Issued July 17, 1911.

U. S. DEPARTMENT OF AGRICULTURE,
FOREST SERVICE—BULLETIN 85.
HENRY S. GRAVES, Forester.

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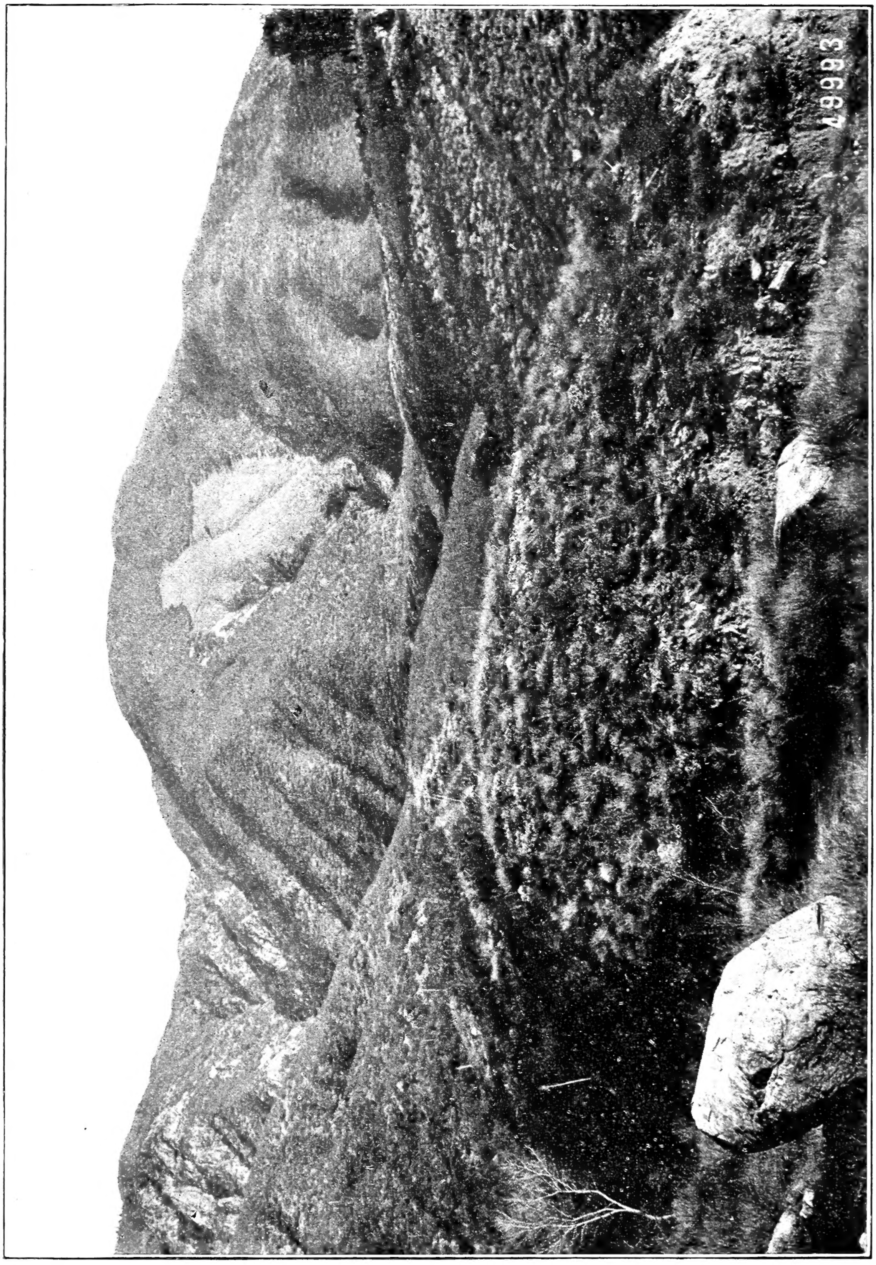

A GOOD COVER OF LOW CHAPARRAL AT ARROWHEAD, CALIFORNIA.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Forest Service,
Washington, D. C., March 28, 1911.

Sir: I have the honor to transmit herewith a manuscript entitled "Chaparral," by Fred G. Plummer, Geographer, and to recommend its publication as Bulletin 85 of the Forest Service. No publication dealing exclusively with chaparral has ever before been issued, and this bulletin is therefore a pioneer in its field.

Respectfully,

Henry S. Graves,
Forester.

Hon. James Wilson,
Secretary of Agriculture.

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CHAPARRAL.

TRUE CHAPARRAL.

True chaparral is one of the types of a plant formation which occurs in several widely separated parts of the world. The formation is known to plant ecologists as sclerophyllous woodland. It may be described (though not defined) as a mixed forest of stunted trees, and is the result of peculiar climatic conditions. As one of the intermediate forms between a flourishing forest and a desert, it represents a sort of balance between certain environmental extremes. At this balance the growth is dwarfed, and the full-grown trees attain only the dimensions of brush, even low brush.

The dwarfing of tree growth results from deficiency of moisture and one or more other conditions, such as excessive transpiration, barren soil, high altitude, and wind. As we advance into high latitudes or climb to corresponding altitudes, the trees diminish in stature, until we find only struggling procumbent or bushy forms of the most cold-enduring species of trees—species which, at lower latitudes or altitudes, were of good forest size. A similar phenomenon is observed as we advance toward regions of desert conditions, but the result is a dwarf forest of an entirely different kind.

Inasmuch as each species of tree has a given set of moisture and temperature conditions under which it does best, the composition of any forest—and the composition determines the type—varies with both these conditions. Leaving out of account, for the immediate purpose of this discussion, such other factors as soil constituents and soil structure, it is easy to see that any given set of climatic conditions will exclude from the forest all but a certain number of species, which are capable of competing with each other under the given conditions.

The combination of conditions in parts of southern California results in a selection of certain species to form a dwarf forest which, on the one hand, leaves out the species generally characteristic of northern latitudes, and, on the other hand, the distinctively tropical vegetation. It includes neither the species characteristic of Canada nor those characteristic of the lowlands of Mexico. It is therefore differentiated, both from the dwarf growth of high mountains and from the mesquite and other dwarf forms of vegetation which extend into the United States from the subtropical areas. Some of the species which make up this type of forest are found, it is true, widely distributed throughout the western United States, but whereever they are found, it is within their limits of moisture and temperature.

The sclerophyllous woodland formation is recognized by ecologists as occurring when, at a medium latitude and altitude, with insufficient precipitation, we have a wet-winter, dry-summer climate. Dr. Schimper, in his "Plant Geography," describes the various regions and presents maps showing them. They are located between 30° and 40° latitude, either north or south, and are therefore almost midway, heliocentrically, between the equator and the poles. After a chapter on "Warm temperate moist summer districts," Dr. Schimper says:

Scleropyllous woodland in general.—Whilst the districts referred to in the previous chapter resemble the Tropics climatically in the coincidence of the rainy season with high temperatures, and accordingly possess a vegetation similar to that of the Tropics, this likeness entirely ceases in countries where the precipitation coincides with low temperatures and at the same time the hot season is quite rainless or nearly so. Here the totally different aspect of the vegetation corresponds to the sharp difference in climatic conditions, and finds no analogy within the Tropics. The mild temperate districts, with winter rain and prolonged summer drought, are the home of evergreen xerophilous woody plants, which, owing to the stiffness of their thick, leathery leaves, may be termed sclerophyllous woody plants.[1]

The sclerophyllous formation is found, outside of southern California, in South America on part of the coastal region of Chile; in Europe and Asia along the borders of the Mediterranean and eastward into Turkestan; in Africa on a small area to the west of the Cape of Good Hope; and in Australia in the southern and southwestern coastal region, including part of Tasmania. The flora differs in each of these widely separated regions. It has many local names: Scrub, elfin-wood, bush-forest, heath-scrub, maqui, shrub-steppe, etc., inclusive terms covering all the plants. There are also many terms which refer to pure growth of a single species—a not uncommon occurrence. Such are brigalow; mulga-scrubs, composed of acacias; malle-scrub, composed of dwarf eucalypts; manzanita, a species of arctostaphylos; and chamisal, the grease-wood, *Adenostoma fasciculatum*.

Concerning the chaparral type Dr. Schimper says as follows:

Sclerophyllous woodland in California.—The California littoral is stocked chiefly with evergreen shrubs, among which isolated trees raise themselves. The most important of the trees, which in dry situations occur also as shrubs,

[1] Schimper, Plant Geology Upon a Physiological Basis, Oxford, 1903, p. 507.

are *Quercus agrifolia*, Nee; *Q. chrysolepis*, Leibm.; *Q. dumosa*, Nutt.; *Q. oblongifolia*, Torr.; and several others, all of them evergreen species having small leathery leaves with entire margins, or provided with sharp teeth; two evergreen trees of different affinity accompany them, the California laurel (*Umbellularia Californica*, Nutt.) and the chinkapin (*Castanopsis chrysophylla*, A. DC). The shrubs composing the main mass of the vegetation, which forms a hardly penetrable thicket on the lower mountains and hills, consists, like the corresponding formations of other sclerophyllous districts, of representatives of the most diverse families, such as oaks, Compositæ, Rosaceæ (*Adenostoma fasciculatum* Hook. et. Arn., *Prunus ilicifolia*, Walp.), Zygophyllaceæ, Anacardiaceæ (species of Rhus), Rhamnaceæ (*Ceanothus cuneatus*, Nutt.; *C. papillosus*, Torr.), Leguminosæ, Hydrophyllaceæ, Ericaceæ (*Arctostaphylos tomentosa*, Lindl.), Labiatæ. Succulent plants are commoner than in other sclerophyllous districts, and are represented by various Cactaceæ. Bulbous and tuberous plants here again occur in great numbers as associates in the sclerophyllous woodland.[1]

Dr. Warming, in his "Oecology of Plants," says:

The term "sclerophyllous" is employed by Schimper in connection with xerophytic bushland and bush forest in subtropical regions where the rain falls in winter. It refers to the small, thick, coriaceous, entire leaves, which are so extremely common in these regions. * * * The prolonged summer drought is hostile to vegetation. Hence the rarity of larger trees. The trees are small, with gnarled trunks and boughs; and most of them may occur in the guise of dwarf trees and shrubs. The leaves of the trees and shrubs are, as a rule, evergreen and protected from desiccation in various ways, yet their structure is not so extreme as that of desert plants. * * * Winter and spring form the true vegetative season of sclerophyllous vegetation, even though brief cold periods sometimes cause a lull.[2]

Thus chaparral as a type of sclerophyllous woodland is distinguished by its different species from:

(*a*) The dwarf forests of the North and of high altitudes.

(*b*) The dwarf forests of the tropics and subtropics.

(*c*) The dwarf forests (if we may call them so) of the sagebrush desert.

It is also distinguished by a different character of forest due to the effect on these species of a particular set of climatic conditions from:

(*d*) The sometimes so-called chaparral of other regions in the southwestern United States, though composed of the same species.

Under the sclerophyllous woodland formation, chaparral is differentiated from other types belonging to the same formation by its composition.

The word "chaparral," in Castillian or Mexican, means specifically evergreen scrub oak or oak brush. In early Spanish California it was applied to *Quercus dumosa*, which is found along the coastal region from latitude 31° to latitude 39° 30′, and also in a few small

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[1] Schimper, Plant Geology Upon a Physiological Basis, Oxford, 1903, p. 535.

[2] Warming, Oecology of Plants, Oxford, 1909, p. 303.

isolated regions in the Sierras Nevada. This species, which is exceedingly erratic in its forms of fruit and foliage, as well as in size, shape, and tolerance, may form a beautiful open woodland in which the trees are as high as 25 feet, with spreading crowns and stems a foot in diameter. On the other hand, in its maturity it may go to form a dense thicket only 8 or 10 feet high, which was originally termed "chaparral."

But "chaparral" has now become an Americanized term for a distinctive type of growth embracing a large number of species, just as do the terms "timberland" and "woodland." It is a general name for the mixed forest of stunted trees under discussion in this paper even though its dominant species differ on adjacent watersheds, as they frequently do. The name, as thus applied, is in common use in southern California, and has unquestionably come to stay. It is recognized that chaparral creates a distinct land type, occupying an intermediate position between timberland and desert. This will be clear from the following classification of wild lands, in which the first three, and part of the fourth, are tree-bearing areas, the balance treeless.

TIMBERLAND.—An area whose principal trees may furnish saw logs, ties, telegraph poles, etc. In the western United States the stand is mostly pine, fir, spruce, cedar, and other conifers, but includes some of the larger broadleafs.

WOODLAND.—An area whose principal mature trees may furnish only cordwood, fence rails, and posts. In the western United States the stand is mostly small oak, maple, cottonwood, and other broadleafs, but includes some piñon, juniper, and other small conifers.

CHAPARRAL.—An area whose permanent and mature crop is a mixed forest of stunted trees, resulting from certain climatic conditions which produce sclerophyllous or hard-leafed dwarfs. In the United States it is found in southern California. The type corresponds to the scrub, elfin wood, bush forest, heath scrub, maqui, shrub steppe, etc., which are peculiar to sclerophyllous woodland regions in other countries.

BRUSHLAND.—An area whose crop is low trees or shrubs having no commercial value. The occurrence of brush creates a distinct land type, but all land supporting brush does not belong to the type. When brush occurs under a cover of large trees in the form of undergrowth, underbrush, or thicket, the classification is either timberland or woodland. Brush may temporarily form an exclusive cover, owing to the removal of large trees from an area, but such a temporary cover of brush does not remove the land from the type to which it previously belonged. When this temporary cover includes some of the species which are found in true chaparral, its form may be termed mock chaparral.

SAGEBRUSH.—Some few areas of this type have a heavy growth and merge with the chaparral. Its individuals have the tree form, but they are so small and so clearly distinctive in habitat that they are by common consent classed with the treeless types.

GRASSLAND.—Parks, etc.

BARREN.—Generally above "timber line."

DESERT.—Arid areas.

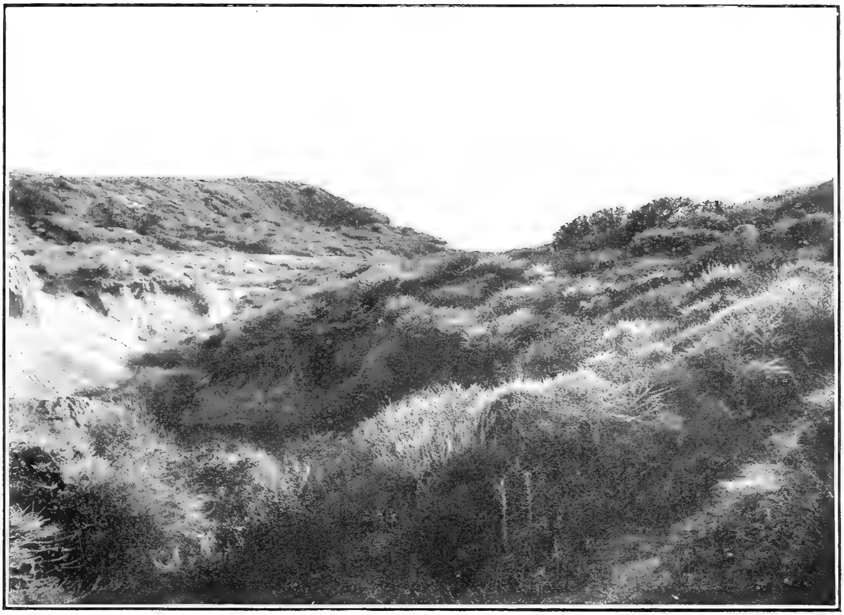

FIG. 1.—LOW CHAPARRAL COVER BORDERING PACIFIC OCEAN.

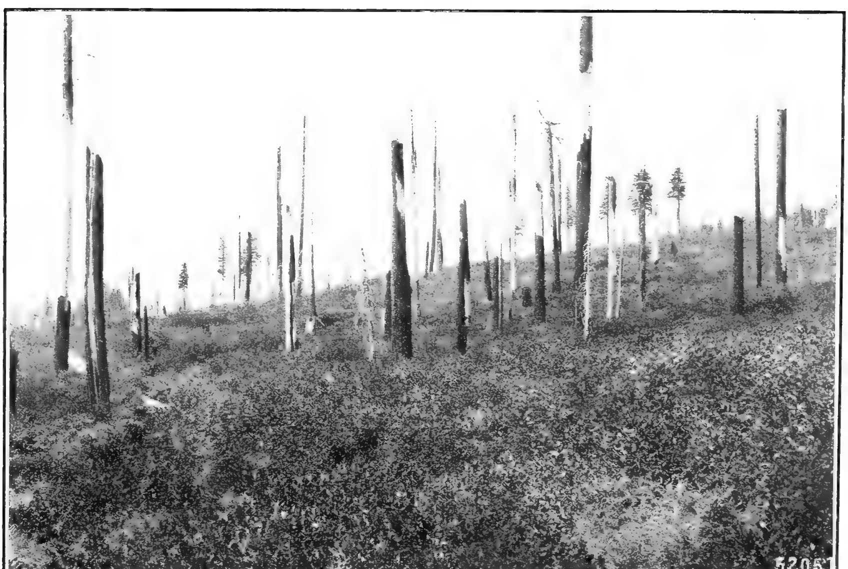

FIG. 2.—MOCK CHAPARRAL COVERING THE SITE OF A RECENT BURN IN NORTHERN CALIFORNIA.

MOCK CHAPARRAL.

Unfortunately, the word "chaparral" has acquired an elastic meaning and is sometimes used to describe dwarf trees and brush found in Arizona, New Mexico, Colorado, Utah, and even as far north as Idaho. It is necessary, for two reasons, to make a distinction between the true chaparral and the mock. First, in California, as a result of the climate, the growth is very much dwarfed, while in other regions, where the seasonal rainfall is more evenly distributed, it is not so stunted. Second, in California chaparral holds complete possession of its domain, neither gaining on nor giving way to conifers or larger deciduous trees. In other States the several chaparral species have generally taken possession of logged, burned, or otherwise denuded forest areas. Their hold upon the soil is therefore temporary. They were preceded by a forest, and will in time give way to a new one if external interference ceases. They form a cover and are desirable only on account of their rapid growth on denuded areas, but having insignificant commercial value, are not to be preferred to the natural forest. (Pl. II, fig. 2.) Because of its tendency to supplant valuable timber growth upon areas where recurrent fires interfere with natural conditions in its favor, mock chaparral often becomes a distinctly undesirable form of forest cover. Its sprouting power enables it quickly to reoccupy the ground after a fire with a denser growth than before, while its generally inflammable foliage makes each succeeding fire hotter than its predecessor, and consequently more destructive to other forms of tree growth. For these reasons foresters consider mock chaparral a pest, the spread of which may be prevented only by keeping fires out.

As it is the prevailing climate which fixes, in any region, the character of the plant life, the growth of chaparral is evidently the best which the conditions will permit. In the areas of mock chaparral, except at high elevations or on exposed sites, the climatic conditions are more favorable to tree growth, and the chaparral can not gain the ascendancy unless the forest has been placed at a disadvantage. There is ever, as Schimper explains, a contest between opponents for dominion over the soil, and while climatic conditions may limit the domain of each it requires but a slight change in those conditions to revive the contest.

In northern California *Adenostoma*, *Arctostaphylos*, *Ceanothus*, and *Quercus* are the principal genera of the so-called chaparral. In Arizona and New Mexico the term is restricted usually to the oak brush, *Quercus gambelii* and *Quercus undulata*. The English term "shinnery" is also applied to the same type. Occasionally a thicket of mesquite, *Prosopis juliflora*, is spoken of as chaparral. In Colorado the term is usually applied to the scrub oak, *Quercus undulata*, but is also used to describe the brush cover, which includes *Ceanothus* and *Prunus*. In Utah the term is applied to *Quercus*, *Arctostaphylos*, and *Ceanothus*. In Idaho it is applied to *Quercus*, *Cercocarpus*, *Ceanothus*, and *Prunus*.

Some of the species forming either the chaparral or the mock chaparral are also found in the adjacent forested regions, and, indeed, being trees, may be considered as part of the forest cover. The species which elsewhere comprise chaparral and mock chaparral are here termed underbrush. If the small trees are of the same species as the larger ones in the forest they are an "understory" or a "thicket."

Since the principal species comprising both chaparral and mock chaparral are trees, that is, woody plants supported by a single stem, they should not be confused with shrubs, which have a number of stems from the same root, each contributing to the crown. It is evident also that areas of chaparral and mock chaparral are forests, the one a permanent cover, the other temporary.

HISTORICAL RECORDS OF PAST FOREST CONDITIONS IN THE CHAPARRAL REGION.

The fact that chaparral often forms an almost perfect miniature of typical woodlands of the temperate zones naturally suggests that the dwarf trees are the stunted survivors of full-sized forests which once covered the same area. In substantiation of this view citations have been made from the accounts of early explorers, as establishing the fact that when the white men first reached the coast of southern California they found a full-grown forest in possession where the chaparral now flourishes. No such change, however, could have occurred unless a radical change of climate had taken place. It is certain that the climate of southern California has not changed radically within historically recent times. Moreover, when the historical records which have come down from the period of exploration are examined closely, they give evidence of a condition similar to that which now exists.

The first Pacific explorer to put foot on what is now American soil was Juan Rodriquez Cabrillo, a Portuguese navigator in the service of Spain, who entered what is now San Diego Harbor September 28, 1542, and landed at Point Loma. The narrative of his voyage was written by Ferrelo, who describes "groves resembling silk-cotton trees except it is hardwood." They also found "thick and tall trees which the sea brought ashore." Cabrillo remained only six days in the harbor, and makes no further mention of trees. On November 10, 1602, Don Sebastian Viscaino arrived in the harbor, and on the following day organized a party to land on Point Loma and "survey a forest of tall and straight oaks and other trees."

This forest must have covered all of Point Loma, since it is described as being three leagues long and one-half league wide. The Indians say that these trees were live oaks, and that they were afterwards destroyed by fire. The Franciscan missionaries who came to California in 1796 said that the site of San Diego was covered with trees. Capt. Bogart, visiting San Diego in 1834, said that the site of that point and a portion of Point Loma was covered with a thick growth of oak, and that the trees were used by the native population and by the crews of trading vessels for tanning purposes. There seems to be a conflict between this testimony and that of the English navigator, Capt. George Vancouver, who, on November 27, 1793, visited San Diego Harbor and said of Point Loma that "some bushes grew on it, but no trees of large size." Dana, in his "Two Years Before the Mast," said that in 1834 Point Loma was covered with trees, but afterwards in his diary said that he had been mistaken and that they were only bushes. He was doubtless deceived by five genera of chaparral which may have attained in this locality a height of 10 feet, with dense and spreading crowns. These genera are *Adenostoma*, *Rhus*, *Eriodictyon*, *Ceanothus*, and *Heteromeles*. Certain maps made by the early cartographers show Punta de los Arboles (Point of Trees), at a location immediately north of San Diego. It is here that the rare pine, *Pinus torreyana*, was discovered growing near the ocean, and it is the only region along this portion of the coast where conifers approach the shore. The name given would indicate that the early navigators did not commonly find trees along the coast, and that Punta de los Arboles was an exception worthy of mention upon the maps. There is no projection on the shore line to warrant the title "point." The place is shown upon more recent maps as "Pine Hill."

On the whole these early records seem to show that the conifers approached this portion of the coast at only one point, as they do to-day; that trees, probably cottonwood, oak, and possibly sycamore, were growing on Point Loma and the site of San Diego, though these have since been destroyed and the chaparral has taken possession of the areas, and that chaparral and treeless areas prevailed generally along the coast, as they do to-day.

GEOGRAPHIC CONDITIONS IN THE CHAPARRAL AREA.

The area within the United States covered by chaparral is shown upon the accompanying map (Pl. VIII) and amounts to about 5,500,000 acres. It will be noticed that there are several small isolated tracts on the west side of the Sierra Nevada. In general, however, the chaparral protects about three-fourths of the upper watersheds of the streams along the coast in California for a distance, along the axes of the Sierras, of 450 miles.

While to a Californian this chaparral region may seem normal enough, a visitor from the Eastern States seems to be entering a new world. One thing to set it apart is the seasonal distribution of rainfall. Over the chaparral region in southern California the scant rains occur during the winter months; there is little, if any, precipitation in summer. At San Luis Obispo, in the northern portion of the chaparral region, only 2.91 per cent of the rainfall is in the summer; at Los Angeles, in the central portion, only 0.83 per cent; and at San Diego, in the southern portion, only 0.89 per cent.

Other interesting geographic conditions beside the wet-winter, dry-summer climate exist in the area. We usually think of the mountain ranges of the United States as running north and south, but the largest and most important range in the chaparral region, the Sierra Madre, including the Sierras San Raphael, San Gabriel, and San Bernardino, trends almost due eastward from Point Conception. It is in these Sierras that the chaparral reaches its best development, both in the number and size of its species and in the density of its cover. The rain-bearing clouds coming from the west do not find this range an effective barrier, but move eastward through broad, low passes on either side. To the northward are the Sierras Nevada and Santa Lucia, and to the southward the San Jacinto, all of which have greater rainfall than the Sierra Madre.

We usually think of springtime as the season when plants begin their growth and when deciduous trees and shrubs spread a new foliage, which remains green until autumn. In the chaparral area this is reversed, and the various species make most of their growth during the winter. Through the summer season the mountains are brown, and, from a distance, look lifeless. Immediately on the advent of the winter rains the whole country puts on a vesture of green, which remains all winter.

There are other conditions which seem topsy-turvy. We think of high mountains as barren and snow covered at their summits; below this the timber line, with its stunted trees of the subalpine zone; descending farther, the forests in full possession of the slopes, and the trees increasing in size until, with the undergrowth, they form a heavy cover upon the coastal plain. In the chaparral region all this is reversed. The forests are on the high elevations. Below is the chaparral, or zone of dwarfed trees. Still farther down is the sagebrush country, the growth becoming thinner and thinner toward the bare sandy belt bordering the ocean. The lower zones, except in favored valleys, are arid, or at least semiarid. The rainfall increases with the altitude above the sea, approximating the rate of Lippincott's formula, which is 0.6 inch for each 100 feet of rise. Along the coast the average annual rainfall is 13 inches. This is insufficient to support a forest, and in only a few cases is it enough for a scattering woodland of oaks. As the rainfall increases with altitude a point is reached where timber can grow. This is the lower timber line. Its altitude varies with latitude and exposure, but averages about 2,000 feet. The upper timber line is not determinable, since the mountains are not of sufficient height. Probably this line would be at about 13,000 feet.

Every school child has drawn maps, making wiggly lines for the rivers, which increase in thickness from source to mouth. This among map-making nations is the recognized conventional symbol for drainage. In the chaparral country, however, the drainage ignores all the conventions. More often a stream is largest near its source, while the water gradually thins out toward its mouth, and disappears entirely without reaching the ocean. The flow is usually intermittent, though there may be short stretches of bed where water is permanent.

Citrus fruits, olives, figs, and guavas are grown on the lowlands, between the chaparral and the ocean, as far northward as Point Conception. North of this point the climate changes, and apple and peach orchards are common. There is, however, an isolated region near Portersville which has a climate favorable for oranges. It will be seen from the map that chaparral is also present in this locality.

The climate southward from Point Conception is considered one of the finest in the world, comparable with that of Ceylon and Jamaica. An unusual climatic feature of the region is called by orchardists the "frostless belt." This is a narrow subzone, seldom more than 200 feet in altitudinal range. In the foothills north of Santa Barbara Channel it lies from 700 to 900 feet above the sea, and has almost a subtropical climate, although frosts occur both above and below it. Southward it is not always so clearly defined, since the mountains recede from the shore, and the belt is therefore spread out over a broader area on the coastal plain. Near San Diego it is certainly lower than farther north, in spite of the fact that it would be naturally expected to increase in altitude with the decrease of latitude. At Point Loma, a promontory nearly 400 feet high, the lower limit of the belt has been defined at 275 feet above the sea. The upper limit has not been determined, since it is above the altitude of the Point. On top of the promontory the climate is almost perpetual spring, with oranges, figs, and bananas growing there. Below the 275-foot contour, where ice has formed in winter, apples, quinces, pears, and peaches are grown.

The peculiar climate of coastal southern California prevails up to the mountains, and even on some of their slopes. Beyond, in the intramontane region, there is a different climate, and in the depressed ultramontane region there is a complete change into severe desert conditions.

If the prevailing winds came from any direction other than west, the delightful climate of the chaparral region would be ruined. Unwelcome proof of this comes now and then, when the northern or eastern desert wind, or "Santa Ana," flows through some of the low mountain passes on to the coastal plain. Compared with the normal temperature, this superheated air stratum feels like a furnace blast. The "Santa Anas," together with the "Sonoras," or southern storms, cause a wide range in the recorded maximum and minimum temperatures. Fortunately they are rare.

The topographic relief is exceedingly diversified, and the mountains are high, ranging, in the National Forests, up to 11,485 feet. Dr. P. C. Ramondino, in 1892, after a careful study of the region, declared that, between the ocean and the mountain summits, five climates could be defined. These are: Insular, peninsular, coastal, lowland, and mountain. In the realms both of air and of water, they range from tropical to Arctic. One may, sandaled and hatless, pick an orange or a fig while gazing at snow-capped hills. The sea fauna from Santa Barbara to San Diego includes almost all forms, from Bering whale and seal to tropic goldfish, abalone, and sea turtles.

The following table, which shows the equable coastal climate, was prepared from data in the United States Weather Bureau:

TABLE 1.—*Climate at three cities in the chaparral region, California.*

Station.	Annual rainfall.	Wind.		Temperature.				Average annual weather.			
		Average velocity per hour.	Direction.	Mean.	Maximum.	Minimum.	Greatest daily range.	Clear.	Partly cloudy.	Cloudy.	Rainy.
	Inches.	*Miles.*		°*F.*	°*F.*	°*F.*	°*F.*	*Days.*	*Days.*	*Days.*	*Days.*
San Luis Obispo	[1] 21.42	5.1	W.	58.6	106	22	56	203	95	67	48
Los Angeles	15.86	4.7	W.	60.3	109	28	49	157	152	56	36
San Diego	9.54	5.6	[2] NW.	60.6	101	32	43	266	49	50	43

[1] The only snowfall was at San Luis Obispo, March 3, 1896, and was one-half inch.
[2] Local topographic conditions at San Diego cause daily variations in the direction of winds.

CHAPARRAL AND THE WATER SUPPLY.

The economic importance of chaparral is due chiefly to the necessity for watershed protection in a region of such geographic conditions as have just been described. Throughout southern California water is of the utmost importance for irrigation and municipal supply. On the arable valley and mesa lands the rainfall is insufficient for any crops but hay and grains. The deficit is met by irrigation. Water for this purpose comes from the streams which run during the growing season and from pumped underground waters, and is distributed by gravity ditches. The demand upon the underground water has, however, exceeded the supply, and the water plane has been lowered year by year. In 1870 flowing water could be obtained in the "artesian basin," while good supplies could be obtained from adjacent areas by pumping. The country developed rapidly, and about 1888 the water plane began to show the drain upon it. The artesian area was reduced and the pumping plants had to draw from lower levels. After some seasons of heavy rainfall the water plane has risen, but with these temporary exceptions the flow has been lowered from 20 to 80 feet.

The streams which rise in the National Forests and receive run-off from chaparral areas are:

Cottonwood Creek.	Santa Ana River.	Santa Ynez River.
Sweetwater River.	San Gabriel River.	Santa Maria River.
San Diego River.	Los Angeles River.	Salinas River.
San Ysabel Creek.	Malibu Creek.	Carmel River.
San Luis Rey River.	Santa Clara River.	Sur River.
Santa Margarita River.	Ventura River.	

The average annual run-off from all these streams is approximately 1,500,000 acre-feet, theoretically sufficient, allowing 3 feet per acre, for the irrigation of 500,000 acres. In some years the flow is much less than this, and at such times greater economy is practiced. The population dependent upon this water supply was, according to the census of 1900, 340,228. It is estimated by the Bureau of the Census that, by 1910, this number had increased to about 730,000, and it is reasonable to suppose that the future population will be limited only by the amount of water which can be conserved and made available. The city of Los Angeles has had to go more than 200 miles to the Owens Lake watershed for its supply, and in southern California it is recognized as imperative that every means should be taken to save for use as much as possible of the rain which falls upon the mountains. To-day there is land in southern California which, without water or the prospect of it, is not worth 50 cents an acre, but which, with water upon it, would be worth as high as $3,000 per acre.

Nearly all of the mountain canyons are narrow and have steep grades and offer no reservoir sites for the storage of flood waters. Moreover, the flood waters are so exceedingly turbid that the reservoirs would soon be filled with silt. Only in such places as the Cleveland National Forest, where the topographic conditions are most favorable, have reservoirs been constructed. There five have been constructed, two are under construction, and eight other sites will be available when the increase in population makes their use necessary. Over all the watershed areas above these reservoirs the annual evaporation from an exposed water surface is greater than the rainfall. In one locality, just above the Sweetwater Dam, the yearly evaporation is equal to 56 inches, while the rainfall is but 10 inches. Conclusions drawn from such figures would be erroneous, however, since much depends upon the distribution of the rainfall. Less than 10 inches of rainfall might produce a flowing stream and fill a reservoir, while a much heavier annual total might be entirely lost by evaporation if it came gently and intermittently. Intermittent showers, with periods of sunshine, permit all the moisture to be withdrawn from the surface soil. The ground is usually so dry that an hour's hard rain will not wet more than an inch or two of the surface. If followed by a hot wind or by sunshine, it might easily be that none of this rainfall would be available for the use of man. Over the chaparral area, as a whole, including the forest area, present conditions of precipitation, run-off, and evaporation are estimated in round figures as follows:

Area of chaparral cover	acres	5,500,000
Area of forest cover	do	2,000,000
Total area of covered watersheds	do	7,500,000
Average annual precipitation:		
At sea level	inches	13
At 2,000 feet: West and south slopes 25 East and north slopes 9	do	17
At 5,000 feet: West and south slopes 43 East and north slopes 27	do	35
At 8,000 feet: West and south slopes 61 East and north slopes 45	do	53
At the average elevation of the covered watersheds, 3,000 feet, inches		23
Average annual precipitation on the covered watersheds	acre-feet	15,000,000
Average annual run-off from the covered watersheds (10 per cent)	acre-feet	1,500,000
Losses by evaporation and for plant food and unknown (90 per cent)	acre-feet	13,500,000

Since the precipitation can not be controlled, the problem narrows down to the saving of the greatest amount of the precipitation and the control of its rate of run-off.

Chaparral serves to conserve moisture and regulate the flow of streams in two ways: (1) By the root systems, which penetrate the soil and assist the water to percolate, while making a binding mat to prevent erosion; and (2) by lessening the evaporation, (*a*) by breaking the force of hot winds, and (*b*) by shading the ground. Every one of the chaparral species, great and small, contributes something toward these ends. There are, however, certain species, not numerous, which by their size, density of growth, and shade-bearing qualities are of first importance. Some of these are particularly desirable

FIG. 1.—LOW AND OPEN CHAPARRAL EVENLY DISTRIBUTED ON ALL SLOPES.

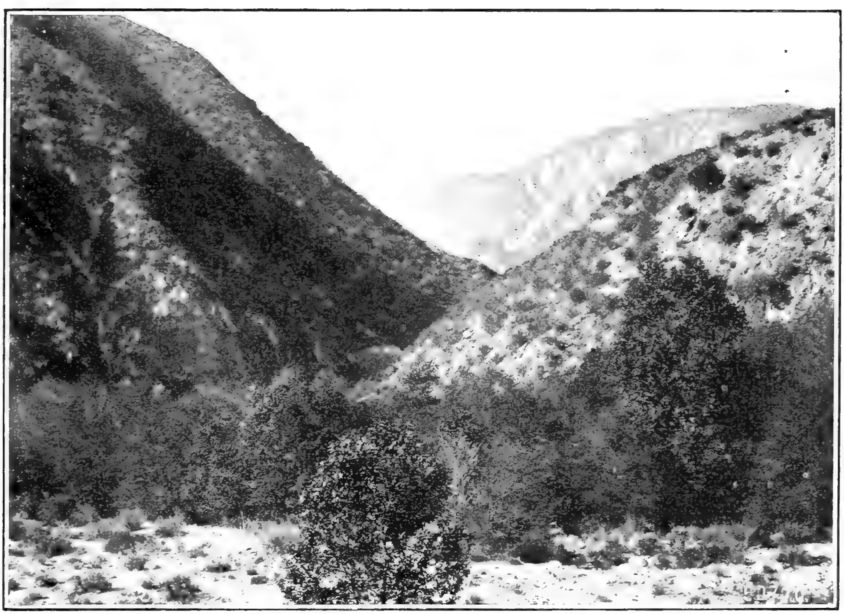

FIG. 2.—HEAVY COVER OF CHAPARRAL ON NORTH SLOPE, AND SCATTERING COVER ON SOUTH SLOPE.

because they are not inflammable or because they will quickly make a new growth from the roots after they have been burned.

On the whole, it is doubtful if chaparral can be credited with being a good protector of snowfall. Its office as a cover is to conserve the rains, which constitute by far the greater portion of the precipitation. It is only in the highest zones that heavy snows occur, and the phenomenon has been observed only once near the level of the sea. That was in the northern portion of the chaparral region, at San Luis Obispo, in 1896.

Mr. L. C. Miller, of the Forest Service, in summing up the results of a detailed investigation of the effects of chaparral cover on watersheds and along streams near Los Angeles, and of a general study in other localities, stated:

> The density and character of the cover is extremely important. Both of these factors have an influence on the water supply of every stream in southern California. The trees and shrubs which form the stream cover are important in retarding evaporation and thus preventing a decrease in the water supply. The vegetation which forms the cover for the mountain slopes is of still greater importance.

The assertion is sometimes made that trees hold off from the ground 8 per cent of the falling rain, which is soon evaporated; and, further, that they take out of the ground an additional 25 per cent, which is either converted into vegetable structure or transpires in vapor. The inference sought to be drawn is that because of the plants there is less water available for use. The case, however, may be presented in another way. In a region with an annual rainfall of 15 inches and an annual evaporation of 60 inches, where the stream beds are entirely dry, except after heavy downpours, and where no flow of water extends far enough down a valley to reach a reservoir or irrigation ditch, conditions could hardly be worse. Such conditions do in fact exist. For seven years there was no flow into the Sweetwater Reservoir, near San Diego. Only a small portion of its watershed was forested, and the chaparral, from repeated burning and overgrazing, made but a poor cover. It is true, of course, that if the watersheds had been covered with chaparral or forests the trees would have taken all the rainfall necessary for their sustenance, and this water would certainly never have reached the reservoir. Without trees, however, the meager precipitation and excessive evaporation kept the reservoir dry. If the evaporation, which is least during the rainy season, could have been sufficiently reduced by a proper tree cover, the streams would have begun to flow. The owners of the reservoir could well have afforded to let the sun take 50 per cent of the water and the trees 25 per cent more, if they could have been sure of getting the remaining 25 per cent. That would have been better than getting no water at all.

The amount of water lost by evaporation from open irrigation ditches is about 25 per cent and the amount lost from an uncovered mountain stream is certainly no less. Often heavy floods completely destroy the cover along streams, exposing them to excessive evaporation. It is a common statement of all who have given the matter careful study that during the years immediately following such a disaster the water supply is perceptibly decreased and small streams often cease flowing altogether.

Among the people of southern California the belief is general that the chaparral regulates the flow of streams. Even though some streams have flood periods and nearly all have intermittent flow, it is assumed that the chaparral makes conditions of stream flow much better than they otherwise would be. Exact evidence of the extent of the chaparral's influence on the water supply is, however, often lacking. After a severe fire on a watershed the flow of a stream may so alter, its period so shorten, and its value so largely disappear as to leave little doubt that the fire has affected the stream. On the other hand, but few data have been collected to show whether streams will resume their normal flow when the chaparral cover has reestablished itself. It is not the purpose of this bulletin to enter into a technical discussion of this subject. Accurate scientific data will not be available until rain gauges are established over the watersheds and measuring weirs placed at proper points to determine the run-off and the data from burned, unburned, and restocked watersheds compared. It is possible, however, to give the evidence of several close observers of conditions in the chaparral region as it bears upon the water supply.

Prof. George Davidson, for 50 years a student of California, said, in 1903:

> It must be patent to everyone who has studied this subject that if the whole area of the western slopes of the California mountain ranges were bare of foliage the rainfall would rush into the waterways and come down into the plains with torrential force, just as it does through many of the eastern treeless slopes of the Alps into the plains of Italy. All the finer material from the whole surface would be quickly brought down, then the heavier materials, gravel, and bowlders. We have clear evidence of this in the southern part of California.
>
> But with all these slopes forested and further protected by undergrowth these rain waters would be held back; they would first saturate the soil, and only a relatively small percentage would promptly reach them directly and by percolation. Damaging freshets would occur only after heavy and continuous rain storms, and then, in spite of forests and chaparral, the storm waters would be hurried forward with torrential force to the plains and be lost in the ocean, unless retained by dams and reservoirs.

During the years from 1881 to 1883, inclusive, fires were set by herdsmen back of Los Angeles. The year 1884 saw a number of disastrous floods in the region, which ruined much agricultural land.

In Soledad Canyon the tracks and bridges of the Southern Pacific Railway were swept away, and traffic was stopped for six weeks. In the Tujunga Valley, where thousands of acres of chaparral had been burned, rains rushed over unprotected slopes and cut deep and impassable gullies in places where water had never done any damage before. Many apiaries were destroyed, although bee masters never placed their hives below the known flood level.

At about the same time a tremendous fire covered practically the whole west face of the Santa Ana Range south of Los Angeles. Its results were felt for years in the reduced and irregular streamflow. One particularly disastrous flood, following soon after the fire, did much damage in the Capistrano Valley. Many hundreds of acres of fine agricultural land were washed away, and others were so gullied as to be valueless. Judge Eagan, of Capistrano, relates that he awoke one morning to find that 12 acres of his finest land had been washed away during the night. Recovery from this fire was slow, but since the restocking of the watershed with chaparral conditions are normal again, and after an ordinary rain the increased flow of the streams is hardly noticed.

In 1901 and 1902 Mr. T. P. Lukens, vice president of the Forest & Water Association, of Los Angeles County, made an examination to determine why the San Antonio River, with a drainage area of 27 square miles, furnished a minimum flow of 190 miner's inches, while the San Gabriel River, with a drainage of 222 square miles, gave a minimum flow of 90 miner's inches. The discrepancy was especially marked because the San Gabriel drainage was in the very center of an area of comparatively high precipitation. He found that no portion of it had escaped fire within a comparatively few years. Devil's Canyon, with an area of 13 square miles and an average altitude of about 4,000 feet, had formerly been noted for its continuous flow of water. After being denuded of its cover by fire and overgrazing it had no conserving power whatever. On the other hand, the San Antonio River basin had suffered much less from fire. It is reasonable to suppose, Mr. Lukens thinks, that if fires had been kept out of both watersheds the minimum flow would have been proportionate to their areas, since their geological formations do not differ. Numerous measurements made by Mr. Lukens show that where the cover was perfect the variations between morning and evening measurements were so slight as to be insignificant, although the weather was very warm and clear. Other measurements on the same stream and on other streams in places where the cover had been destroyed showed that there was a loss of from 35 to 50 per cent between morning and evening. Mr. Lukens states:

Near Pasadena there are two small canyons from which some years ago an equal amount of water was flowing. About 1885 a fire swept over the drainage of one of these canyons. The water supply from this burned canyon decreased immediately, and the season following it ceased to flow entirely. As the chaparral and trees came back the water reappeared, until the supply, while not equal to the original flow, is on the increase. The water in the canyon that was not burned continued to flow. These canyons are very near together, on the south slope of the San Gabriel Reserve.

An instance in which the clear memory of one man extends over a period of destruction and restoration of the cover on a watershed is given by the testimony of Mr. Walter Nordhoff, a close observer of natural phenomena. His observations were made upon his own property. One area is located in the Maximinos Canyon in Baja California, south of Punta Banda, between Todos Santos Bay and Santo Tomas. The watershed extends inland from the coast for about 10 miles and has an approximate area of 20,000 acres. Rain-gauge records were kept for 12 years, from 1888 to 1900. The annual rainfall was from 5 to 22 inches. Nine brooks, permanent at their sources, but dry before reaching the main canyon, joined to form the drainage, which ran underground for 5 miles through dry-sand wash into a lagoon at the ocean line. This lagoon was about a quarter of a mile long and 15 feet deep, and discharged into the ocean over a sand pit. At the head of the lagoon, in 1880 and until 1903, there was a perpetual flow of water from several springs, some of which had not been known to change their volume appreciably in either good or bad years. The discharge from these springs was used to irrigate about 1½ acres of land. It was estimated that with careful use 5 acres could have been covered and at least 1,000 head of cattle watered.

About 1893 the whole watershed was burned. Following the next heavy rain a flood swept down the main canyon to the sea, filling the lagoon with silt, charcoal, and half-burned branches, and tearing out the sand spit. For the next six or eight years there was barely enough water at the head of the lagoon for a few head of ranch stock, and even this eventually dried up. It was not until 1902, nine years later, when the chaparral cover was restored, that the springs at the mouth of the canyon again began to flow. Since then their flow has steadily increased. Although there were some floods after heavy rain during the time that the chaparral was restocking the watersheds, no destructive floods have occurred since 1903, despite the fact that there have been rainfalls which, when the watershed was bare of cover, would have produced floods and caused the canyon to run from head to ocean.

Unfortunately, the 1½ acres of arable land formerly irrigated by the springs was swept away by the floods, thus removing what would have constituted a fair basis of comparison of present conditions with those prior to 1893. So far as the flow of water is concerned, the conditions existing before the fire are now almost completely restored. The rainfall since the burning has been practically the same as it was before. While the watersheds were denuded, the whole visible run-off occurred within 60 hours after a storm. At present a heavy rainfall for a week is followed by an even flow in all the canyons, beginning slowly and lasting from a week to a month. At the time of the flood the canyon was so cut up and so filled with quicksand that the vaqueros rode the side hills or "cuchillos." At present the canyon can be traveled at all times.

While it is true that the springs were observed during only five successive years before the fire, this testimony is supplemented by resident Mexicans, who say that for 20 years prior to 1903 they considered the springs as "permanente," perfectly steady and reliable, and that they were not "de temporado," that is, intermittent.

Another example of the influence of chaparral upon run-off on Mr. Nordhoff's property was shown in the Potrero de Avenal (Pasture of Oats), a canyon containing the only water supply for about 6,000 acres of grazing land. The region is mountainous, and the next nearest water is from 3 to 5 miles distant over a divide 1,200 feet high. The stream which ran through the canyon had a surface flow for a mile, then an underground flow for 4 miles, and finally a surface flow of half a mile. Between the two surface-flowing sections a spring flowed from a side hill. On the upper watershed was a heavy growth of chaparral, lilac, or "Palo Colorado" (*Ceanothus spinosus*), some of it 20 feet high. In 1893 the vaqueros burned off the chaparral. During the years following the lower section of the flowing water dried up, but so gradually that the vaqueros had time to "develop" a side-hill spring, which was made to supply water for 100 head of cattle and horses. But this spring, too, gradually dried up, and the region was then available only for horses, which can travel longer distances for water. The upper section of the flowing water never entirely dried up, but its volume diminished greatly. The spring remained dry for some years and then gradually began to flow again. Later, water reappeared in the lower section, first only in winter, then at night throughout the year, until in 1904 it began to give promise of permanency. In this connection Mr. Nordhoff states:

It is to be noted that, after a burning, the stream never, within one man's memory, is as good as it was before the fire. It may be, as Indians and Mexicans claim, that it takes 50 years at least to complete the water-flow cycle. The effect of a fire on the water supply is so well known that you may hear Indians, Mexicans, and cattlemen discuss their great problem thus: "If there is brush the cattle find it hard to get at the grass, and, moreover, they become wild. If the chaparral is burned, then there is much less grass and very much less water, and the water comes in floods which are permanently destructive." I, myself, am exactly in this situation now. I have permanent grass and water for ten times the cattle I now run, providing the cattle could get at the grass and could be kept gentle at reasonable expense. I know, from experiences of 1893, that if the chaparral is burned the floods which follow will tear the pasture all to pieces, and that the grass, though more accessible, will be less in quantity. This grass, however, becomes almost useless because the permanent water supply is gone.

VERTICAL RANGE OF CHAPARRAL.

While it is true that the typical chaparral lies in a belt below the timber and above the sage-brush plains, the elevations vary with latitude and exposure. In some places the chaparral extends to sea level and in others reaches an altitude of 8,000 feet. This entire range will, for the purpose of this report, be considered as the chapparal zone. Figure 1, prepared from notes by the author and from a large collection of other data, gives a profile of the forest zones on the Pacific coast. The range of Douglas fir, *Pseudotsuga*

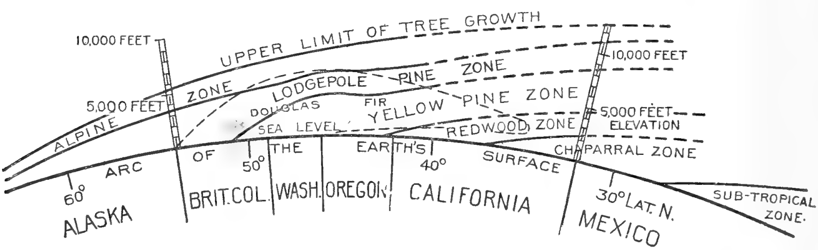

FIG. 1.—Forest zones of the Pacific slope.

taxifolia, is shown, since this tree is very important in the Northwest. The most southerly point in the United States at which the alpine zone exists is on the summit of San Jacinto Peak, at the northern end of the Cleveland National Forest. The zone here extends from 10,000 feet to the summit, or to 10,805 feet. It should be remembered that the chaparral extends into the redwood and even into the yellow pine zones, although on the diagram the names given to the different zones are of trees which, in an important locality, dominate it. This tree may be absent in some parts of the zone, but the type of forest recognized by foresters remains virtually the same.

The very irregular division line between the chaparral and the redwood and yellow pine forests evidences the struggle between forest and chapparal for possession of the soil. The trees have been quick to seize any area which favors them against their competitors.

The following table gives the extreme vertical range of the most important chaparral species observed:

TABLE 2.—*Vertical range of chief chaparral species.*

Species.	Observed vertical range.	Species.	Observed vertical range.
	Feet.		*Feet.*
Adenostoma fasciculatum	0–8,000	Fraxinus dipetala	3,000
Adenostoma sparsifolium	500–5,000	Heteromeles arbutifolia	0–4,000
Amelianchier alnifolia	4,000	Lotus glaber	500–5,000
Arctostaphylos glauca	400–7,500	Pickeringia montana	2,000–5,000
Arctostaphylos manzanita	1,400–7,000	Prunus ilicifolia	0–6,000
Arctostaphylos tomentosa	750–5,000	Quercus densiflora	3,250–5,000
Artemisia californica	0–6,000	Quercus dumosa	1,000–7,300
Artemisia tridentata	2,100–4,000	Quercus wislizenii	1,500–6,200
Audibertia polystachya	1,000–4,500	Rhamnus californica	0–5,000
Ceanothus crassifolius	1,000–6,000	Rhamnus ilicifolia	750–5,600
Ceanothus cuneatus	0–5,000	Ribes malvaceum	3,000
Ceanothus divaricatus	750–7,000	Ribes menziesii	3,000
Ceanothus hirsutus	100–3,250	Ribes speciosum	3,000
Ceanothus integerrimus	2,000–5,000	Rhus diversiloba	0–5,700
Ceanothus papillosus	500–6,000	Rhus laurina	0–3,000
Ceanothus sorediatus	1,200–8,000	Rhus ovata	0–5,000
Ceanothus spinosus	2,500–7,000	Rhus trilobata	2,000–5,000
Cercocarpus ledifolius	5,500–8,000	Salvia leucophylla	0–4,500
Cercocarpus parvifolius	750–6,000	Salvia mellifera	750–3,250
Eriodictyon californica	500–3,000	Sambucus glauca	5,000
Eriodictyon glutinosum	1,000–5,000	Symphoricarpus mollis	2,000–5,000
Eriodictyon tomentosum	2,000–4,000	Yucca whipplei	0–5,000
Eriogonum fasciculatum	250–6,500		

SUBZONES.

The chaparral zone may be divided into lower, middle, and higher subzones, since the character of the chaparral and the species which compose it clearly change at certain elevations, on an average at 2,000 and 5,000 feet. Some of the species peculiar to the lower zone, from sea level to 2,000 feet, will occasionally extend into the middle zone, and there is a gradual merging of the several species at various elevations. Still, these subzones exist. In the Santa Barbara National Forest notes were taken on 116 species, which were found distributed as follows:

	Species.
Only in the lower subzone, 0–2,000 feet	19
Only in the middle subzone, 2,000–5,000 feet	38
Only in the higher subzone, 5,000–8,000 feet	2
In both lower and middle subzones, 0–5,000 feet	38
In both middle and higher subzones, 3,000–8,000 feet	8
In the lower, middle, and higher subzones, 0–8,000 feet	11
	116

From this it may be seen that there are, in the combined lower and middle subzones, 106 species, of which 87 are in the middle subzone. Since this subzone contains the most important cover, its range of 3,000 feet was given the most detailed study.

COMPOSITION OF CHAPARRAL.

The composition of the chaparral varies with slope, exposure, soil, and altitude. This makes it very difficult to estimate accurately over a large area the proportion of any given species in the stand. The best that can be done is to average a large number of estimates, giving each its proper weight according to the area which it represents.

In determining the proportion of the different species of the chaparral, three methods were employed. The first was to take an average sample plot of one-eighth or one-quarter of an acre and count each species represented on the plot. The second was to make an estimate of all the plants within a certain distance of the observer. This method is, of course, much quicker than the first, but experience showed that the estimates of different persons varied considerably, and that such estimates, however careful, might be far from the truth. The third was the strip method, in which the observer started up a hillside, made a careful estimate of the dominant species, and continued this until he reached an altitude where the character of the chaparral began to change. This point was considered the upper limit of the subzone, and a new estimate was then begun for the higher altitude.

The averages given are the result of several hundred observations made by five experts over a period of seven years, from 1898 to 1904, inclusive. The observations were made in the general course of field work, and not for the special purpose of this bulletin. It is thought that the nomenclature given is sufficiently justified by current use. Much is yet to be done, however, in determining the proper standing of a number of the binomials employed.

DOMINANT SPECIES.

In the following table is given the proportion of the dominant species in the chaparral within the National Forests of southern California. These species form approximately 90 per cent of the entire stand.

TABLE 3.—*Proportion of dominant species in the chaparral.*

Species.	National Forests.				Average for the region.
	Monterey.	Santa Barbara.	Angeles.	Cleveland.	
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Adenostoma fasciculatum	30	15	57	40	33
Adenostoma sparsifolium				20	6
Arctostaphylos glauca	9	4	2	10	6
Arctostaphylos manzanita	4	2	3	8	4
Artemisia californica	2	10			4
Ceanothus crassifolius		3	1		1
Ceanothus cuneatus	6	5	1	1	3
Ceanothus divaricatus	6	6	13	7	8
Ceanothus hirsutus	1	2			1
Ceanothus papillosus	5	1			1
Cercocarpus parvifolius	4	9	3	1	5
Eriogonum fasciculatum	2	6			2
Heteromeles arbutifolia	1	2			1
Quercus dumosa	6	20	12	7	13
Quercus wislizeni	5	1			1
Salvia mellifera	2	3			1
Other species	17	11	8	6	[1] 10

[1] See next list.

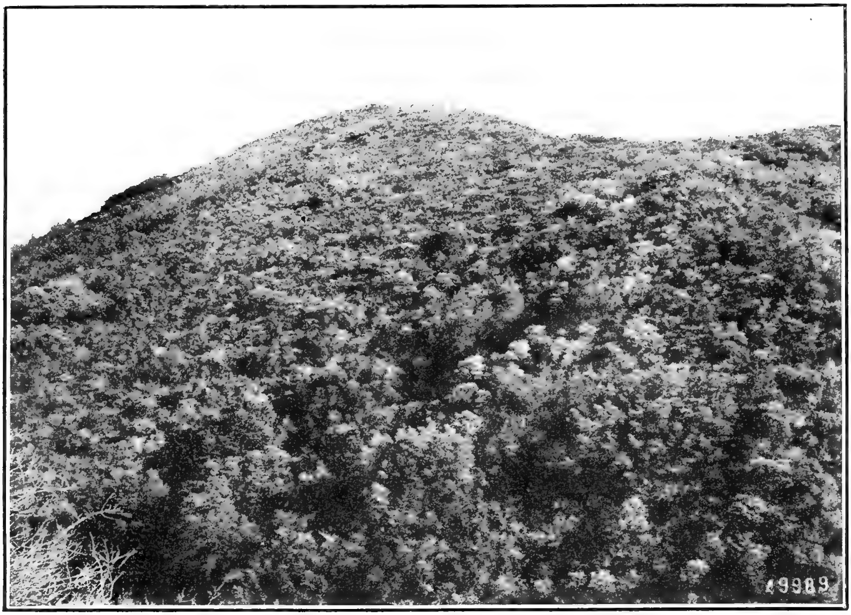

FIG. 1.—A HEAVY BLANKET OF OLD CHAPARRAL.

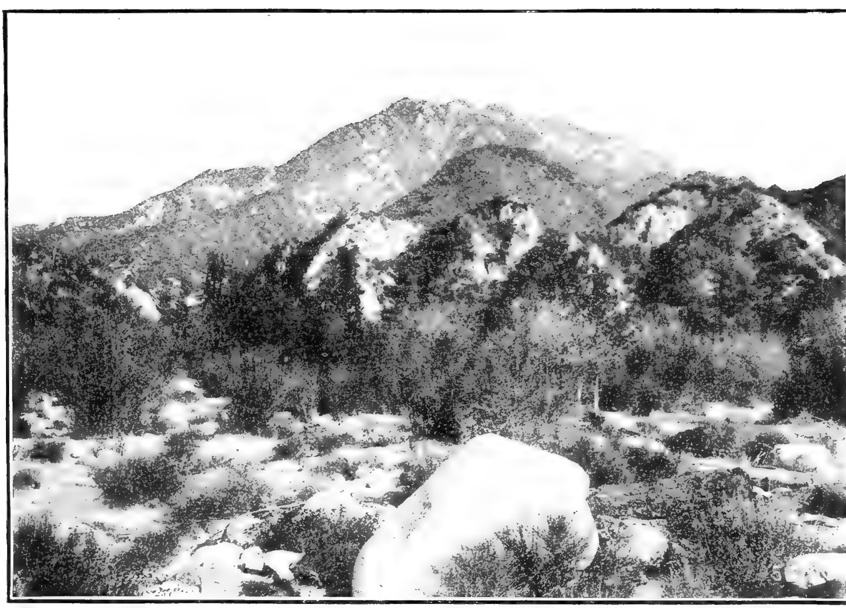

FIG. 2.—IRREGULAR CHAPARRAL, RESULT OF BARREN SOIL.

FIG. 1.—GOOD COVER OF OLD CHAPARRAL UNDAMAGED BY FIRE.

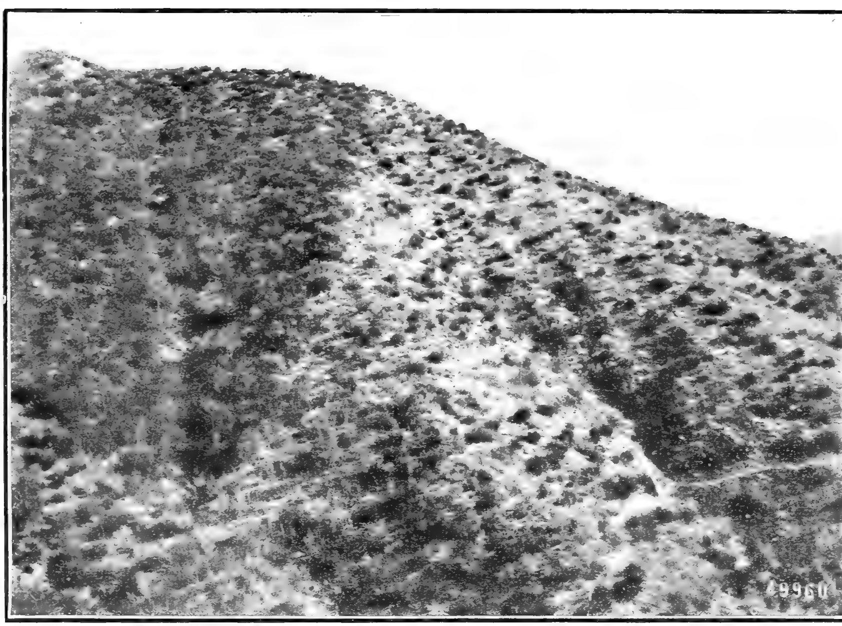

FIG. 2.—UNBURNED CHAPARRAL BORDERING A NEW GROWTH ON A BURN 4 YEARS OLD.

SECONDARY SPECIES.

The species which, taken together, comprise 10 per cent of the chaparral, and which are important in some localities, are:

Amorpha californica	In Santa Barbara National Forest.
Aplopappus squarrosus	From Monterey to Santa Barbara National Forest.
Arctostaphylos andersoni	In Santa Barbara National Forest.
Arctostaphylos bicolor	In Cleveland National Forest.
Arctostaphylos tomentosa	In Santa Barbara and Angeles National Forests.
Artemisia tridentata	This is the common sagebrush and is generally classified as a separate type and not with chaparral, but on the north side of Santa Barbara National Forest it merges into the chaparral type.
Audibertia polystachya	In Santa Barbara National Forest.
Baccharis viminea	In Santa Barbara National Forest.
Bigelovia arborescens	In Monterey National Forest.
Ceanothus dentatus	In Monterey National Forest.
Ceanothus integerrimus	In Monterey and Santa Barbara National Forests.
Ceanothus sorediatus	In Santa Barbara National Forest.
Ceanothus spinosus	In Santa Barbara National Forest.
Cercocarpus ledifolius	In Santa Barbara National Forest.
Clematis lasiantha	In Monterey and Santa Barbara National Forests.
Cornus californica	In Santa Barbara National Forest.
Cornus pubescens	In Monterey National Forest.
Dendromecon rigidum	In Santa Barbara and Monterey National Forests.
Ericameria microphylla	In Santa Barbara National Forest.
Eriodictyon californica	In Santa Barbara National Forest.
Eriodictyon glutinosum	In Monterey and Santa Barbara National Forests.
Eriodictyon niveum	In Santa Barbara National Forest.
Eriodictyon tomentosum	In Monterey and Santa Barbara National Forests.
Eriogonum elongatum	In Monterey National Forest.
Eriophyllum confertiflorum	In Monterey National Forest.
Fraxinus dipetala	In Santa Barbara National Forest.
Fremontodendron californicum	In Santa Barbara National Forest.
Garrya veatchii	In Monterey and Santa Barbara National Forests.
Lonicera interrupta	In Monterey National Forest.
Lotus glaber	In Monterey National Forest.
Pickeringia montana	In Monterey National Forest.
Prunus demissa	In Monterey and Santa Barbara National Forests.
Prunus ilicifolia	In Monterey and Santa Barbara National Forests.
Quercus chrysolepis	In Angeles National Forest.
Quercus densiflora	In Monterey National Forest.

Quercus douglasii	In Angeles National Forest.
Rhamnus californica	In Monterey and Santa Barbara National Forests.
Rhamnus crocea	In Monterey National Forest.
Rhamnus ilicifolia	In Monterey and Santa Barbara National Forests.
Rhus diversiloba	In Monterey and Santa Barbara National Forests.
Rhus integrifolia	In Santa Barbara National Forest.
Rhus laurina	In Santa Barbara and Cleveland National Forests.
Rhus ovata	In Santa Barbara and Angeles National Forests.
Rhus trilobata	In Santa Barbara National Forest.
Ribes menziesii	In Monterey and Santa Barbara National Forests.
Ribes sanguineum	From Monterey to Angeles National Forest.
Ribes speciosum	From Monterey to Angeles National Forest.
Rosa californica	From Monterey to Angeles National Forest.
Salix sessilifolia	From Monterey to Santa Barbara National Forest.
Salvia leucophylla	From Monterey to Santa Barbara National Forest.
Sambucus glauca	In Monterey and Santa Barbara National Forests.
Shepherdia argentea	In Santa Barbara National Forest.
Symphoricarpus racemosus	In Monterey National Forest.
Symphoricarpus mollis	In Monterey National Forest.
Yucca whipplei	In Monterey and Santa Barbara National Forests.

UNIMPORTANT SPECIES.[1]

Actæa arguta.
Adenostoma parvifolius.
Æsculus californica.
Amelanchier alnifolia.
Arbutus menziesii.
Arctostaphylos glauca.
Baccharis consanguinea.
Baccharis pilularis.
Berberis dictyota.
Berberis pinnata.
Castilleia foliolosa.
Ceanothus lemmoni.
Ceanothus pinetorium.
Ceanothus rigidus.
Ceanothus spicata.
Ceanothus thyrsifloris.
Ceanothus tomentosus.
Ceanothus verrucosus.
Ceanothus vestitus.
Clematis lingusticifolia.
Cneoridium dumosum.
Eriophyllum stæchadifolium.
Espidium munitum.
Forestiera neo-mexicana.
Gaultheria shallon.
Isomeris arborea.
Lonicera ledebourii.
Malvastrum thurberi.
Marrubium fremontii.
Marubian vulgare.
Nuttallia cerasiformis.
Pentstemon centranthifolius.
Pentstemon cordifolius.
Pentstemon ternatus.
Prosopis juliflora.
Rhamnus purshiana.
Rubus nutkanus.
Solanum umbelliferum.
Solanum xanti.
Sphacele calycina.
Spirea discolor.
Stenotus linearifolius.
Styrax californicum.
Trichostema lanatum.
Vaccinium ovatum.
Zauschneria californica.

[1] Dr. E. L. Greene, of the National Museum, while examining the specimens of chapparal collected in Southern California by the author, noted new species of Arctostaphylos, Eriodictyon, and Hazardia, to which no names have yet been given by botanists.

AMOUNT OF SHADE PRODUCED.

Chaparral cover may be roughly graded as heavy, medium, light, and scattered. In some cases where comparative studies have been made to determine the value of cover on different watersheds the amount of shade or the density of the chaparral has been estimated by percentage. If these two methods are reduced to a common basis for comparison, heavy will equal from 75 to 100 per cent of shade, medium from 50 to 75 per cent, light from 25 to 50 per cent, and scattering less than 25 per cent. The surface total of shade, or 100 per cent, is rare, and is likely to occur only where the chaparral consists of two stories; that is, of species of varying height forming two or more strata of cover. The heavy cover is, of course, the most desirable, provided that it is not of undesirable species. In the mock chaparral, where the cover is only temporary, complete shade is undesirable, since it will prevent the growth of forest-tree seedlings.

The very heaviest chaparral is impassable to man, owing to the closely matted growth and the spines carried by some species. Sometimes these dense growths are in large patches, with areas of more scattered growth between, so that by carefully selecting a route one may travel through the growth with comparative ease.

The density and composition of the chaparral varies on different slopes. (Pl. III, fig. 2.) Altitude also has much to do with the development of the different species, and hence with the density of the cover. Notes on the density of the chaparral on different sites and exposures, at altitudinal intervals of from 2,000 to 3,000 and from 3,000 to 5,000 feet, were made during the course of a study of the chaparral on the Angeles National Forest. The results are given in the following table:

TABLE 4.—*Percentages of shade on selected plots of chaparral.*

PASADENA WATERSHED, CALIFORNIA, 1903.

No. of survey.	Slope.							
	North.		South.		East.		West.	
	2,000 to 3,000 feet.	3,000 to 5,000 feet.	2,000 to 3,000 feet.	3,000 to 5,000 feet.	2,000 to 3,000 feet.	3,000 to 5,000 feet.	2,000 to 3,000 feet.	3,000 to 5,000 feet.
1	85	80	60	25	50	20	60	75
2	75	60	70	75	85	95	70	90
3	80	40	40	50	70	60	35	70
4	90	70	80	....	50	85	65	40
5	....	60	85	95	60	85	60	90
6	90	60	50	60	65	90	40	35
7	....	55	65	80	....	50	50	90
8	....	85	35	90	....	90	90	90
9	....	60	35	90	....	100	70	40
10	....	95	60	85	....	65	30	80
11	....	65	50	70	....	80	35	60
12	....	....	75	90	....	....	65	55
13	....	....	50	45	....	....	55	90

TABLE 4.—*Percentages of shade on selected plots of chaparral*—Continued.

PASADENA WATERSHED, CALIFORNIA, 1903—Continued.

No. of survey.	Slope.							
	North.		South.		East.		West.	
	2,000 to 3,000 feet.	3,000 to 5,000 feet.	2,000 to 3,000 feet.	3,000 to 5,000 feet.	2,000 to 3,000 feet.	3,000 to 5,000 feet.	2,000 to 3,000 feet.	3,000 to 5,000 feet.
14			20	80			90	45
15			80	80			75	
16				75			80	
17				30				
18								
19								
20								
21								
Average density	84	66	57	70	63	75	61	68

SANTA ANA WATERSHED, CALIFORNIA, 1903.

No. of survey.	Slope.							
	North.		South.		East.		West.	
	2,000 to 3,000 feet.	3,000 to 5,000 feet.	2,000 to 3,000 feet.	3,000 to 5,000 feet.	2,000 to 3,000 feet.	3,000 to 5,000 feet.	2,000 to 3,000 feet.	3,000 to 5,000 feet.
1	45	70	35	60	40	50	65	50
2	75	75	20	70	55	50	40	60
3	75	55	20	70	80	30	55	50
4	60	50	35	50	50	85	60	50
5	30	50	30	60	55	70	50	60
6	90	50	40	50	40	60	40	70
7	60	90	25	50	30	65	50	65
8	75	60	60	25	50		30	70
9		60	40	35	70		60	65
10		40	20	50	45		35	40
11		75	60	60	40		60	
12		35	40	40	60		45	
13		70	70	60	30		70	
14			50		60		35	
15					50		45	
16					55		50	
17							40	
18							30	
19							60	
20							70	
21							40	
Average density	64	60	39	52	51	59	49	58

These tables show that on these watersheds the density of chaparral was greater in the zone between the 3,000 and 5,000 foot levels than in the zone between the 2,000 and 3,000 foot levels, on east, south, and west exposures. The density of the cover on north exposures was greater in the lower than in the higher zone. This is perhaps due to a difference in topography between the two zones. In the lower zone the slopes are extremely abrupt, while in the upper they are more uniform.

The difference in the density of the different slopes holds true for both the Pasadena and the Santa Ana watersheds, and is due chiefly to three causes. On north slopes, and in fact in all protected situations, fire is about the only agency which tends to limit the density of chaparral. Even when fires occur on such situations little permanent damage is done, since the chaparral soon regains possession of the ground. On south slopes, on the other hand, exposure to intense heat and poor soil conditions results in a poor and scattered growth, while after fire the hard-baked ground is inhospitable to a new stand.

VALUE OF THE DIFFERENT SPECIES.

In the chaparral as it now exists the most desirable species are not the most numerous. Artificial means are needed to encourage the extension of the better sorts, to discourage the undesirables, and, possibly, to introduce foreign in place of some of the native species. The study of chaparral as a type of plant formation, and of the relative importance of the various genera as cover, is by no means complete. Much is yet to be done in determining which species are least inflammable, are evergreen, cast the most shade, recover most quickly after burning, make the best soil binders, and have naturally a wide distribution and range. The following description of those species which are important, either generally or in certain localities, or because their characteristics are particularly desirable, is given merely as a start in the right direction:

Adenostoma fasciculatum, grease-wood, is the most abundant and widely distributed chaparral species in California, and is commonly known as chamisal. It ranges from sea level to 8,000 feet, is evergreen, tolerant, grows under all conditions of soil and exposure, and after burning makes a quick coppice growth from the surviving roots. In spite of these excellent qualities, it can hardly be considered a good cover for watersheds. It branches close to the ground, and has a shrublike form with many stems which sometimes attain a height of 10 feet. These stems are practically without permanent branches. This form does not produce much shade, nor does it protect the ground from dry or hot winds. It is exceedingly inflammable, and not only makes a fast-running fire when in pure stand but also, when in mixture with other species, greatly increases the inflammability of the cover as a whole. It sends down a large tap root with few laterals, which makes it poor as a soil binder. This species should not be confounded with the "grease-wood," *Sarcobatus*, of the Rocky Mountain region. (Fig. 2.)

Adenostoma sparsifolium, Yerba del Pasmo (spasm herb), is found in the southern portion of the chaparral region and is important in the northern portion of the Cleveland National Forest. Leiberg estimates that on certain eastern slopes, between 3,500 and 5,000 feet, it forms 55 per cent of the cover. It is exceedingly inflammable, and therefore undesirable. The Mexicans and Indians considered it a remedy for lockjaw, colds, cramps, inflammations, and snake bites.

Arctostaphylos glauca, big-berried manzanita, is distributed in patches over the Coast Range. It is confined chiefly to the middle subzone, between 2,000 and 3,000 feet, although it grows both at higher and at lower elevations. It thrives upon all kinds of soil, but is a very slow grower, and therefore does not recover rapidly after burning. It reproduces by seed and coppice, and, like the other manzanitas, forms a broad crown of solid wood at the surface of the soil, from which the roots ramify in all directions. As cover it is a very desirable species.

Arctostaphylos manzanita, manzanita, is found throughout the chaparral region. It has the same qualities as *glauca*, and is therefore desirable.

Arctostaphylos tomentosa, woolly manzanita, is found along the coast as far south as the Cleveland National Forest, at altitudes of

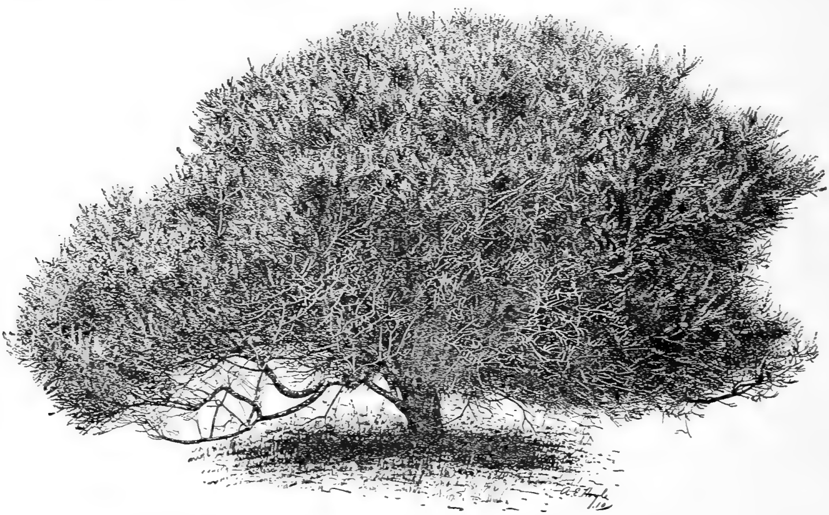

FIG. 2.—Grease-wood, *Adenostoma fasciculatum*, 6 feet high.

from 750 to 5,000 feet. In northern California it forms part of the mock chaparral, and at still higher altitudes often grows in a pure impenetrable stand. It has the same desirable qualities as *glauca*.

Artemisia californica, wormwood, is an important part of the cover from Santa Barbara National Forest northward and ranges as high as 6,000 feet. It is undesirable, because it is low, casts little shade, and is inflammable.

Ceanothus crassifolius, wild lilac. All of the *ceanothi* are called lilac, wild lilac, or mountain lilac. This species is distributed throughout the chaparral region, but is most common in the Santa Barbara National Forest and southward. Reproduction is almost always from seed, and coppice is rare. It is intolerant of shade and very inflammable.

Ceanothus cuneatus, Nuttall's ceanothus (fig. 3), is distributed throughout the chaparral region, but is most common in the northern areas, where it ranges up to 5,000 feet. It is from 3 to 12 feet high, and though almost impenetrable to man, seldom makes a continuous cover.

Ceanothus divaricatus, deer brush, is distributed over the entire chaparral area below an elevation of 7,000 feet and is an important part of the cover, particularly in the Angeles National Forest. However, it is not desirable.

Ceanothus papillosus, deerweed, is found only north of the Santa Maria River, but is an important part of the cover in the Monterey National Forest. It is low, inflammable, and undesirable.

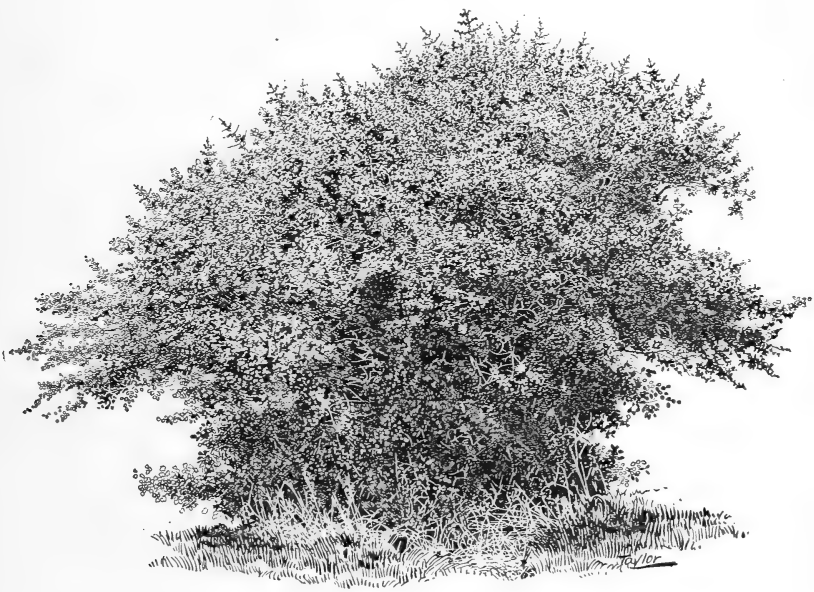

FIG. 3.—Lilac, *Ceanothus cuneatus*, 7 feet high.

Ceanothus sorediatus, buckthorn, is represented throughout the Coast Range and in the Sierra Nevada and forms an important component part of the chaparral on some watersheds in the Santa Barbara National Forest. It reproduces well on burned-over areas and produces vigorous coppice after burning. Its branches are armed with spines, and a pure stand is impenetrable. Although it attains a height of 10 feet, and in some cases assumes a tree form, its leaves are small and widely distributed, giving only a meager shade. On the whole, it is an undesirable species.

Cercocarpus parvifolius, mountain mahogany. There are several recognized varieties of this species, one of which, *betulaefolius*, is found in the chaparral region and northward along the Coast Range into southern Oregon. In its chaparral form it is found at elevations up to 6,000 feet, and is usually from 6 to 10 feet high, though under especially favorable conditions it attains a height of 25 feet. It is evergreen to the extent that the leaves persist until a new growth begins, but casts little shade, and is very slow growing. It sprouts vigorously, and is often closely cropped by stock. In this respect it resembles *Garrya veatchii.*

Eriodictyon tomentosum, yerba santa, ranges down to sea level, and is important on lower slopes. The common name is often applied to *E. californica.* (Fig. 4.)

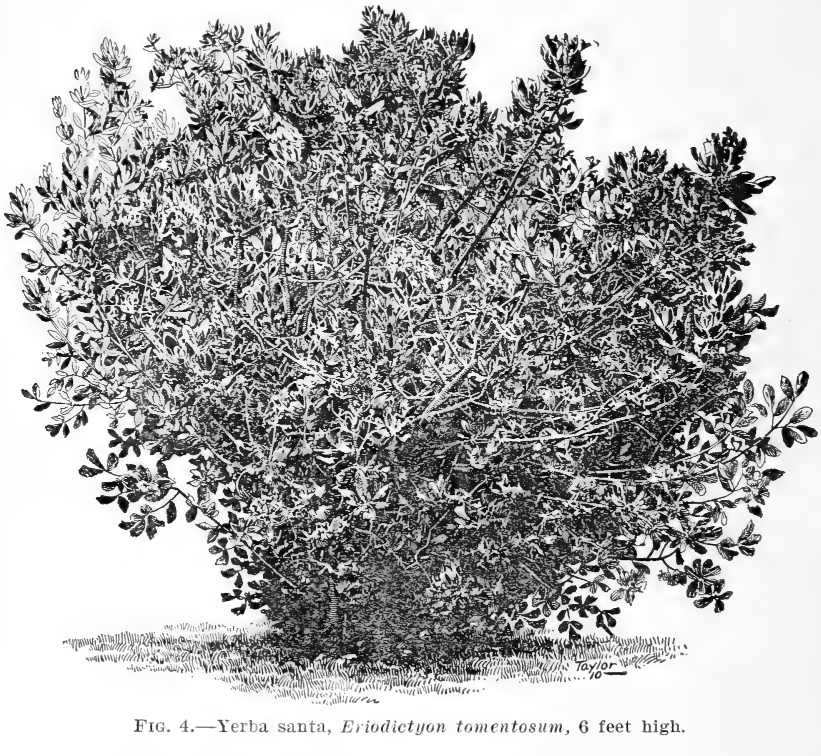

Fig. 4.—Yerba santa, *Eriodictyon tomentosum,* 6 feet high.

Eriogonum fasciculatum, wild buckwheat, is distributed over the entire chaparral region, but reaches its best development in the Santa Barbara National Forest and lower subzones to the eastward and southward. It is comparatively unimportant, because it attains a height of only 2 or 3 feet and casts a poor shade. On the other hand, it will grow on the poorest soils and the most exposed situations.

Fremontodendron californica, fremontia, is found along the Coast Range. Though unimportant in the cover at present it might be a desirable species to extend, since it attains a height of from 15 to 20 feet. Its leaves persist for two years, and it casts a good shade. In addition, it is good browse for cattle and goats, and will grow on very poor soil. It is tolerant and an abundant seeder.

Heteromeles arbutifolia, Christmas berry (fig. 5), grows throughout the chaparral region and on the western slopes of the Sierras as far north as latitude 40°. It ranges from sea level to 4,600 feet, and, though at present not abundant, is important, since it attains a height of 15 feet and casts a good shade. Its leaves remain on the trees until a new growth begins, and it is not inflammable.

Lotus glaber, deerweed, does not resemble the typical chaparral, and is neither important nor desirable. It is dealt with here because it is the first species to reclaim a burn. Its crown is bushy about

Fig. 5.—Christmas berry, *Heteromeles arbutifolia*, 10 feet high.

3 feet from the ground, and offers a fair temporary protection from excessive evaporation. It is a perennial and has a vigorous root system, which enables it to live on the most exposed slopes and the poorest soils.

Prunus ilicifolia, hollyleaf cherry, is distributed along the Coast Range from San Francisco southward into Baja California, and has a vertical range from sea level to 6,000 feet. Because it is a large evergreen and casts a good shade it is a desirable species, but it forms less than 1 per cent of the present chaparral. It grows on any soil or site, is tolerant of shade, reproduces by seeds, and makes a vigorous coppice after fire. Seedlings are rare, since the seeds are much relished by rodents. Its artificial extension should be encouraged.

Rhus laurina, sumac (fig. 6), is found from the Santa Barbara National Forest southward into Baja California, but is usually confined to the lower zones below the 3,000-foot level. Unfortunately, though a very desirable species, it is not common in the present cover. It is evergreen, produces a dense shade, endures extreme heat and dryness, seeds abundantly, and makes vigorous coppice growth after fire. It has a spreading root system and is a good soil binder.

Rhus ovata, sumac, extends from Point Conception southward along the coast to Baja California, and is native to the lower subzones, although it ranges as high as 5,000 feet. Though a desirable species, because it throws a good shade and makes rapid coppice growth after burning, it forms but a small part of the present cover. Its leaves are large and thick, and make a good leaf litter. A less important but similar species, *Rhus integrifolia* (fig. 7), is common at lower elevations, frequently along the seashore.

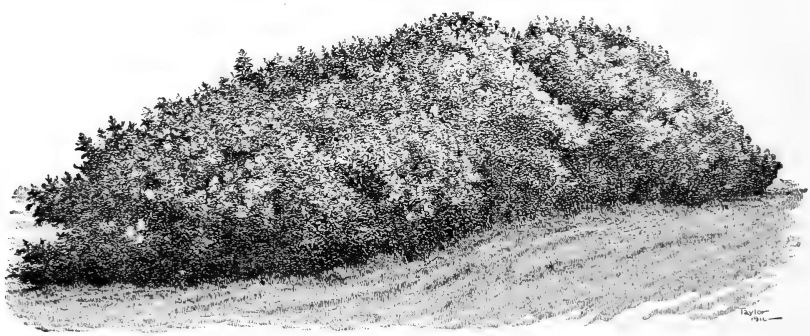

Fig. 6.—Sumac, *Rhus laurina*, 6 feet high.

Salvia mellifera, black sage, grows on dry situations throughout the chaparral area up to elevations of 3,250 feet. It is important in the Santa Barbara National Forest and northward, but undesirable, since it is low, casts only a medium shade, and is inflammable.

Audibertia polystachia, white sage, is common in the Angeles National Forest and southward, and in favorable situations forms 10 per cent of the cover. In general, however, it is unimportant and undesirable.

Quercus chrysolepis, canyon live oak, is by no means confined to canyons, but is distributed generally over California above the 1,000-foot contour, and extends into Oregon, northwestern Arizona, and Mexico. Normally it is a large tree, and grows in mixture with highland oak and big-cone spruce. When a part of the chaparral it is smaller, and, except on certain areas in the Angeles National Forest, forms only an insignificant part of the cover. It is a desirable species, however, since it is evergreen, longlived, tolerant, especially when young, and in its chaparral form makes a dense cover for the ground.

Quercus densiflora, California tanbark oak, is distributed through the Coast Range as far south as the Angeles National Forest. Normally it is a large tree, from 50 to 70 feet high, but in the chaparral, especially near its southern limit, it is a scrub, usually less than 10 feet high. An evergreen, its leaves remain on the branches for three or four years. Unlike the *chrysolepis*, it seeks the high regions and the exposed summits, where it is desirable on account of its dense shade.

Quercus dumosa, California scrub oak, is native to the Coast Ranges of California and Baja California, and is found sparingly in the Sierra Nevada. In the chaparral it is very desirable, since it has a wide range, is evergreen, and grows on all kinds of soils and sites.

FIG. 7.—Lemonade berry, *Rhus integrifolia*, 6 feet high.

It reproduces both by seed and coppice, but though it bears cones abundantly, even on 3-year-old coppices, seedlings are exceedingly rare. If not too severely burned, it will produce a fair coppice cover within three years, a much shorter time than the average for the chaparral species. It may be killed, however, by very severe fires; burned areas have shown 15 per cent of dead stubs. Its value as cover should strongly urge its extension by artificial means.

Quercus wislizeni, highland oak, is distributed throughout the chaparral area, and extends northward into the Sacramento Valley to latitude 41°. Its altitudinal range, which extends to 6,200 feet, is frequently above the chaparral zone. Some of the trees attain a height of 30 feet and a diameter of 12 inches, but, when part of the chaparral, have a scrubby form. It is an important species in the present cover and a desirable one, since it is evergreen and makes a good cover on all slopes. Occasionally it forms a pure stand in which the trees are tall and slender. Although considered tolerant of shade, young trees growing in a dense stand of knobcone pines frequently die from overshading. The species coppices quickly after fire, though its slow growth would delay the establishment of a good cover. It is host for mistletoe, *Phoradendron villosum.*

REPRESENTATION OF DESIRABLE AND UNDESIRABLE SPECIES ON TWO WATERSHEDS.

The following table gives the results obtained by the late L. C. Miller, of the Forest Service, in a study to determine the proportion of desirable and undesirable species on the Tujunga and San Gabriel watersheds. The sample plot method described on page 24 was used.

TABLE 5.—*Composition of chaparral on Tujunga and San Gabriel watersheds.*

Species.	North slope.				South slope.			
	Tujunga.		San Gabriel.		Tujunga.		San Gabriel.	
	2,000 to 3,000 feet.	3,000 to 5,000 feet.	2,000 to 4,000 feet.	4,000 to 6,000 feet.	2,000 to 3,000 feet.	3,000 to 5,000 feet.	2,000 to 4,000 feet.	4,000 to 6,000 feet.
DESIRABLE SPECIES.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Arctostaphylos tomentosa			0.23					2.35
Arctostaphylos glauca	12.60	21.54				2.90		
Heteromeles arbutifolia	1.30		.23				0.74	
Prunus ilicifolia	5.10	.46	2.11			.55	.24	2.13
Quercus chrysolepis	3.00	4.28				.02		2.59
Quercus dumosa	13.20	2.21	34.66					.31
Quercus wislizeni	9.80	3.26						9.58
Rhus laurina	.60				0.27			
Rhus ovata			2.81			.04	1.72	
Quercus douglasii	.60							
Fremontodendron californicum								2.67
Total	46.20	31.75	40.04		.27	3.51	2.70	19.63
UNDESIRABLE SPECIES.								
Adenostoma fasciculatum	7.80	31.80			31.40	60.81	29.91	19.23
Ceanothus crassifolius	25.40	13.30	.23		1.11	13.90	4.66	
Ceanothus cuneatus		12.92				1.85		.78
Ceanothus sorediatus	4.30	2.24	14.76			.33		14.18
Ceanothus divaricatus	.70							.16
Eriogonum fasciculatum	8.30	2.50			27.60	7.40	19.11	16.33
Cercocarpus parvifolius	2.26	1.90	19.71		.08	.24		9.43
Eriodicyon glutinosum		1.30				1.80		
Eriodictyon tomentosum					2.18	1.26		
Symphoricarpos mollis	1.20	.70	1.17					.78
Rhus trilobata		.50				.42		
Mimulus bivipes								
Artemisia tridentata		.30						
Rhamus californica								.08
Gilia californica	.14	.30				1.60		.86
Yucca whipplei		.20			4.00	6.80	6.13	5.74
Pentstemon cordifolius		.20						.08
Rhamnus ilicifolia	2.80	.09	3.28		.35	.06	.24	4.08
Salvia mellifera	.30				13.30		7.10	
Audibertia polystachya	.60				5.48		21.11	
Lotus glaber					14.15	.02	8.80	
Ceanothus intererrimus			7.73		.08			
Fraxinus dipetala			7.26					
Vicia americana								
Clematis ligusticifolia			5.62					
Prunus emarginata								1.57
Ribes speciosum								
Rhus diversiloba							.24	
Artemisia californica								7.07
Total	53.80	68.25	59.96		99.73	96.49	97.30	80.37

TABLE 4.—*Composition of chaparral on Tujunga and San Gabriel watersheds*—Continued.

Species.	East slope.				West slope.			
	Tujunga.		San Gabriel.		Tujunga.		San Gabriel.	
	2,000 to 3,000 feet.	3,000 to 5,000 feet.	2,000 to 4,000 feet.	4,000 to 6,000 feet.	2,000 to 3,000 feet.	3,000 to 5,000 feet.	2,000 to 4,000 feet.	4,000 to 6,000 feet.
DESIRABLE SPECIES.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Arctostaphylos tomentosa				0.24				
Arctostaphylos glauca	0.10	11.50	1.04	.24	2.60	13.18		
Heteromeles arbutifolia			.63	5.11	.10			
Prunus ilicifolia		.40	.83	.36	.43	.29		
Quercus chrysolepis				10.30	.43	5.18		
Quercus dumosa		.50	2.30	1.78	.63			
Quercus wislizeni		.50		11.87	.20	1.80		
Rhus laurina	.60							
Rhus ovata				3.80		.06		
Quercus douglasii								
Fremontodendron californicum								
Total	.70	12.90	4.80	33.70	4.39	20.51		
UNDESIRABLE SPECIES.								
Adenostoma fasciculatum	44.90	22.30	33.61	21.64	18.60	34.90		
Ceanothus crassifolius	15.70	61.80	12.84	.59	27.61	19.25		
Ceanothus cuneatus						20.60		
Ceanothus sorediatus			13.38	4.04	.30	1.30		
Ceanothus divaricatus				12.60	22.60	1.20		
Eriogonum fasciculatum	25.90	.10	8.14	11.64	2.00	.75		
Cercocarpus parvifolius		.30	2.51	.24		.06		
Eriodicyon glutinosum				1.78	9.10	1.70		
Eriodictyon tomentosum	.70	1.80				.12		
Symphoricarpos mollis				.47		.12		
Rhus trilobata								
Mimulus bivipes			1.50					
Artemisia tridentata								
Rhamus californica						.02		
Gilia californica					5.90	.96		
Yucca whipplei	2.00	.80	.20	.71				
Pentstemon cordifolius				.59	1.90	.17		
Rhamnus ilicifolia	.30				6.10			
Salvia mellifera	6.90		4.38	.36	1.50	.20		
Audibertia polystachya	.30		1.46	2.02		.14		
Lotus glaber	2.60		16.07	7.96				
Ceanothus intererrimus								
Fraxinus dipetala								
Vicia americana			.50					
Clematis ligusticifolia				1.42				
Prunus emarginata								
Ribes speciosum				.24				
Rhus diversiloba			.63					
Artemisia californica								
Total	99.30	87.10	95.20	66.30	95.61	79.49		

COMMERCIAL USES.

While the chaparral's chief utility is to conserve the water supply, some of its species have been used for fuel, fencing, and forage. A few of the plants are reputed to have medicinal value. Formerly the Indians gathered the nuts of *Aesculus californica* and *Umbellularia californica*, the seeds of *Ceanothus integerrimus*, fruits from *Prunus*, and berries from *Ribes*, *Heteromeles*, *Sambucus*, and *Vaccinium*.

During the early settlement of southern California, before the discovery of oil and the importation of coal and lumber from the north coast, a good part of the fuel supply was furnished by the larger species of chaparral, such as *Quercus*, *Arctostaphylos*, *Ceanothus*, *Adenostoma*, *Cercocarpus*, and *Rhus*. In addition the roots of *Adenostoma* and *Arctostaphylos* were considered good fuel. Since much labor was required to produce a cord of such material, and the haul was so long, the cost averaged about $12 per cord. In recent years the demand for chaparral fuel has practically ceased. In the regions of the mock chaparral, timber is usually near at hand and supplies the demand for fuel.

FENCING.

Adenostoma parvifolius has been used for fence posts near the Cleveland National Forest. This species frequently attains a height of 10 feet and a diameter of 5 or 6 inches. Others of the larger species furnish false posts for barb-wire fencing. Sticks from one to two inches in diameter are sufficient for this purpose. Fencing is so constructed in southern California that posts are from 20 to 30 feet apart. Such a fence is not easily seen and is therefore dangerous to both travelers and cattle. False posts are put between the supporting ones, and while they do not add to the strength of the fence, they make it more visible.

BROWSE.

Cattle, sheep, and goats do not browse on chaparral if they can get better forage. In time of drought, however, when no pasture can be obtained in the grassy regions below, chaparral may provide forage for stock. It is, in fact, better liked than young conifers. Goats can always do well on it; sheep can do fairly well, although it is difficult for them to get through the dense growth; but cattle are driven to it only by hunger. In the early days it was the custom for the cattlemen to set fire to the chaparral in the belief that it might be replaced in future years by a new growth of better forage. This practice has virtually ceased, since it has been realized that chaparral is much more valuable as a cover for the watersheds than as forage for stock.

BEE PASTURAGE.

Bee culture is an established industry in the chaparral region, and there is scarcely a time of the year when some of the species do not furnish honey for bees. On the Santa Barbara National Forest, 47 permits for apiaries have been issued, on the Angeles, 14, and on the Cleveland, 25. Exact figures on the annual production of honey are not available, but the quantity is about 700 tons.

Prof. Ralph Benton, apiarist, State Normal School, Los Angeles, has furnished the following list of honey plants, grouped in the order of their importance.

1. Audibertia polystachya.
   Eriogonum elongatum.
   Eriogonum fasciculatum.
   Lotus glaber.
   Phacelia sp.
   Salvia leucophylla.
   Salvia mellifera.
2. Arctostaphylos manzanita.
   Eriodictyon californica.
   Rhus diversiloba.
   Yucca whipplei.
3. Aesculus californica.
   Prosopis juliflora.
   Ceanothus divaricatus.
   Rhus laurina.
4. Berberis pinnata.
   Lonicera hispidula.
   Lonicera interrupta.
   Rhamus californica.
   Salix sessilifolia.

Where one member of a genus yields honey, it is probable that the other members do. *Prunus*, *Ribes*, *Rubus*, *Spirea*, and *Symporicarpus* are honey yielders. *Quercus* probably yields, through an aphis, a honey-dew, which, though not marketable, is of value in the summer breeding of the bees. *Marrubium vulgare* furnishes bee food, and *Rosa californica* is visited chiefly for its pollen.

PROTECTION AGAINST FIRE.

Protection of the chaparral from fire is of the utmost importance, for man's efforts can not repair the damage done. Artificial restocking is slow, and when it must cover millions of acres the task seems well-nigh hopeless.

In the heavy coniferous forests of the West, three classes of fires are distinguished—ground, surface, and crown fires. The chaparral is so low and so inflammable that any fire in it is likely to be equivalent to a crown fire, which destroys all growth above the ground, and all litter or dry brush on the surface. The extent and character of a chaparral fire will, of course, depend on both the topography and the wind, as well as on the quantity of the inflammable material. If a fire burns uphill, and is pressed by a strong wind, its progress will be very fast, especially if the atmosphere is dry and the fire starts in the daytime. Such a fire in the chaparral may have a velocity of 5 or 6 miles an hour. On the other hand, with topography and wind unfavorable, and with scattering uninflammable chaparral, it is difficult to start a fire in the growth, nor is it likely to spread if started.

A fire in the chaparral not only destroys the cover but, if sufficiently severe, may bake the soil to such an extent that it becomes inhospitable to a new growth. If the burned area is large, and if it extends to the top of a ridge or mountain, it is not easily reseeded by the unburned chaparral surrounding it. Although some seeds may be carried long distances by wind, their tendency is to travel downhill, and it is unfortunate if there is no uninjured area above.

Before the creation of the National Forests in southern California public sentiment with regard to fire in the chaparral was practically dormant. Year after year cattlemen fired the chaparral in the erroneous belief that younger and tenderer plants would come in and afford better pasturage. Some prospectors would burn over the region which they intended to explore. If a hunter wished to start a fire to drive out a wounded deer, no one objected. But with the larger demands upon the water supply which went hand in hand with the increasing development of the country, the people of southern California came to realize that only by maintaining intact the chaparral cover on the watersheds could they be sure of enough water for their needs.

The establishment of the National Forests has been the chief factor in decreasing the number of severe fires in the chaparral. The preventive and protective measures against fire established by the Forest Service on the National Forests of southern California include patrol during the danger seasons, fire lines, roads and trails, telephone lines, and a fire-fighting force equipped with the necessary tools. The principal causes of fire in the chaparral are sparks from locomotives, incendiarism, brush burning, carelessness of campers, and lightning. All of these, except lightning, are controllable,

The efficiency of the patrol is shown by the fact that in 1907 58 per cent of the chaparral fires were extinguished before 5 acres had been burned; in 1908, 62 per cent; in 1909, 57 per cent; and in 1910, 56 per cent. These percentages of fires extinguished before great headway was made, however, are not as high as those for other National Forests where the stand is composed of the typical western conifers. This difference is to be expected, and it merely bears witness to the truth that chaparral is more inflammable than other forests.

High points which command a view of a large area of country are used as lookout stations by rangers on patrol. The news of a fire is sent to headquarters by telephone, telegraph, heliograph, or flag signals.

Fire lines are constructed in the chaparral areas on the National Forests to limit the spread of flames. (Pl. VI, fig. 2.) These lines are supplemented by roads and trails, which in themselves are often effective barriers. Usually the fire line is cleared along the ridges, while roads and trails follow gradients on the sidehills. A chaparral fire may burn itself out at the top of a ridge, either because of a change in the air currents or because of its inability to travel downhill, but a fire line makes this limit more certain. In addition, it furnishes an open line of communication through which a force of men

FIG. 1.—DISTANT VIEW OF CHAPARRAL FIRE ON THE CLEVELAND NATIONAL FOREST.

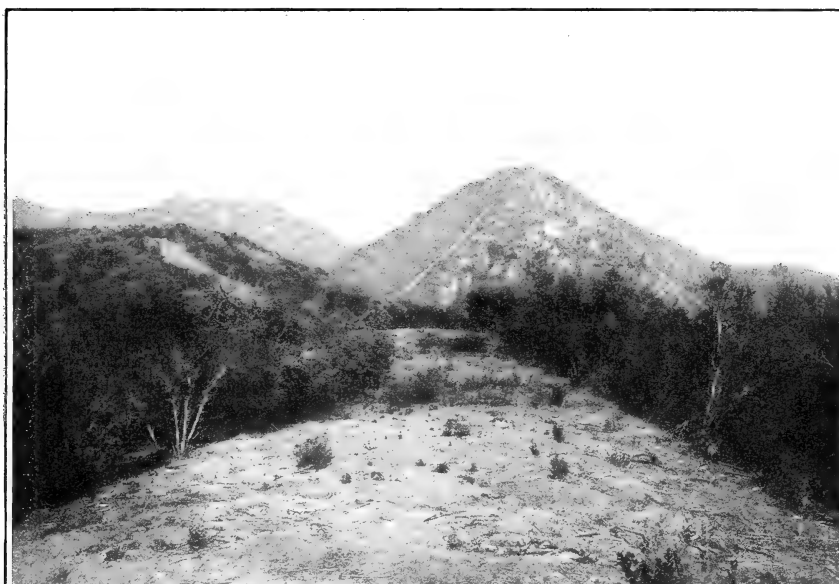

FIG. 2.—NEAR AND DISTANT VIEWS OF FIRE LINES 20 FEET WIDE FOR THE PROTECTION OF CHAPARRAL.

may reach the scene of a fire, and is a line of vantage where a stand may be made to back-fire. Fire lines in the chaparral vary in width from 6 to 60 feet, and cost from $100 to $200 per mile. They are cleared of inflammable material at intervals of two years, at a cost of from $50 to $75 per mile. In some cases goats have been introduced to browse along and near the lines in order to keep them clear.

Water is so scarce in southern California that, in fighting fires, substitutes for it must be found. Gunny sacks, preferably damp, are used to beat out a blaze, or sand is shoveled upon it. If time permits, a special fire line may be cleared through the chaparral. Usually a fire, as it advances uphill, is attacked on both wings, and gradually the fire fighting crews come together, squeezing the fire out between them. It is difficult and usually dangerous to get directly in the path of a chaparral fire, and this is seldom done unless the intention is to back-fire, or to take up a stand at the summit of a hill or on a fire line.

Besides the Federal statutes and regulations regarding fire, the laws of the State of California provide for a State forester and fire wardens, for fire patrol in brush and forest lands at the expense of the counties, for cutting fire lines and trails, and for posting warning notices. In addition, the State laws forbid: (1) The use of fire in the dry season, from May 15 to the first soaking rains of autumn or winter, except with the written permission or under the direction of a fire warden; (2) the willful, malicious, or negligent setting of fire to one's own woods, or permitting a fire to extend beyond one's own land; (3) the leaving of fires unextinguished; (4) the setting of fires, either willfully or accidentally, unless back-fires to prevent the spread of flames; (5) the use of logging locomotives which burn fuel other than oil, or which are not provided with spark arresters and ash pans. Residents of the State living in the vicinity of a fire, who are liable to the road poll tax, may be called upon to assist in extinguishing it. They may be impressed into service for not over five days in any one year.

RESTOCKING AFTER FIRES.

The opinion is often expressed that chaparral is not injured by fire, and that no matter how often the slopes are burned over the stand will not be in the least impaired, but will "spring up with renewed vigor." This opinion, based solely on casual observation, is far from the truth. Not only is the vitality of chaparral greatly lessened by burning, but the trees are often killed. The number killed will depend, of course, upon the severity of the fire, but also upon the species composing the stand. A greater number of dead stubs will be found after fire on an area occupied by lilac, *Ceanothus* *crassifolia*, and grease-wood, for example, than where the stand is a mixture of oak, sumac, and buckthorn.

Burned chaparral areas will eventually restock with chaparral species. The rapidity with which the new cover is established depends upon the severity of the fire, upon the proportion of species in the original stand which will coppice from the roots, and upon the position and species of chaparral around the burned area. These variable and uncertain factors make it difficult to say with certainty how long it will take to recover a burned area. If a stand of the taller chaparral, such as *ceanothi*, was totally destroyed, it might be 20 or 30 years before the cover is fully restored. On the other hand, a mixed stand of *rhus* and *quercus*, if burned, would quickly restock the ground with a dense cover. In general, however, 10 years are required to restock a burned area to the extent that its limits are not clearly defined to the casual observer.

The new crowns which spring from old roots after a fire in the chaparral are of the greatest importance in the establishment of a new cover, because they insure the presence in it of fire-surviving plants.

ARTIFICIAL RESEEDING.

There are many places in the chaparral area barren of growth now, and which, because of some accident of situation or climate, are not likely to be forested by natural means; and there are others where the chaparral cover, if it comes at all, will be composed largely of undesirable species. In such situations the only course open to secure the necessary cover is artificial sowing. The most extensive experiment in the artificial seeding of chaparral was made by Mr. T. P. Lukens in the San Gabriel Forest Reserve, now a part of the Angeles National Forest, in 1902. *Rhus laurina* was the species used, since it will grow on very steep and rocky slopes, furnishes good shade, is not easily killed by fire, and sprouts from the old roots. In all, about a thousand pounds of seed were scattered. One planting site was on a rocky cliff, several hundred feet high, facing the east, below the astronomical observatory on Mount Wilson. Astronomers had been annoyed by heat waves rising from this cliff, which made it difficult on sunny mornings to use the optical instruments. No attempt was made to remove the glutinous covering from the seed before sowing. The greater number of seed were sown from the brink of the cliff, with the idea that the natural fall would distribute them fairly evenly over its surface. On the whole the experiment was successful; many trees have started upon the cliff, which probably will, in time, be thoroughly covered—this despite the fact that the elevation of the site, 5,000 feet, is high for the species used.

Another sowing of the same species was made on the hot slopes below Henningers Flats, but this was followed by a drought of

10 months and was a failure. Later sowings, however, which were followed by wet weather, were thoroughly successful and resulted in a good cover. These experiments with *Rhus laurina* serve to emphasize the fact that in the artificial extension of chaparral everything depends upon the weather conditions which follow the sowing. It might seem that all that would be necessary would be to wait until the rains begin, and then scatter the seed. Yet even if the sowing were postponed until the rains began it would be necessary to employ thousands of men to cover any large area, and the services of these would have to be obtained immediately upon the start of the rainy season and could be used for a few weeks only. After that it would be problematical whether the remainder of the rainy season would be favorable for the germination of the seed.

INTRODUCTION OF LARGER TREE SPECIES IN THE CHAPARRAL.

The advisability of introducing larger tree species in the chaparral area has often been considered, since the chaparral, even at best, can not furnish as good a cover as larger trees, nor does it yield a crop of commercial wood. Above the chaparral is a forest composed principally of conifers, with a mixture of broadleafs as the chaparral is approached, while narrow fringes of moisture-loving broadleaf trees follow the streams down through the chaparral and out upon the plain. The following list gives the species which, with the chaparral, form the forest cover of southern California:

CONIFERS.

Pinus attenuata	Knobcone pine.
Pinus contorta	Lodgepole pine.
Pinus coulteri	Coulter pine.
Pinus flexilis	Limber pine
Pinus jeffreyi	Jeffrey pine.
Pinus lambertiana	Sugar pine.
Pinus torreyana	Torrey pine.
Pinus monophylla	Single-leaf piñon.
Pinus monticola	Western white pine.
Pinus ponderosa	Yellow pine.
Pinus quadrifolia	Parry piñon.
Pinus sabiniana	Gray pine.
Pinus radiata	Monterey pine.
Pseudotsuga macrocarpa	Bigcone spruce.
Pseudotsuga taxifolia	Douglas fir (red).
Abies concolor	White fir.
Abies venusta	Bristle-cone fir.
Libocedrus decurrens	Incense cedar.
Cupressus goveniana	Gowen cypress.
Juniperus californica	California juniper.
Juniperus occidentalis	Western juniper.
Sequoia sempervirens	Redwood.

BROADLEAFS.

Quercus agrifolia	California live oak.
Quercus californica	California black oak.
Quercus chrysolepis	Canyon live oak.
Quercus densiflora	California tanbark oak.
Quercus douglasii	Rock oak.
Quercus dumosa	Scrub oak.
Quercus engelmanni	Engelmann oak.
Quercus gambelii	Gambel oak.
Quercus pricei	Price oak.
Quercus lobata	White oak.
Quercus oblongifolia	Blue oak.
Quercus wislizeni	Highland oak.

MOISTURE-LOVING BROADLEAFS.

Acer macrophyllum	Oregon maple.
Acer negundo	Boxelder.
Alnus rhombifolia	White alder.
Alnus oregona	Red alder.
Juglans californica	California walnut.
Platanus racemosa	California sycamore.
Populus fremonti	Fremont cottonwood.
Populus trichocarpa	Black cottonwood.
Salix laevigata	Smoothleaf willow.
Salix lasiandra	Western black willow.
Salix fluviatilis	Longleaf willow.
Salix lasiolepis	White willow.
Salix nigra	Black willow.
Salix scouleriana	Nuttall's willow.
Salix sessilifolia	Silverleaf willow.
Umbellularia californica	California laurel.

SUBTROPICAL.

Neowashingtoniana filamentosa	Washington palm.

There are many isolated groups of spruce, pine, and oak throughout the chaparral region, varying in size from a group of a dozen or more trees to a stand covering many acres. Again, individual trees may be found growing far from others of their kind. Yet where chaparral holds complete possession of the ground it is plain that it does so because of the inability of the larger tree species to extend their range farther than they have already done. The coniferous forests on the higher slopes above the chaparral areas are well situated to distribute their seeds to the lower levels, yet the limits of the coniferous forests remain where they have always been. Here and there throughout the chaparral area exceptional conditions of soil or climate favor the larger tree species as against the chaparral, and it is on these areas that the isolated groups of spruce, pine, and oak grow. That favorable conditions which have resulted in the growth of

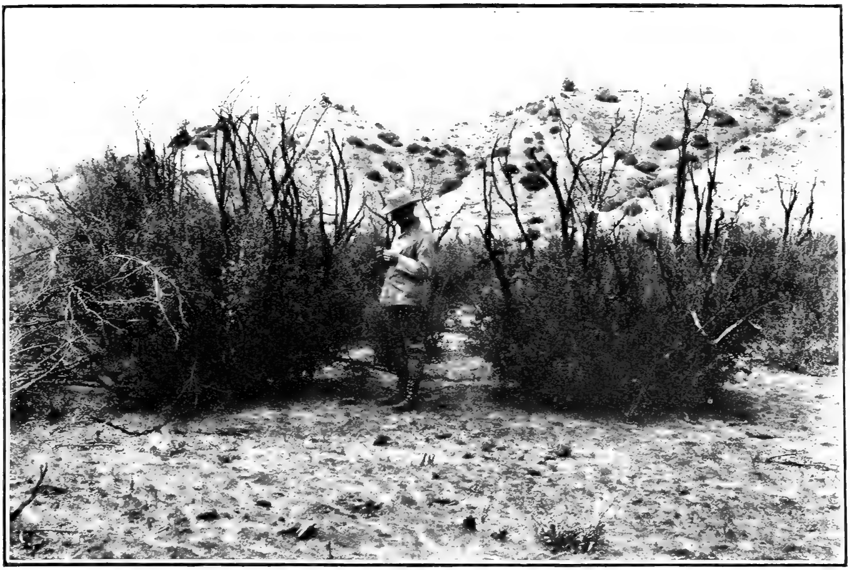

FIG. 1.—A RECENTLY BURNED AREA WITH GREASEWOOD SPROUTING FROM THE ROOTS.

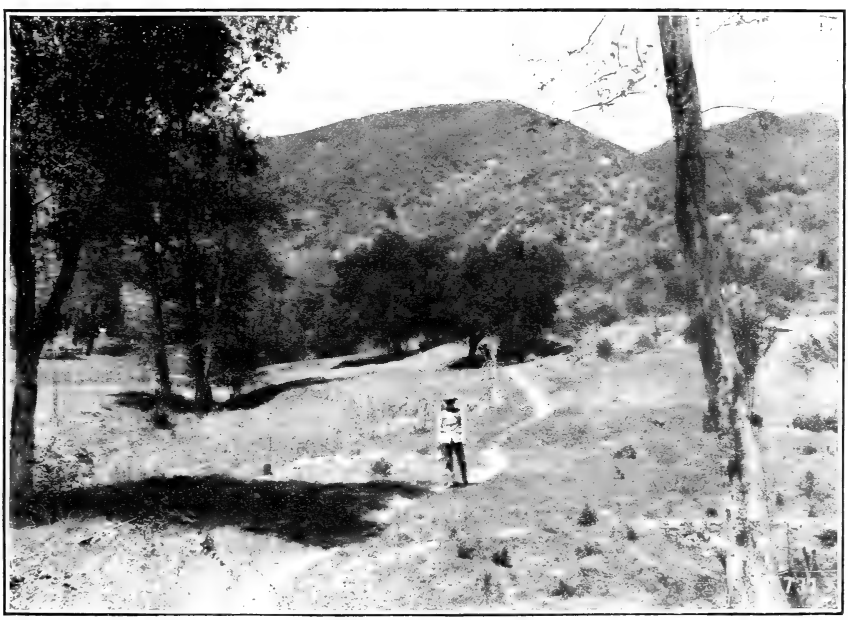

FIG. 2.—VALLEY WOODLAND WITH CHAPARRAL-COVERED HILLS.

larger species among the chaparral are confined strictly to the areas of which the larger trees have already taken possession is proved by the fact that, though on such areas the distribution of seed is in no way interferred with, no extension of the stand is taking place.

On the whole, there is little chance that by any natural means larger tree species will gradually take possession of the chaparral regions. All of them, whether growing above, below, or in the chaparral, have failed to vanquish the smaller growth on the areas which it now dominates, though they have had hundreds of years in which to do so. Artificial extension on a hitherto untried scale will be necessary to wrest from the chaparral its present domain.

There are, it is true, a few exceptions to the general rule regarding the encroachment of the coniferous species upon the chaparral. One of the most significant is found near the summit of Mount Gleason, in the San Gabriel Mountains. Here mature yellow-pine trees on the summit have seeded an adjoining south slope covered with an exceedingly dense stand of buckthorn, *Ceanothus sordiaatus.*

CONIFERS.

The introduction of conifers into the chaparral area has been tried at different times, but, it must be confessed, without very great success. In 1898 a number of citizens of Pasadena, led by Mr. T. P. Lukens, began experimental seed sowing. In 1901 the Forest Service, then the Bureau of Forestry, cooperated with the Water and Forest Association of Los Angeles in gathering the seeds of conifers for watershed planting. Seed was furnished to owners of chaparral land who would agree to plant in accordance with instructions, and about 1,000 acres, principally on exposed south slopes, were planted during that year. The following winter was excessively dry, and the ground never became thoroughly saturated. As a result, the number of seedlings which came up was very small, and those which did appear were unable to withstand the heat of the following summer. Notwithstanding the failure of that year's work, sowing was resumed in the fall of 1902, but with a different method. Previously the seed had been dropped into a hole made with an iron bar; now seed spots were prepared, in each of which were placed a dozen or more seeds. Though the rainfall which followed the sowing was exceedingly light, seedlings came up in great abundance. Pests of one sort or another soon began to destroy these, however, and it was but a comparatively short time before the greater number of them were killed. Precautions were then taken to protect the remaining ones, and many managed to live through the summer. No rain fell until late in December, however, and all of the seedlings finally perished.

The outcome of this experiment, besides disclosing the difficulties sure to be met with in any attempt to reforest bare and exposed mountain slopes in southern California, proved that the methods of reforestation used were not the right ones. It was therefore determined to experiment with nursery-grown seedlings which had been once or twice transplanted, and to grow seedlings in situations as nearly as possible like those in which they were ultimately to be set out. Accordingly, in 1903, a nursery site was leased near Pasadena, on the south slope of the San Gabriel Mountains, at an altitude of about 2,400 feet. The site was in a natural depression, surrounded by gentle slopes. The soil of the site was fertile, and water was available. Four and one-half acres were cleared of brush and fenced with a rabbit-proof woven-wire fence, and in October, 1903, actual nursery operations began. During 1904 and 1905 16,000 transplants were set out on the slopes below the nursery. The results were discouraging, since the trees did not survive. Nevertheless, the work was continued in 1906, when 32,000 transplants were set out, and in 1907, when 43,000 were planted. Of these plantings, 23 per cent survived. Other nurseries were established by the Forest Service and experimental planting was applied on a fairly extensive scale. In almost every case, however, results emphasized the fact that to establish native tree species in the chaparral areas is a task requiring patience and a thorough knowledge of the best planting methods, The following table shows the total amount of planting done by the Forest Service in the chaparral:

TABLE 6.—*Approximate number of trees planted and seeds sown in the Monterey, Santa Barbara, Angeles, and Cleveland National Forests, California.*

Species.	Number of trees planted.			Pounds of seeds sown.		
	Prior to July 1, 1909.	July 1, 1909, to June 30, 1910.	Total to June 30, 1910.	Prior to July 1, 1909.	July 1, 1909, to June 30, 1910.	Total to June 30, 1910.
Abies concolor	11,450		11,450			
Cedrus libani	12,370	10,210	22,580			
Eucalyptus, 6 species	2,260	83,900	86,160			
Libocedrus decurrens	28,400	8,610	37,010		18	18
Pinus attenuata	37,370	1,000	38,370	30		30
Pinus coulteri	24,375	9,740	34,115		15	15
Pinus jeffreyi	121,230	61,470	182,700	100	17	117
Pinus ponderosa	12,000		12,000			
Pinus radiata	12,650		12,650			
Pinus sabiniana	600		600			
Pisthachia chinensis		735	735			
Pseudotsuga taxifolia	3,100		3,100			
Pseudotsuga macrocarpa	32,500		32,500			
Quercus suber		5,260	5,260			
Total	298,305	180,925	479,230	130	50	180

EUCALYPTS.

Since artificial stocking of the chaparral areas with native conifers is both difficult and expensive, the question naturally presents itself whether there are not certain exotic species, better adapted to the soil and climate, which will furnish satisfactory cover and at the same time yield commercial timber. The possibility of growing eucalypts is suggested by the fact that both in their habitat and in various regions into which they have been introduced, certain species of this tree thrive under climatic conditions like those which produce chaparral. The genus Eucalyptus, of which there are more than 150 recognized species, is a native of Australia and Tasmania and was introduced into this country in 1865. About 100 species have been grown in parts of California, Arizona, Texas, and New Mexico with varying degrees of success. Many of the species, however, are, for one reason or another, undesirable, while still others have little value except for landscape gardening, yet the requirements of the more desirable species are so varied that one or more may be used under almost any condition of soil and exposure. None, however, will endure very cold weather. Blue gum, *Eucalyptus globulus*, may be killed by frost, as may also the species *corynocalyx* and *citriodora*. Others will endure temperatures as low as 10° and 15° F., depending on the length of exposure, but 18° F. would be a safer minimum.

Forest Service Bulletin No. 35, by the late Prof. Alfred J. McClatchie, says regarding eucalypts as a forest cover, pages 31 and 32:

"It is as forest trees that the eucalypts are most useful; planted as ornamental or as shade trees they are often disappointing. Planters who have put them out as forest trees are the ones who have derived the greatest benefit from them. * * * Much of the treeless land of semitropic America might be covered with these trees. As the conditions under which the different eucalypts grow in Australia are very diverse, it is evident that, if the species are properly selected, they will cover nearly all kinds of situations. * * * In the Southwest there are large areas of hilly country, of little or no use for other purposes, that might be transformed into useful forests by covering them with these trees. This covering of the hills with forests will not only furnish shade, a source of honey, and a supply of fuel and timber, but will prevent the too rapid run-off of rain water, which results in the cutting and washing of hillsides and in other forms of damage below. * * * The eucalypts can be utilized as a forest cover for mountains as well as hillsides. Several species grow naturally upon the mountains of Australia. These will serve as a covering for bare mountain sides in the Southwest, and the writer believes that they would prove quite valuable for re-covering those that have been denuded of their natural forests by fire. The rapid-growing species, less resistant to frost could be planted on the lower parts of mountains, and the somewhat slower-growing, more hardy ones farther up the mountain sides. Those adapted to alpine situations may be planted to a height of from 4,000 to 6,000 feet."

Perhaps 1,000,000 acres of the chaparral area would support a growth of the more desirable species of eucalypts, and on an additional 1,000,000 acres certain more hardy but less commercially valuable species could be grown. Before any attempt is made to introduce eucalypts into the chaparral on a large scale, however, much more must be known about the habits and requirements of the different species than is known now. It must be known, for example, whether desirable species will grow on the dry, rocky, and inhospitable slopes where even the chaparral can barely maintain an existence. It is not enough to know that certain desirable species of eucalypts can be grown in favorable locations in southern California. What must be found are species adapted to each slope, altitude, and climate. The magnitude of the task, too, compels caution. To introduce eucalypts or other trees over an area of 1,000,000 or 2,000,000 acres will entail an expense which would never be justifiable, unless it is practically certain that the work will meet with success.

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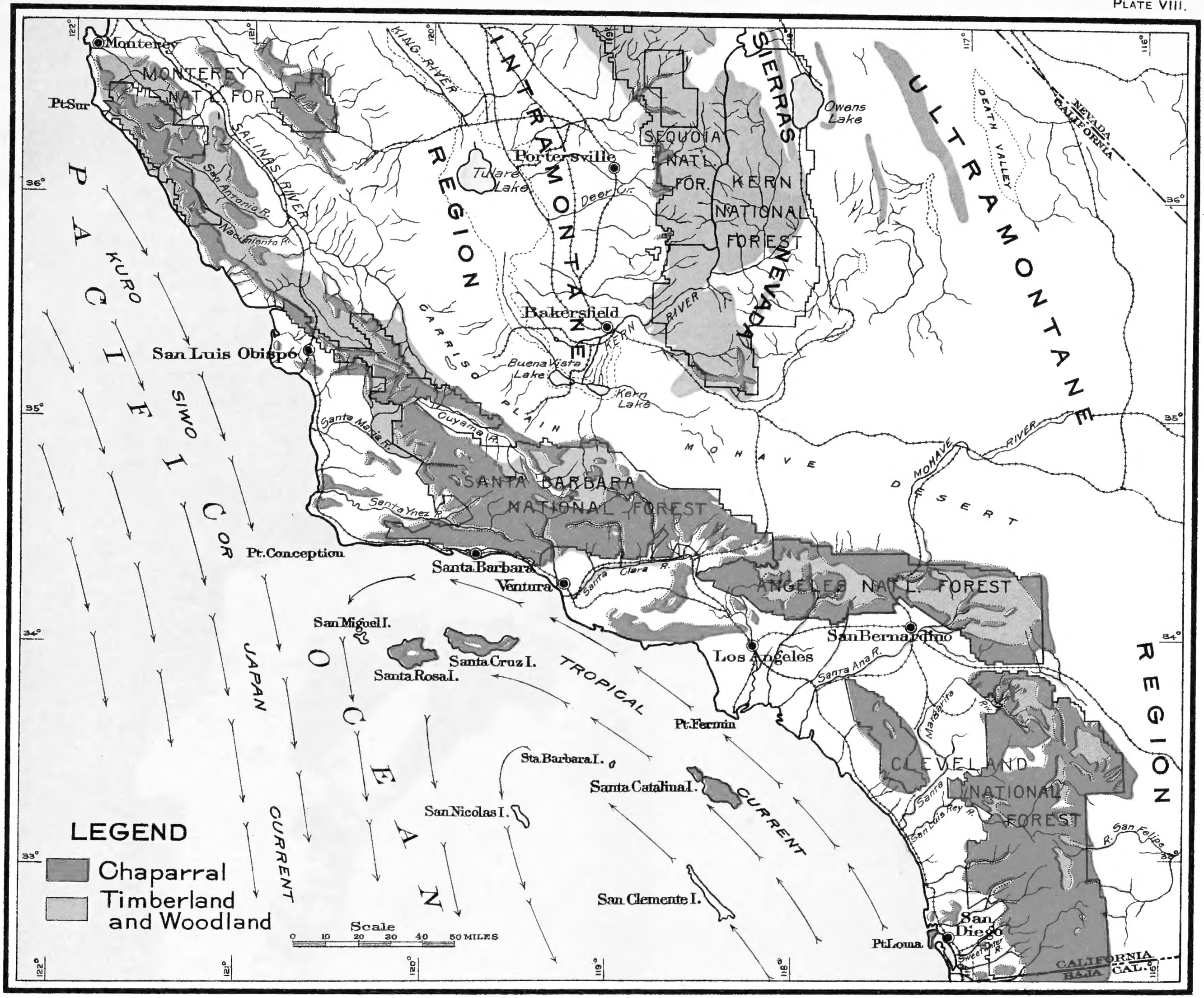

CHAPARRAL REGION OF SOUTHERN CALIFORNIA.

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