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The Influence of Fire on California's Pristine Vegetation

- - A Consideration in Controlled Burning.

L. T. Burcham

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## THE INFLUENCE OF FIRE ON CALIFORNIA'S PRISTINE VEGETATION

L. T. Burcham\*

Range lands and forests are among the most valuable of California's natural resources. Livestock grazing was the first industry in the state; forests supplied building materials and other products from the beginning of settlement. These resources have continued to make important contributions to our growth and economic wealth. During recent years a great deal of attention has been given to developing better practices for managing range lands and forests, to maintain and increase their natural productivity.

For many years ranchers have faced a problem of brush encroachment on their grazing lands. They have endeavored to increase production of these lands by eliminating stands of dense brush, seeding improved forage plants, and improving management of grazing animals. In many instances it has been feasible and economical to remove stands of brush by burning. During the last fifteen years brush has been burned under permit--commonly referred to as "controlled burning" or "control-burning"--by ranchers, in a large number and variety of range improvement projects (Calif. Div. of Forestry, 1959). Much research has been undertaken by public agencies to develop effective and economical methods of range improvement. Many of these studies have included controlled burning at one or more stages.

Because brush encroachment is a problem in some forest areas also, burning has been tried limitedly in California for clearing forest sites for planting. Other studies have been attempted, to investigate the possibility of controlled burning for disposal of logging slash and reduction of fire hazards, development of game habitat, removal of brush from watersheds in attempts to increase water yield, and in other phases of resource management. But only a few of these studies have been directed specifically toward developing sound facts on the applications of fire to wild land management--probably none has been directed exclusively

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Assistant Deputy State Forester, Range and Watershed Management, California Division of Forestry, Sacramento. Based on a talk before the Sacramento-Tahoe Forest Forum, Auburn, California, January 16, 1959.



toward the use of fire in accomplishing land management goals.

Although early results of these practical projects of ranchers and research studies of public agencies have varied greatly, considerable interest has been aroused in the use of fire for managing range and forests. Favorable results have been obtained in sufficient cases to convince many laymen and some research workers that controlled burning is a practice which should be used widely for wild land management in California. Advocates of the use of fire argue that it is a cheap, efficient means of removing brush and preparing a seedbed on range lands; that it can be used in forests to eliminate accumulations of logging slash, clear dense thickets of competing understory shrubs, and thin stands of young growth timber. It also is stated that burning brush and slash on range and forest lands would eliminate fire hazards and reduce danger of incendiary fires, increase water yield, improve game habitat, and enhance watershed protection and conservation.

Much of the belief that fire would be extremely useful for these purposes stems from traditions that the Indians of California did a great deal of burning in grasslands, chaparral, and forests before the state was settled. It is believed, too, that natural fires were frequent and widespread. Brush areas were kept to a minimum and forests maintained in an open, parklike condition by this burning, it is said, and devastating fires were thus prevented. It also is argued that frequent fires constituted an important ecological factor in development of the plant cover, without which the important species could not reproduce and develop properly. Therefore, it is stated, burning of forest and range lands at relatively frequent intervals is required for best management of these resources, to insure their proper growth and to protect them from destruction by wild fires.

A detailed analysis of the records confirms these concepts as originating from extensive burning by prospectors, stockmen, settlers, lumbermen, and others during a period extending from gold discovery in California until the early 1900's. Vast areas of grassland, chaparral, and forest were burned during these years--by many people and for many different reasons (Barrett, 1935; Calif. State Board of Forestry, 1888). This extensive burning, together with disturbances due to mining, grazing, lumbering, and settlement, had far-reaching effects on composition of natural plant cover over large tracts of land. Particularly in the foothills and coniferous forests, the landscape was so altered that the original character and condition of the natural vegetation quite generally have been misunderstood.



Before reaching conclusions as to whether controlled burning is a practice suitable for general use in managing California's forest and range resources, we should attempt to establish clearly the character and condition of the pristine vegetation, before it was modified by actions of white men. A number of other factors that help determine the effect of fire on vegetation development should also be examined. Another question requiring review is the probability that Indians had need and knowledge to burn large tracts of land purposely, or were physically capable of doing the job. Three principal sources of evidence are available for this analysis: Records of the earliest settlers, fur trappers, and Spanish expeditions in California; studies made by anthropologists; and field observations and research by foresters, plant ecologists, and other scientists.

### Pristine Vegetation in California

References are commonly made to great expanses of grassy plains, extensive tracts of open parklike forests, and the limited extent of chaparral in California during the period from fifty to one hundred years ago. But the character and distribution of plant cover found by the earliest European travelers in California have not been clearly revealed. The combination of sources previously mentioned offer the best opportunity for establishing the nature of our pristine vegetation.

The first detailed knowledge of California comes from diaries kept by members of the Portolá Expedition in 1769. Between July 14, 1769, and January 24, 1770, Portolá traveled from San Diego to San Francisco and returned. Three diaries of the travels of this expedition along the coast and through the mountains of the South Coast Ranges are available: one by Portolá (Portolá, 1909); one by Miguel Costansó, the engineer who accompanied him (Costansó, 1770); and one by Fray Juan Crespi, the missionary friar (Bolton, 1927). Entries in Portolá's diary are succinct--concerned chiefly with distances traveled, availability of pasture, and abundance of water for his men and animals; evidently the published version is either the actual diary he kept on this trip or a copy made without elaboration. Both Costansó and Crespi record a greater amount of detail. Costansó evidently was concerned with directing the scouts who went ahead to seek a route, and who cut a road through brush and forests, prepared crossings over steep-sided arroyos, and built at least three bridges for crossing streams or washes; but Costansó tells us chiefly what he saw and what he did.

The diary of Crespi is most voluminous of the three. Evidently he traveled with the main party of the expedition; he tells us not only the things he saw and did himself, but what others said and told him. Crespi's official diary was prepared after the return to San Diego, from notes kept during the trip (the usual practice); because it corresponds closely or is identical with that of Costansó in many passages, he must have had access to Costansó's report--and probably vice versa.

From these diaries a fairly good topographic and vegetation map could be prepared. They record an extremely varied country--now level, now rolling hills, now so steep and mountainous that even goats and deer could not travel. They tell of great variations in vegetation, too. Extensive grasslands "abounding in pasture"; "willows, cottonwoods, alders, and some live oaks" along stream courses. Stretches of open woodland covered with "...white oaks and live oaks as high and of as great girth as can be found in the finest parks of Europe" (Costansó, 1770). In the Santa Lucia Range, the mountains were covered with pines (Portola, 1909); they also were the first to see the coast redwoods, in vicinity of Palo Alto (Bolton, 1927). Just north of San Diego, Crespi says they "saw some very small oaks and chaparral"; later there are frequent records of "little trees unknown to us," "slopes thickly grown with different sorts of bushes"--"rosemary, sage, and Castilian rosebushes" and other shrubs. Near El Monte they "traveled about two leagues through brush and low woods, which delayed us for a long time, making it necessary to cut the brush down at every step that was taken" (Bolton, 1927). In the Santa Lucia range it required several days to cut a road through the trees and undergrowth. Traveling from Salinas River to the present site of Monterey, they found "all the ground we traversed is sandy, covered with brush, with some patches of small live oaks, and very little pasture" (Bolton, 1927). Yet today Salinas Valley commonly is held to have been a natural grassland! On the return journey, Portola tried to cross Santa Monica Mountains by a route different from that taken going north. Two of the oldest Indians of the village offered to serve as guides. These guides became lost, and they found out--too late--that the pack train could not pass through the dense thickets of chaparral (Bolton, 1927; Costansó, 1770). This indicates that in some areas at least chaparral was so dense and so extensive even the Indians could not find their way through it.

In view of the natural environmental conditions of the South Coast Ranges, this entire picture of the plant cover is just about what we should expect: it was greatly varied, and it included all the kinds, and the conditions



of distribution with which we are familiar today.

Let us look now at another record. In November, 1832, a party of Hudson's Bay Company trappers, under John Work, camped along the eastern shore of Goose Lake, Modoc County (Work, 1945). It had just arrived from the Columbia River country. This party remained in California until September 16, 1833, during which time its members traveled and trapped for beaver as far south as Stanislaus River, west to Fort Ross, and northward in the North Coast Ranges to the vicinity of Shelter Cove, Humboldt County. In a day-to-day diary of this expedition, John Work recorded dense timber or "thick woods" which made traveling difficult in nine different areas in the Sierra-Cascade and Coast Range mountains--not including riparian growth along streams. He stated that travel was hindered by underbrush or "underwood" in at least seven different areas in the forests--including along Pit River between Fall River and Hat Creek. This underbrush does not include riparian thickets he found in the timber along streams of the north coast. In crossing the inner North Coast Ranges from Russian River to Sacramento Valley he encountered extensive thickets or brush fields (chaparral) in several places, mentioning them specifically on the north side of Mount Konocti and between Clear Lake and Berryessa Valley. In the latter place he said the road was rough and stony, and "...in many places so thicketty that the branches were likely to tear the clothes off the people and the skin off the horses" (Work, 1945). This account, too, belies the common statement that Indian burning kept the hills clear of chaparral so that it could be traveled through easily. Work also recorded that travel was hindered by dense stands of timber and thick underbrush along stream courses in several different places.

This record also presents an accurate picture of pre-settler vegetation in this region. A country with vegetation varied in composition, distribution, and density; a vegetation in dynamic balance with its environment. Records of these two expeditions agree with many other accounts containing descriptions of California's pristine vegetation which have been carefully reviewed (Belcher, 1843; Bolton, 1930; Dale 1918; Leonard, 1934; Wilkes, 1845; et al). From this evidence it is concluded that these records represent the best portrayal of natural vegetation in California as it existed for a long period prior to the arrival of white men.

#### Burning of Vegetation by Indians

A logical corollary question in this discussion is:



"Prior to the advent of Europeans, what was the influence of Indian burning on California vegetation?" Any reply must primarily consider Indian customs and culture before European influence was established. From the very beginning of Spanish settlement in California, Indians were rapidly gathered into missions, under conditions where they quickly acquired European culture traits, and modified or discarded native ways. Although Spanish activity was centered in the coastal region from San Diego to Sonoma, contacts between mission Indians and natives in the San Joaquin and lower Sacramento valleys gave opportunity for European culture traits to diffuse widely at a comparatively early date. For example, John Work met Indians from the mission at San Jose visiting relatives in vicinity of Stockton, in 1833 (Work, 1945). When the missions were secularized in the 1830's, Indians scattered quickly and over considerable distances, further disseminating European culture elements. It is noteworthy in this connection that one of the significant elements in the Spanish pastoral industry was burning to improve grazing lands. In view of their contacts with the Spanish and other Europeans, it is probable that culture traits of many Indians in California were greatly different in 1840--or even in 1800--from those of 1769 and earlier. Then to ascertain with any degree of precision what the Indians may have done in the way of burning vegetation under aboriginal conditions we must utilize only the earliest records, especially in the south coastal area. Records of somewhat later date--to the 1830's or 1840's--may be used in the north coast, Sacramento Valley, and the Sierra Nevada, which were influenced by white men but little prior to discovery of gold.

For information on burning by Indians it is instructive to look again at diaries of the Portolá expedition. Portolá does not mention fires or burned vegetation (Portolá, 1909). Crespi records eleven cases where he says the vegetation is burned (Bolton, 1927). Costansó notes only two cases, one of which duplicates (and confirms) an instance cited by Crespi (Costansó, 1770). Thus, a total of twelve separate cases was recorded by these two witnesses.

During his stay in California, John Work recorded three separate cases where he found vegetation burned, probably by Indians. In one additional instance he says "The large plain to the Southward of us is all on fire" (Work, 1945).

The sixteen incidents from records of these two expeditions must be considered as positive evidence that California Indians did burn vegetation at times.

But--let us look at these records again. Crespi tells of eleven cases of burning, as stated. Portolá contradicts

Crespi--in whole or in part--in at least four of those cases with sufficient force to indicate Crespi probably is in error. (We accept the word of Portolá here, over against that of Crespi, because the diary of Portolá evidently was written each day, whereas the account of Crespi was compiled from notes made during the trip and enlarged upon after it was finished.) In certain other cases it is evident that when Crespi says the grass is "burned" he means that it has dried. For example, on July 30 he says "A plain ... with much grass, although we found it burned"; and on October 18 he wrote "Nothing but grass, and that was burned"--would he say there was "much grass" and "nothing but grass" if the only evidence of its existence was ashes? Also, of conditions on July 30, Portolá says "... there was much pasture and water" (Portolá, 1909). Eliminating cases where there is a reasonable doubt, we have six different instances where it is apparent that vegetation was burned by fire--probably at the hands of the Indians. Five of these cases certainly were in grassland; one was in woodland or forest--probably the former--because Crespi says the area was "... all burned over and despoiled of trees."

Of the six cases of burning recorded by the Portola expedition, two were between San Diego and a point just north of San Juan Capistrano; four were in Salinas Valley and around the south end of San Francisco Bay. It is significant that no instance of burning is mentioned between July 30 and September 30, while the expedition traveled from south of Los Angeles to the upper part of Jolon Valley. The portion of this route along the north side of Santa Barbara Channel was one of the areas most densely populated by Indians in all of California. While it is recognized that these diaries probably do not record every instance of burning encountered, the evidence they do contain certainly does not lead to the conclusion that any great proportion of the country traversed by the expedition was burned, at least during the summer of 1769--and we have no reason to believe this season was markedly different from any other in its effect on burning by Indians. It is noteworthy, too, that nearly all burning mentioned was in grassland, not in brush or timber.

All four of the cases mentioned by John Work are separate, distinct incidents with no contradiction. One instance was the delta area south of Stockton, where he recorded that the plain was all on fire. One was near Woodland--a dwelling in one of the Indian villages was burned, and the fire had spread into adjacent grassland, burning a considerable area--demonstrating that at least some Indian fires were not intentional. Two other areas were noted east



of Sacramento River between Stockton and Marysville Buttes. All four cases were in grassland. Work's notes on the daily state of the weather make it appear improbable these fires were caused by natural agencies; therefore, they are to be taken as examples of burning by Indians, either accidentally or intentionally.

The records reviewed above agree with many others studied. They indicate some burning was done by Indians in grassland; but there is very little evidence of Indian fires in forests, until an appreciably later time. While it can be established with relative ease that Indians did at times burn vegetation, there are many indications that the frequency and extent of their burning was limited.

#### Some Considerations Regarding Burning by Indians

It is sometimes stated that the Indian tribes of California commonly burned over all--or essentially all--the grassland, chaparral, and forested lands within their respective tribal boundaries each year, or at least every few years. When we consider the possibility of such more or less systematic burning by Indians we must take into account many points of Indian culture and technology, the density of the population, and the magnitude of the task involved. We may ask the question: "Is it probable that people in the state of cultural and technological development of the California Indians would be able to accomplish the physical job of purposefully burning a great acreage of land each year? Would they have need to do so?"

Among Indians land as such was not really owned; its use was free and common to all (Kroeber, 1953). The parts of native California which actually contained permanent settlements at one time or another formed a small fraction of the total area of the state; and there were no true nomadic tribes. Every tribe had some spot that it considered its home; here stood its most durable houses, and here the winters, or a considerable part of each year were normally lived. These spots were not distributed randomly over the whole of California, but clung to main watercourses, valleys or their edges, and the more open canyons. The higher mountains, dense timber, rolling hills, the plains in the intervals between streams, and of course, the vast preponderance of the deserts never held permanent settlements (Kroeber, 1953). Great areas of the state, then, were but little used.



While Indians of the coast and desert areas of southern California traveled considerable distances upon occasion, there was relatively little communication between northern tribes. The Indians in the state were, as a whole, remarkably well settled (Heizer, 1959). No northern Californian would go far from his home; twenty miles is said to have been an unusual distance for a hill or mountain Indian to travel (Kroeber, 1953). Beyond a dozen or two nearby villages the country was almost entirely unknown to inhabitants of any given place. Even within the circle of a man's acquaintance, half the villages were likely to be hostile or under suspicion. These conditions limited the area within which any group of Indians could operate, and precluded co-operative undertakings on any appreciable scale. While it is true that there were probably few regions in the state not visited by Indians at some time, there were great tracts over which no group exercised effective control.

It is known--from records of Coronado's expedition in 1540--that the Indians along the lower Colorado River knew how to use a torch (Winship, 1896). Anthropologists have established existence of similar knowledge of using the torch among twelve other groups in southern California; but in prehistoric times such knowledge was lacking among at least five groups here (Drucker, 1937). During the course of his survey to determine distribution of culture elements, Drucker concluded that in much of southern California the Indians did not set fire to brush or trees (Drucker, cited in Sampson, 1944); nothing was found in the literature to refute this conclusion (Sampson, 1944). It is uncertain to what extent Indians in the remainder of California had general knowledge of the use of the torch. Studies by anthropologists indicate many groups must have lacked this knowledge, although the use of a "slow match" of bark or other material for transporting fire from one place to another was fairly common (Driver, 1937, 1939; Essene, 1942; Harrington, 1942, Voegelin, 1942). However, the use of a slow match was denied by all Indians in the central Sierra region, lying between Consumnes and San Joaquin rivers (Aginsky, 1943); apparently these Indians did not know the use of the torch either. Indians of my acquaintance, in position to know their tribal culture, when interrogated on this specific point have firmly insisted that a separate fire was started each time and place a fire was wanted--no matter how close or distant the location. It would be extremely difficult to burn in any systematic manner large tracts of standing vegetation which had to be ignited by making many separate fires with the hand drill--or even with a bark slow match. This is but one point to illustrate the lack of certain kinds of technological knowledge among California Indians, without which their purposeful treatment of extensive areas of vegetation by burning would

be so difficult an operation as to be highly questionable.

Contrary to widely prevalent belief, many California Indians did not employ fire for driving out game when hunting (Aginsky, 1943; Driver, 1939; Drucker, 1937; Essene, 1942; Voegelin, 1942); its use for this purpose was entirely absent from the central coast region of California (Harrington, 1942). Among tribes who did use fire to drive game, some employed it only when hunting rabbits, squirrels, rats and other small animals among tules or in grassland; others used it only when hunting certain kinds of big game (Driver, 1939; Essene, 1942). No evidence has been found to indicate more than very infrequent use of fire for hunting in brushy or forested lands.

The estimate of the aboriginal population of California made by Kroeber (1953) was based on critical analysis of statistics of Franciscan missions, size and location of native villages and village sites, available food supply, and many other factors. This estimate placed the Indian population at between 120,000 and 150,000 persons in 1770. Heizer (1959) states that the areas most productive of food along the coast and in the valleys supported one and one-half to two Indians per square mile; the foothill areas about one per square mile; while in the high mountains and deserts the population was only about one person for each eight square miles. On this basis the total population of the state can be calculated at between about 110,000 and 125,000 persons--only a little smaller than Kroeber's estimate. For purposes of our discussion, and for convenience of calculation, let us exclude the deserts, and let us assume that the highest population estimate above--150,000 persons--applies to the remainder of the state. We have then, in California of aboriginal times, 150,000 people living on seventy-five million acres of land. To accomplish the burning of this acreage annually--and it is sometimes contended that the Indians did--would require that 500 acres be burned each year for every man, woman, and child in the total population. For sake of a comparison, to which exception may be taken, with the aid of a considerable amount of modern mechanical equipment 5,614 ranchers in California controlled burned 1,597,941 acres of brush covered land during fourteen years--1945-1958, inclusive (Calif. Div. of Forestry, 1959). This is an average of just about 285 acres per man per year! It appears highly improbable that the California Indians, essentially lacking in manpower and physical facilities, would attempt to purposefully burn any but small tracts of land in which they were particularly interested, on a systematic basis. It is equally improbable they made a concerted effort to burn over major portions of their tribal holdings each year, or at intervals of a few years.



### Some Evidence from the Land

One important primary source of evidence on the question of the effect of fire in vegetation is the countryside under consideration here--the face of the earth itself. That source has not always been carefully consulted and critically evaluated.

In those situations where a plant community is dependent upon fire for its maintenance or perpetuation its members exhibit unmistakable signs of this dependence. One of the usual signs of this condition is a reduction in number of species constituting the community, and dominance of a few species or a single species. We find areas of chaparral that illustrate this point. The coniferous forests of California are direct contradictions to such a condition. In the "so-called" pine region, where the chief dominant over a great area is ponderosa pine, no less than four other conifers are dominant in various situations--white fir, Douglas-fir, sugar pine, and incense cedar; and the giant sequoia is a marked feature in the southern Sierra Nevada. Oaks also are abundant, and with other ecologically similar hardwoods achieve local dominance, especially on dry ridges and rocky sides of canyons. A wide range of shrubs and a great variety and profusion of herbs also characterize the pine forest (Burcham, 1957; Jepson, 1925). This condition would not prevail in a plant community swept by frequent fires, whether light or intense. Similar conditions are characteristic of the other segments of the coniferous forest throughout California.

We must consider another significant point when evaluating the probability that frequent fires have occurred in any area. Plants--whether trees, shrubs, or herbs--develop adaptations to carry them through critical periods in their life cycle. These adaptations do not come into existence as responses to trivial or constantly recurring factors of environment. They are developed only in response to an extreme factor or factors threatening the very existence of the species--to prevent its destruction. When present, such adaptations constitute marked physiological or morphological features that are readily observed and identified. Germination of seed in profusion after heating, sprouting, and closed cones which open to release seed after heating are examples. Plants of the coniferous forests of California are singularly lacking in any adaptations that would effectively prevent their destruction by fire. This is particularly true in the case of the dominant conifers. For the important conifers--ponderosa and sugar pine, white and red fir, Douglas-fir, incense cedar, and giant sequoia--the only adaptation of consequence that would aid in preventing destruction by fire is thickening of the bark; even this



feature varies greatly among these species, and does not become effective to any considerable degree until trees have reached an appreciable age--on the order of a hundred years. Such an adaptation is inadequate to prevent destruction of the species in a habitat which may be swept by fires at intervals of two to five or ten years.

To illustrate another point let us look at a specific area. One quarter-section of land in El Dorado County, lying between 3,500 and 4,100 feet elevation is forested with ponderosa pine and its characteristic associated and understory vegetation. A selective harvest in 1946 removed about 14,000 board feet of timber per acre, leaving a residual stand of six to eight thousand board feet per acre; this is about average productivity for this site. On this tract of land are found a granite ledge where Indian women ground acorns for countless generations, and a spring about which Indians camped for many centuries so that over an acre or two charcoal and ashes are thoroughly mixed with the topsoil to a depth of more than twenty-one inches. On evidence from the granite ledge and campsite it appears that this quarter-section probably had as intensive use by Indians as any similar tract in the pine region in California.

When stumps of trees cut during timber harvesting were examined it was found some of them had been scarred by fires--in some instances still unhealed when the trees were cut; in other cases, scars were healed over. Most of the stumps showed no sign of fire. All the timber was old-growth; some trees were more than three hundred years of age. Now, fire scars noted by Boyce (1920) during a study of the pathology of dry-rot in incense cedar have been offered as evidence that during more than two centuries fires burned at frequent intervals over essentially the entire pine forest of the state (Biswell, 1958; Kotok, 1930, 1934; Shaw and Kotok, 1924). This contention has been maintained despite the facts this study by Boyce was quite limited as to area, and the author pointed out explicitly there had been a highly significant difference in frequency of fires in the two regions where trees were examined (Boyce, 1920). If these fires occurred frequently, and if many were of Indian origin, and if they blanketed the pine forests completely--all of which are commonly implied--how can we account for the fact that on this quarter-section of land, heavily used by Indians, we find some trees that show scars caused by fires, while on the same tract we find trees of equal or greater age showing absolutely no sign of fire?

Fires are not uniform with respect to the area they cover or the intensity with which they burn. They burn slowly in one situation and fiercely in another. They reach long fingers

among the tree trunks in some places; they race rapidly through the treetops elsewhere. During the long past, fires must have occurred throughout California, at least sporadically. Some probably were caused by Indians; many started from lightning. When they occurred, in all probability some were destructive, especially in the lower mountains where terrain and weather combine to essentially preclude "light" fires; but other fires were relatively innocuous. During any particular fire some patches of ground were burned, others unscorched; some trees were destroyed, some merely injured, and some were unharmed. But each fire was limited in area--whether that area was great or small; and a sufficient interval of time elapsed between most of them to permit vegetation to make some degree of recovery.

Only one conclusion appears reasonable: Fire is but one factor of the environment; trees--and other vegetation--persist in spite of fire, rather than because of it.

Results of practical experience and research efforts indicate that controlled burning eventually may be developed into a practice useful in management of California's wild land resources. If we do find it valuable we are not required to look to the Indians for precedent to justify its use--it will stand or fall on its own merits. Foresters and range men of today are much more capable of appraising its worth as a management practice than were the California Indians. What we must do is to adapt that practice to our own conditions and needs.

At present we do not have enough exact, dependable knowledge of how to apply and manage fire to enable the rancher or forester to employ controlled burning consistently, on a widespread scale. We must give a great deal of concerted attention to both its applications and limitations. Before a non-selective agent like fire can be employed widely in resource management there is much basic research in its behavior and control, and in effects of its application to vegetation and soil, that must be done. Difficulties of control must be minimized; it must be determined that costs are within practicable limits. It is imperative that reliable methods be developed which will insure exact and reproducible results from burning, before fire is employed as a general practice in managing our range lands and forests.



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