desired size. The mosaic is to be maintained by repeated burning at intervals sufficiently short to prevent accumulations of highly flammable material.

This general technique has been successfully applied for many years in the pine timber stands of the Southern States, where low intensity fires are used at intervals to remove accumulated dead material and unwanted understory vegetation. It has also been extensively applied in the eucalyptus forests of Australia.

But chaparral stands are not the same as timber stands. Although rotational burning is a valuable technique for fuel modification in the areas for which it was developed, its application to southern California chaparral presents certain problems.

Adverse Effects

Southern California chaparral can become flammable enough to burn intensely within 20 years after a wildfire. Hence, for rotational burning to be effective, the interval between prescribed burns must be short—perhaps 15 years or less. Wildfires seldom burn an area with this frequency; it is more probable that 40 to 50 years will elapse between successive large fires over the same area—some areas have not burned for 70 years or more. Because of the shorter time between burns, the average annual burned area can be substantially greater under a full rotational burning program than without. Thus, rotational burning will not necessarily reduce the amount of area burned; it may just replace a few large fires with numerous smaller ones.

Loss of buildings and other improvements directly from prescribed fire is unlikely. Flood and erosion damage, impairment of water quality, air pollution from smoke, and similar undesirable fire effects will occur from prescribed burning, however, just as from wildfire. Esthetically, rotational burning is not likely to be much of an improvement over wildfires—a few large fire scars will be replaced with many smaller ones. In time, the accumulated adverse effects of rotational burns may not be smaller—and may even be greater—than those that would occur from wildfires.

High Costs

Unlike timber stands, much of the chaparral in southern California has little readily burnable surface fuel. Most of the fuel is standing, and a large part of it—65 to 85 percent—is living, with high moisture content. The dead fuel is fairly uniformly distributed through the living material. The chaparral fuel beds are also quite porous—a little solid material occupies a large volume of space. For example, in a typical stand of chamise 6 feet tall, to total standing fuel is equivalent to a solid layer less than one-fourth inch thick. With these characteristics, southern California chaparral does not burn easily in its natural condition unless the burning conditions are well up in the scale of severity—relatively dry fuels and at least moderate wind speeds.

Under such circumstances, fire burns and spreads just as hot and fast outside a planned burn area as inside. Thus, prescribed burning in the natural fuel would require considerable prefire firebreak construction and a sizable control force on hand during the burning to reduce the risk of escape fires to an acceptable minimum. This would be costly, and the costs would recur each time the area is burned. There are also relatively few days during the year when the fuels are dry enough to burn well and burning conditions are such that risk of fire escape is not excessive. Hence rotational burning over an area the size of southern California would require that manpower and equipment be available in quantity.

To increase the amount of fuel consumed and to allow effective burning during periods when vegetation will not normally burn, the chaparral may be treated. Mechanical crushing of part or all of the brush in place is most effective. This reduces the fuel bed porosity and decreases the moisture content of the living material to a point where it will burn well. Herbicides or desiccating agents to increase the amount of dead and dry material may also be used. But these treatments materially increase costs, and also must be repeated each time the area is burned.

Possible Increased Fire Hazard

Whether rotational burning in chaparral will actually reduce the fuel loading and fire hazard for more than a short time is open to question. Wildfires during severe burning conditions remove a large part of the fuel; in the more intense fires nearly all of it is burned. Under the moderate conditions in which prescribed fires must be conducted, the aboveground portions of most of the shrubs will be killed. But of such material, only the portions less than one-half inch in diameter can normally be expected to be consumed by the fire. In the dry southern California climate, little of the dead and standing shrub skeletons will decay before the next prescribed burn. Thus, rotational burning can add to the amount of dead fuel present—the fuel that is so important in determining the flammability of chaparral.

The possible long-range effects of rotational burning on fuel characteristics must also be considered. Fire has long played a role in the species composition of southern California chaparral. Those species that could not withstand occasional fires were simply eliminated. When lightning was the main source of ignitions, most fires were probably small and burned with low intensity, since lightning is usually associated with poor burning conditions and also tends to occur in the same general areas. Although it is likely that there were some large fires, it is also likely that most of these burned with low or moderate intensity, because the development of the weather and fuel moisture conditions needed for intense fires following an ignition by lightning is a rare event. But with the advent of man-caused fire sources, the fire potential has changed. Man-caused fire ignitions now occur much more frequently than those from lightning, and often occur when intense fires can develop.

The intensive fire protection which has kept the number and frequency of large fires low despite the large number of fire starts, is sometimes cited as the cause of fuel buildup and conflagration fires. There is little evidence, however, that the fuel buildup was less and that the chaparral lands of southern California burned over more frequently under the lightning fire regime than under present conditions. Rather, the low- or moderate-intensity lightning fires appear to have been replaced with high-intensity man-caused fires.

Since man has become the primary fire starting agent, it is quite probable that the species composition of the chaparral has been changing. Species that can survive occasional low- or moderate-intensity fires can be eliminated by repeated high-intensity fires, and such fires now burn most of the area. For example, there is some indication that the hard chaparral in some areas is being replaced by buckwheat and sage, which burn hot and have an extreme rate of fire spread. Long-lived species, such as big-cone spruce, that withstood earlier fires are disappearing.

To be effective, rotational burning must be done at intervals that are shorter than wildfires are likely to burn the same area. Prescribed fires will generally be of lower intensity than conflagrations, but the repeated burning at short intervals can be expected to increase the fire stress on the chapparal and the species composition may move to a more flammable type.

Although rotational burning, in concept, may seem an appropriate step toward alleviation of the conflagration fire problem, the difficulties of putting the method into practice and its potential adverse effects suggest that its widespread use in southern California may be inadvisable. Rotational burning should probably be confined to situations where other and more permanent fuel modification is not feasible.

Fuel-Breaks Provide Strips of Modified Fuel

During the 1930's, a program was undertaken to break up the extensive areas of chaparral in southern California through a system of firebreaks. Along many of the major ridges all fuel was removed in a band 300 to 500 feet wide, and lesser firebreaks of the same type were constructed along the spur ridges. The primary purpose of the firebreak system was to provide barriers that would stop the spread of fire without the necessity of using fire crews in hazardous situations or in areas of difficult access. This attempt at conflagration control had disadvantages, however. The firebreaks were expensive to construct and maintain even with the relatively low cost manpower supplied by the Civilian Conservation Corps and similar programs. The swaths cut through the chaparral were unsightly, and erosion from the bared soil was a major problem. Perhaps most important, the unmanned firebreaks failed to stop the spread of fire in the conditions under which conflagrations occur. With the termination of the emergency labor programs, the firebreak concept was largely abandoned.

When the difficult fire season of 1955 again emphasized the problem of extensive areas of chaparral without adequate access, the general concept of preconstructed firebreaks was revived; but with important differences. Now, instead of leaving the treated areas completely devoid of vegetation as was done in firebreak construction, the tall and dense chaparral is removed and replaced with vegetation that burns less intensely—usually grass. Only a narrow strip near the middle of the modified band of fuel is kept free of vegetation to serve as an access way and a place where backfiring or burning out can be started. The edges of the band are usually made irregular and a few shrubs may be left within the band to give a more natural appearance. These modified bands or "fuel-breaks" vary in width, but are usually 100 to 400 feet wide and are strategically located for fighting fires. Their chief value comes from the rapidity with which a fire barrier can be made in the light fuel, either by removal of the vegetation with manpower and equipment, or more often by burning the fuel in advance of the wildfire.

Fuel-breaks are intended to be manned for use in fire control. But like the firebreaks that preceded them, they are not effective in stopping the head of a hot, fast-running fire in a strong wind. As the band of modified fuel is relatively narrow, the hazard at the head of the fire is still great; often precluding manning of the fuel-break at all. And the spotting problems, along with the difficulty of safely burning out even light fuel in adverse wind conditions, frequently makes fuel-breaks an ineffective barrier to fire in extreme conditions.

A considerable number of miles of fuel-breaks have been constructed. But because of their limitations in fire control, and also because they are generally widely spaced, fuel-breaks have not had a great impact in reducing the burned area or damage caused by conflagration fires. Fuel modification of this type can be effective for less than severe conditions, however, and on some parts of conflagration fires. And a more intensive fuel-break system than presently exists could broaden their usefulness. But fuel-breaks alone are not a complete answer to conflagration fires.

Fuel-Type Mosaics Can Lower Energy Output

The basic philosophy of both fuel-break construction and rotational burning—the replacement of dense chaparral with low energy fuels—holds promise for solution of the conflagration fire problem. In practice, however, each method has limitations. The best approach to conflagration control through fuel modification appears to be the creation of a mosaic of fuel types rather than the mosaic of chaparral age classes envisioned in rotational burning. Extensive areas of chaparral can be broken up by areas of low-energy fuels, thereby providing the fuel situation in which fire suppression techniques are now effective in conflagration conditions. Native chaparral will still be present, but will tend to appear in "islands" rather than uninterrupted stands.

The primary purpose of wildland fire control is the minimization or prevention of fire damage; if fires did not do damage there would be no need to suppress them. Because it is unrealistic to expect that all fires can be prevented, some fire damage is bound to occur even with the best of fire control and any reasonable type and amount of fuel modification. The fuel-type mosaic is designed to assure the control of a fire before it can do an unacceptable amount of damage. The amount of fuel modification needed, then, is partly determined by the direct and indirect fire damage potential in any given area. For high-value watersheds, the acceptable fire size may be less than 100 acres, while in areas of low fire damage potential, burns of several thousand acres may not represent intolerable damage.

Fire behavior also determines the amount and kind of fuel modification required, and this is controlled by the weather, the fuels, and the topography. Topography varies widely over southern California, and local weather also varies greatly from place to place even under severe conditions. Natural fuel patterns are controlled largely by the soils and climate and these are also variable—some areas cannot support the kind and amount of vegetation that creates a conflagration hazard. In some areas little or no fuel modification will be needed, in others the conventional fuel-break will be adequate, and in still others the fuel modification must be extensive to keep the fire damage within acceptable limits. The amount and kind of fuel modification, then, must be determined by a broad survey of southern California.

Fuel-Type Mosaics Can Be Created in Many Ways

The opportunities and methods for developing fuel-type mosaics are numerous. Where soils and climate permit, chaparral can be replaced with grass as it often is on fuel-breaks. Low-volume and slow-burning plants adaptable to harsh sites are being sought out and developed through research and can be used to replace native vegetation—some plantings have already been made. Use of waste water to irrigate selected plant species to create "green belts" of hard-to-burn vegetation has been demonstrated to be feasible. Thinning of native vegetation to develop recreation areas, such as campgrounds and picnic areas, when combined with modification of fuel on adjacent areas can provide zones where fire can be readily stopped. Golf courses and land planted to useful crops make excellent fire barriers, and encouragement through zoning, tax policies, or subsidies of the use of private land in selected areas for these purposes will aid in the development of fuel-type mosaics.

Many communities in southern California now have ordinances requiring the clearing of dense vegetation from around structures. Along with these ordinances have come intensive education and information programs for homeowners in landscaping techniques to lessen the fire hazard to their homes, and in self-help measures that can be used to help protect their property from wildfire. When applied, all these have been effective in reducing fire losses. Most fire control agencies would like to see existing ordinances strengthened and expanded to include provision for adequate water supplies and access roads for firefighting in housing developments in wildlands, and also to include requirements for fire-resistant building material and construction. There is also growing interest in revamping zoning regulations to prevent building at all in areas where protection of structures from fire would be extremely hazardous and difficult, if not impossible.

Although fuel reduction around individual structures can be effective in reducing fire losses, this action does little to reduce fire size, since the modified fuel areas are seldom continuous enough to provide an adequate fire barrier. But the fuel reduction measures could be expanded community-wide, extended into adjacent wildlands, and combined with adequate access roads, water supplies, and fire-resistant buildings. Then areas so modified would be relatively safe from wildland fire, and would also provide a barrier to the spread of conflagrations. In effect, housing developments in wildlands could become an asset to conflagration control instead of a liability.

In southern California, compared with other parts of the State, relatively little effort has been made to convert chaparral to grass, particularly on public lands. Mainly this is because suitable areas for conversion are generally too small and grass production too low to make their use attractive for grazing–the economic benefits gained from grazing use alone do not offset the conversion and maintenance costs and the costs of handling livestock in small and scattered areas. But for grass areas to be most effective in conflagration control, the volume of grass must be kept low. An effective way to do this is through livestock grazing. Thus, a land management policy for public lands allowing for free or subsidized use of converted chaparral lands could be justifiable in the interst of fire control.

Few chaparral shrubs are palatable to livestock or game; hence fuel reduction or modification through livestock use is not generally workable. Many of the saltbrush species, however, including natives, are highly palatable and nutritious–some have a nutritional value comparable to alfalfa. Because of their high mineral content, the living material in most saltbrushes burns slowly, and they are well adapted to harsh sites. They develop considerable dead material with age, however, and can become nearly as flammable as chaparral when mature. But managed livestock use of chaparral lands converted to saltbrush can keep both the amount of dead material and total fuel loading low. Hence, free or subsidized use of such lands can result in an effective and durable conflagration barrier.

Similarly, low-cost leasing or subsidized use of public lands for agriculture, or for recreational development by private interests, where the area affected can be of sufficient extent, would encourage the chaparral modification needed for conflagration control.

Fuel-Type Mosaics Are Not a Quick Cure

In an area the size of southern California, development of fuel-type mosaics cannot be accomplished in a short time. Means of financing must be found, and enabling legislation and policies may have to be formulated to permit effective development of some types of mosacis. And public acceptance of such widespread changes in the wildlands must be obtained.

First, costs of fuel-type mosaics are likely to be high. But besides quick control of fires during severe conditions and substantial reduction of fire damage, important side benefits can accrue. Recreation opportunities should be increased, wildlife habitat improved, more forage produced, and in some areas water yield increased. When properly planned, fuel-type mosaics can also result in a more pleasing landscape than extensive areas of a uniform vegetative type.

Because fire damage is the major consideration in fire control, first priority in the development of fuel-type mosaics should be given to areas where fire damage is likely to be great. When these are reasonably secure, the mosaics can then be expanded to areas of lesser damage potential. It is possible that in some areas adequate fuel-type mosaics cannot be created because of extremely steep terrain and poor soils. In these, rotational burning may be judiciously used.

Complete and Coordinated Planning Is Essential

In essence, the envisioned fuel modification will replace the present wildland vegetation patterns with planned and managed ones. To achieve this, complete and coordinated plans must be developed. As fire does not recognize administrative boundaries, such planning will involve not only fire control agencies, but also local governments, land use planning commissions, and sometimes private interests. Social, economic, land use, and environmental impacts must be determined and evaluated, and the best combinations of fuel modification to achieve adequate fuel-type mosaics for a given area established. Inputs into these plans will be needed from fire control and fire behavior experts, meteorologists, land-use planning specialists, economists, landscape architects, plant ecologists, biologists, recreation planners, and wildland research groups.

Much of the technology needed to create fuel-type mosaics is now available, is being developed, or is susceptible to development through research. Many of the techniques by which type conversion can be done have been demonstrated to be feasible. What is needed now is a comprehensive action plan that will effectively bring this technology to bear on the one factor controlling fire behavior that can successfully be managed and manipulated–the fuel.

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To some, the extensive "monkeying with nature" required to replace the present wildland vegetation patterns with planned and managed ones may seem abhorrent. But the impact of man and man-caused fires has already had a massive effect on the natural vegetation, so much so that it is difficult if not impossible to specify what a "natural" vegetative pattern in southern California really is. And this impact will continue as long as conflagrations are a part of the environment. The only alternative to planned and managed vegetation patterns in southern California appears to be acceptance of the great economic damage, threat to human life, and the unpleasant esthetic and environmental effects of unmanageable wildfire.

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