SOME ASPECTS OF

WATERSHED MANAGEMENT IN SOUTHERN CALIFORNIA

By

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FOREWORD

The material presented in this publication was prepared in May 1947, for a watershed-management seminar held at that time on the San Dimas Experimental Forest. The seminar was attended by members of the Forest Influences Division of the California Forest and Range Experiment Station, representatives of the Forest Service Regional Office in San Francisco, and staffs of the Los Padres, Angeles, San Bernardino, and Cleveland National Forests in southern California.

The discussions prepared by the Experiment Station staff were summarized and mimeographed, and copies were distributed among the group attending the seminar. The supply of copies remaining for distribution after the seminar was soon exhausted, but requests for copies are still being received. The present edition is intended to satisfy these requests and to provide wider dissemination of the seminar discussions.

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INTRODUCTION

C. J. Kraebel and J. D. Sinclair

Most of California's water supply originates in its mountain areas, about half of which are occupied by the 18 national forests of the State. While the mountains receive from 30 to 90 inches of rainfall annually, the valleys in general receive less than 15 inches. The runoff of mountain water is depended upon for hydroelectric power, for irrigation, and for domestic and industrial use. In this rapidly growing State, the water yield of the mountain forests is fully as important a resource as are lumber and forage.

The first Forest Reserves were established in southern California more than 50 years ago, primarily to protect mountain watersheds and insure the continuation of local water supplies. These one-time reserves are now known as the Angeles, Cleveland, Los Padres, and San Bernardino National Forests, embracing about 3,400,000 acres of southwestern California from Monterey County to the Mexican border.

Watershed protection has assumed increasing importance through the decades. Today the problems of water shortage, floods, and erosion in southern California are among the most serious in the United States. They result from a unique combination of natural conditions, a dense population, and vast developments in agriculture and industry. Some 5,000,000 acres of rugged mountains, upon which the principal cover is brush, with limited stands of timber, are the source areas of local water supplies essential to the population living in valleys. Southern California supports about 50 percent of the State's population and is still growing rapidly; yet this region has somewhat less than 2 percent of the State's water supply. It is generally recognized that shortage of water will be the limiting factor in the future development of this area. Conversely, these mountain watersheds are sources of disastrous floods, causing loss of life and destruction of property.

Studying the influence of vegetation on water yield, soil stability, and local climate is the job of the Division of Forest Influences of the California Forest and Range Experiment Station. Its long-range objective is to develop principles and methods for managing mountain watershed lands to produce the maximum yield of usable water compatible with adequate control of soil erosion and floods, and with other legitimate uses of those lands.

Specifically, forest influences research seeks, (1) to determine the effects upon water yield of forest uses and abuses (including lumbering, grazing, road building, and fire), (2) to devise methods for correcting poor forest practices or repairing watershed injuries that damage the water crop, (3) to develop principles and methods of forest management which will improve the quality and quantity of water yield.

The research program is directed from Berkeley headquarters, using experimental forests, smaller work centers in special problem areas, field surveys, and special "hot-spot" studies as required. Work centers have been established in the San Joaquin and Kings River watersheds, tributary to California's great Central Valley, and local studies have been made as needed elsewhere in the State. But the principal research effort has been centered south of the Tehachapi Mountains because water shortage, flood, and erosion problems are most acute in southern California.

Preliminary studies of the relation of watershed condition to streamflow and erosion were begun in southern California by the Forest Service more than thirty years ago. After an interruption of several years, these studies were resumed in 1927 by the California Forest and Range Experiment Station at Devil Canyon on the San Bernardino National Forest. In 1933 the Station began a comprehensive program of watershed research on a portion of the Angeles National Forest specially designated as the San Dimas Experimental Forest.

The objectives of research at this experimental forest are: (1) to study the influence of watershed conditions, including topography, geology, soils, and vegetation, on disposition of rainfall and (2) to develop methods of watershed management which will assure both the maximum yield of usable water, and satisfactory regulation of flood runoff and erosion. Intensive studies are being made of precipitation, streamflow, erosion, and the use of water by vegetation. Results of the work will have specific application in the mountains of southern California, but some of the principles developed there will have application to similar problems elsewhere in the world.

During 1945 and 1946 the Division of Forest Influences and Fire Control have cooperated in a special study of watershed conditions in the national forests from San Luis Obispo to the Mexican border -- to determine, among other things, the effects of watershed denudation by fire on the size of floods and rates of erosion in some 240 mountain watersheds. This study has brought together and analyzed much information which should help to improve our understanding and practice of watershed management in southern California. In the present paper only a few sample results of that study are included. The full reports will be supplied to the forests as they are completed.

THE CLIMATE OF SOUTHERN CALIFORNIA

E. L. Hamilton

Located in the path of prevailing westerly winds of the Pacific Ocean, the coastal portion of southern California enjoys a Mediterranean type of climate. Coastal fogs frequently extend to the summit of the coast mountain ranges. The interior mountains act as a barrier to the cold air from the north, and air from the interior plateau is warmed as it descends the slopes to the valley plains. Mean monthly temperatures range from about 45° to 76°F. Minimum temperatures rarely drop below 10°F. and maxima of 115°F. are not uncommon at the lower elevations. Maximum temperatures of 100°F. have been recorded at stations 5,000 feet above sea level.

The amount of precipitation received by any locality in this region depends upon its distance from the ocean, the altitude, the shape and steepness of mountain slopes, and the direction of the slopes in relation to the direction of moisture-bearing winds. As a rule, precipitation increases from south to north and is much heavier on southern and western than on northern or eastern mountain slopes.

In southern California almost all of the precipitation occurs between October and April, as is shown for the San Dimas Experimental Forest in Table 1. The four wettest months, December, January, February, and March, produce 78 percent of the annual total. This rain normally occurs in about twenty storms per season. The summer rainfall, such as it is, is derived principally from sporadic thunderstorms which originate over the great deserts and reach their maximum development over the mountains. These Sonora-type showers appear to be especially prevalent in the high country of the San Bernardino National Forest. Snow is practically unknown at the lower elevations but falls in appreciable amounts at elevations above 4,000 feet. Annual snowfalls reach 200 inches at elevated stations, with an approximate average of 60 inches yearly at 6,000 feet.

The concentration of exceedingly heavy rainfall in a few months creates special problems for the watershed manager in southern California. Illustrative of the high intensities of rainfall in this region are the following records: In 1926, at Opid's Camp in the Angeles National Forest, 1.02 inches of rain fell in 1 minute, a world record. In 1891 at Campo, in San Diego County, 11.50 inches of rain fell in one hour and 20 minutes (a world record until exceeded at Holt, Missouri, in June 1947). On January 22, 1943, 26.12 inches of rain fell in a 24-hour period at Camp LeRoy, Angeles National Forest, establishing a new record for the United States.

Most of the precipitation occurs in a few of the winter storms. During a 14-year period on the San Dimas Experimental Forest, 23 percent of the total precipitation fell in 3 percent of the storms; yet 30 percent of the storms produced only about 2 percent of the rainfall. Details of rainfall distribution are shown in Table 2.

The average annual rainfall at several different locations on each of the four southern California national forests is shown in Table 3. The last two columns in the table show the wide range in annual rainfall experienced over the period of time since the recording was started.

Table 1.- Number of storms and total rainfall by months for the period 1933 to 1947, San Dimas Experimental Forest[1]

Month	Storms		Rainfall	
	Number	Percent	Inches	Percent
October	25	9.3	23.66	5.2
November	18	6.7	31.69	7.0
December	43	16.0	99.09	21.9
January	33	12.3	62.68	13.9
February	42	15.6	106.60	23.6
March	47	17.5	84.74	18.7
April	34	12.7	30.91	6.8
May	10	3.7	2.74	.6
June	6	2.2	1.61	.4
July	0	-	.11	.02
August	4	1.5	1.56	.3
September	6	2.2	6.80	1.5
Total	268	100	452.19	100

1/ Standard raingage at Tanbark Flat (elevation 2750 feet) on the San Dimas Experimental Forest.

Table 2.- Number of storms and amounts of rainfall by storm size classes for the period 1933-1947, San Dimas Experimental Forest[1/]

Storm size class, inches	Storms		Rainfall	
	Number	Percent	Inches	Percent
0 - .25	95	30	11.30	2
.26 - .50	47	15	16.98	3
.51 - 1.00	62	20	45.86	10
1.01 - 2.00	47	15	68.49	15
2.01 - 3.00	22	7	53.51	12
3.01 - 4.00	9	3	31.24	7
4.01 - 5.00	9	3	39.50	9
5.01 - 6.00	8	2	43.23	10
6.01 - 7.00	6	2	39.07	9
over 7.00	9	3	103.01	23
Total	314	100	452.19	100

1/ Standard raingage at Tanbark Flat (elevation 2,750 feet)

Table 3.- Precipitation recorded at selected locations in four southern California forests[1]

Location and national forest	Elevation above sea level	Annual rainfall		
		Average	Minimum	Maximum
	Feet	Inches	Inches	Inches
LOS PADRES N. F.				
Jolon	960	17.29	5	34
Santa Barbara	130	18.04	6	43
Cuyamaca	--	10.13	5	18
Mono Ranch	3210	34.21	14	55
ANGELES N. F.				
Los Angeles	338	14.95	4	40
Newhall	1200	17.55	4	39
Tanbark Flat	3750	28.25	7	70
Mount Wilson	5850	31.20	8	80
SAN BERNARDINO N. F.				
Santa Ana River	2850	28.08	11	47
Cajon	2700	13.53	6	24
Bear Valley	6700	35.85	13	95
CLEVELAND N. F.				
San Diego	87	9.67	3	17
Barrett	1600	19.36	8	33
Campo	3000	19.92	9	34
Julian	4222	33.26	20	57

1/ Lengths of record variable; all records terminate in 1947.

GEOLOGY AND SOILS

H. C. Storey

GEOLOGY

Geology is important in any consideration of factors influencing watershed behavior. This is particularly true in the Los Padres, Angeles, San Bernardino, and Cleveland National Forests, in which the soil mantle is relatively thin. Although geology is not one of the hydrologic factors that can be altered by man, it is important to know what the capacity of the rock may be for the entrance and storage of water. Any program of watershed management leading to increased infiltration of water must presuppose adequate storage in the soil and rock to handle this additional volume. Moreover, the degree and rate of weathering for the different rocks has an important bearing on erosion.

For hydrologic purposes, the rocks of southern California may be grouped in two main divisions: (1) sedimentary; (2) igneous and metamorphic. There is considerable variation in the water-carrying capacity and the susceptibility to erosion of these formations.

Sedimentary formations, consisting of interbedded shales, sandstones and conglomerates, underlie almost the entire forest area north of the Santa Clara River. Laid down in the Cenezoic Era (during the past 60 million years), they vary in water-holding capacity and erosibility according to their composition and the position of their bedding planes. Coarse-grained, loosely compacted sandstone or conglomerate allows ready entry and movement of water. Such rocks usually form good sources of water for wells. On the other hand, a hard, platey shale furnishes great resistance to water movement, particularly movement at right angles to the bedding plane. Generally speaking, in formations of interbedded sandstones and shales, the shales are eroding faster than the sandstone. Normally, none of these sedimentary formations break up as badly when faulted as do the igneous and metamorphic crystalline rocks.

The igneous formations consist largely of granitic types, varying from true granites to diorites. These rocks underlie large areas of the Angeles, San Bernardino, and Cleveland National Forests. There are some volcanics, but these are generally very localized. The largest part of the granitic rocks occur in the form of massive batholithic bodies made up of several successive intrusions. (The most active period of intrusion was some 130 million years ago in the Jurassic Period.) This type of rock does not carry water between its constituent minerals, but rather along the joint planes and fractures caused by faulting. The great amount of jointing and fracturing has allowed ready access to weathering agents, and for this reason weathering is often deep and the surface material easily eroded.

The metamorphic rocks, consisting of schists and gneisses, were formed by alteration of both sedimentary and igneous rocks. These formations may strongly resemble sedimentary rocks because of a pseudo-bedding developed by the alignment of minerals during the process of metamorphism. These rocks vary greatly in their capacity to receive and store water. Practically no water is carried within the rock structure, but because of the great age of these rocks and the consequent long period of repeated faulting and fracturing, there are abundant cracks for water passage. These rocks, as well as the igneous types, are largely crystalline and tend to shatter extensively when faulting occurs. The large amount of fracturing plus the tendency to break along schist planes causes these rocks to weather fairly rapidly.

Faulting is very extensive in southern California and has important hydrologic implications. The shattered rock allows ready penetration and storage of water. Large crush zones favor rapid erosion. The major fault zone of this area, and the entire State, is the San Andreas Fault. This fault traverses about three-fourths of the length of the State, starting north of Pt. Arena (Mendocino County), running southeast along Tomales Bay, through western San Francisco, along the east side of the Santa Cruz Mountains, along the upper Pajaro River, and along the Temblor Range and Elkhorn Hills east of the Cuyama Valley. There it swings more to the east and passes north of Mt. Pinos and Frazier Mountain, past Lebec, along the north side of the San Gabriel Mountains, through Cajon Pass, along the south side of the San Bernardino Mountains, through San Gorgonio Pass and thence on into the Salton Sea Basin. Horizontal displacement along this fault has been estimated to be as much as 40 miles. A horizontal movement of 20 to 30 feet along this fault zone caused the famous San Francisco earthquake. Major branches of this fault are quite active, having had periods of recent movement. The presence of a series of hot springs in this area usually indicates the location of a recently active fault.

Underground basins, the largest of which are located along the south side of the San Gabriel Mountains, are important to the water supply of southern California because of the large quantities of water that they can hold. These basins are filled with thick deposits of sand, gravel, and boulders that have been carried down from the mountains and deposited in the valleys. The basins are bounded by impervious rock ledges and fault planes. The relatively large amount of pore space in the fill material, coupled with the impervious boundary formations, makes these basins ideal underground storage reservoirs that are protected against excessive water losses through evaporation. Water reaches the basins by infiltration of rainfall, by percolation from streams, and by deep percolation through rocks of the adjacent mountain masses.

SOILS

The soils found in the four southern forests vary considerably, both in composition and depth. Compared with valley soils the mountain soils are generally not very deep; limited areas are 6 to 8 feet deep; large areas are 3 feet or less in depth, and in some places soil depth is measured in inches.

Owing to their youthful nature, the soils correlate quite closely with the geology, in most cases consisting of physically disintegrated parent rock. Some scattered locations show the beginning of profile development, for example, the flat upland country in the Cleveland National Forest and the old alluvial fans along the south front of the San Gabriel and San Bernardino Mountains. Here may be found a higher percentage of clay, due to the chemical decomposition of the feldspar particles.

Whether deep or shallow, the watershed soils serve as an important water-regulating medium. At the beginning of the rainy season, soil moisture is at or below the wilting point, and the capacity of the soil to store water is at or near its maximum. At that point soils 2 feet deep may absorb from 2 to 4 inches of rain before they reach field capacity.[1/]

As soon as the soil moisture reaches field capacity, drainage into the underlying rock structure begins. At that point, some storage space for water still remains in the soil, namely the volume between field capacity and saturation. Where the capacity of the underlying rock to take in water is less than that of the soil, the storage space in the soil serves as a temporary reservoir, reducing surface runoff and allowing additional time for the water to enter the rock. A good vegetative cover insures the maintenance of a high soil infiltration capacity, thus protecting the regulating quality of the soil. Therefore, to maintain such a vegetative cover is a primary objective of watershed management.

Soils vary considerably in their erosibility, both as to rate and type. The deep clayey soils of the meadows in the Cleveland National Forest erode very rapidly if the vegetative cover is disturbed, and extensive gully systems result. The sandy, gravelly soils on the slopes are more subject to sheet erosion. Barren areas of sandy or gravelly soil sometimes tend to develop a comparatively low rate of erosion because of the formation of an erosion pavement. This occurs largely in areas where there are abundant rock fragments mixed through the soil; when the fines are removed, the rock residue completely covers the surface, slowing the velocity of surface runoff, covering the soil beneath, and materially reducing the erosion rate.

1/ Field capacity represents the maximum amount of water that can be held in the soil against gravity drainage. It is usually considered to be the moisture content of a soil after two or three days drainage following a large storm or heavy irrigation.

VEGETATION

J. S. Horton

The mountain land of southern California is covered mainly by chaparral, woodland, and forest. These three major plant formations are broken into several component cover types. An understanding of the natural plant cover and the ways in which it is affected by forest fire is of the greatest importance to watershed managers.

The chaparral formation, a dense growth of many shrub species, presents the most critical problems of watershed management because it extends over a large area in which the precipitation may occur as intense rain storms; because the chaparral is highly inflammable; and because destruction of the plant cover suddenly increases the opportunity for flood and erosion damage and decreases the yield of usable water.

Chaparral grows at elevations of 1,000 to 6,000 feet above sea level, usually on loose soils and steep slopes that favor rapid runoff and high erosion rates when denuded of the protecting plant cover. Increases in runoff and erosion are felt for many years while the chaparral recovers. Moreover, burning tends to perpetuate and extend the chaparral into areas originally occupied by the other plant formations, thereby increasing the extent of the problem area.

The woodland formation is an open stand of trees, usually having a ground cover of grass and small shrubs. Woodland grows generally at elevations below 5,000 feet. The typical woodland formation on the coastal side of the mountains is an oak-grass-sagebrush complex that is best developed on the Cleveland and Los Padres National Forests. On the desert side of the mountains, the woodland formation is dominated by pinyon pine and juniper. Both types of woodland suffer from forest fire, and throughout much of their range have probably been replaced by chaparral because they have been burned more frequently in historical times than in earlier periods. Woodland is a valuable watershed protection cover, and its management problems are somewhat less critical than those of the chaparral.

The forest formation is developed at elevations generally above 5,000 feet, where the winter precipitation occurs largely as snow. Maintenance of the forest cover is important in good watershed management, but the problems of its protection are also less critical than those of the chaparral. However, since the coniferous trees do not sprout, burning of the forest often results in the replacement of forest areas by chaparral or woodland. Charred stumps show that the extent of the true forest in southern California has been appreciably reduced by cutting and fire during the period of occupancy by the white man.

All the major plant formations are profoundly affected by fire, which causes changes in their component species, reduces the range of some cover types, and extends the range of others. Fires in the past may have played as important a part as altitude and climate in determining the main characteristics and distribution of the major plant formations. Therefore, any analysis of the native vegetation of southern California in relation to watershed management is bound to consider fire and its effects at every turn. For example, from the long range viewpoint, the chaparral may be called a "fire type" of vegetation because it retains its identity as a plant formation and holds its ground despite repeated burning. Further, many of its component species actually require fire for their reproduction and survival. Before there was any human occupancy of southern California lightning was practically the only cause of fire. It is highly probable that the frequency of burning has increased since man first appeared in the area. If lightning fires had not occurred in the prehuman period most of what is now the chaparral formation would probably have been occupied by coniferous forests at the higher altitudes, and by the oak-woodland-grassland-sagebrush complex lower down.

For convenience in study and management, the vegetation of southern California may be broadly classified as follows:

- Chaparral formation
    - Chamise chaparral type
    - Sage-buckwheat type
    - Scrub oak type
    - Desert chaparral
- Woodland formation
    - Coastal oak type
    - Pinyon-juniper type
- Forest formation
    - Jeffrey (or ponderosa) pine type
    - Ponderosa (or Jeffrey) pine-white fir type
    - Sugar pine-white fir type
    - Lodgepole (or limber) pine type
    - Bigcone-spruce (or Coulter pine) type

CHAPARRAL FORMATION

Chaparral occupies the bulk of the watershed area in the four national forests of southern California. This formation probably developed from woodland or forest types during the geologic period when the present mountains were being uplifted. During this period lightning fires became frequent enough to insure perpetuation of the chaparral formation and to prevent its replacement by woodland or forest, which would otherwise have been the natural course of plant succession.

Chamise-chaparral type

Chamise (Adenostoma fasciculatum) is the most widely distributed species of the chaparral formation. It occurs in pure and mixed stands on all sites except north-facing slopes and extremely dry south-facing slopes. This species may be associated with hoaryleaf ceanothus (Ceanothus crassifolius), buckbrush (Ceanothus cuneatus), white sage (Salvia apiana), black sage (Salvia mellifera), bigberry manzanita (Arctostaphylos glauca), Eastwood manzanita (Arctostaphylos glandulosa), or other minor chaparral species.

Besides extending the range of chaparral, fires since the coming of man have probably changed the relative percentages of the associated species in the chamise chaparral type. Hoaryleaf ceanothus and buckbrush thrive under repeated burning. Because they are short-lived species, they may be expected to disappear in the relatively short span of 100 years if the chaparral is not reburned. On the other hand, if the chaparral is reburned oftener than once every 20 years, the long-lived bigberry manzanita will probably disappear because the plants of this species are slow growing and do not produce abundant seed crops until the shrubs are about 20 years old.

There is too little evidence to show conclusively what would replace the chamise chaparral type if fire were eliminated as a habitat factor. There are some indications that California live oak (Quercus agrifolia) and some of the chaparral species such as hollyleaf cherry (Prunus ilicifolia), laurel sumac (Rhus laurina), or hollyleaf redberry (Rhamnus crocea var. ilicifolia) would slowly invade and take the place of the chamise. As the sites on which chamise grows are not good enough to support a heavy cover of these species, it is probable that the stand would be open, with inter-shrub spaces covered by grass or sage, depending upon the soil characteristics. It must be pointed out that the rate of this invasion is extremely slow.

Sage buckwheat type

Dry sites in the chaparral formation, which usually have unstable soil, are dominated by white sage, California buckwheat (*Erigonum fasciculatum* var. *foliolosum*), and other shrubs of similar character. Also, certain geologic formations such as unconsolidated sediments favor development of the sage-buckwheat type.

According to field evidence, burning does not control the distribution of sage and buckwheat. The boundary between sage and chamise chaparral appears to remain practically constant, regardless of the frequency of fire.

Scrub oak type

Chaparral consisting of California scrub oak (*Quercus dumosa*) associated with hairy ceanothus (*Ceanothus oliganthus*), or other chaparral species within their range, is found on north-facing slopes. Above 4,000 feet, the California scrub oak is usually replaced by interior live oak (*Quercus wislizenii*), but the type sometimes occurs on south-facing slopes at these altitudes. The scrub oak type is not destroyed by fire.

Desert chaparral

An open chaparral is developed where rain is deficient, as on the desert side of the mountains or in local areas such as Piru Creek canyon or the upper Cuyama River valley. The openness of the stand is not conducive to severe burning, and hence chamise and the other chaparral species that require fire for survival are absent. Oak, manzanita, sugar bush (*Rhus ovata*), flannel bush (*Fremontia californica*), and the several varieties of desert ceanothus (*Ceanothus greggii*) are the most abundant plants. This association occupies the same altitudinal limits as the pinyon woodland and frequently replaces pinyon pines destroyed by fire.

WOODLAND FORMATION

Coastal oak type

An oak woodland consisting primarily of California live oak, often associated with other tree species, develops in canyon bottoms and other areas (especially near the coast) that are somewhat protected from the severe fires that ravage the chaparral slopes.

This oak woodland is a complex grouping of oak, sage, and grass species. California live oak is the principal dominant, but it may be associated with Engelmann oak (*Quercus engelmannii*) in the Cleveland National Forest, and California white oak (*Quercus lobata*) and blue oak (*Quercus douglasii*) in Los Padres National Forest. The sagebrush components are usually species of subshrubs -- sage (*Salvia*), sagebrush (*Artemisia*), or buckwheat (*Eriogonum*) -- with a great variety of associated subshrubs, perennial and annual herbs, and grasses. In the foothill areas the sagebrush species cover large areas, often without accompanying trees. This plant association is not discussed separately because of its relative unimportance in the mountains and because of its close relationship with woodland types. The same is true of the grasslands which occur principally at low altitudes in Los Padres National Forest.

After severe burning, established California live oak may sprout and ultimately restore their dominance. The Engelmann, California white, and blue oaks are more apt to be killed. Seeds of the chaparral species usually germinate more vigorously after fire than seeds of the woodland species. Hence fire tends to spread the chaparral type into the oak woodland. A large portion of the oak woodland (especially north of the Santa Maria River in Los Padres National Forest) has been converted to a chaparral type by the increased burning during human occupancy of the region.

The spread of oak woodland into areas dominated by cover types which are favored by fire is extremely slow. For example, invasion of the California live oak into scrub-oak chaparral starts rather soon after the chaparral reaches maturity, but growth of the live oak seedlings is so slow that unless the area is protected for many years -- probably centuries -- the young oaks may not withstand the effects of a severe fire.

Pinyon-juniper type

Pinyon pine or juniper woodland occurs on the desert side of the main mountain ranges. The pinyon pine (*Pinus monophylla*), and to a lesser extent the California juniper (*Juniperus californica*), is usually associated with the desert chaparral species discussed previously. In the Big Bear Lake region, Sierra juniper (*Juniperus occidentalis*) or pinyon pine are associated with subshrub species.

If fires burn through this woodland, the trees are largely removed and the area is converted to an open chaparral or sagebrush. Fires are relatively infrequent in the pinyon-juniper type, however, because of the scanty plant growth.

FOREST FORMATION

The forest formation is composed of coniferous trees of 9 principal species, including 6 pines. The forest zones usually receive 30 inches or more annual rainfall. Where the rainfall is less than 30 inches, the forests do not extend much below 6,000 feet elevation.

Increased frequency of fire since the coming of man has somewhat reduced the area covered by coniferous forest. Some brushfields are now found within the forest area, and there are indications that, throughout a significant percentage of its range at lower altitudes, the forest has been replaced by chaparral or woodland. Fires in the prehuman period, however, perpetuated a certain percentage of the fire-caused chaparral and woodland and undoubtedly prevented the forest from developing on some sites suitable for the growth of coniferous trees.

Jeffrey (or ponderosa) pine type

Open forests of Jeffrey pine (*Pinus jeffreyi*) or ponderosa pine (*Pinus ponderosa*) are found on the poorer soils or in areas of limited rainfall within the forest zones. Burning will kill most young coniferous trees but will usually only scorch the trunks of mature trees. It may, however, cause a considerable increase of associated chaparral species such as deerbrush (*Ceanothus integerrimus*), mountain whitethorn (*Ceanothus cordulatus*), pine manzanita (*Arctostaphylos parryana* var. *pinetorum*) and bush chinquapin (*Castanopsis sempervirens*). If the mature trees are logged, fires after logging may change this forest to a chaparral type or to a woodland of California black oak (*Quercus kelloggii*).

Ponderosa (or Jeffrey) pine-white fir type

On the better sites where moisture is adequate there is developed a dense forest of ponderosa or Jeffrey pine, sugar pine (*Pinus lambertiana*), white fir (*Abies concolor*) and incense cedar (*Libocedrus decurrens*). In some instances after logging and fire, this forest will be replaced by black oak woodland or by chaparral.

Sugar pine-white fir type

This is an open forest that grows on steep unstable slopes. Jeffrey pine is almost always associated with the sugar pine and white fir. Occasionally sugar pines occur only as scattered individuals. Fires rarely burn in this type because of the widely spaced trees and the general lack of shrub or herbaceous cover. When fires do occur they tend to increase the relative abundance of chaparral shrubs.

Lodgepole (or limber) pine type

These alpine species of pines (*Pinus contorta* var. *latifolia* and *P. flexilis*) grow in open stands at high elevations, usually above 8,000 feet. The ground cover is naturally sparse, and there is much bare soil and rock; hence fire hazard is low, and the infrequent burning has no appreciable effect on the composition of the stand.

Bigcone-spruce (or Coulter pine) type

Bigcone-spruce (*Pseudotsuga macrocarpa*) and occasionally Coulter pine (*Pinus coulteri*) are found at altitudes between 4,000 and 6,000 feet, or even higher if rainfall is deficient. The bigcone-spruce forest and its associated chaparral and woodland types constitute a "tension zone" between the chaparral of lower elevations and the forest above. North-facing slopes in this zone are occupied by stands of bigcone spruce or canyon live oak woodland; bigcone-spruce will slowly invade the live oak woodland if fires are kept out for a considerable period. South-facing slopes at these altitudes, where covered with a chaparral consisting of interior live oak and associates, may be very slowly invaded by bigcone-spruce.

Fires in the prehuman period undoubtedly prevented the development of extensive bigcone-spruce forests on some sites although remnants of old stands show that this species was much more abundant and widely distributed in early days. Each major fire that burns through this tension zone reduces the extent of the bigcone-spruce. After burning, this forest is replaced by canyon live oak, deerbrush ceanothus, interior live oak, or other chaparral species. During the period of human occupancy, the bigcone-spruce has given way rather markedly and the zone is characterized by many burned-out areas.

RECOVERY OF CHAPARRAL AFTER FIRE

Knowledge of plant succession in the chaparral after forest fire is a valuable watershed-management tool. Plant succession in the chaparral shows a beautiful adaptation to the environmental factor of fire. Along with the evolutionary development of chaparral shrubs, there has also occurred the development of many species of annuals and perennials requiring fire for their reproduction. Seeds of these species lie dormant in the litter or soil during the long periods which may occur between burnings, but when fires occur the seeds are stimulated to immediate germination. The succession of vegetation which develops after fire in the chamise chaparral, for example, is as follows:

1. The first year after burning shows a vigorous development of annual herbs. Certain chaparral plants such as chamise, scrub oak, etc., send up shoots from the burned stumps. Seed of both sprouting and non-sprouting chaparral species (principally Ceanothus) germinate during the first winter, as well as many species of short-lived perennials such as deerweed (Lotus scoparius), bush lupine (Lupinus longifolius), and sticky nama (Nama parryi). These seedlings do not grow more than a few inches in height by the end of the first growing season.

2. The second year shows a great increase in development of the short-lived perennials and the sprouts of the sprouting chaparral. Annuals may be as numerous as during the first year, though certain annual species do not appear at all in the second year. The seedlings of chaparral species are still very small.

3. The third year shows a marked increase in the dominance of short-lived perennials which by now far surpass the sprouting chaparral. The annuals are decreasing, and the chaparral shrub seedlings are still too small to be of much importance.

4. By the fifth year the annuals are usually pretty well gone, and the short-lived perennials have become minor in importance. The bulk of the cover is produced by the sprouting chaparral stumps. The small chaparral seedlings have grown to a height of perhaps 8 or 10 inches, but are still not a vigorous part of the plant cover.

5. Usually by the eighth year the cover is composed entirely of chaparral species. Ceanothus, if present, is rapidly becoming the dominant, and promises soon to surpass the sprouting shrubs such as chamise.

6. By the fiftieth year the short-lived shrubs such as ceanothus are losing their dominance, and at this time the cover opens because the chamise does not produce as heavy a canopy as the ceanothus.

The density of chaparral cover increases very rapidly through the first ten years following fire. Then it increases less rapidly until the maximum density is reached at about forty years after burning. The cover tends to stabilize at this age, but may open up gradually as in the case of the chamise-ceanothus combination. The density attained at forty years depends upon the dominant species, the climate, soil and topography. As a rule, unless there has been exceptional erosion following fire, the chaparral vegetation eventually recovers to about the same density as before burning.

THE HYDROLOGIC CYCLE

P. B. Rowe

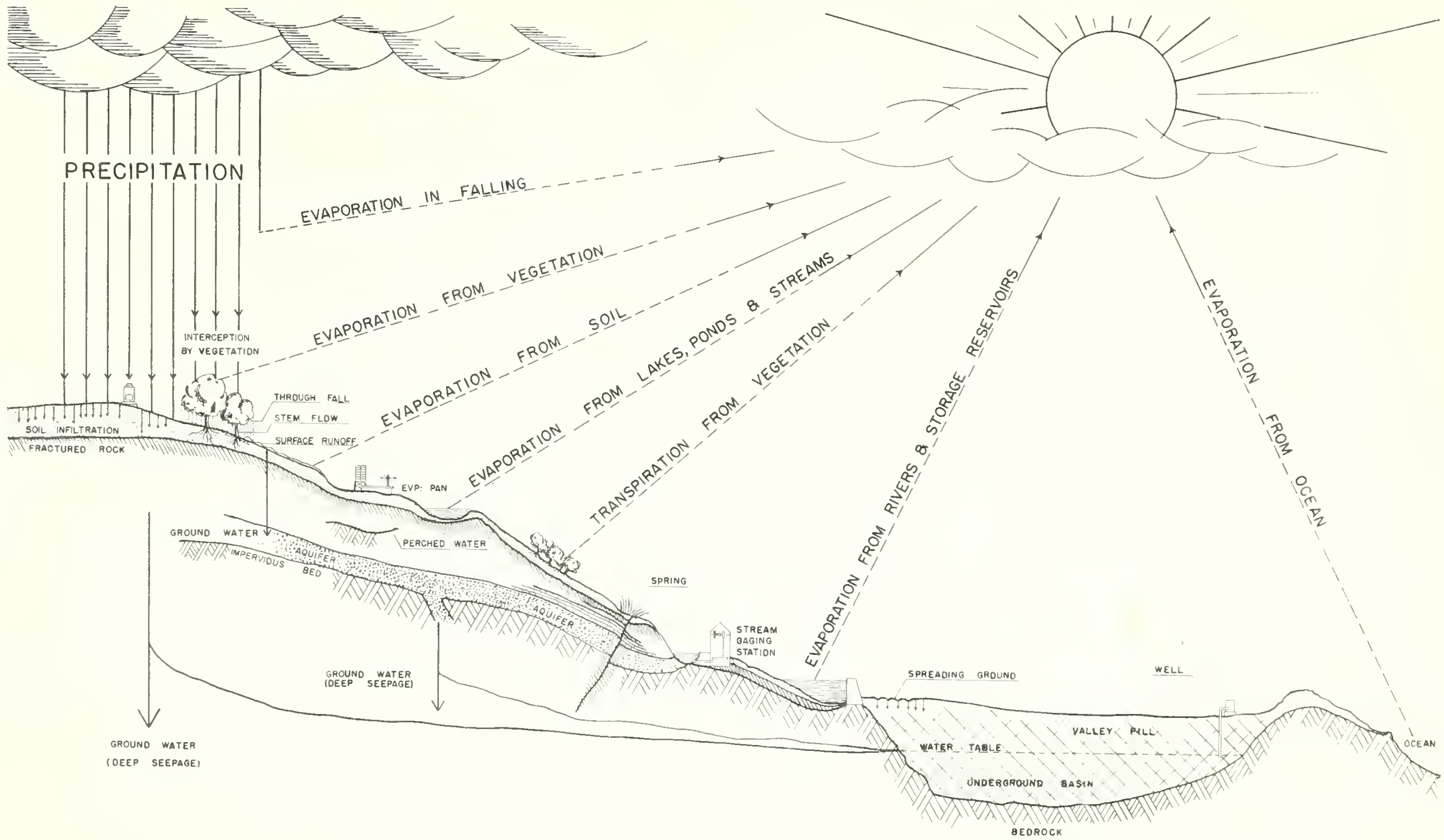
To watershed managers the hydrologic cycle is a helpful concept, for it accounts for all the water in the earth's upper layers and atmosphere. The quantity of this water remains essentially constant over long periods of time but its form and location are constantly changing. In general water follows a natural circulation from the atmosphere to the earth and back to the atmosphere, as illustrated in Figure 1.

In watershed management, water first assumes hydrologic importance when deposited on the earth's surface in some form of precipitation. A portion of the precipitation is intercepted by the vegetation or other obstructions above the land surface. Part of this intercepted precipitation is returned to the atmosphere by evaporation. Of the precipitation reaching the earth, part falls directly on the surfaces of streams, lakes, and oceans; part reaches streams through surface runoff from the land; and part enters the surface soil and underlying rock structures through infiltration. Part of the water entering the land surface is returned to the atmosphere as direct evaporation, or as transpiration by the vegetation, and part reaches streams, lakes, subterranean water bodies, or the ocean, as underground flow. In the long run, then, the hydrologic cycle is maintained by a balance between precipitation and evaporation from the land and water surfaces.

Watershed management is a recognized practice because water on the earth's surface is subject to some control by man. While man may not yet be able to regulate the quantity of precipitation, he can apply important controls to evaporation, transpiration, infiltration, and surface runoff. Control over these portions of the hydrologic cycle is accomplished by maintaining or changing certain physical conditions in watersheds. This is the function of the watershed manager.

Although we know and recognize all of these phases of the hydrologic cycle, we still lack much knowledge of their magnitudes and of the relationships between them and physical conditions in watersheds. Gaining a better knowledge of these quantities and relationships is a major function of watershed-management research.

THE HYDROLOGIC CYCLE



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SOME RESULTS OF HYDROLOGIC RESEARCH

P. B. Rowe, H. C. Storey and E. L. Hamilton

RUNOFF, EROSION, AND INFILTRATION STUDIES

North Fork Experiments

Watershed management research with small plots was conducted at North Fork, in the Sierra Nevada foothills of the San Joaquin Velley, before and during the establishment of the San Dimas Experimental Forest. In this work fundamental data were obtained that influenced the design and installation of the experiments at San Dimas. For this reason, and because results of the Sierra Nevada studies have application in southern California, a resume of the North Fork experiments is given here.

Experimental installations used at North Fork included: (1) one pair of 1/40-acre plots on which the natural vegetation was undisturbed; (2) one pair on which the vegetation was burned in the fall of 1929, and annually from 1931 to 1937; (3) one pair on which the vegetation was burned in the fall of 1930 and again six years later in the fall of 1936. Interception and stemflow, lysimeter, and various meteorological data were also collected in connection with the plot studies.

Changes in vegetation.--Although density of the total vegetative cover on the plots (brush, herbaceous, and litter cover) was reduced 50 to 55 percent by the first burning, herbaceous cover increased 35 to 40 percent the first season after the fire. Apparently a result of additional soluble nutrients, decreased competition, and favorable weather, this increase was short-lived. On the twice-burned plots, density of herbaceous cover was greater than on unburned plots for only four seasons after the first fire. After the second and succeeding burns, density of herbaceous cover on all burned plots declined from 26 to 60 percent below that on unburned plots. The proportion of unpalatable species continually increased.

Changes in water and soil relations.--The most striking results of burning on these small plots are shown in Table 4. Annual burning during the period of the studies resulted in (1) a slight decrease in average evaporational losses, (2) large increases in surface runoff and erosion, and (3) a correspondingly large decrease in percolation. Although quantitatively much less, changes in these water relations were similar on the twice-burned plots. Differences between twice-burned and undisturbed plots were greatest the first year after each burn.

Table 4.- Average yearly disposition of precipitation on plots at North Fork, 1934-38

Plot treatment	Precipitation	Evaporation losses[1]	Surface runoff	Percolation[2]	Erosion
		- - - Inches depth - - -			Lbs/plot
Undisturbed	45.26	19.1	Trace	26.2	0
Burned annually	45.26	17.2	10.3	17.6	1,335

1/ Includes evaporation from the soil, transpiration, and interception loss. (Interception not measured on annually burned plot.)

2/ Percolation through a 48-inch soil depth.

To watershed managers, the significant feature of these changes lies not in the total water yield, but rather in the quantity and distribution of the water. A large proportion of the surface runoff from the burned plots occurred during flood periods. Much of this water was loaded with silt and debris and was therefore unsuited for many uses.

Differences in the water-soil relations of undisturbed and burned plots were caused principally by the effects of burning on infiltration capacity of the soils. By March 1938 average infiltration capacities of the undisturbed, twice-burned, and annually burned plots were approximately 3.5, 0.55, and 0.12 inches per hour, respectively. This reduction in infiltration capacity as a result of burning was caused in most part by (1) the destruction of litter cover and the reduction of organic matter in the surface soil, (2) the reduction in the activities of certain of the soil fauna such as earthworms and burrowing insects, and (3) the plugging of soil pores and the destruction of surface soil structure caused by direct exposure to rainfall, surface runoff, and erosion.

Plot studies at San Dimas

Further studies of runoff and erosion from watershed slopes have been made on two series of nine 1/40-acre plots in the chaparral cover of the San Dimas Experimental Forest (Table 5). The Tanbark Flat series at 2,750 feet elevation is in the ceanothus-oak-chamise subtype and the Fern Canyon series is located in the oak-woodland subtype at 5,000 feet elevation. The vegetative cover on the Tanbark Flat plots has been unburned since 1919. It is representative of probably 20 percent of this subtype on the four southern forests. The Fern Canyon plot vegetation had been unburned for at least 55 years until 1938 when a fire destroyed the cover and consumed most of the litter. Due to the age of the pre-1938 vegetation it was representative of only about 5 percent of this type.

Table 5-Annual rainfall, runoff, and erosion for 1/40-acre plots, San Dimas Experimental Forest, California

Hydrologic year[1/]	Fern Canyon plots				Tanbark plots			
	Rainfall	Runoff		Erosion	Rainfall	Runoff		Erosion
	In.	In.	Percent of rain	Cu.ft./A	In.	In.	Percent of rain	Cu.ft./A
1935-36	25.0	.3	1.4	1.0	22.0	.2	.7	1.5
1936-37	44.1	.4	1.0	.6	41.0	.1	.2	1.2
1937-38	52.4	.3	.6	1.3	45.1	.5	1.1	1.5
1938-39[2/]	22.0	1.4	6.4	272.5	20.2	T.	.1	.7
1939-40	32.3	.6	1.9	33.0	32.3	T.	.1	.5
1940-41	57.8	.6	1.0	10.0	46.6	.1	.1	.5
1941-42	19.5	T.	.2	T.	16.4	T.	.1	.5
1942-43	53.5	.2	.5	T.	45.2	.1	.2	.3
1943-44	40.5	.4	1.0	T.	32.7	T.	.1	T.
1944-45	35.5	.1	.2	T.	29.7	T.	.1	T.
1945-46	30.0	.1	.4	T.	26.1	T.	.2	T.

1/ October 1 through September 30 of succeeding year.

2/ Fern plots burned November 1938.

A marked increase in runoff and erosion was noted from the Fern plots immediately after the vegetation on them was burned in November 1938. This is in contrast to the comparatively uniform performance of the Tanbark plots during the same period. No significant runoff or erosion was measured on either of the two series of plots before the fire. This period included the capital storm of March 1938 when during a three-day period the rainfall on the Tanbark plots was 20.20 inches and on the Fern 22.19 inches. During this storm the maximum hourly rainfall was 1.26 inches, and intensities of approximately 1 inch per hour continued for 4 hours. Yet runoff and erosion from both series of plots were inconsequential. However, after the Fern plots were burned over, a storm of 10.62 inches in December 1938 caused run-off amounting to 6 percent of the rain. With a maximum hourly intensity of 0.68 inches, this storm was sufficient to start an erosive process producing really significant debris movement during the first year after the burn. The reaction resulting from the loss of plant cover on the Fern plots persisted for three years, after which they appear to behave similarly to the Tanbark plots. The yearly runoff of 0.2 and 0.1 percent of the rain on the Tanbark plots means that practically all of the rain went into the soil -- a good illustration of the value of vegetative cover.

Data from plots of this type cannot be applied directly to whole watersheds, but they do supply pointed information concerning the amount of water running off or entering the soil under certain cover conditions.

Infiltrometer studies

Some quantitative influences of vegetation and different types of land use on the infiltration capacities of soils are shown in Table 6. It is of interest that in more than 1,000 infiltration tests in the Pajaro, Santa Maria, and Santa Ynez River drainages, and in the Kennett and San Joaquin areas, no case was found in which heavy grazing or burning of the vegetation, other conditions being equal, failed to result in a decrease in infiltration capacity of the soil. It should be remembered, however, that in some soils with initially high infiltration capacities, large reductions may occur, yet infiltration capacities will still exceed the maximum rainfall intensities of the region. In such soils, reductions in infiltration capacities may have little or no direct effect on surface runoff.

Table 6.- Some effects of land treatment on average infiltration capacities of soils in various cover types of the Santa Maria River drainage, California

Cover types	Degree of use, age of cover, or treatment	Weighted mean infiltration capacities 1/
		Inches/hour
Grassland and sagebrush	Heavy grazing	0.19
	Moderate grazing	0.57
	Light grazing	0.94
Pinyon-juniper	Heavy grazing	0.34
	Moderate grazing	0.51
	Light grazing	0.84
Semi-barren	Heavy and moderate grazing	0.12
	Light to no grazing	0.55
Chamise	0-3 years after burning	0.21
	4-15 years after burning	0.36
	Over 16 years after burning	0.40
Chaparral and chaparral-woodland	0-3 years after burning	0.36
	4-7 years after burning	0.95
	7-15 years after burning	1.46
	Over 16 years after burning	1.96
Cultivated	Cleantill	0.09
	Treated (cover crop)	0.34

1/ Infiltration capacities determined by use of the North Fork infiltrometer, and adjusted to experienced watershed conditions by analyses of precipitation and streamflow for several storms.

Rainfall interception studies

A study of the interception of rainfall by chaparral vegetation was made at Tanbark Flat on the San Dimas Experimental Forest during the years 1942-45 on a plot with an area of 970 square feet (10 ft. x 97 ft.). The vegetation on this plot had a density of about 70 percent and was composed chiefly of California scrub oak and hairy ceanothus. The amount of throughfall, rain falling on the ground or reaching it as drip from the vegetation, was measured in a trough 80 feet long and 9 inches wide set at ground level under the canopy. The 149 stems on the area were collared with sheet-lead troughs which diverted into measuring tanks all of the rain that collected on the shrub canopy and ran down the stems.

Measurements of throughfall and stemflow for 50 storms indicate the following disposition of the total rainfall of 83.25 inches:

67.03 inches or 81 percent of the rain reached the ground as throughfall.

6.96 inches or 8 percent of the rain reached the ground as stemflow.

9.26 inches or 11 percent of the rain was intercepted by the canopy and evaporated. Thus 11 percent of the precipitation made no contribution to ground water or surface runoff.

The above figures are simple totals for all storms measured. If the storms are segregated into size classes we find that the interception loss becomes proportionally less as the storm magnitude increases, as shown in Table 7.

Table 7.- Summary results of interception study on the San Dimas Experimental Forest, California

Storm size class, inches	No. of storms	Rainfall	Throughfall		Stemflow		Interception loss	
		In.	In.	Percent of rain	In.	Percent of rain	In.	Percent of rain
.10 - .25	10	1.70	.79	46	.06	4	.85	50
.26 - .50	6	2.33	1.47	63	.14	6	.72	31
.51 - 1.00	14	10.28	7.69	75	.76	7	1.83	18
1.01 - 2.00	10	13.26	10.76	81	.97	7	1.53	12
2.01 - 6.00	5	16.05	13.09	82	1.34	8	1.62	10
6.01 - 12.00	5	39.63	33.23	84	3.69	9	2.71	7
Total	50	83.25	67.03	81	6.96	8	9.26	11

Seven seasons of interception-stemflow measurements in chaparral types of the Sierra Nevada foothills near North Fork showed an interception loss averaging only about 5 percent of the total precipitation. Nearly 20 percent of the total precipitation was caught by the vegetation, but of this amount 75 percent, equivalent to 15 percent of the total precipitation, reached the soil as flow down the stems of the brush. The density of the vegetation averaged from 40 to 50 percent. In a 70-year-old second growth ponderosa pine stand at Bass Lake, near North Fork, with a canopy cover of 40 to 50 percent density, the interception loss averaged 12 percent of annual precipitation.

WATERSHED STUDIES

To make the results of water-cycle and soil studies more applicable to watershed management, it is desirable that experimental work be done on whole watersheds. Facilities for work on this scale are available on the San Dimas Experimental Forest. These include small, medium, and large watersheds, some of which have been protected from fire and other disturbances for many years; gaging stations for measuring runoff; reservoirs for measuring eroded debris; and instruments for measuring climate, vegetation-soil-water relations and other related factors.

Disposition of precipitation

Of the many studies under way on the San Dimas Experimental Forest, the one of perhaps the most direct interest to watershed managers concerns the disposition of precipitation after it reaches the ground. How much of the precipitation is accounted for by streamflow? How much is lost through interception? How much returns to the atmosphere through evaporation and transpiration? How much is retained in underground reservoirs?

Measurements of precipitation and streamflow for four seasons in several watersheds of the San Dimas Experimental Forest are given in Table 8. The values in this table bring out the great variation in precipitation-streamflow relations from year to year.

A more complete picture of the disposition of precipitation in a single rain year is shown in Table 9, which gives an accounting for 12 watersheds in southern California, and also the average behavior of 19 watersheds, as calculated from the results of forest influences studies. It will be noted that the disposition of precipitation, as well as the amount, varies considerably among the several watersheds, even in the same year. This is particularly true of streamflow and retention (see footnote 1, Table 9).

Table 8.- Some precipitation-streamflow relations for four watersheds on the San Dimas Experimental Forest, California

Season and watershed	Area	Precipitation	Streamflow	Streamflow as percent of precipitation
	Sq.mi.	Inches	Inches	
Season 1934-35				
Wolfskill	2.39	31.3	2.0	6.3
North Fork, San Dimas	4.23	32.5	2.2	6.7
Volfe	1.16	34.5	2.4	6.9
Monroe	1.37	33.5	2.6	7.7
Season 1935-36				
Wolfskill	2.39	23.1	1.5	6.4
North Fork, San Dimas	4.23	22.8	1.3	5.7
Volfe	1.16	25.5	2.1	8.2
Monroe	1.37	25.5	1.5	5.8
Season 1937-38				
Wolfskill	2.39	43.8	14.4	32.8
North Fork, San Dimas	4.23	43.8	16.4	37.4
Volfe	1.16	41.9	16.5	39.4
Monroe	1.37	41.4	14.5	35.0
Season 1940-41				
Wolfskill	2.39	48.9	9.5	19.4
North Fork, San Dimas	4.23	48.8	12.5	25.6
Volfe	1.16	50.9	12.3	24.2
Monroe	1.37	50.4	11.1	22.0

Table 9.- Disposition of precipitation in some representative watersheds of southern California, October 1, 1940, to September 30, 1941

Watershed unit	1 Precipitation	2 Streamflow	3 Interception loss	4 Evaporation, transpiration	5 Retention 1/ 1-(2+3+4)	6 Maximum retention 2/
			- - - Inches depth - - -			
Piru Creek	45.2	9.8	2.5	17.0	15.8	23.4
Pacoima Creek	48.9	17.4	3.1	14.8	13.6	22.3
Haines Canyon	57.1	9.3	3.1	16.7	28.0	36.5
Big Santa Anita Creek	65.2	25.1	3.5	13.8	22.8	33.7
Fish Canyon	60.2	26.9	3.4	14.9	15.0	28.9
East Fork San Gabriel	59.7	27.7	3.1	16.0	13.0	29.9
Dalton Creek	48.8	11.5	3.4	14.0	19.9	27.1
San Dimas Creek	48.0	11.1	3.4	13.7	19.8	27.5
San Antonio Creek	78.6	38.3	3.1	16.7	20.5	47.3
City Creek	62.5	17.5	4.4	15.7	24.9	32.8
Big Rock Creek	60.0	29.2	2.6	15.7	12.5	33.6
West Fork Mojave River	37.1	14.5	2.5	17.2	2.9	13.9
Average of 19 watersheds 3/	56.1	20.0	3.2	14.5	18.4	28.9

1/ Includes underground flow that feeds the natural underground basin of the valleys by drainage through the soil and subsurface rock, without appearing as surface streamflow.

2/ Retention toward end of rainy season, before streamflow and evapo-transpiration losses of late spring, summer, and fall.

3/ Average of 19 typical watersheds of the Angeles National Forest, extending from Pacoima Creek to San Antonio Creek along south slope of the San Gabriel Mountains, including 8 of the watersheds listed above.

Water retention capacity

The determination of water retention capacities for whole watersheds is another problem of importance to watershed managers. "Water retention capacity" is the capacity of the soil and substrata to hold water in temporary storage. The water so held is released slowly by subterranean flow to springs and streams, and by deep seepage to the valley fill or the ocean. It is obvious that the degree to which increases in infiltration can reduce surface runoff and streamflow is dependent upon the capacity of the soil and the underlying rock formations to absorb, hold, and transmit water.

Water retention capacities of 36 representative watersheds of the southern California national forests have been determined in connection with the fire-damage-appraisal study. Precipitation and runoff records of the 1940-41 rain season were used in this analysis because that year brought an unusually large amount of rainfall in well-distributed storms, and at rates sufficiently low to favor maximum water intake and retention.

This study showed that the maximum depth of water was retained toward the end of the rain season, during late winter and early spring, and averaged nearly 30 inches in depth (see last column of Table 9). The maximum depth in individual watersheds ranged from below 20 inches to over 40 inches.

In only one watershed did the amount of streamflow during a storm period of this 1940-41 rain season exceed 30 percent of the storm precipitation. In fact, during the many years for which streamflow records are available for these streams, there were only three cases in which the stream runoff of a storm period was as much as 50 percent of the precipitation. These three cases of unusually high runoff occurred during the great storm of March 1938, which was marked by exceptionally high intensities as well as large amounts of rainfall. Analysis of these cases showed that the high storm runoff resulted from the fact that rainfall rates, at times during the four-day storm, exceeded the capacities of the watersheds to take in water.

These results indicate that, for the period of record included in the analysis, no watershed reached or closely approached complete saturation. This means: (1) that the temporary water-storage capacities of most of the mountain watersheds of southern California are in most years well in excess of the highest expected amounts of storm precipitation, and (2) that if, through watershed management, a larger portion of storm precipitation is delivered to temporary subsurface storage, flood peaks and erosion rates can be reduced and interstorm streamflow increased.

EFFECTS OF FOREST FIRE ON FLOOD PEAKS AND EROSION RATES

Because of its function in promoting infiltration and reducing surface runoff and erosion, maintenance of the plant cover is of primary importance in the chaparral watersheds of southern California. Removal of the vegetation by fire normally results in increased peak flows of stream runoff and rates of soil erosion.

Records of streamflow from burned and long-unburned (unburned for 40 or more years) watersheds in southern California show that the first year after burning, peak flows are increased from 2 to 30 times, depending upon the size of storm. Peak flows from burned areas do not return to normal until 20 to 60 years after a fire. These general relationships are shown in the following tabulation:

Size of storm	Increase in peak flow following fire	Period of return to normal flow
	Times	Years
Small	10-30	20
Medium	3-10	40
Large	2-3	60

Annual erosion rates are increased, on the average, about 35 times the first year after a complete burning of a good chaparral cover, and 8 to 10 years are required for erosion rates to return to normal. Erosion rates during this recovery period average 9 to 10 times those before burning. If deep gullying, such as occurs in some areas, is started after burning, the long-time average erosion rates and the time required for recovery may be greatly increased. Data were not available to permit determination of the effects of burning on deep gullying and the resulting erosion rates.

It should be remembered that the foregoing figures of average increases in runoff peak and erosion rates as a result of burning are for watersheds with initially good cover. In watersheds with appreciabl amounts of barren areas, or areas of very sparse vegetation, these effec of burning may not be so pronounced.

Normal and after-burn flood peaks and erosion rates for some representative watersheds of the southern California national forests are given in Table 10.

Table 10.- Estimated one hundred-year flood peaks and annual erosion rates for some representative watersheds of the southern California national forests 1/

Watershed units	100-year flood peaks 2/						Annual erosion rates			
	Unburned 3/	Years after 100% burn: 1st	3d	7th	10th	30th	Unburned 4/	Years after 100% burn: 1st	3d	5th
	- - - Cu.ft./sec./sq.mi. - - -						- - - Cu.yds./sq.mi. - - -			
LOS PADRES NATIONAL FOREST										
Sisquoc River	120	230	180	150	140	130	720	24,000	5,500	2,700
Juncal Creek, above dam	290	580	430	370	340	310	2,100	72,100	16,300	8,000
Matilija Creek	280	570	430	370	330	310	2,600	90,700	20,500	10,100
ANGELES NATIONAL FOREST										
Tujunga, above dam	300	540	420	370	340	320	1,800	51,800	11,900	6,000
Santa Anita, above dam	390	780	580	500	460	420	3,800	133,000	30,000	14,800
San Gabriel, W. Fork above dam	500	910	710	620	570	540	6,100	176,300	40,300	20,700
SAN BERNARDINO NATIONAL FOREST										
Mill Creek, above dam	250	410	330	290	270	260	1,400	30,400	7,200	3,800
Lytle Creek	280	400	340	310	300	290	2,500	35,800	9,100	5,400
Cucamonga Creek	330	630	470	410	380	350	4,700	131,600	30,200	15,300
CLEVELAND NATIONAL FOREST										
San Juan Creek	200	370	290	250	230	220	640	19,100	4,400	2,200
Sweetwater Creek, above dam	190	300	250	220	210	200	1,400	26,000	6,400	3,500
Cottonwood Creek, above dam	200	300	250	230	220	210	5,600	27,700	10,200	7,600

1/ Estimates based on analysis of available precipitation, streamflow, erosion, and other pertinent data.

2/ Flood peak expected to be equaled or exceeded on an average of once in 100 years.

3/ Vegetation unburned for 40 or more years.

4/ Vegetation unburned for 10 or more years.

CALIFORNIA FOREST AND RANGE EXPERIMENT STATION*
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Inflammability of Chaparral Depends on How It Grows

By Charles C. Buck
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Southern California chaparral has long been noted for its inflammability. Most of the blame for this bad reputation is usually assessed to general character of the vegetation, steep slopes, and severe weather conditions. Probably not enough emphasis has been given to changes in the vegetation itself that affect its fuel qualities.

All evergreen California chaparral species normally grow new twigs and leaves in the spring and drop a portion of the older leaves in the summer and fall. When vegetation of this type is first established, the volume of green branchwood and number of leaves increase annually until the vegetation completely occupies the site. Then the quantity of stems and the density of the canopy depend on the soil and on the amount of moisture available in it. For the canopy to reach full development usually requires 8 to 12 years, during which time little dead wood or litter is produced and fire presents no particular problem.

When the site becomes fully occupied the annual production of new twigs and leaves continues, but is balanced by the death of older branches and leaves. In normal years there is a seasonal cycle in inflammability caused by an increase in numbers of leaves with high moisture contents in the spring, then a decrease in numbers and a decline in leaf moisture in summer and fall. Normally, this annual cycle of balanced growth and death causes a gradual build-up of dead fuels. But inflammability is usually kept within reasonable, though seasonally variable limits by the slow compacting and decay of accumulated litter, and by the overstory of green leaves which shields against sun, wind, and desiccation.

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*Maintained in cooperation with the University of California, Berkeley, California.

This normal state of affairs has been upset since 1945--the beginning of the present southern California drought. By 1948 the shortage of rainfall began showing its effects on the chaparral cover. The first apparent sign was the appearance of individual dead bushes scattered over the landscape. Soil moisture had by then become insufficient to support the existing volume of cover.

By the time the 1950 fire season got under way it could be seen that catastrophe might well be in the offing. The top soil was powder dry. In some areas there was little if any growth of new leaves. More than average numbers of old leaves, too, had fallen. Instead of full-bodied dense crowns, thin, transparent, drab-colored foliage met the eye. By mid-summer the chaparral looked and felt parched. That it could be so dry and still be alive was unbelievable. The canopy over large areas was punctured with stark, dead branches, and many more than the usual number of dead shrubs could be seen.

This marked change in growth--or lack of it--meant a much higher than normal ratio of dead to green fuel, extremely inflammable foliage, higher fuel temperatures from increased exposure to the sun, more freedom of air movement--meaning more wind close to the ground.

Years of drought are often characterized by low humidities and high temperatures. These occurred often in the summer of 1950. The lack of moisture in soil and vegetation also held the pickup of humidity and fuel moisture at night to a minimum, resulting in extra long daily burning periods.

The combination of deteriorated cover and severe weather had by 1950 reached the point of near-maximum conflagration potential. Only more deaths of individual shrubs could make it worse. So far this year the southern part of the state has received only half or less of its normal seasonal rainfall. The odds in early May are that there will be little more. The outlook for the 1951 southern California fire season is thus for more thinning and dying out of shrubs with a consequent increase in inflammability beyond anything yet experienced in our time.

FOREST SERVICE

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U S DEPARTMENT OF AGRICULTURE

MISCELLANEOUS
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FIRE AND WATER IN SOUTHERN CALIFORNIA'S MOUNTAINS[1/]

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Fire protection is big business in the mountains of southern California. It has been big business for many years. Millions of dollars have been invested in equipment and in the construction of lookouts, roads, and communications to guard the mountains against fire, or make its control as effective as possible. The best skills, the most advanced machines, and the most vigorous research have been combined to keep fire detection and suppression adequate to the job. And each year nearly a million dollars are spent in suppressing those fires that do occur.

Why do we fight fires in southern California? Why is the public willing to make such large investments in protection? What have we at stake in these mountains that makes fire protection so important?

As you know, the dominant vegetation of the southern California mountains is chaparral. Chaparral occupies roughly 70 percent of the mountain land between San Luis Obispo and the Mexican border; the remaining 30 percent is made up of isolated forest stands at high elevations, and meadows and potreros lower down. Chaparral grows and remains on the mountains despite drought and despite fire. It grows in the winter and spring when rains provide water for its use. In the summer, when the soil becomes dry, it passes into a dormant state, and in this state it can survive long periods of drought. If fire burns it to the ground it is not destroyed. Some species sprout at the root-crown and thus re-form a cover from their burned stumps. Other species are killed by fire, but their seeds germinate under the stimulus of the fire's heat, and new plants grow to replace those that have been killed.

1/ Talk presented at meeting of the Southern California Association of Foresters and Fire Wardens, at Pasadena, April 23, 1951.

The California Forest and Range Experiment Station is maintained in cooperation with the University of California, Berkeley.

If you subscribe to the philosophy that vegetative cover on the mountains is an essential element in the control of erosion, of floods, and of water supply, then you have reason to believe in the importance of fire protection in the mountains. If you consider the chaparral as the most easily maintained vegetative cover that can be held on these mountains, then you can see some justification for even high costs of fire prevention and fire suppression.

Let me refresh your memories about some of the consequences of chaparral fires in southern California. First, let's look at some examples of fire and flood.

In November 1933 seven square miles of chaparral burned in the mountains above the cities of Montrose and La Crescenta. On New Year's Day in 1934 this area was in the path of a severe storm which covered most of southern California. Although unburned watersheds nearby produced only normally high stream flow, the burned area loosed a flood that devastated several towns, brought death of 30 persons, damaged or destroyed 483 homes, and caused $5,000,000 worth of damage. More than 600,000 cubic yards of debris were scoured from the mountains and deposited in the valley. Boulders as large as kitchen stoves rode the thick mud flows and smashed all before them.

In July 1945 an airplane crashed into the chaparral in the headwaters of Santa Ana Canyon, east of San Bernardino. The fire it started burned 4,000 acres of brush and timber. Although this burn denuded only one twenty-fifth of the upper Santa Ana River watershed, the mud and rocks released from it during thunderstorms that autumn caused far-reaching damages. Debris-laden flows interrupted the operation of three hydroelectric plants that depend upon the flow of this stream. Irrigation schedules on 10,000 acres of citrus land between Riverside and San Bernardino were disrupted because silt clogged the furrows and water would not seep into the soil. Even beyond Riverside bacterial pollution of drinking water coming from this stream rose so high as to be a menace to health.

Last July we witnessed the most prompt fire-and-flood sequence of our experience. On July 4 a grain field on the Jackson Ranch, some 4 miles north of Yucaipa, caught fire from a harvesting machine. The flames spread rapidly to the hills above, and burned off about 630 acres of chaparral. Two days later, as the fire was being mopped-up, a severe thunderstorm struck the burn and the area surrounding it. Rain records obtained in three places around the burn showed that about 3/4 of an inch fell, some of it at rates of more than 2 inches per hour. Within a short time after the start of the rain, mud and boulders poured from the burned area in such quantities that roads below were blocked and bulldozers had to clear a way for removal of fire camp equipment. For nearly 2 miles below the burned hills, these mud flows did several thousand dollars worth of damage to road crossings and farm improvements.

During October and November we made a careful study of the burned canyons, of the debris flows, and of adjacent unburned canyons. We found that 6,725 cubic yards of mud and rock had been washed from one burned drainage of 211 acres. As usually expressed this indicates an erosion rate, for one storm, of over 20,000 cubic yards per square mile. But in and below adjacent drainages that had not burned there was ample evidence that no runoff or erosion had occurred.

I want to emphasize here that great floods can occur in southern California even though the mountain watersheds are long unburned. Most of you recall the floods of March 1938. The rains that caused these floods were among the heaviest and most prolonged of record in this area. Great damage was done in the valleys below mountain watersheds that had not been burned in many years and that had what we consider to be excellent vegetative cover. Our studies on the San Dimas Experimental Forest showed that during this storm there was almost no runoff over the surface of the ground. The record peaks of streamflow came after the soil mantle of our watersheds had filled with water. Then, with continued rain there was a rapid seepage of water underground from the hill soils into stream channels. It was this seepage water that swelled the streams and it was the cutting of stream banks and the gouging of channel gravels that produced the debris loads that did so much damage downstream.

I want to point out also that floods do not always follow fire in the southern California mountains. In 1932 the Matilija fire burned off 219,000 acres of mountain land in Los Padres National Forest. The next winter there was severe erosion on the burned slopes and great damage was done to reservoirs and other developments downstream. In 1948 the Wheeler Springs fire burned 26,500 acres east and south of the Matilija burn, but no floods and little erosion have been reported since that fire. The reason for the difference is to be found in the rainfall. After the Matilija burn, rainfall was heavy for several years. Since the Wheeler Springs burn, rains have been light and annual rainfall has been far below normal. Similar comparisons can be made in burned mountain areas in other parts of southern California.

Finally I want to point out that a burned watershed does not recover quickly. It takes years for the re-growing vegetation to regain its control over the eroding and runoff-producing action of heavy rains, and much of the soil material washed from burned hillsides into stream channels may be long delayed in reaching reservoirs and valley lands. A study recently completed by the Forest Experiment Station shows that erosion rates remain above normal for at least 8 years after watersheds have been denuded by fire, and that flood peaks of stream flow stay above normal for at least 20 years.

So much for floods. Now, what of the relation between fire and water supply? The water supply of most of southern California is closely dependent upon the health of the local mountain watersheds. Healthy watersheds give good water; burned watersheds can give muddy water. Mountain water is made available for human use in several ways. Some streams are provided with diversion works which spill water into canals leading to distant orchards and croplands. Dams span the mouths of some canyons so that the high flows of winter and spring can be held in reserve for summer use. Spreading grounds occupy the outwash plains of other canyons. Stream water is led in ditches across these grounds so that it will sink into the porous gravels; from there it travels underground to add to the supply for wells in the valley.

All these water-handling works require protection. Siltation can destroy the storage capacity of reservoirs. Since their construction between 1920 and 1937, eight reservoirs in the Los Angeles River drainage have lost an average of one-quarter of their original storage. Debris-laden storm flows can wreck diversion works. Silt-laden water plugs the gravels of spreading grounds, preventing water from sinking into underground storage. Muddy flows cannot be used on croplands because they seal the irrigation furrows so that water cannot enter the soil.

Protection of water handling works is accomplished in two ways. Wherever possible they are equipped to by-pass flood flows which would cause them damage. This means wasted water: water carried downstream as directly as possible, and dumped into the sea. Prevention of waste requires protection of another kind: that accomplished by preserving an adequate cover of chaparral on the mountain watersheds. This kind of protection insures the long life of reservoirs and good regulation of stream flow.

I can give you an example of the effect that burning has upon water yield. Two typical chaparral watersheds lie in the mountains above Monrovia. Their waters flow into the north side of the San Gabriel Valley where they are diverted to irrigate many hundreds of acres of citrus, and to supply the domestic needs of several towns. Santa Anita Canyon, to the west, has an area of about 10.5 square miles; Fish Canyon, a short distance east, covers about 6.5 square miles. Stream flow from both canyons has been measured continuously since 1918.

In late August of 1924 the entire watershed of Fish Canyon was burned, but Santa Anita was untouched. Records of stream flow between 1918 and 1924 showed how the water yield of these watersheds compared before the fire. Similar records taken between 1924 and 1930 showed, by comparison, how the yield of Fish Canyon had changed.

The following interpretations of stream flow records obtained between 1918 and 1930 is based upon a series of technical papers on the subject which appeared between 1932 and 1934. The original analysis of the records was presented in 1932 by W. G. Hoyt and H. C. Troxell, of the U. S. Geological Survey.[1/] Their conclusions and interpretations were challenged by W. C. Lowdermilk[2/] of the U. S. Forest Service, and others,[3/] in papers which appeared in 1933 and 1934. I believe that there is now general agreement with the interpretation that follows.

1/ Hoyt, W. G., and H. C. Troxell. Forests and Streamflow. Proceedings American Society Civil Engineers. 58:6. 1932.

2/ Lowdermilk, W. C. Forests and Streamflow: Discussion of the Hoyt-Troxell Report. Journal of Forestry: 31:296-307. 1933.

3/ Hoyt, W. G., and H. C. Troxell. Forests and Streamflow (with discussion). American Society Civil Engineers Paper No. 1858. 1934.

For several years after the fire Fish Canyon yielded more water in relation to the flow from Santa Anita, than it had before the fire. Burning, therefore, had clearly increased stream flow. If volume of flow alone were considered then it would have to be admitted that burning had been beneficial. But volume of stream flow is not the only criterion, nor is it even the most important one. The way in which water is delivered to the valley can be of far greater importance, and it is in this light that the results of burning must be considered.

More than 90 percent of the yearly yield of water from Fish Canyon is delivered to the valley during the winter and spring, when high stream flow is maintained by frequent rains. Before the fire almost all of this water could be used; only the peak flows from the heaviest storms had to be wasted. After the fire, however, the normal storm flows were turned into muddy flood waves. In this condition they were completely unusable. Some of them could be held within the stream channel and passed safely to the sea. But others were so violent that they jumped the stream banks and ran wild through the valley lands.

The summer flow of Fish Canyon was also increased by the fire. For several years after the burn summer stream flow was more than four times as great as normal. But summer flows from Fish and Santa Anita Canyons are mere trickles, accounting for less than 5 percent of the yearly stream flow. A four-fold increase in this usable water could hardly make up for the water lost in winter and spring floods, or for the damage which some of these floods had done to the land.

There remains one very important question: were the increased summer flows really the result of burning the chaparral? The soil under the chaparral on slopes is completely drained shortly after the end of the rainy season. We cannot therefore expect stream flow to be fed from this source during the summer. What, then, caused the measured increase in summer flow?

The answer to this question is found in the stream-bank vegetation: the alders, willows, and sycamores that live with their roots in the saturated channel gravels. During the dry season they survive by the use of water flowing underground. When fire removes them, as it did in Fish Canyon, this source of water loss is gone, nor does it return until the stream-bank vegetation is re-established. It was the destruction of this vegetation, not of the chaparral on the slopes, that must have caused the increase in Fish Canyon's summer flow.

And so the water-yield story is told. Fire in the chaparral can increase water yield. But this increase does not mean that more water will be available for human use. It means, rather, that more water may be wasted and that valley lands will be threatened by floods that can wipe out the very investments which receive sustenance from a safe, well-regulated water supply.

The relations I have just described between fire and water have, I hope, shown you why we in the Forest Service have been so vigorous in advocating and practicing fire control in the mountains. In fact, an understanding of these relations was one of the principal reasons for the establishment of national forests in southern California.

But as you know it is not only in the mountains that there has been activity in providing flood control and in working toward an adequate water supply. Work has been going on elsewhere as well. Years ago reservoirs were built in the mouths of many mountain canyons for both flood control and water conservation. More recently large dams, such as the Santa Fe and Hansen, were built to protect valley lands from floods. Lined channels and levees were built to carry flood waters safely to the sea or to divert them from where they might do damage. And for additional water southern California has tapped rivers hundreds of miles away.

In view of all these engineering works are we still justified in protecting our local mountains against fire? Is watershed protection still important in the headwaters when so much has been done in the valleys?

Let's look first at floods. What have engineers provided with their dams, lined channels and levees? They have provided, or are providing, sufficient storage space and channel space to take care of the greatest floods of water that are expected, even from burned watersheds, on the major streams of southern California.

But floods are not made of water alone. They are also made of mud, sand, gravel, boulders, and other debris. We have seen this material fill reservoirs and choke flood channels. Claims have been made that reservoirs can be cleaned by sluicing at a very low cost, although this has not yet been demonstrated as feasible on a large scale. But suppose we assume that some of the reservoir accumulations can be removed in this way. Then we find that the sluiced material will be moved into channels downstream that have very low gradients. There is no simple and inexpensive way to clear these channels, yet they must be kept clear or they will cease to be effective in carrying the high flows for which they are designed.

Suppose, though, that reservoirs can be cleaned and that channels can be cleared. Then the ultimate resting place for debris from the mountains is the Pacific Ocean. There is no room to dump the debris along stream courses, as nature used to do. That can no longer be done because the land along stream courses is all being used for homes and industries or will be in the not too distant future. So the mountain streams will pour their loads directly into the sea. But don't picture the whole Pacific Ocean as the resting place of these loads. The main resting places will be on or near the California shore. It is true that our beaches will receive a larger supply of sand than they get now and this would be good. But so also will harbors receive a larger supply of sand and mud and there it must be dredged to maintain clear space for shipping.

What about water? Local water supplies have for many years been inadequate to satisfy the needs of southern California. I have already mentioned the ways in which local water supplies are developed, and the wastage of water that is often caused by mountain fires. So valuable has water become that steps are now being taken to treat sewage in the Los Angeles area so as to reclaim from it large quantities of water that are normally wasted.

But in its rapid development southern California has also looked beyond its mountains for water. Los Angeles reached out 300 miles to the Owens River for additional water. The Metropolitan Water District tapped the Colorado River and brought water 300 miles to supply the Los Angeles area and cities as far south as San Diego. At the present time only about 1/8th of the 1,200,000 acre feet of water that will ultimately be available each year from the Colorado is being used, so there is still water to spare, at a price, from this source. And in case all these water sources become insufficient to supply future needs the State Division of Water Resources has surveyed a route by which water can be carried to southern California from the Sacramento River, and even from the Klamath River near the Oregon line.

Considering all the engineering developments that are providing, or will provide, flood protection and water for southern California, do we need to worry any longer about the source areas of local floods and local water supply? Can we justify the costly job of protecting the watersheds of southern California? Is fire control needed in the mountains?

I think that I can answer these questions by referring to three words: area, feasibility, and time.

First, area. Adequate flood protection is being provided only for major centers of development: large cities in the valleys and along the coastal plain, important rail centers, and zones of industrial development. Communities built in or near mountain canyons, and most areas along the mountain fronts away from the main river courses are not protected adequately from floods that can come from burned watersheds above them.

Second, feasibility. It has not yet been demonstrated or proven that the storage capacity of silted reservoirs can be restored. Every acre-foot of debris in a reservoir reduces its capacity to control floods and to store water for later use. Nor has it been demonstrated that channels and levees can be maintained as effective flood control structures when their capacity is reduced by debris-laden water.

Third, time. Flood control works in the valleys are not yet complete. For some time to come those lands that will one day receive even some protection from dams and floodways will be vitally in need of the extra protection afforded by fire control in the mountains above. Furthermore, adequate flood control can only last as long as structures remain in usable condition. In most cases reservoirs are planned to have a useful life of 50 years. Reservoir sites are scarce in southern California. The choice is between adequate protection of reservoir storage now and in the future, and ineffective reservoirs in a half-century. As for water supply, at present a good deal more than half the water used in southern California is yielded from the local mountains. And even though imported water will eventually become more plentiful, and will be used more widely than it is at present, the local water will still be in demand, for it is the less expensive, by far, of the two.

All these considerations lead me to only one conclusion: that for as far as we can see into the future, southern California will have to protect its mountains against fire. A large part of its present development has depended upon protection of the mountains in order to minimize the catastrophe of floods, and to insure the greatest yield of good water. I can see no reason why mountain fire protection should be less important in the future than it has been in the past.

MISCELLANEOUS PAPER No. 4
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CALIFORNIA FOREST & RANGE EXPERIMENT STATION

FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE

DIRECT-HEAT LUMBER DRY KILNS[1]

By Harvey H. Smith
Forest Products Technologist

During World War II the Forest Products Laboratory of the U. S. Forest Service, in Madison, Wisconsin, spent considerable time on the development of a kiln that could be used at small mills where gasoline or diesel engines or electric motors were used for power and no steam was available for heating the kiln. Sawdust was used for fuel in these early experimental kilns. The results obtained were encouraging; they indicated that such a kiln could be made to dry lumber satisfactorily. Commercial kiln companies have since made significant improvements in engineering and design of the heating systems, using both gas and oil for fuel. These fuels are easier to handle in a wide variety of commercial burners than sawdust or similar wood waste, and the difficulties experienced in the experimental sawdust-burning kilns have been overcome.

These kilns may be called direct-heat kilns, for the heat-generating mechanism is close-coupled with the drying chamber. The mechanism is an integral part of the kiln, constructed so the heat is either delivered directly into the kiln or transferred through a simple heat-exchanger or manifold.

The great number of oil- and gas-fired kilns that have been built during the past five years further indicates that direct-heat kilns can be made to dry lumber satisfactorily. They are now common in the central south, where gas is relatively cheap. There are also many kilns of this type in California, and some of them can now be found in most sections of the country.

This kiln design in which the heating system is close-coupled with the drying chamber has a number of advantages, but also some disadvantages. Perhaps the most important advantage is the fact that the kiln is an independent unit. No boiler is required. Operators of small sawmills and remanufacturing plants who have no steam plant find this a very real advantage.

1/ Paper given at the annual meeting of Western Lumber Dry Kiln Clubs, Corvallis, Oregon, May 11 and 12, 1951.

A second advantage is the economy of operating the heating system. The B.T.U.'s produced per gallon of oil or thousand cubic feet of gas are immediately available for heating the air within the drying chamber. There is little loss between the firebox and the lumber in the kiln. One commercial design, for example, has the heating system located within the kiln between two tracks of lumber.

A third advantage is the availability of moisture generated by combustion of the fuel for controlling the humidity within the kiln. This moisture supplements that given up by the lumber being dried, so that adding moisture from an outside source is seldom necessary during the drying cycle. For every gallon of high-grade fuel oil burned about 1 gallon of water is produced, and for every 1,000 cubic feet of natural gas burned, 11.5 gallons of water are produced. This latter figure is for the Rio Vista natural gas common to the central California area, but the figure should be fairly accurate for gas used in other areas as well.

This feature is most advantageous when drying certain species that require a fairly high humidity during the drying cycle, even well on toward the end of the run when little water is being given up by the lumber being dried. It may, on the other hand, be a distinct disadvantage when drying a species that requires a low humidity even at the start of the drying cycle, as in kiln drying sugar pine where low humidity is desirable to prevent or reduce the development of chemical brown stain. The additional venting necessary to get rid of the moisture from the gases of combustion increases the heat loss.

This type of equipment is also relatively easy to operate. Most manufacturers of these kilns are now furnishing pneumatic or electrical instruments for completely automatic control of the drying conditions. The better direct-heat kilns are able to maintain the drying conditions prescribed by the kiln schedules now in common use.

The low initial cost of these kilns is another advantage. Some direct-heat kilns have been built at a cost of 25¢ to 35¢ per board-foot capacity. These are well-constructed kilns of tile or cement block, with good heating and air-moving equipment.

Operating costs for these kilns are also low. Most of them are equipped with electric motors totaling 7½ to 25 HP for operating both the heating system and the fan system. At current commercial rates in central California, electricity will cost from $6.00 to $15.00 per day. Fuel costs (both gas and oil) vary from 60¢ to about $1.50 per thousand board feet dried. The direct operating costs of such an operation may therefore be as low as $1.00 per thousand for some species that can be kiln dried on a fast schedule. A more realistic figure for the direct operating costs would be from $3.00 to $4.00 per thousand board feet. To this must be added the yarding, piling, and handling costs as well as all other costs incidental to such an operation.

Now let us look for a moment at some of the negative factors. The one that is no doubt uppermost in your minds is the fire hazard. There is a hazard. Some kilns of this type have been lost due to failure of the control equipment or break-down of the heating system. The temperature inside a gas-, wood-, or oil-fired furnace may exceed 2000° F., and if something should go wrong a serious fire may result. While experimenting with a kiln that burned sawdust for fuel we experienced two fires in one four-truck unit. The causes of the fires were apparent and steps were taken at once to correct these weaknesses, but the fact remains that the fire would probably not have occurred had the kiln been heated with steam. The firebox, with its high temperatures, is a constant danger point. Recognition of this fact should be helpful in reducing the likelihood of damage from uncontrolled fires. Some of the recently installed gas- and oil-burning kilns have been expertly engineered to reduce this fire hazard, and great progress has been made to reduce the fire risk in direct-heat kilns.

A second, and perhaps equally important disadvantage, is the difficulty encountered by most kiln manufacturers and operators in attaining the high final humidities required for stress relief. I have mentioned the case of controlling the humidity according to a predetermined drying schedule during the drying cycle. This can and is accomplished in most of the newer direct-heat kilns. There is still some difficulty, however, in producing the quantity of vapor necessary to raise the humidity within the kiln to the high level necessary for final equalizing and relief of drying stress. Water sprays located at the burner and throughout the kiln have been tried with varying degrees of success. I have been told by some of the leading kiln engineers that the greatest load on the heating system is at the start of a drying cycle when the kiln building and the lumber charge are cold. The demand for heat becomes less as the drying continues, even though the temperatures maintained within the kiln are increased. This initial peak load is not again reached, even during final conditioning. This would seem to indicate that a direct-heat kiln engineered to produce sufficient heat to satisfy the initial peak demand, has sufficient heat-generating capacity to vaporize water by the proper use of water spray nozzles at the combustion chamber or throughout the kiln.

This is not a particularly easy problem to solve, even in steam-heated kilns where the super-heat of the steam used for humidifying may cause the dry-bulb temperature to rise as the wet-bulb temperature rises, and high final humidities cannot be attained. This problem has lead to the use of steam-pressure reducers in the spray line and water injection pumps to mix water into the steam of the spray line. It is therefore not a problem peculiar to the direct-heat kilns. That this problem can be overcome was demonstrated at the Forest Products Laboratory, where a final wet-bulb depression of less than 5° was maintained with a dry-bulb temperature of 180° F. Our Forest Utilization Service representative from New Orleans recently reported that one manufacturer of direct-heat kilns in Arkansas has perfected a humidifying system for final conditioning at high temperatures and humidities.

Thus far I have spoken of direct-heat kilns in rather general terms. There are several types of these kilns now in use, and I'm sure you will be interested to know something about them.

The several types of kilns can be classified on the basis of differences in design and operation; as for instance, fan kilns and natural-draft kilns or compartment kilns and progressive kilns. For the purpose of this discussion I propose to divide them into two main types: (1) Those in which the hot gases from the combustion chamber are carried through the kiln in a system of pipes or ducts, then vented to the atmosphere; heat radiating from the surfaces of this heat-transfer system, or manifold warms the air within the kiln. (2) Those kilns in which the hot gases from the combustion chamber are dumped into the drying chamber.

Both of these types are similar in some respects. The burner and combustion chamber form an integral part of the kiln, and the temperature within the kiln is controlled by the rate of burning. This is accomplished by an automatic control of the burning rate at a "high" fire or a "low" fire, or by an automatic control of the fire at a burning rate that will maintain the set temperature. Automatic control of the draft damper on the sawdust burner very effectively maintained the temperatures within the experimental kilns in which sawdust was used for fuel.

The heat-manifold type includes both natural-draft and fan-type kilns. In the natural-draft kiln the heating tubes or manifold are located below the loads of lumber, in a pit similar in arrangement to the steam coils in the natural-draft kilns popular a few years ago. In one internal-fan kiln the firebox is located below track level outside one end of the kiln and the hot gases are conducted into the kiln through a large iron supply duct. The heat exchanger, located down through the center of the kiln, consists of many smaller iron pipes that extend up through the roof of the kiln from the supply duct, in the same location as a booster coil in a steam-heated kiln. The fan system consists of the typical long shaft with disc fans designed for cross-circulation of the air through the limber on both tracks.

A very simple design of kiln of the second type has a row of burners located down through the length of a double-track kiln between the two tracks of lumber. The location is similar to that of the heating system just mentioned, but the products of combustion are dumped directly into the kiln. Where fans are used, they are located above the burner through the longitudinal center of the kiln. They turn in a horizontal plane and the air circulation is up through the central plenum chamber past the heater and outward above the loads of lumber to both side walls and thus back through the loads. The direction of circulation can be reversed. The total air travel is the width of only one load of lumber, 7 to 10 feet, even in this double-track kiln.

One western kiln design is in some respects similar to our fruit dehydrators. Lumber is loaded cross-piled in a chamber through which air is driven lengthwise of the kiln. The air is returned through a bypass tunnel in which the burner is located. The two high speed fans that circulate the air can be reversed.

One of the more popular designs is a double-track kiln with the burner located outside at one end of the kiln between the tracks. Air from the kiln is forced both around and through the combustion chamber and then distributed along the length of the kiln from a large supply duct. Air from the kiln in large quantity at a normal kiln temperature of 120° to 180° or 190° F. mixes with and dilutes the air from the combustion chamber. The temperature of the air within the combustion chamber is thus reduced from 2000-2500° F. to about 300-350° F. as it enters the kiln. In this kiln the fans are also located in a horizontal plane through the longitudinal center of the kiln just above the tracks of lumber. The air travels from the central plenum chamber, over the loads toward the side walls, and then back through the lumber to the central plenum chambers, where it is reheated by additional hot air from the supply duct. The fans are reversed periodically, forcing the air down into the central plenum chamber, through the loads of lumber on each track, to the plenum chambers at the side walls, and thus back to the fans.

There are several other designs that are modifications of these general types. In fact, there is a multitude of designs of direct-heat kilns. This in general is a good thing, for it shows that many engineers are giving the problem considerable thought, and out of this should come a few best designs just as there are a few best designs of steam-heated kilns.

Our present-day kilns weren't created on a drawing board at a single sitting. They represent years of work, of modification and improvement. A brief review of the records shows how far we have progressed. According to Mr. Harry D. Tiemann, who recently retired from the Forest Products Laboratory, there are now over 370 U. S. Patents pertaining to the drying of lumber. The first was issued in 1862, to a Mr. Oliver for use of steam coils in drying lumber. In 1891 the internal fan was patented. It is interesting to know that a direct-heat kiln was patented in 1895. In the period 1910 to 1912 Mr. Tiemann developed the water-spray kiln with the first conception of humidity control, and in 1913 steam jets were introduced for the first time.

I have a record of eleven different direct-heat dry kilns now in use in California, and there are no doubt some I have not seen or heard of. This great interest in the direct-heat kilns indicates that this type of drying equipment is filling a very real need. The great variety of designs would also seem to indicate that some kilns may be less than the ultimate in design and engineering. It is my firm belief that further progress can be made in kiln design and operating techniques. This is an encouraging thought, for it holds out to us the promise of more well-seasoned lumber--an important factor in the fuller, more efficient use of our forest resources.

The California Forest and Range Experiment Station is maintained by the U. S. Forest Service, in cooperation with the University of California, at Berkeley, California.

Agriculture--Berkeley

Visitors' Guide

to the

INSTITUTE OF FOREST GENETICS

Miscellaneous Paper No. 5 - September 1 1951
CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
U S. Department of Agriculture--Forest Service

The Institute of Forest Genetics is a field branch of the California Forest and Range Experiment Station, which the U. S. Forest Service maintains at Berkeley in cooperation with the University of California.

--Stephen N. Wyckoff,
Director.

AGRICULTURE--Berkeley

GUIDE TO THE

INSTITUTE OF FOREST GENETICS

This guide is intended to help visitors find their way to, and understand, the various collections and field experiments at the Institute of Forest Genetics. A general account of the objectives, history, and accomplishments of the Institute is given in Miscellaneous Publication No. 659 of the United States Department of Agriculture, entitled "Tree Breeding at the Institute of Forest Genetics." This is available on request.

Briefly, the objective of the Institute's program is to develop better pine trees through the science of genetics and the techniques of plant breeding. Improvements sought are faster growth, improved form and wood properties, and resistance to diseases, insects, and climatic hazards. The visitor can see here evidence of improvement in each of these qualities.

The principal means of improvement are selection and hybridization. Selection is a search for trees that show superior qualities in the forest so seed or cuttings from these trees may be used in planting new forests. The trees, and cuttings from them, are also used in hybridization work. Hybridization creates new kinds of trees by controlled pollination, which can combine the qualities of two varieties of trees in the hybrid. This is done by dusting pollen of one variety on the seed-bearing conelets of another variety under controlled conditions. (Canvas bags tied around the tips of branches are used to protect the conelets, and many trees on the Institute grounds bear this evidence of controlled pollination in the spring.) In the tree-breeding research of the Institute, selection and hybridization are often used as complementary methods, carefully selected parent species being crossed to produce pedigreed offspring.

The outdoor facilities at the Institute are the Eddy Arboretum, which contains about 70 species of pines and numerous other trees; the nursery, in which hybrids and other pedigreed pine seedlings are propagated and tested for early performance; and the hybrid plantations, in which later development of improved trees is studied and in which hybrid and pedigreed seed for large-scale reforestation is produced. A fourth area of special interest is a large plantation of elevational races of ponderosa pine. These areas are shown on the accompanying map.

The Eddy Arboretum

This collection of pines is named in honor of Mr. James G. Eddy, whose gift of the Eddy Tree Breeding Station to the people of the United States in 1935 gave rise to the present Institute. The Eddy Arboretum has served three principal purposes. First, the species of pines assembled here from many parts of the world furnish the materials for the Institute's program of pine breeding. Almost every one of the world's 90 species of pines has been planted. Of these only about 70 survive, and some of these do not thrive here. Many species, not native to this region, have grown well for more than 25 years. Thus the Arboretum also serves as a pine introduction test garden. Thirdly, this living collection of pines is constantly studied by botanists and horticulturists and is used for demonstration purposes by many teachers and their classes.

Foresters and geneticists, particularly, will be interested in the general plan of the Eddy Arboretum, which is as follows: Ponderosa pine (Pinus ponderosa Laws.), from about 50 distinct geographic areas throughout western North America, grow along the eastern edge of the Arboretum in the hard-pine group. This is a reflection of the great commercial importance of this species and of the fact that it is composed of many widely differing geographic races. (This collection differs in location and purpose from the extensive ponderosa pine plantations shown on the map to the southwest of the hard-pine group. These plantations are largely composed of open-pollinated progenies of single trees located on the west slope of the central Sierra Nevada.) The remainder of the Arboretum consists of other species of pines, arranged according to their assumed relationships. The basic unit of planting is a square of 16 trees, although this plan was not invariably followed. Thinnings, to promote growth and cone production, have further broken up the groups of trees. Original spacing between trees was 15 by 15 feet. Trees are marked by one of two methods. Older tree tags are set on stakes and carry both the Latin and English names of the tree, the origin of the seed from which the tree was grown, and sometimes the nursery in which the seed was sown. The year date denotes the year in which the seed was sown, and thus present age of the tree may be calculated. Row and line (or tree) numbers on the tags are for use in maintaining research records. Newer tree tags are wired to branches or nailed to the stems. They are somewhat abbreviated, omitting English names. The bottom line on these tags gives row and line number, followed by the last two digits of the year in which seed was sown.

Informational signs will be found at points of special interest in the Arboretum. A list of trees growing in the Arboretum (Research Note No. 53) is available on request.

The Nursery

Nursery tests are used for four purposes: (1) to study the early growth of hybrids and other pedigreed seedlings; (2) to grow pedigreed planting stock for plantation tests at the Institute and elsewhere; (3) to accommodate insect and disease studies; and (4) to demonstrate techniques and results. No planting stock for general reforestation purposes is grown here.

For those interested in the techniques employed in this nursery, a general account is available (Research Note No. 56). The nursery experiments are usually set up either as (1) tests in which a group (sample) of hybrid or other pedigreed seedlings is pitted against a group of seedlings grown from wind-pollinated seeds from one of the parents — usually the seed-parent tree; or (2) tests in which the hybrids or other pedigreed seedlings are pitted against the natural progenies from both the seed- and pollen-parent trees or species.

Generally, each sample included in a test is allocated to several rows (plots) running across the seedbed. The rows assigned to hybrid and non-hybrid groups are determined at random. The nursery rows (plots) are numbered from west to east, and each experiment is laid out accordingly. An aluminum label, bearing the experiment number, kind of test, etc., is attached to the north sideboard of the seedbed at the beginning of each experiment. For experiments started in 1950 and thereafter, the kind of trees in each row is designated by a spot of color printed on the sideboard, as follows: Yellow, hybrid; white, natural progeny of seed parent; black, natural progeny of pollen parent.

Signs located about the nursery give information about tests of special interest.

The Hybrid Plantations

Small test plantations of hybrids and other pedigreed trees are located to the east of the buildings. These plantings are set out at the spacing normally used for reforestation in the California region (8 by 8 feet), and, with moderate thinning, should serve to test the performance of these new types up to harvest age. These plantations serve also as material for further breeding and selection experiments, and have for some years furnished large quantities of hybrid seed for cooperative tests by other institutions. The more interesting tests are posted with explanatory signs.

Elevational Races of Ponderosa Pine

The easternmost plantation is a test, established in 1938, of elevational races of *Pinus ponderosa* from the west slope of the Sierra Nevada. This pine is of leading commercial value in the pine region of California. The object of the study is to determine from which elevation seed of this species should be collected for reforestation purposes. Details of this experiment and of the results so far obtained are furnished on a signboard to the west of the plantation.

WE ASK VISITORS:

1. Not to smoke except on paved roads.

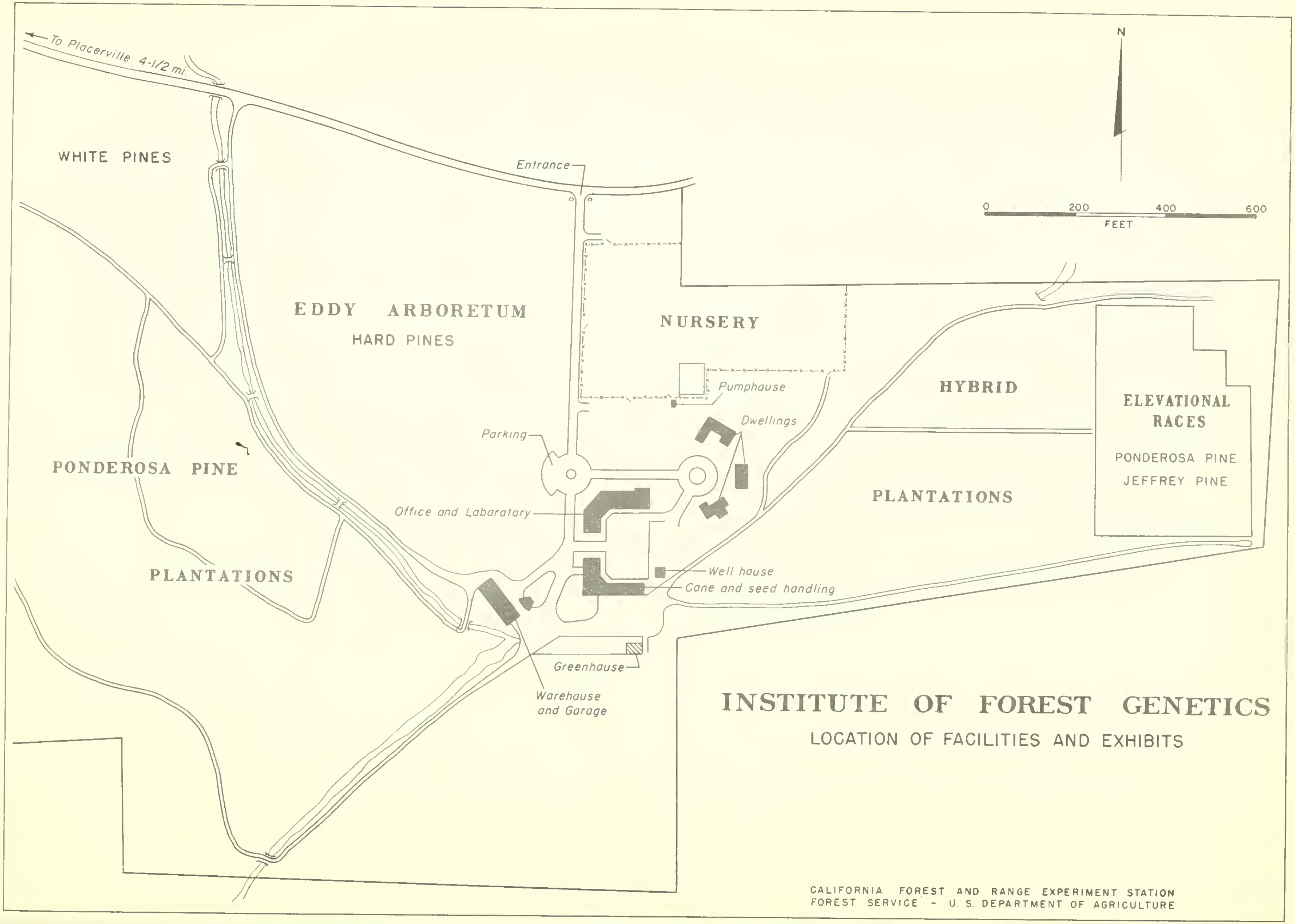
2. Not to picnic. Our resources must all be devoted to research; and we cannot afford to maintain picnic facilities.

3. To close all gates which are found closed.

4. To sign our register.

5. To help themselves to any cones lying on the ground.

All of our plants are propagated for experimental purposes. As a government agency, we cannot sell or give away plants or seed.


To Placerville 4-1/2 mi.
WHITE PINES
Entrance
EDDY ARBORETUM
HARD PINES
NURSERY
Pumphause
Dwellings
Parking
Office and Labaratary
PONDEROSA PINE
PLANTATIONS
Well hause
Cane and seed handling
Greenhouse
Warehause
and Garage
HYBRID
PLANTATIONS
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FEET
INSTITUTE OF FOREST GENETICS
LOCATION OF FACILITIES AND EXHIBITS
CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE

FOREST SERVICE

CALIFORNIA
FOREST & RANGE
EXPERIMENT STATION

U. S. DEPARTMENT OF AGRICULTURE

MISCELLANEOUS
PAPER No. 6
OCTOBER 24, 1951

TREE-HEIGHT CHART FOR TOPOGRAPHIC LEVEL

By E. M. Hornibrook

For a long time the Abney level and the engineers chain have been used by foresters for both land surveying and measuring the height of trees. When slopes are steep, trees tall, and crowns dense, the task of making the required corrections for horizontal distance in calculating tree height becomes quite laborious. This is especially true when the base and top of the tree being measured are not visible at full chain intervals, thus forcing the observer to compute horizontal distance for irregular slope distance.

In 1927 McArdle and Chapman[1/] prepared a chart giving graphical solution of tree-height measurements for use with the percent scale of the Abney and slope distances measured in feet. This chart, however, cannot be used with the topographic scale and distance measured in chains.

The attached chart has been designed to provide a graphic solution of tree-height measurements when using the topographic Abney scale and slope distance measured in chains and links.

1/ R. E. McArdle and R. A. Chapman. 1927. Measuring tree heights on slopes. Journal of Forestry 25:843-847.

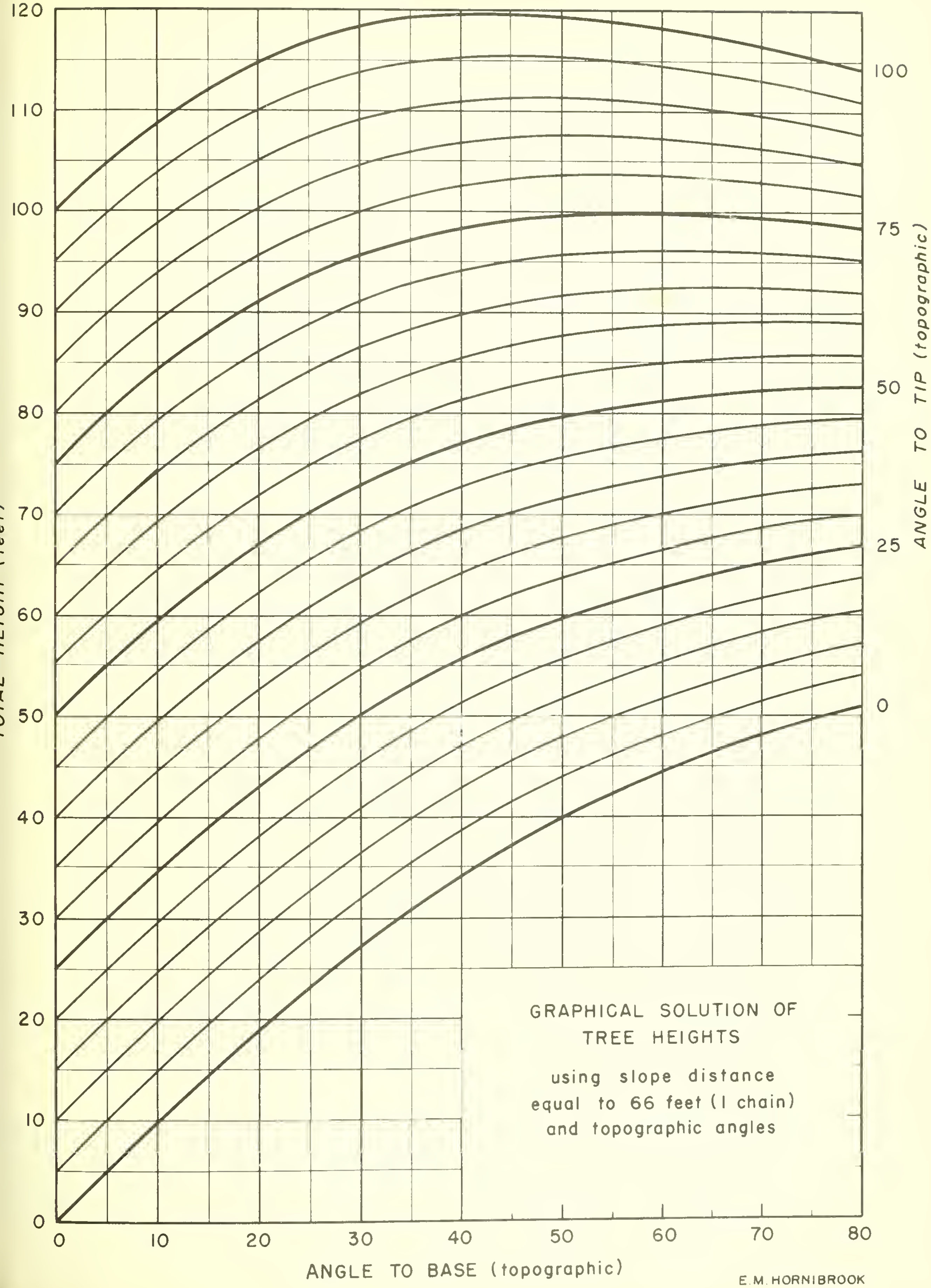
The California Forest and Range Experiment Station is maintained at Berkeley in cooperation with the University of California.

How to use the chart.-- Select a point from which both the base and top of tree are visible. Measure the distance from tree base to observer's eye in chains and links. The observer's eye must always be level with or above the level of the tree base. The chart cannot be used if the angle to the base of the tree is positive. Measure the angle from observer's eye to tree base and to top, using the topographic scale. Enter the chart with these angles. The total height of the tree (read at the left of chart) is represented by the point where the vertical line representing the angle to the base (found at bottom of chart) intersects the curved line representing the angle to the top (read at right of chart). If the slope distance is one chain the height is read directly from the chart. If more or less than one chain, multiply the chart reading by the number of chains or decimal fractions thereof. Interpolations between the lines for angles not shown are easily made.

Example:

Angle to base is -30, angle to top is +70, slope distance is 1 chain. Total height is 91 feet.

If the slope distance was 1/2 chain (50 links) the height would be 0.5 x 91 = 45.5 ft. If the slope distance was 2 chains the height would be 2 x 91 = 182 ft. Likewise if the slope distance was 2 chains 77 links the height would be 2.77 x 91 = 252 ft.



E.M. HORNIBROOK
OCTOBER 1951

CHECKLIST OF THE VERTEBRATE FAUNA OF SAN DIMAS EXPERIMENTAL FOREST

BY JOHN T. WRIGHT AND JEROME S. HORTON

MISCELLANEOUS PAPER No. 7
November 1951

CALIFORNIA FOREST and RANGE EXPERIMENT STATION
STEPHEN N. WYCKOFF, DIRECTOR

FOREST SERVICE

U. S. DEPARTMENT OF AGRICULTURE

FOREWORD

The information presented in this publication was prepared in August, 1946, for a field meeting of the Cooper Ornithological Society held in Big Dalton Canyon. It was mimeographed and copies were distributed to interested individuals and groups. The supply of copies was soon exhausted and the present edition is intended to satisfy recent requests and to bring the material up to date.

The California Forest and Range Experiment Station is maintained by the Forest Service, U. S. Department of Agriculture, in cooperation with the University of California, Berkeley, California.

Agriculture--Berkeley

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CHECKLIST OF THE VERTEBRATE FAUNA OF SAN DIMAS EXPERIMENTAL FOREST

By John T. Wright and Jerome S. Horton

During the first phase of watershed management research on the San Dimas Experimental Forest[1/], inventories were made of the physical features of the Forest which directly influence waterflow; namely, vegetation, soils, and geologic structure. Although there was no pressing need for an inventory of the vertebrate fauna in connection with the hydrologic research program, it was felt that such an inventory for the mountain area represented by the Experimental Forest would be of considerable scientific interest, and might indirectly give information of value in the interpretation of watershed problems. The opportunity to make such a study presented itself during the course of an emergency works program (W.P.A.) when the services of a naturalist-collector became available. Most of the collecting and identifying were done at that time.

The San Dimas Experimental Forest contains approximately 17,000 acres situated in the San Gabriel Mountains of eastern Los Angeles County, California. It includes the watersheds of Big Dalton and San Dimas Creeks, tributaries of the San Gabriel River.

The Experimental Forest lies between 1500 and 5500 feet in altitude, the bulk of it below 4000 feet. Thus the Forest is well within the Upper Sonoran life zone with small areas in the Transition life zone at higher altitudes. The topography is rugged, characterized by steep slopes and precipitous canyons. A striking contrast is presented by Brown's Flat, a level area of approximately fifty acres covered with an open forest of ponderosa pine.

The vegetation types in the San Dimas Experimental Forest are shown in the accompanying table. The use of the term "chaparral" in describing habitat in the checklist indicates that the species is found in both the chamise and oak chaparral associations. Likewise, the term "woodland" refers to both stream and oak woodland associations, and "forest" to both the bigcone spruce and ponderosa pine forest associations. Plantations of Coulter and knobcone pines have been established in the vicinity of the Tanbark Flat field headquarters (2700 foot elevation). These trees were planted between 1920 and 1933 by Los Angeles County Department of Forester and Fire Warden.

1/ A branch of the California Forest and Range Experiment Station, established for research in the management of southern California watersheds.

Flood control and water conservation dams, built by the County of Los Angeles in San Dimas and Big Dalton Canyons, impound water during most of the year. Many species of water birds have been observed resting upon these artificial bodies of water during the winter. Other species have become resident in the vicinity of the dams.

Vegetation Associations of the San Dimas Experimental Forest

Association	Dominant Species	Density	Altitude
Chamise chaparral	*Adenostoma fasciculatum* *Ceanothus crassifolius* *Arctostaphylos glauca*	Open to fairly dense	Below 5000 feet
Oak chaparral	*Quercus dumosa* (below 4000 feet) *Quercus wislizenii* (above 3500 feet)	Very dense	Throughout
Stream woodland	*Quercus agrifolia* *Platanus racemosa* *Acer macrophyllum* *Populus trichocarpa* *Alnus rhombifolia* *Salix* species	Open (sometimes with grassy areas) to dense	Below 4000 feet
Oak woodland	*Quercus chrysolepis*	Dense	Above 4000 feet
Bigcone spruce forest	*Pseudotsuga macrocarpa* *Pinus lambertina* (above 5000 feet only)	Open to fairly dense	Above 4000 feet
Ponderosa pine	*Pinus ponderosa*	Open, large part grassy	4300 feet Brown's Flat

Dr. Alden H. Miller, Director of the University Museum of Vertebrate Zoology, Berkeley, California, has very kindly identified many of the species and has reviewed the manuscript.

Most of the observations in the checklist were made by John T. Wright during the period 1936-38. Paul S. Bartholomew contributed data during 1940-42. Subsequent observations and preparation of the checklist were made by Jerome S. Horton. H. Paul Keiser, custodian of Big Dalton Dam, has been very cooperative in many ways, especially in reporting occurrences of water birds on that reservoir. A reference collection of most of the vertebrate fauna has been assembled at the headquarters of the Experimental Forest. Joseph Gorman assisted in the collection of the reptiles and amphibians. Species marked with an asterisk are not represented in the collection.

Authorities for the nomenclature used in the list are Joseph Grinnell's "Review of the recent mammal fauna of California," University of California Publications in Zoology, Vol. 40, pp. 71-234, 1933; Grinnell and Miller's "Distribution of the birds of California," Pacific Coast Avifauna, No. 27, pp. 1-608, 1944; and Gayle Pickwell's "Amphibians and reptiles of the Pacific States," Stanford University Press, 1947.

MAMMALS FOUND IN THE SAN DIMAS EXPERIMENTAL FOREST

POUCHED MAMMALS

Virginia Opossum (Didelphis virginiana virginiana)
Stream vegetation in major canyons below 2000 feet.

INSECTIVOROUS MAMMALS

Southern California Mole (Scapanus latimanus occultus)
Common throughout in fairly rich, loamy soil.

Adorned Shrew (Sorex ornatus ornatus)
Rare; collected from both chaparral and grassy areas; elevation 3000 feet.

BATS

Southern Little California Bat (Myotis californicus californicus)
Common near stream vegetation.

Black-nosed Bat (Myotis subulatus melanorhinus)
Stream Woodland.

Merriam Cañon Bat (Pipistrellus hesperus merriami)
Collected foraging over Flood Control Reservoir.

Large Brown Bat (Eptesicus fuscus)
Stream Woodland.

*Hoary Bat (Nycteris cinerea)
Specimen collected by H. Paul Keiser near Dalton Dam is in University of California Museum of Vertebrate Zoology.

Mexican Free-tailed Bat (Tadarida mexicana)
Collected roosting in building.

CARNIVOROUS MAMMALS

California Coon (Procyon lotor psora)
Numerous primarily in the canyons near water.

San Diego Ring-tailed Cat (Bassariscus astutus octavus)
Few individuals in major canyons below 2000 feet.

*Southern California Striped Skunk (Mephitis mephitis holzneri)
Throughout but commonest near water.

*California Gray Fox (Urocyon cinereoargenteus californicus)
Common in chaparral.

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*No specimen in Experimental Forest collection.

California Valley Coyote (Canis latrans ochropus)
Common throughout.

*California Mountain Lion (Felis concolor californica)
A frequent visitor; not permanent resident.

*California Wildcat (Lynx rufus californicus)
Fairly common throughout.

RODENTS

Beechey Ground Squirrel (Citellus beecheyi beecheyi)
Throughout; commonest along roads and about habitations.

Merriam Chipmunk (Eutamias merriami merriami)
Abundant in dense chaparral and woodland between 3000 and 5500 feet; occurs as low as 1500 feet.

Anthony Gray Squirrel (Sciurus griseus anthonyi)
Common in woodland associations. Girdled many young Coulter pines (approximately 25 years old) in the Tanbark plantation during the spring and early summer of 1949 and 1950.

Grapeland Pocket Gopher (Thomomys bottae pallescens)
Below 3000 feet; abundant in San Dimas Canyon below 1800 feet.

San Gabriel Mountain Pocket Gopher (Thomomys bottae neglectus)
Above 4000 feet. Abundant in Brown's Flat.

Allen California Pocket Mouse (Perognathus californicus dispar)
Occasional in open chamise chaparral below 3000 feet.

Gambel Kangaroo Rat (Dipodomys agilis agilis)
Abundant in Brown's Flat; elsewhere occasional colonies in cleared ground or open chamise chaparral.

Long-tailed Harvest Mouse (Reithrodontomys megalotis longicaudus)
Grassy areas below 3000 feet.

Southern Parasitic Mouse (Peromyscus californicus insignis)
Common throughout in oak chaparral.

Dulzura White-footed Mouse (Peromyscus eremicus fraterculus)
Open chamise chaparral in Big Dalton Canyon.

Gambel White-footed Mouse (Peromyscus maniculatus gambelii)
Common throughout in all types of vegetation.

Rowley White-footed Mouse (Peromyscus boylii rowleyi)
Abundant in oak chaparral and woodland where near permanent water.

San Bernardino White-footed Mouse (Peromyscus truei chlorus)1/
Occasional; open chamise chaparral.

1/ Identified by Dr. Alden H. Miller.

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*No specimen in Experimental Forest collection.

Intermediate Wood Rat (*Neotoma lepida intermedia*)
Occasional; chamise chaparral or sage; below 3000 feet.

San Diego Wood Rat (*Neotoma fuscipes macrotis*)
Abundant throughout; especially in dense chaparral or along stream courses. See Horton and Wright, "The wood rat as an ecological factor in southern California watersheds," Ecology 25:341-351, 1944

Southern California Meadow Mouse (*Microtus californicus sanctidiegi*)
Permanent colony in Brown's Flat. Occasional elsewhere in grassy areas.

RABBITS

San Diego Cottontail (*Sylvilagus auduboni sanctidiegi*)
Open areas in the chaparral; especially abundant around edges of pine plantations at Tanbark Flat.

HOOFED MAMMALS

*California Mule Deer (*Odocoileus hemionus californicus*)
Common throughout.

BIRDS FOUND ON THE SAN DIMAS EXPERIMENTAL FOREST

GREBES

*Pied-billed Grebe (*Podilymbus podiceps podiceps*)
Occasional migrant; Big Dalton Reservoir.

PELICANS, CORMORANTS

*White Pelican (*Pelecanus erythrorhynchos*)
Migrant; occasionally rests on the Flood Control Reservoirs.

*Double-crested Cormorant (*Phalacrocorax auritus albociliatus*)
Migrant; Big Dalton Reservoir

HERONS

*Great Blue Heron (*Ardea herodias hyperonca*)
Summer visitor, no record of nesting.

*Common Egret (*Casmerodius albus egretta*)
Rare migrant.

*Western Snowy Egret (*Leucophoyx thula brewsteri*)
Occasional migrant.

*Black-crowned Night Heron (*Nycticorax nycticorax hoactli*)
Rare; small colony nested in 1936 in live oaks at the head of San Dimas Reservoir.

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*No specimen in Experimental Forest collection.

DUCKS, etc.

*Mallard (Anas platyrhynchos platyrhynchos)
Abundant in the winter and occasional in the summer on Big Dalton Reservoir.

*Cinnamon Teal (Anas cyanoptera)
Rare migrant; Big Dalton Reservoir.

*Green-winged Teal (Anas carolinensis)
Migrant; Big Dalton Reservoir.

*Baldpate (Mareca americana)
Migrant; Big Dalton Reservoir.

*Canvas-back Duck (Nyroca valisineria)
Winter visitor; Big Dalton Reservoir.

*Ring-necked Duck (Nyroca collaris)
Migrant; Big Dalton Reservoir.

*American Merganser (Mergus merganser americanus)
Winter visitor; Big Dalton Reservoir.

VULTURES, HAWKS, and EAGLES

*Turkey Vulture (Cathartes aura teter)
Occasionally observed in flight.

Cooper Hawk (Accipiter cooperii)
Common throughout.

Red-tailed Hawk (Buteo jamaicensis calurus)
Common throughout.

Sharp-shinned Hawk (Accipiter striatus velox)
Common throughout.

*Golden Eagle (Aquila chrysaëtos canadensis)
Occasional, sometimes nests near top of cliffs in San Dimas Canyon, elevation 2000 feet; nests made of Yucca leaves.

*Marsh Hawk (Circus cyaneus hudsonius)
Rare; foothills at mouth of San Dimas Canyon.

Sparrow Hawk (Falco sparverius sparverius)
Fairly common up to 3000 feet in the foothills near the valley.

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*No specimen in Experimental Forest collection.

QUAILS

Mountain Quail (Oreortyx picta eremophila)
Abundant above 1600 feet.

California Quail (Lophortyx californica californica)
Abundant in the foothills and occasional up to 3000 feet.

CRANES, RAILS, etc.

*American Coot (Fulica americana americana)
Common winter visitor; Big Dalton Reservoir.

SHORE BIRDS

Killdeer (Oxyechus vociferus vociferus)
Yearly visitor; Flood Control Reservoirs.

Spotted Sandpiper (Actitis macularia)
Yearly visitor, Flood Control Reservoirs.

PIGEONS, DOVES

Band-tailed Pigeon (Columba fasciata monilis)
Common especially above 3500 feet; winters in large flocks in the foothills and out into the valley. Always associated with live oaks.

Mourning-Dove (Zenaidura macroura marginella)
Occasional, usually below 3000 feet.

CUCKOOS, etc.

*Yellow-billed Cuckoo (Coccyzus americanus occidentalis)
Heard in dense willow thicket in Big Dalton Canyon at 1500 feet.

California Road-runner (Geococcyx californianus)
Occasional up to 3000 feet.

OWLS

Barn Owl (Tyto alba pratincola)
Occasional in the canyons below 2000 feet.

Screech Owl (Otus asio quercinus)
Common throughout; associated with live oaks.

Horned Owl (Bubo virginianus pacificus)
Common throughout; in or near woodland associations.

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*No specimen in Experimental Forest collection.

*Burrowing Owl (Speotyto cunicularia hypugaea)
Rare; firebreaks and grassy areas below 2000 feet.

*Spotted Owl (Strix occidentalis occidentalis)
Rare. One individual caught in deep wooded canyon at 1800 feet.

Short-eared Owl (Asio flammeus flammeus)
Migrant; one individual collected at 3400 feet.

GOATSUCKERS, etc.

Poor-will (Phalaenoptilus nuttallii californicus)
Common in summer; frequently seen at night along roads.

SWIFTS and HUMMINGBIRDS

White-throated Swift (Aeronautes saxatilis saxatilis)
Common; nests on the high cliffs in San Dimas Canyon.

Black-chinned Hummingbird (Archilochus alexandri)
Summer visitor; along streams below 3000 feet.

Anna Hummingbird (Calypte anna)
Abundant resident; usually nests near streams.

KINGFISHERS

Belted Kingfisher (Megaceryle alcyon caurina)
Occasional; Flood Control Reservoirs; no record of nesting.

WOODPECKERS

Red-shafted Flicker (Colaptes cafer collaris)
Common throughout.

Acorn Woodpecker (Balanosphyra formicivora bairdi)
Occasional in woodland with live oaks; abundant in valley.

Yellow-bellied Sapsucker (Sphyrapicus varius daggetti)
Occasional throughout.

Hairy Woodpecker (Dryobates villosus hyloscopus)
Common in Quercus chrysolepis woodland; above 3000 feet.

Downy Woodpecker (Dryobates pubescens turati)
Occasional; below 2000 feet, among willows.

Nuttall Woodpecker (Dryobates nuttallii)
Abundant throughout; usually in live oaks.

*White-headed Woodpecker (Dryobates albolarvatus gravirostris)
Occasional winter visitor in Tanbark Flat pine plantation.

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*No specimen in Experimental Forest collection.

PERCHING BIRDS - FLYCATCHERS

*Western Kingbird (Tyrannus verticalis)
Occasional below 3000 feet, in summer.

Ash-throated Flycatcher (Myiarchus cinerascens cinerascens)
Common throughout, in summer.

Black Phoebe (Sayornis nigricans semiatra)
Abundant near water.

Hammond Flycatcher (Empidonax hammondii)
Migrant; April.

Western Flycatcher (Empidonax difficilis difficilis)
Common below 3000 feet near streams, in summer.

Wood Pewee (Myiochanes richardsonii richardsonii)
Common throughout, in summer.

SWALLOWS

Violet-green Swallow (Tachycineta thalassina lepida)
Nests on Big Dalton Dam. Observed also at San Dimas Reservoir.

Rough-winged Swallow (Stelgidopteryx ruficollis psammochrous)
Nests in steep banks in San Dimas Canyon, below 2000 feet.

*Cliff Swallow (Petrochelidon albifrons albifrons)
Nests on Big Dalton Dam in large numbers.

JAYS, etc.

Steller Jay (Cyanocitta stelleri frontalis)
Abundant in summer above 4000 feet; in winter, frequently abundant in woodlands as low as 1500 feet.

California Jay (Aphelocoma californica californica)
Abundant throughout; especially fond of acorns.

*American Crow (Corvus brachyrhynchos hesperis)
Occasional visitor up to 1700 feet.

TITMICE, CHICKADEES, etc.

Mountain Chickadee (Parus gambeli baileyae)
Abundant above 4000 feet.

Plain Titmouse (Baeolophus inornatus transpositus)
Common in woodlands throughout.

Bush-tit (Psaltriparus minimus minimus)
Common below 3000 feet.

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*No specimen in Experimental Forest collection.

NUTHATCHES

White-breasted Nuthatch (*Sitta carolinensis aculeata*)
Occasional; in summer above 4000 feet; in winter as low as 2000 feet.

CREEPERS

Brown Creeper (*Certhia familiaris zelotes*)
Occasional in forests and oak woodland primarily above 4000 feet.

WREN-TITS

Wren-tit (*Chamaea fasciata henshawi*)
Common in chaparral.

DIPPERS

American Dipper (*Cinclus mexicanus unicolor*)
Absent when several consecutive years of low rainfall have caused streams to stop flowing during the summer. Common between 1938 and 1943 in San Dimas Canyon.

WRENS

*Winter Wren (*Troglodytes troglodytes pacificus*)
Rare winter resident.

Bewick Wren (*Thryomanes bewickii correctus*)
Common throughout; in chaparral.

Canyon Wren (*Catherpes mexicanus conspersus*)
Common in deep canyons or around buildings as low as 1200 feet.

Rock Wren (*Salpinctes obsoletus obsoletus*)
Occasional, rocky areas throughout.

THRASHERS, etc.

Mockingbird (*Mimus polyglottos leucopterus*)
Foothills below 1500 feet.

California Thrasher (*Toxostoma redivivum redivivum*)
Abundant throughout; in chaparral.

THRUSHES, etc.

Robin (*Turdus migratorius propinquus*)
Occasional winter visitor, rare in summer.

*Varied Thrush (*Ixoreus naevius meruloides*)
Irregular winter visitor; common at Tanbark Flat during winter of 1935-36. Not reported since.

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*No specimen in Experimental Forest collection.

Alaska Hermit Thrush (*Hylocichla guttata guttata*)
Fairly common winter resident.

Monterey Hermit Thrush (*Hylocichla guttata slevini*)
Migrant.

Mexican Bluebird (*Sialia mexicana occidentalis*)
Common resident throughout; commonest in summer above 4000 feet (nesting colony in Brown's Flat); in winter commonest below 4000 feet.

Townsend Solitaire (*Myadestes townsendi townsendi*)
Sometimes common in the winter above 4000 feet.

KINGLETS and GNATCATCHERS

Blue-gray Gnatcatcher (*Polioptila caerulea amoenissima*)
Occasional below 2000 feet in open stretches of the canyons.

Ruby-crowned Kinglet (*Regulus calendula cineraceus*)
Common winter visitor throughout.

SILKY FLYCATCHERS

Phainopepla (*Phainopepla nitens lepida*)
Common summer visitor below 2000 feet.

SHRIKES

Loggerhead Shrike (*Lanius ludovicianus gambeli*)
Occasional up to 3000 feet; firebreaks and other open grassy areas.

VIREOS

Hutton Vireo (*Vireo huttoni huttoni*)
Common in stream woodland below 3000 feet.

Warbling Vireo (*Vireo gilvus swainsonii*)
Common in oak woodlands up to 5000 feet.

WOOD WARBLERS

Orange-crowned Warbler (*Vermivora celata lutescens*)
Occasional summer visitor.

Yellow Warbler (*Dendroica aestiva brewsteri*)
Common summer visitor in willows along streams.

Audubon Warbler (*Dendroica auduboni auduboni*)
Occasional summer visitor above 2000 feet; abundant in winter below 3000 feet.

Black-throated Gray Warbler (*Dendroica nigrescens*)
Occasional summer visitor throughout.

*Chat (Icteria virens auricollis)
Occasional summer visitor along streams below 1500 feet.

Pileolated Warbler (Wilsonia pusilla chryseola)
Occasional summer visitor along streams.

BLACKBIRDS, ORIOLES, etc.

*Western Meadowlark (Sturnella neglecta)
Occasional on firebreaks and other grassy areas below 3000 feet.

Bullock Oriole (Icterus bullockii)
Common along streams, especially in cottonwoods, and below 3000 feet.

Brown-headed Cowbird (Molothrus ater obscurus)
Rare; reported at 2700 feet.

TANAGERS

Western Tanager (Piranga ludoviciana)
Summer visitor; commonest above 4000 feet; occasional as low as 1500 feet.

FINCHES, SPARROWS, etc.

Black-headed Grosbeak (Hedymeles melanocephalus maculatus)
Common in summer throughout; usually near streams.

Lazuli Bunting (Passerina amoena)
Occasional below 2000 feet.

Purple Finch (Carpodacus purpureus californicus)
Deep canyons of San Dimas drainage as low as 2500 feet. Also in heavy chaparral above 4500 feet.

House Finch (Carpodacus mexicanus frontalis)
Primarily around buildings; abundant at Tanbark Flat.

Pine Siskin (Spinus pinus pinus)
Rare migrant.

Arkansas Goldfinch (Spinus psaltria hesperophilus)
Abundant in summer below 4000 feet. Occasional in winter.

Lawrence Goldfinch (Spinus lawrencei)
Common in the summer.

Spotted Towhee (Pipilo maculatus megalonyx)
Common throughout.

Brown Towhee (Pipilo fuscus crissalis)
Abundant below 4000 feet.

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*No specimen in Experimental Forest collection.

*Bell Sparrow (Amphispiza belli belli)
Occasional below 3500 feet.

Oregon Junco (Junco oreganus thurberi)
Abundant throughout; nests above 4000 feet.

White-crowned Sparrow (Zonotrichia leucophrys gambelii)
Abundant migrant; occasional in the winter.

Golden-crowned Sparrow (Zonotrichia coronata)
Common in the winter below 3500 feet.

Kodiak Fox Sparrow (Passerella iliaca insularis)
Rare migrant.

Sooty Fox Sparrow (Passerella iliaca fuliginosa)
Rare migrant.

Slate-colored Fox Sparrow (Passerella iliaca schistacea)
Migrant.

Yosemite Fox Sparrow (Passerella iliaca megarhynchus)
Winter visitor.

Lincoln Sparrow (Melospiza lincolnii lincolnii)
Rare migrant.

Song Sparrow (Melospiza melodia cooperi)
Common along streams up to 3000 feet.

AMPHIBIANS AND REPTILES FOUND IN THE SAN DIMAS EXPERIMENTAL FOREST

SALAMANDERS

Pacific Coast Newt (Triturus torosus)
Very abundant near streams especially below 4000 feet.

Northern Slender Salamander (Batrachoseps attenuatus attenuatus)
Occasional in moist locations.

FROGS and TOADS

Desert Tree-toad (Hyla arenicolor)
Occasional below 2000 feet.

Pacific Tree-toad (Hyla regilla)
Common near water.

Southern Yellow-legged Frog (Rana boylii muscosa)
Abundant near water.

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*No specimen in Experimental Forest collection.

LIZARDS

Western Blue-bellied Lizard (*Sceloporus occidentalis biseriatus*)
Commonest below 3000 feet; stream woodland.

Blainville Horned Toad (*Phrynosoma coronatum blainvillii*)
Common throughout in open areas or thin chamise chaparral.

San Diego Alligator Lizard (*Gerrhonotus multicarinatus webbii*)
Common throughout; usually in woodland or heavy chaparral.

Silvery Legless Lizard (*Anniella pulchra pulchra*)
Occasional in chaparral.

Stejneger Whip-tailed Lizard (*Cnemidophorus tessellatus stejnegeri*)
Common throughout.

Western Skink (*Eumeces skiltonianus*)
Occasional.

SNAKES

*Western Worm Snake (*Leptotyphlops humilis humilis*)
Occasional along streams under logs and other organic debris.

California Boa (*Lichanura roseofusca roseofusca*)
Common in woodland associations.

San Bernardino Ring-necked Snake (*Diadophis amabilis modestus*)
Occasional in stream woodland.

*Western Yellow Bellied Racer (*Coluber constrictor mormon*)
Occasional in woodland below 2000 feet.

California Striped Racer (*Coluber lateralis*)
Common in chamise chaparral.

California Patch-nosed Snake (*Salvadora hexalepis virgultea*)
Occasional in chaparral.

San Diegan Gopher Snake (*Pituophis catenifer annectens*)
Commonest in grassy areas.

Coast Range Coral King Snake (*Lampropeltis multicincta multifasciata*)
Common in woodland associations.

California King Snake (*Lampropeltis getulus californiae*)
Occasional in grassy areas below 2000 feet.

California Garter Snake (*Thamnophis hammondii*)
Abundant along streams.

Pacific Rattlesnake (*Crotalus viridis oreganus*)
Common throughout.

TURTLES

Southern Pacific Terrapin (*Clemmys marmorata pallida*)
Common along streams and in Flood Control Reservoirs.

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*No specimen in Experimental Forest collection.

HERE'S HOW ....a guide to tree planting in the California Pine Region

MISCELLANEOUS PAPER No. 8
March 17, 1952

FOREST SERVICE

CALIFORNIA FOREST and RANGE EXPERIMENT STATION
Stephen N Wyckoff, Director

U S DEPARTMENT OF AGRICULTURE

FOREWORD

We foresters are in the business of growing trees. If we can get them started by managing our stands properly--fine. Wherever we can't, we've got to plant. How to do a better job of planting is outlined in this booklet. Let's follow its suggestions. Our planting efforts should result in not dead statistics of so many acres planted, but living examples of our abilities as foresters to do the planting job well and follow through until a good stand of reproduction is assured.

Clare W Hendee
Regional Forester, Region 5

Stephen N. Wyckoff.
Director, California Forest
and Range Experiment Station

HERE'S HOW - - - a guide to tree planting in the California pine region

By

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and

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Illustrated by

A. E. Kursinski, California Forest and Range Experiment Station

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1/ The California Forest and Range Experiment Station is maintained by the Forest Service, U. S. Department of Agriculture, in cooperation with the University of California at Berkeley.

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A 7-year-old experimental plantation on the Plumas National Forest.

Many thousands of acres of burned or cut-over pine timber land in California need to be reforested. But natural seedfall can not always be depended on to do the job. Sometimes no seed trees, or too few of them, survive fire or logging. Even when adequate seed trees are left, a light seed crop or damage by seed-eating rodents may result in a poor stand of trees. Twenty-five years or more have gone by before some cut-over areas were even partly stocked with seedlings. Natural regeneration, of course, is preferred, but foresters do not want to wait this long to start another tree crop. Furthermore, they sometimes find that the natural seedlings are not the tree species they want to grow or that brush soon covers the ground so completely that too few or even no trees can grow. Then they must turn to artificial regeneration, either by sowing seeds or planting trees.

Now, you undoubtedly have heard that seeding or planting forest trees is a difficult job in California. It is, but it is not impossible. Both practical experience and the findings of research have shown that seeding or planting can succeed--if done

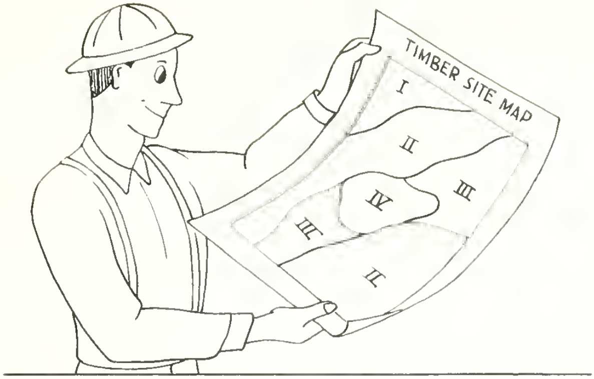
in the right place
at the right time
with the right stock
in the right way

In this booklet we are going to summarize these points to help you do a better job of getting the new forest started.

THE RIGHT PLACE

Obviously you'll want to choose the place where your available money and manpower will do the most good. In general this means the areas having high site quality for timber and no competing vegetation. Throughout the California region plantations on good timber sites have been more successful than those on poor sites. Also, on timber burns, plantings made within a year or two after the fire have been more successful than those made later when brush, grass or other competing vegetation has become established. Here is the reason. In this climate, the young trees must get their water from moisture already in the ground by the beginning of summer. But brush or grass with established roots will quickly use up the moisture needed for tree growth. If you find much competing vegetation on an area you'd like to plant, then, you must first destroy the competition.

On good way to do this is to clear the brush in strips 10 to 12 feet wide, with bulldozers. Narrower strips just <u>will not</u> be effective. The strips should be spaced 20 feet apart on center, and trees planted 6 feet apart down the center of the strips. At this spacing there will be about 350 trees per acre. On slopes where erosion is a hazard, strips should follow the contour, or run across the slope. Instead of strips, you can use cleared blocks about one chain square, with the blocks one chain apart. Plant the trees at 6 x 6 spacing, at least 5 feet away from the cleared edge.



Burning is another way to clear the ground where danger of erosion is not excessive. However, brush seedlings and sprouts will come in after the fire. They must be controlled. You can do this by bulldozing, ripping, or disking strips through the planting area, or by spraying the sprouts and seedlings with an herbicide. Sprouts of many common brush species, including bear clover, can be killed with a water solution of 2,4-D or 2,4,5-T at a concentration of 2,000 to 3,000 parts of acid per million. One hundred gallons of this solution, sprayed under pressure, will cover an acre effectively.

Another consideration when you select the right place to plant is the possibility of damage by deer or rabbits. These animals have destroyed entire plantations, and no practical method of controlling them in such large areas is known at present. If you find evidence that rabbits or deer are concentrated on an area, choose some other place to plant.

Of course you don't want to waste money planting trees where livestock congregate, as along stock driveways, around waterholes, close to meadows, and similar places.

If you are choosing among several possible planting sites, here are some priorities established to guide your selection--the best places listed first:

1. Areas burned or logged 1 to 3 years ago with little or no brush cover, and of timber site quality I through III (soils normally 4 or more feet deep).

2. Areas burned or logged 4 or more years ago, with brush coming in or already forming a dense stand, and of site quality I through III (soils normally 4 or more feet deep).

3. Areas burned or logged 1 to 3 years ago, with little or no brush, and of site quality IV and V (soils normally 2 to 3 feet deep).

4. Areas burned or logged 4 or more years ago, with brush coming in or already established and of timber site quality IV and V (soils normally 2 to 3 feet deep).

Maps of forest soils (the vegetation-soil maps prepared by the California Forest and Range Experiment Station) may be available for your planting areas. Use them to help establish priorities when the timber site quality is not known.

THE RIGHT TIME

When it comes to picking the time to plant, spring is your best bet. Both fall and spring planting have been tested in California. Results have been equally good in the two seasons when freshly lifted stock was used, planting was carefully done, and soil moisture and the weather were favorable. But because favorable conditions are less likely to prevail in the fall, planting in the spring is more likely to succeed.

Of course you may have to plant in the fall at the higher elevations, where snow covers the ground until late in the spring. By the time the snow melts from these areas, the weather is apt to be too warm and too dry for planting. If you must plant in the fall, make sure the soil is thoroughly wet at least a foot deep. Don't rely on the first fall rains, though. They seldom wet the soil evenly, particularly on recently logged areas, so you should check the soil moisture before starting to plant. The only way to be sure is to dig some holes and see whether the soil is really wet down to a depth of one foot.

You may seed either in the fall or in the spring. In the fall it is not necessary to wait until after the rains; however, late-fall sowing is best because early seeding lengthens the period during which seed is exposed to rodents. Spring-sown seed should be stratified for prompt germination.

To sum up, here's a rule of thumb for picking the right time: Plant in the spring as early as possible or in the fall, when necessary, as late as possible.

THE RIGHT STOCK

Using the right stock means you have these things to consider: Seed source, quality and age of stock, and tree species. Seed source is important to make sure that trees in the plantation will be adapted to local growing conditions. Except for proved superior strains or exotic species of trees, it is safest to sow seed collected in an environment like that of the planting site. If you are to sow seed directly on the site, know which one of California's 13 seed collection zones contains the planting site. Use only seed from that zone. And if you are ordering planting stock from a nursery, specify the seed zone in which the stock will be planted.

It is the nursery's job to provide you the best stock for your planting job. The trees are graded for quality at the nursery so that only those with good top and root growth are shipped out. A minimum stem diameter of 0.11 inch has been set for grade 1 ponderosa pine and Jeffrey pine stock. (Size grades have not yet been established for other species.)

Ordinarily you will receive from the nursery trees that have been 1 year in the seed bed and 1 year in transplant beds, or 1-1 transplants. This age class of planting stock has consistently survived well. Older classes, such as 1-2 and 2-1, have not been enough better to justify the extra cost of producing them. Cheaper trees, such as 1-0 and 2-0 root-pruned stock, have given satisfactory survival under favorable planting conditions, but it still is not possible to predict just when this stock can be used successfully. You will have more consistent success if you use 1-1 transplants.

For most of the planting for timber growing purposes the species to use will usually be either ponderosa pine or Jeffrey pine. They grow well in most localities where you will be planting in California. You should order ponderosa pine for planting at the lower elevation sites, say 5,000 to 6,000 feet or below. Order Jeffrey pine for higher elevations because this species seems to be more cold resistant than ponderosa pine. Where the two species naturally merge, or have grown in mixed stands, you can plant either one successfully.

Douglas-fir, sugar pine, white fir, and red fir are also desirable for planting. Planting stock of these species is not available now and probably will not be until there are better facilities for producing it. When they do become available, select those species native to the planting site. Sugar pine, though, should be planted only within blister rust control units where it will be protected from the white pine blister rust disease.

In a nutshell, then, the <u>right stock</u> means: species adapted to the site, correct seed zone, proper age, and graded for quality.

THE RIGHT WAY

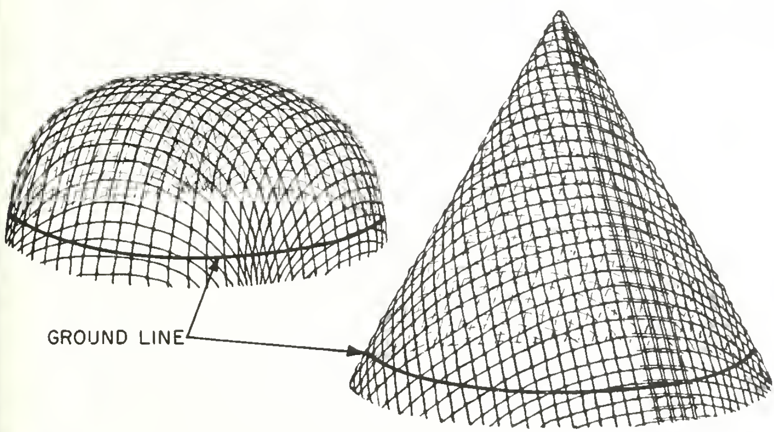
A good start in life is important. Whethe: the plantation is to be started by sowing seed directly in the field where the trees are to grow or by planting nursery-grown trees, this stage in the plantation's life is critical. Yet there is no secret to success. What you need to do is give the young plants the best start possible and then protect them from destructive pests.

Direct Seeding

For direct seeding the right way requires that you take three essential precautions. The first of these is to provide the proper seed be which for pines is mineral soil. The second is to protect the seed from rodents, which have been the most common cause of failure in direct seeding projects. The third is to free the tender seedlings from competition by brush and other vegetation.

Sowing the seed in spots, rather than broa casting it over the ground, seems to be the mos practical method of direct seeding. So far direct seeding has been successful in only a few of the times it has been tried on a large scale in California. Broadcast sowing has been unsuccessful in nearly every trial. But when rodents were controlled, spot seeding has been as successful as planting.

Covering the seed spots with screens is the most effective method now known for preventing damage by rodents. No way of treating the seed with poison or repellents, or of encasing it in a pellet, has yet been found to keep the rodents away. These measures are being studied, however, and an effective one may be found.



You can make the screens of quarter-inch mesh hardware cloth, giving them a dome or cone shape so that the small seedlings will have room to grow. For pine plantations, here's how you use the screens:

1. Plan on at least 680 spots per acre, that is, a spacing of 8 feet by 8 feet. You'll need 5 seeds for each spot. That many is necessary because under ordinary conditions the chances are about 1 in 4 that a seed will germinate and the seedling live.

2. At each seed spot scrape away litter and trash so that mineral soil is exposed in a foot-square area. If ground cover is heavy, scalp off the vegetation with the planting tool. If the spot is near a clump of brush, move 4 or 5 feet away, even if this means you cannot stick to a regular pattern of 8 by 8 spacing.

3. Put the 5 seeds on the prepared seed-bed and cover them with one-quarter to one-half inch of soil.

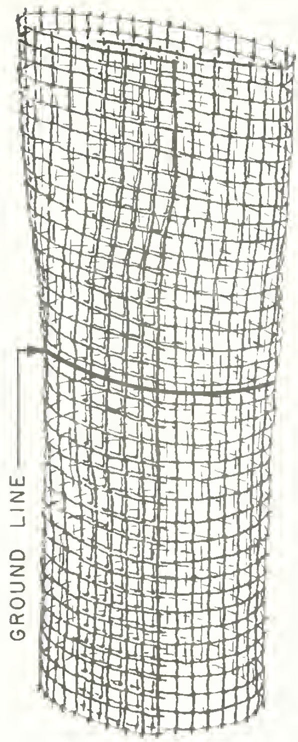
4. Center a screen over each seed spot. Set the screen into the ground at least an inch deep by twisting it down; otherwise it may be disturbed, and rodents will get the seed after all!

5. Remove the screens at the end of the first or second year so that seedlings will not be injured in trying to grow through them--and so you can use them again.

Material and labor costs are relatively high for these screens, and even though you use a set of screens several times, seed spotting with screens is as expensive as planting.

Small, inexpensive cylindrical screens, called K-screens, are now being tested as a possible means of reducing costs. K-screens are made from 4-inch squares of hardware cloth rolled around a broom handle or 3/4 inch pipe. The hardware cloth should be 4-mesh or finer.

These screens are set about 2 inches deep in dibble holes, and filled nearly to ground level with soil on which the seed is placed and covered. Then the top of the screen is pinched together to make an opening about 1/4 inch across. The theory is that rodents will not get at the seed, but the seedling will grow through the opening so the screen will not have to be removed. The screen will spread as the tree grows in diameter.



The K-screen has shown promise in small-scale tests. Rodent damage has been light, but seedling survival has been poor for other reasons. You may wish to test K-screens yourself, but better techniques for using them will have to be worked out before they can be recommended for large-scale use.

Poisoning the rodents is another method you can use to protect the seed. It has been fairly effective in some direct-seeding work. The procedure now used is to distribute poison bait, such as "1080" or thallium-treated oat groats, several weeks before seeding, on both the area to be seeded and a buffer strip one-fourth mile wide. You'll need about one-half pound of poison bait per acre. A second poisoning when the seed starts to germinate may be necessary to make sure the seed or tender young seedlings are safe. You can determine the need for retreatment by setting traps to sample the rodent population. If you catch two animals in 100 trap-nights, the population is dangerously high. Remember, too, that under California law only duly authorized persons may distribute certain poison bait, so you had better check with your county agricultural commissioner about getting and using the bait.

Sowing the seed in prepared spots seems to be the best procedure when rodents are controlled by poisoning. By spot seeding you can make sure that all the seed is in mineral soil free of competition from brush and other plants. The seed can be sown by hand, using 5 seeds per spot. Or you can use one of the so-called walking stick planters designed to place and cover the seed by means of a spring mechanism. If the planter drops only 1 seed, you should sow 5 or 6 times the recommended 680 spots per acre.

All this may seem to be a lot of trouble just to get some seed in the ground, but the results will justify the work. Direct seeding will be successful with pine when you make sure there is:

1. A mineral soil seedbed.

2. Rodent control.

3. No competing vegetation.

Planting

Planting nursery-grown trees has been more dependable, and over the years more successful than direct seeding. Care is the watchword here--care in handling, planting, and protecting the young trees. They are living plants, even though they are dormant when they are shipped and set in the ground. It's your job to keep them alive.

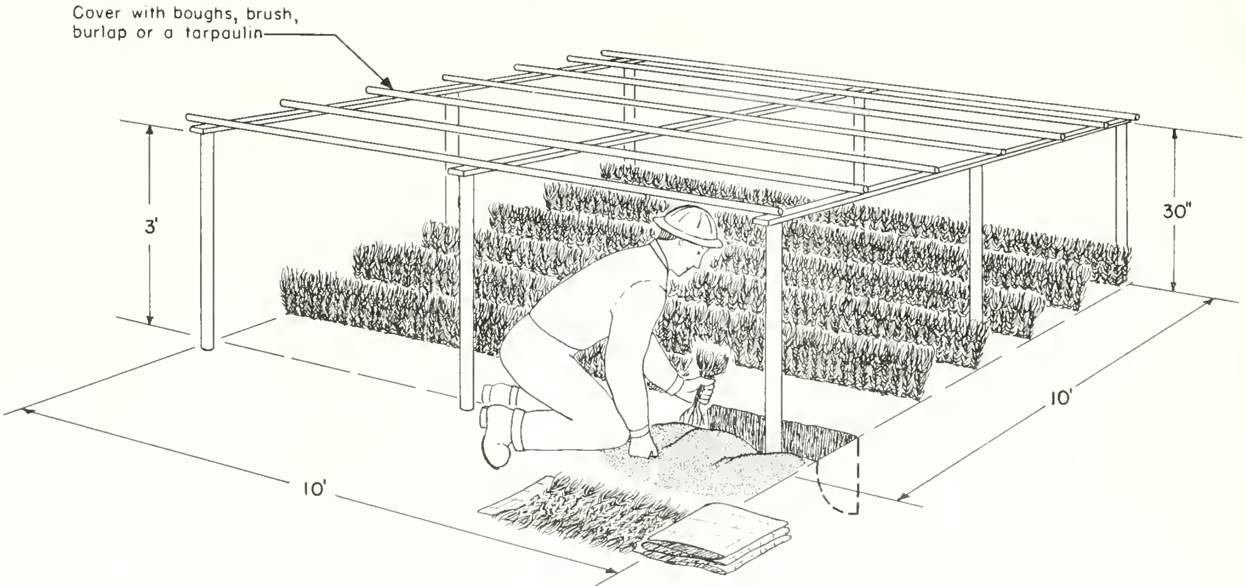
Start the planting job correctly at the very beginning, that is, in transporting the trees from the nursery to the man who will plant them. Here's the right way:

1. Keep the period in transit as short as possible. If more than 24 hours will be required, arrange for refrigerated transport. Shipments made by open truck should be covered with a canvas.

2. Unload the trees immediately on arrival. If they can be planted within two weeks, take them out of their containers and heel them in at the planting site. (See sketch of a heel-in bed.) If the trees must be held longer than two weeks, however, put the crates or bales in cold storage, keeping the temperature in the range of 32 degrees F. to 38 degrees F. and the relative humidity 80 percent to 90 percent. Be sure to stack the crates or bales so as to permit circulation of air.

3. If the trees are kept in storage, take only enough to the planting area for a day's work. If they are heeled in at the site, remove them only as needed. The less the trees are handled, the better.

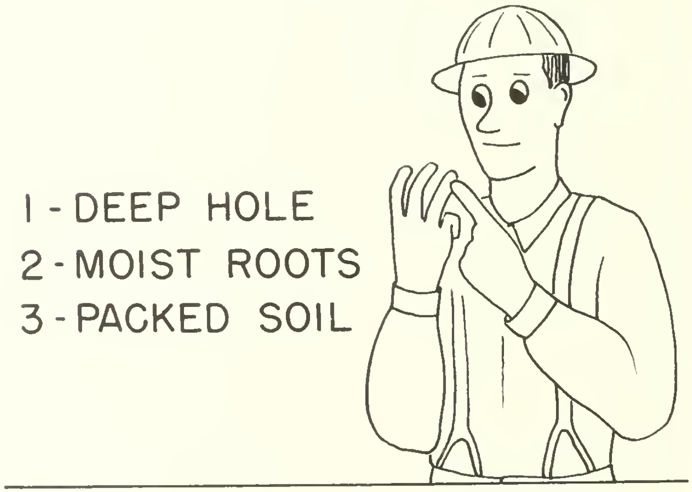
4. Distribute the trees to the planter in lots of 100. Pack them well in wet moss in the plant carrier (bag, tray, or pail). Be sure that the roots of the trees are protected with wet moss in the carrier at all times.



HEEL-IN BED

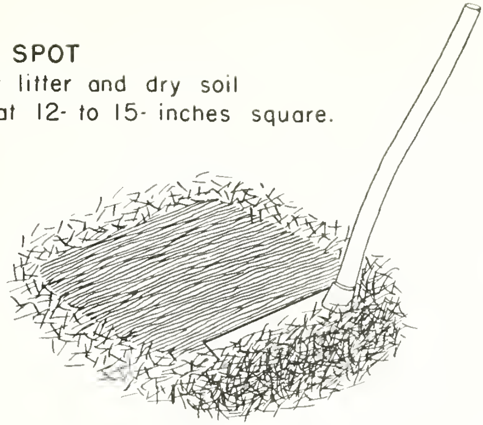
In setting the tree in the ground, you must take care to do these three things: Dig the planting hole at least as deep as the roots are long, keep the roots moist (handle only one tree at a time), and pack moist soil firmly around the roots.

Of course there are several ways of doing this by hand and by machine. In fact several tree planting machines now on the market do a good job quickly. But these machines work well only when the ground is flat or gently sloping and the soil surface is practically clear of brush, stumps, large stones, fallen trees, and logging debris. Such conditions in California forest areas are rare. So you'll probably have to rely on hand planting. The right way to do it is outlined on the next few pages. These sketches show, step-by-step, the method of planting that is recommended for the California pine region.

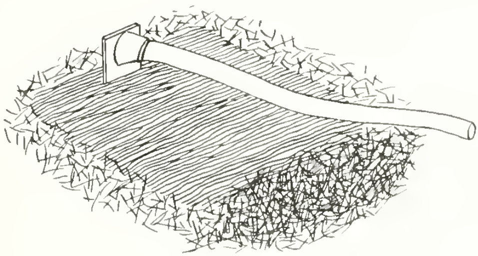


① PREPARE SPOT

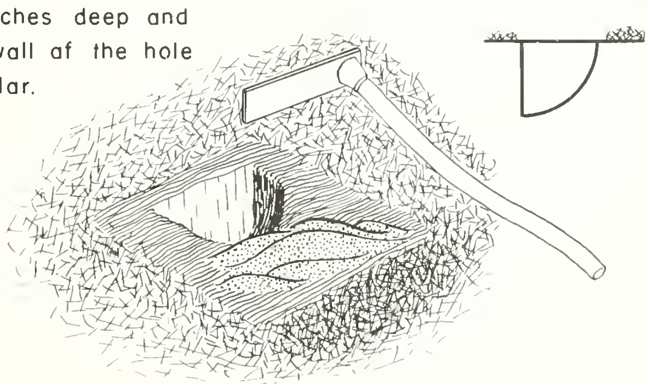
Clear away litter and dry soil from a spat 12- to 15- inches square.



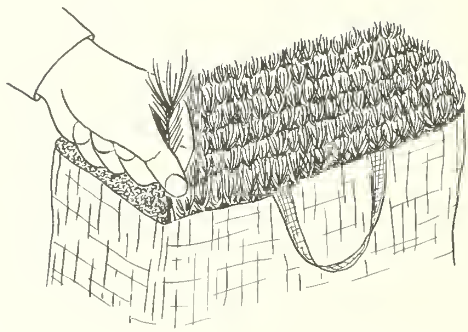
② DIG HOLE



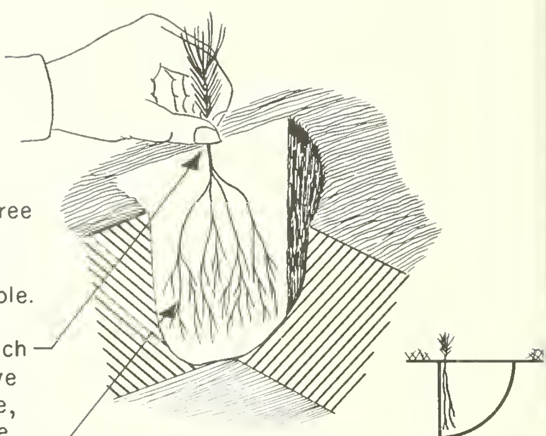
Dig a hale at the upper edge of the cleared space. Make the hale not less than 10-inches deep and the rear wall af the hole perpendicular.



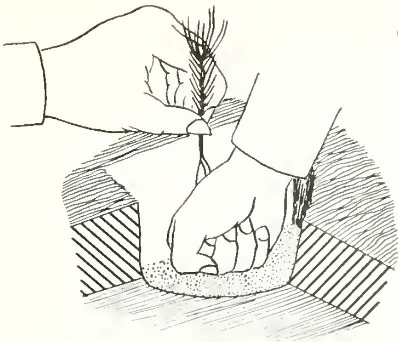
(3) Remove ONE tree from the planting bag.



(4) SET TREE

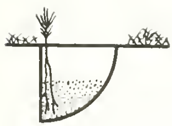


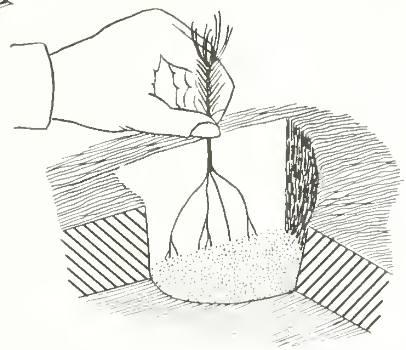
Suspend the tree against the perpendicular wall of the hole. Hold the first needles one inch—no more—above the ground line, and spread the roots out fanwise—

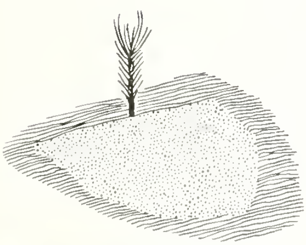


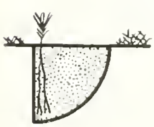
⑤ FILL HOLE

Holding the tree in position with one hand, fill half the hole with moist soil and tamp with the other hand.

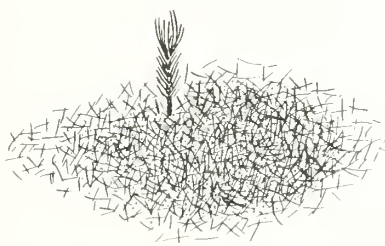








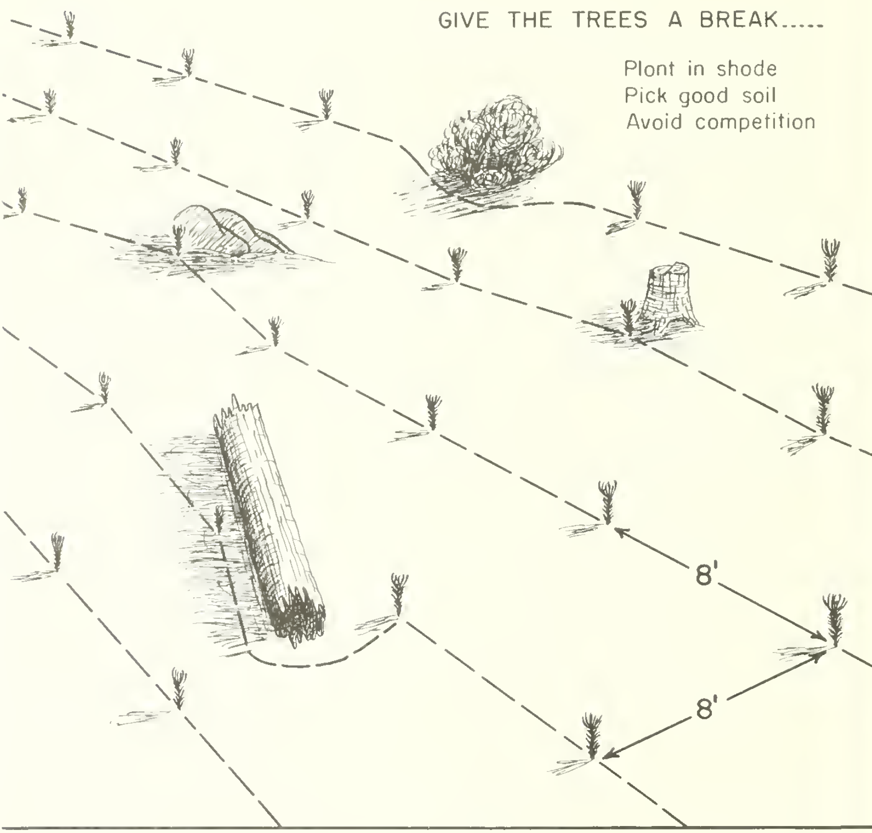
Complete filling the hole with moist soil and tamp this firmly in place.



⑥ MULCH

Push loose earth and litter around the base of the tree.

Trees are usually planted 8 feet apart in rows 8 feet apart (680 trees to an acre), but it is far more important to plant each tree in the best spot you can find than to stick to a geometrical pattern. Planting the tree in the right spot often means the difference between failure and success. The more favorable spots are on the shady side of logs, stumps, and rocks. Avoid less favorable spots such as mounds or ridges of loose earth, rocky places



with little soil, depressions where water stands, accumulations of bark, chips, rotten wood, or other trash, severely burned soil, and any place within 5 feet of dense vegetation or a growing tree.

You can see by now that quality of workmanship should be stressed more than speed of planting. Careful, frequent inspection of the planters' work is necessary to make sure they are doing a good job. Here are some of the most common mistakes that you should look for:

1. Trees planted in unfavorable spots.

2. Poor preparation of the holes. "Pumping the handle" of the planting tool is a common fault. This action either makes a slit or a V-shaped hole which is then improperly closed.

3. Poor placement of the tree. Roots bunched or doubled up and rammed into the hole. Trees set too high or too low or planted in a horizontal position. Trees tucked into the hole with the blade of the tool.

4. Failure to tamp soil firmly around the roots and fill the hole with soil.

5. Failure to mulch around base of planted tree with loose soil or litter.

6. Removing more than one tree at a time from the plant container.

Protecting the Plantation

Your planting job is not done when the last tree is planted. Much of the failure in past plantings has been the result of damage that could have been prevented if noticed in time. You ought to check the plantations at least once a year to see whether damage is occurring. Fit these checks into scheduled trips that take you near the plantation if you can, but if necessary make a special trip. If you find that the plantation is being damaged, take action immediately. Delay may be fatal. These are the chief sources of damage, and the protective measures you can take:

Grazing animals. Cattle, sheep, and deer often damage planted trees by browsing and trampling. For best results cattle should be excluded from planted areas for at least three years, and sheep should be excluded until the terminal buds, or growing tips of the planted trees, are out of reach of the sheep. If you direct-seed with screens, it's still best to keep cattle out because they kick over or trample the screens. Deer are more difficult; it is next to impossible to exclude them and the use of repellents is not yet practical. About the best you can do is avoid planting where you know that deer are numerous or likely to congregate.

Insects. One of the worst insect pests is the pine reproduction weevil, which has wiped out several plantations in California. Yellowing foliage is the most noticeable sign of weevil attacks. With a little whittling you may find the tunnelled galleries of weevil larvae in twigs and stems of yellowed trees. Weevil-infested plantations can be saved, however, by early application of the proper insecticide. If you suspect that this insect is attacking the trees, ask the Forest Insect Laboratory, 29 Forestry Building, University of California, Berkeley, for instructions. You'll need to watch for damage by this insect until the trees are about 6 feet high; ordinarily the weevil does not attack larger trees. Damage by this insect has been most serious in the northern part of the state.

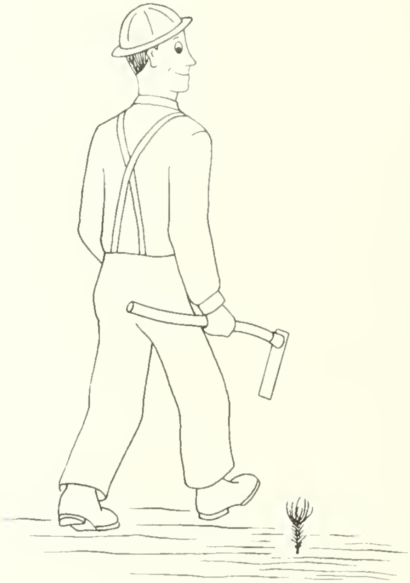
Porcupines. Porcupines seldom destroy entire plantations, but they do deform many trees, and kill some, by chewing off the bark. You can easily control porcupines, though, by putting poison salt in their dens and setting out poison salt blocks in trees in which they feed or rest. Of course it's best to do this as soon as you find evidence of damage--before the porcupines build up their population. Porcupine damage usually occurs in trees several inches in diameter so you will have to guard against it for a long time.

Rabbits. Rabbit damage has been most severe in brushfield plantations. Although no practical method of control has been discovered, the damage can be held low. Apparently these animals prefer to stay close to protective cover. Consequently damage can be minimized by planting in wide strips or blocks cleared of brush. Rabbits usually cause damage by nipping off the terminal bud. The trees are safe when they grow beyond the reach of the rabbits.

WHAT IS SUCCESS?

Finally, what _is_ the measure of a good planting job? Have you succeeded if most of the trees live through the first year? Well, not quite. Your goal is to have not less than 300 vigorous undamaged trees per acre at the end of 5 years. Count the trees periodically by running sample lines through the plantation to see if this goal is being met. If it is not and if brush has not taken over, replant the empty spaces with screened seed spots or nursery-grown trees.

Success is possible. Some excellent plantations attest to what can be done in the _right place_, at the _right time_, with the _right stock_, in the _right way_.



A 17-year-old plantation, established in 1932 on a timber burn in Modoc National Forest, Site III.

This plantation, established in 1933 on a timber burn, also was 17 years old when photographed. Modoc National Forest, Site III.

SOME USEFUL REFERENCES

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FOREST SERVICE

CALIFORNIA
FOREST & RANGE
EXPERIMENT STATION

U. S. DEPARTMENT OF AGRICULTURE

MISCELLANEOUS
PAPER No. 9
SEPTEMBER 1952

SHOCK RESISTANT LUCITE GRADUATE

By
E. L. Hamilton, L. F. Reimann, and L. A. Andrews

Technicians making field measurements of water in rain gages, at infiltration plots, and in other related activities on the San Dimas Experimental Forest in southern California have found need for graduated cylinders more resistant to breakage than commercial glass graduates. This need became evident several years ago when the rainfall sampling network for the experimental forest was established. The network included several hundred non-recording rain gages. Reduction in the cost of such a large number of gages was effected by eliminating the inner brass tube used to magnify the gage catch 10-1, which is an essential part of the standard Weather Bureau type gage. In place of the brass tube, each field observer was provided with a laboratory type glass cylinder graduated in inches of rainfall. As time progressed, however, it was found that although the system was good, the breakage rate of glass cylinders was high, despite the use of protective cases of various types.

The situation was eventually remedied by making the cylinders of lucite, a clear plastic material that is relatively tough and easily reparable. Shock resistant graduates of this type might be adapted to many other uses where breakage of glass cylinders is a problem. The following description of materials and graduation procedure has been prepared for the guidance of those who wish to construct similar graduates.

Materials, Dimensions, and Accessories

The graduate illustrated in the accompanying photograph was designed for the measurement of rainfall caught in 8-inch diameter rain gages. It has a capacity of $2\frac{1}{2}$ inches of rain and is graduated in increments of 0.02 inch. It is 18 inches tall and $3\frac{1}{2}$ inches in outside diameter. The cylinder is commercial lucite tubing with 1/8-inch wall thickness and $3\frac{1}{4}$ inches inside diameter. The bottom is a disc of $\frac{1}{4}$-inch sheet lucite cemented to one end of the cylinder. Lugs of $\frac{1}{4}$-inch lucite, semicircular in shape and about $1\frac{1}{2}$- by 5/8-inch in size, are cemented to the outside of the cylinder at the top and the bottom. The lugs are drilled with $\frac{1}{4}$-inch holes through which a leather carrying thong may be attached.

The California Forest and Range Experiment Station is maintained at Berkeley in cooperation with the University of California.

Agriculture--Berkeley

Construction Guides

Construction of the bottom disc and graduation of the cylinder are best accomplished through the use of a metal-turning lathe. The bottom disc, $3\frac{1}{2}$ inches in diameter, is cut out of the flat $\frac{1}{4}$-inch stock, which should be trimmed roughly circular so that it can be gripped by the lathe chuck. Next, a recess or tenon is turned to a scant $3\frac{1}{4}$ inches on the disc to make a snug fit in the cylinder. This cut is 5/32-inch wide, leaving a flange 3/32-inch thick and 1/8-inch wide that fits over the end of the cylinder and flush with the outside diameter. After the bottom disc has been turned, a wooden disc similar in form but about 3/4-inch thick should be made. This wooden disc will be used to support the cylinder at the tailstock during graduation, as shown in the photograph. The bottom disc is cemented to one end of the cylinder using a commercial cement suitable for lucite. Satisfactory cement can be made by dissolving lucite shavings in chloroform until the solution is slightly viscid.

Graduation Procedure

The bottom end of the cylinder is gripped in a three-jaw chuck on the lathe headstock. The wooden disc is placed in the other end of the cylinder and centered at the tailstock. A thin, sharp-pointed cutter bit or a fine formed-threading tool mounted on the lathe carriage is used to scribe the graduations. Longitudinal lines can be scribed by locking the bull gear and running the lathe carriage along the bed with the hand feed. Transverse lines are scribed by hand-rotating the spindle.

In practice, first a line is scribed the length of the cylinder. The cylinder is removed from the lathe, set on a level surface and graduation points for .02, .10, .50, 1.00, 1.50, 2.00 and 2.50 inches are established along the scribed line by pouring in appropriate amounts of water--16.47 cubic centimeters of water are equivalent to 0.02 inches depth in an 8-inch rain gage. These points are marked with a scriber; then with dividers, the half-inch intervals are subdivided into tenth-inch intervals and these into the smallest intervals of .02 each.

The cylinder is replaced in the lathe, and the circular graduations are scribed by advancing the cutter bit to each point of calibration and rotating the cylinder by hand for the required length of line as shown in the photograph. The graduations are numbered by pressing hot metal numeral stamps into the lucite.

A lucite graduate of this size costs about $3.50 for material, the tubing costing $2.50 a lineal foot and the sheet material about $1\frac{1}{2}$ cents per square inch. The cylinders are very shock resistant but are not unbreakable. A fall on a rock or a concrete floor can crack the material or sometimes break it. If a bottle of cement is carried in the field, temporary repairs can usually be made by painting cracks with cement or cementing broken pieces in place.

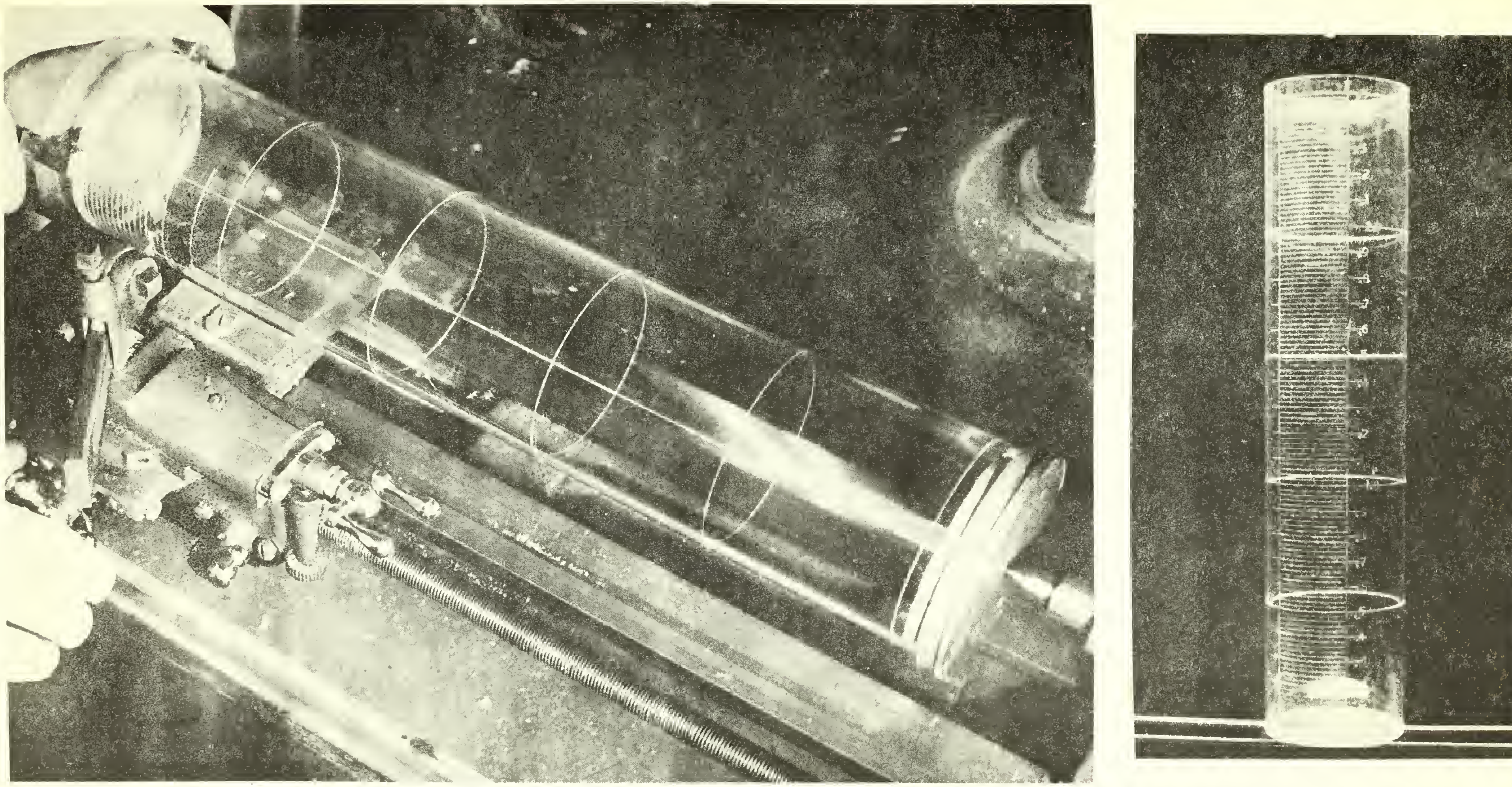

Figure 1.--(Right) Lucite cylinder calibrated for measurement of the rain catch of a standard 8-inch diameter rain gage. (Left) Graduation procedure, showing lucite cylinder chucked in lathe.

FOREST SERVICE

CALIFORNIA FOREST & RANGE EXPERIMENT STATION

U.S. DEPARTMENT OF AGRICULTURE

MISCELLANEOUS PAPER No 10
MARCH 6, 1953

REGENERATION PROBLEMS AND RESEARCH IN CALIFORNIA[1]

By H. A. Fowells

Many of you no doubt have heard or found out by experience that artificial regeneration is a difficult problem in California. Some may believe that it is impossible. Planting and seeding admittedly are more difficult here than in some other forest regions. But we foresters shouldn't admit or even think the job to be impossible. We should, however, be aware of the factors which make the job difficult. It might be well, then, to consider what these obstacles to successful reforestation are and what is being done or should be done in the way of research to cope with them.

The most obvious and often used excuse for poor success in reforestation in California is that the weather is just too unfavorable. Obviously there isn't much we can do about the weather. But we can try to find procedures and techniques that will allow us to make the best of it. Fortunately the trees with which we are primarily concerned are adapted to this climate. Otherwise they wouldn't be here.

Climate makes the regeneration job difficult for at least two reasons. First, newly planted trees are often put under a severe moisture stress when warm dry days follow too closely on the planting period. We often find that much of the loss in planted stock occurs in the first month or so after planting, when there is available moisture in the soil. This loss results from the inability of the planted tree to absorb moisture fast enough. However, in experimental planting we have observed many times that trees carefully lifted from the nursery and immediately planted out are able to survive under severe conditions. In large-scale planting this care and timeliness may be difficult to attain. As a result, the root system is injured or degenerates and cannot absorb moisture adequately. There are several possible solutions.

1/ Presented at the annual meeting of the Northern California Section, Society of American Foresters, in Oakland, California, November 29, 1952.

One procedure might be to condition the plants during storage or before planting so that a functioning root system is regenerated. So far attempts to do this by changing the storage conditions have not been successful. Treatment of the root system with various growth promoting substances has not been successful either. But certainly there are other techniques and substances which should be tried. Finding out how to condition planting stock is one of our most important research problems.

A second way of cutting down moisture stress is to lower the rate of transpiration. The most obvious way is to give the tree some shade. A more economical way--if it would work--is to use a transpiration retardant. These materials, used on ornamental plants by some nurseries, are waxy or latex coatings applied to the stems and leaves. So far we have been unable to demonstrate that these substances will increase survival. The problem of how these materials affect the moisture relations of the plant is now being studied in southern California.

Still another approach is to find trees which are better able to take the treatment we give them. These may be hybrids or selections from our own native species. Possibilities with hybrids now produced are many but a lot of field testing must be done. These field tests are just being started and will need to be continued as new hybrids are developed. Practically no work is being done on the selection of superior individuals except in the process of grading in the nursery. There is some experimental evidence here and from other parts of the world that careful grading of stock will eliminate individuals most apt to fail. Ultimately we should be able to grade stock to meet the severity of the planting conditions.

A very short planting season is the second major difficulty with our climate. The year 1952 is a good example. At the middle elevations of the Sierra Nevada, snow did not leave until May or even later. By then planting should have been finished. In the fall the soil did not become wet enough for planting in much of the mountains until the middle of November. And then the areas were snow covered. The uncertainty as to planting time, and the differences in growing seasons between the nursery and the planting sites make it necessary for us to lift stock and store it until it can be used. Although we have successfully stored stock over winter in experimental work, the techniques for long period storage need a lot more study. The problem may be solved only when we know how the plant is acting physiologically under storage conditions. And, of course, the storage problem is tied up with the process of stock conditioning mentioned earlier.

Another obstacle to successful regeneration is the rapid invasion of brush on logged or burned forest land. During their first year, planted trees or seedlings cannot compete successfully with established brush. How fast this brush develops is shown by conditions on the 1950 Wright's Creek fire on the Stanislaus National Forest. Here, two years after the fire, brush came in so quickly and densely that much of the area yet to be planted will need some form of brush eradication if planting is to succeed. From small-scale tests we know we can control most of the species of sprouting brush and seedlings with the 2,4-D types of spray. The big problem remaining is one of working out minimum dosages and economical spray techniques for large-scale operations.

Forest rodents and insects are also obstacles to successful regeneration in some areas. Several plantations in the brushfield reclamation program of northern California were badly damaged by snowshoe rabbits. Various attempts to control them by poisoning were ineffective. For example, in one large test there was only about 1 percent difference in amount of damage between trees treated with strychnine and untreated trees. Some prevention action is possible, though, because these rabbits will not venture far from cover for fear of predators. Thus damage by rabbits can be minimized if strips 10 or so feet wide, or blocks about 60 feet across, are cleared for planting.

Some insects, principally the pine reproduction weevil, have wiped out plantations or caused severe damage. The Bureau of Entomology has been able to control the weevil by aerial spraying. And the Institute of Forest Genetics is working on hybrids which appear to be resistant to the weevil. We should know, however, the conditions which lead to epidemics of the pest and thus be able to prevent them.

If we didn't have seed-eating rodents, most of the obstacles discussed so far could be dismissed. We could seed at will with reasonable assurance that we would get regeneration. Nature does the job occasionally by saturating the ground with such an amount of seed that rodents just do not take it all. By way of illustration, in a good seed year there may be 30,000 sugar pine seed or over 100,000 ponderosa pine seed per acre. This means 10-15 pounds of seed. Obviously, with seed worth \$5 to \$10 per pound, we cannot expect to duplicate Nature's method.

There are several possible solutions:

1. Get rid of the rodents temporarily,
2. Protect the seed by means of screens, or
3. Make the seed unattractive to the rodents.

Success in getting rid of the rodents by poisoning has been variable. We have not known what rodents we were trying to poison or what their habits were. However, studies by the Fish and Wildlife Service and by the Division of Zoology of the University of California are rapidly supplying the information. We should soon be able to plan an effective rodent control program.

A good many trials show we can direct-seed with wire screen cones. In some cases we have obtained 80 percent or better establishment. However, the screens are expensive to make and to use. And unless they are re-used six to ten times, there is no saving in cost over planting. Their utility may be greatest in areas inaccessible during good planting weather. Future work with screens should be directed towards reducing their initial cost and their use cost. The K-screen, a cylindrical screen, cheap to make and use, is one innovation being tested. It needs some improvement, however, to overcome certain limitations.

The most effective way of thwarting the rodents would be to make the seed unattractive to them. Hundreds of different materials have been tried - none of them effective. Recent tests by the Fish and Wildlife Service with a new compound, "Tetramine," indicate that this may be effective. Tetramine is a poisonous compound which apparently also has repellent qualities. Tests are being made with treated Douglas-fir seed on public and private land in northern California and the Forest Experiment Station plans some trials with ponderosa pine in 1953. Those who have used the material have high praise for it.

To sum up, then, California's climate makes the regeneration job difficult but not impossible. Better stock handling procedures and better stock will give success in planting. We know that we can control the competing brush but we need to get costs down. And, finally, through the concerted effort of several agencies, we are making progress on rodent control methods which will make direct seeding possible.

A GUIDE TO
THE SAN DIMAS EXPERIMENTAL FOREST

Glendora, California

FOREST SERVICE

CALIFORNIA
FOREST & RANGE
EXPERIMENT STATION

U. S. DEPARTMENT OF AGRICULTURE

MISCELLANEOUS
PAPER No. 11
JANUARY 1, 1953

A GUIDE TO THE SAN DIMAS EXPERIMENTAL FOREST

By J. D. Sinclair and E. L. Hamilton

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Records	- L. A. Andrews, L. F. Reimann
Plant physiology	- H. Hellmers, J. M. Kelleher
Soils	- O. C. Olson

Cover: Upper left, Bell small watershed No. 4; upper right, Raingage Hill at Tanbark Flat; lower left, San Dimas lysimeter installation; lower right, streamgaging station, Intermediate watershed No. III.

The California Forest and Range Experiment Station is maintained by the Forest Service, U. S. Department of Agriculture at Berkeley, in cooperation with the University of California.

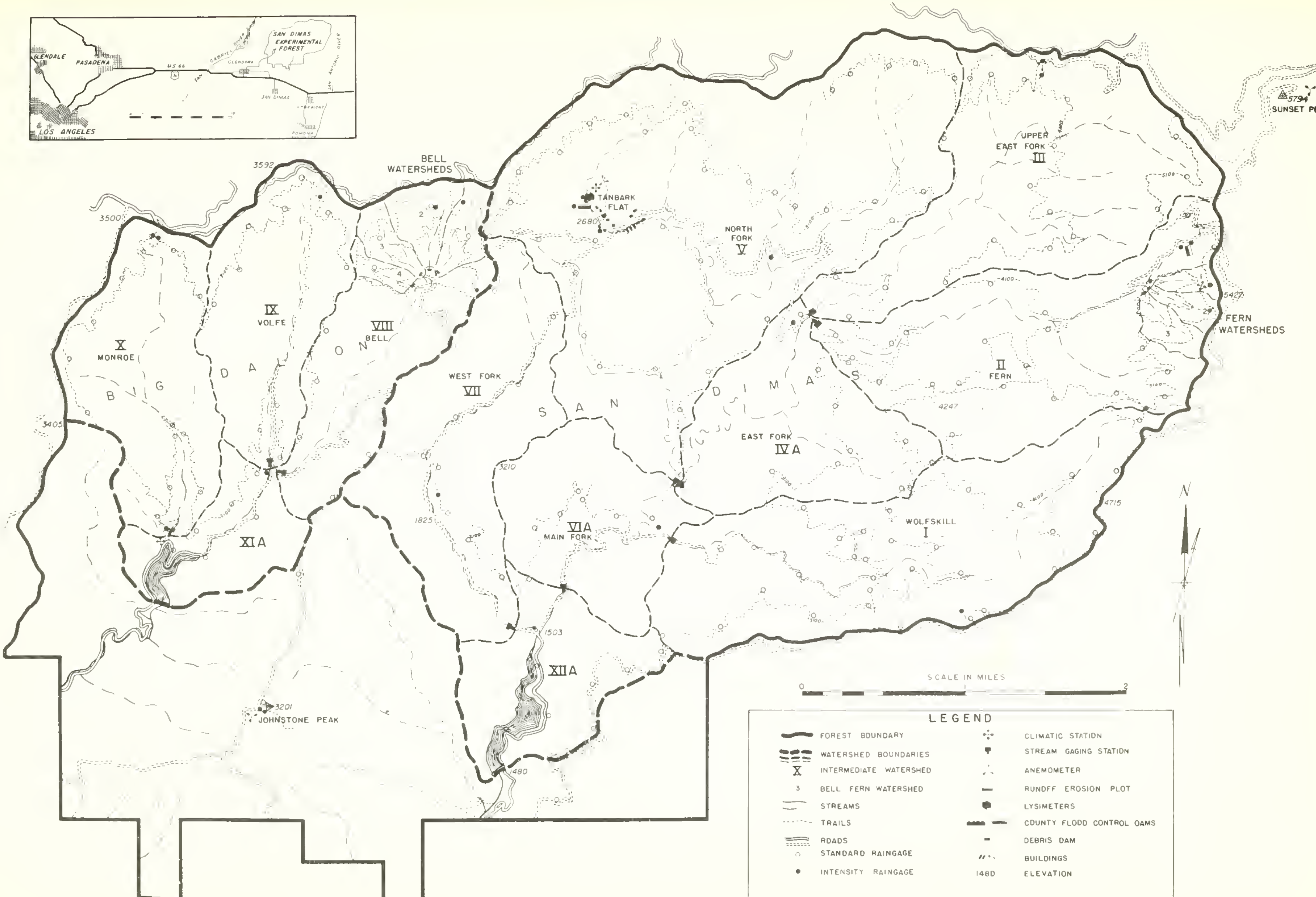
Berkeley--Agriculture

THE SAN DIMAS EXPERIMENTAL FOREST

Watershed Areas

Watershed	Drainage area Square miles	Acres	Range in elevation
		MAJOR	
San Dimas	15.75	10,080	1500-5500
Big Dalton	4.46	2,855	1700-3500
		INTERMEDIATE	
San Dimas			
I Wolfskill	2.39	1,530	1700-5200
II Fern	2.14	1,370	2600-5500
III Upper East Fork	2.14	1,370	2600-5200
IV East Fork	5.48	3,510	1900-5500
V North Fork	4.23	2,710	1900-4500
VI Main Fork	13.14	8,410	1600-5500
VII West Fork	1.72	1,100	1600-3100
Total XII (San Dimas)	15.75	10,080	
Dalton			
VIII Bell	1.36	870	1900-3500
IX Volfe	1.16	740	1900-3500
X Monroe	1.37	875	1800-3400
Total XI (Dalton)	4.46	2,855	
		SMALL	
Bell			
No. 1	0.121	77	2500-3400
No. 2	0.158	100	2500-3500
No. 3	0.097	62	2500-3400
No. 4	0.058	37	2500-3100
Total	0.434	276	
Fern			
No. 1	0.055	35	4500-5400
No. 2	0.063	40	4500-5400
No. 3	0.084	53	4500-5400
Total	0.202	128	

SAN DIMAS EXPERIMENTAL FOREST



WATER PROBLEMS IN SOUTHERN CALIFORNIA

Water is generally recognized as the most important factor affecting the existence and future growth of the great metropolitan, agricultural, and industrial developments in southern California.1/ The phenomenal growth of this region in 60 years, indicated by an increase in population from 217,000 in 1890 to 5,700,000 in 1950, has brought about serious problems of which water supply and flood regulation are paramount.

Natural conditions of climate, topography, and vegetation contribute to the severity of local water problems. Most of the region is hot and dry from May to October and subject to intense rains in other months. Rugged mountains that rise abruptly near populated and highly developed valleys are sources of floods that have caused extensive damages downstream. Brush, also known as chaparral, is the dominant vegetation on the mountains below elevations of about 5,000 feet. Open coniferous forests form the principal cover at higher elevations. During the summer seasons the vegetation, especially the chaparral, becomes very inflammable. When mountain watersheds are denuded by fire the magnitude of floods from them is sometimes greatly increased.

Water Supply Problems

Early settlers in southern California obtained water from streams and springs whose sources were the nearby mountains. Needs for greater supplies were met by digging shallow wells, some of which produced artesian flows, and by developing water-collecting tunnels and small storage reservoirs in the foothills. Later the growing demands for water made it necessary to sink deeper wells in the valleys to reach water tables lowered by the increased draft upon them. Continuing overdraft in recent years has lowered the water tables near the coast and permitted sea water intrusion in certain basins, with resultant loss of usable water. In some other localities curtailment of water use has been necessary, particularly during periods of low rainfall.

Growing water needs led to importation of water into southern California, starting in 1913. Aqueducts have been built to bring water from the eastern slopes of the Sierra Nevada and from the Colorado River, each more than 250 miles distant. These developments, made at tremendous cost, are indicative of the value of water in a region where other natural advantages abound.

Southern California now contains about 50 percent of the State's population, but its streams carry only about 2 percent of the State's water supply. In 1950 southern Californians used more than 3½ million acre-feet of water. About half of this amount was used for irrigation

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1/ Southern California is considered here to include the counties of San Luis Obispo, Santa Barbara, Ventura, Los Angeles, Orange, Riverside, San Diego, and Imperial, with a total area of 31,370,000 acres, or about 31 percent of the State of California.

in the Imperial and Coachella Valleys, and came from the Colorado River. About 70 percent of the water supply for the remainder of the region came from local watersheds. Although portions of southern California are supplied with imported water, supplies from the local mountains are relied upon in many areas.

Flood Regulation Problems

Southern California also has serious flood problems. Major floods caused by heavy winter rains usually carry large quantities of debris which greatly increases the difficulties and costs of flood regulation. This debris comes from the rugged and geologically unstable mountains where erosion of soil and rock is naturally severe. Flood flows, bulked with mud and rock, have caused losses of life, and property damages amounting to millions of dollars. Repeated experiences have shown that destruction of the vegetation on the mountains by fire may greatly increase surface runoff and erosion, thereby adding to the magnitude of floods and the damages done by them. Disturbance of the vegetation and soil by the construction of highways in the mountains also has accelerated erosion in some watersheds. Other serious consequences of floods are the siltation of reservoirs and the wastage to the sea of water that cannot be caught for use. Water-spreading, a method of replenishing underground supplies, cannot be done with flows carrying a debris load.

Downstream flood control works such as debris basins, reservoirs, large retarding basins, and channel improvements have been constructed by Federal and local agencies. More than 200 million dollars have been expended for these works. The completion of similar works that are planned will raise total expenditures for flood regulation in southern California to more than 500 million dollars.

Protection of Mountain Watersheds

Before 1892 foresighted leaders in southern California recognized the relationship of mountain watersheds to the water problem in this region. Through the efforts of these leaders several forest reserves were established between 1892 and 1907 for the primary purpose of protecting local watersheds to "insure favorable conditions of water flows" as well as the "preservation of timber for the use and necessities of citizens of the United States." These reserves later became the national forests of southern California, administered by the Forest Service of the U. S. Department of Agriculture. Thus, national recognition was given to the protection of about 3 million acres of public watershed lands in southern California.

Watershed Research

The need for information concerning the influence of watershed conditions upon water supply, floods, and erosion prompted the Forest Service to start preliminary studies in southern California about 40 years ago. The studies were continued by the California Forest and Range Experiment Station in 1927, soon after its establishment. The San Dimas Experimental Forest was set up as a center for watershed research in 1933, with the cooperation of the State of California, county and municipal agencies, conservation groups, water companies, engineers, and agriculturists.

SAN DIMAS EXPERIMENTAL FOREST

Monthly Climatic Data

Tanbark Flat Field Headquarters (Elevation 2,800 feet)

Month	Rainfall 24-year average	Evaporation 17-year[1] average	Air temperature[2] Absolute maximum		
			Absolute maximum	Absolute minimum	Mean
	------- inches -------		------- degrees -------		
October	1.2	5.8	102.0	25.5	60.5
November	2.1	3.9	87.0	29.0	53.8
December	5.7	2.5	84.5	21.5	49.1
January	4.9	2.4	80.5	18.0	46.2
February	6.0	2.4	82.0	22.0	46.7
March	4.8	3.5	80.0	24.0	48.8
April	2.4	4.2	88.0	29.0	53.4
May	0.5	5.9	99.0	28.5	57.3
June	0.1	7.1	101.0	34.0	62.6
July	T	10.1	104.0	39.0	71.5
August	0.1	10.1	106.0	38.0	72.2
September	0.3	8.4	107.0	37.5	69.5
Annual	[3]28.1	66.3	107.0	18.0	57.6

1/ Weather Bureau type evaporation pan.

2/ Air temperature for 19 years of record.

3/ 24-year average based on San Dimas Experimental Forest records 1933 through 1952, and Los Angeles County records for the 5-year period 1928 through 1932.

SAN DIMAS EXPERIMENTAL FOREST

Annual Climatic Data

Tanbark Flat Field Headquarters (Elevation 2,800 feet)

Year	Rainfall	Evaporation[1]	Air temperature: Absolute maximum	Air temperature: Absolute minimum	Air temperature: Annual mean
	inches	inches	degrees	degrees	degrees
1933-34	24.4		104.0	30.0	60.9
1934-35	34.8		96.0	25.0	56.8
1935-36	24.3	67.6	101.5	29.0	57.7
1936-37	43.8	67.9	98.0	19.0	57.9
1937-38	48.1	65.8	101.0	30.0	58.7
1938-39	27.0	72.6	100.5	22.0	57.8
1939-40	22.0	77.7	99.5	30.5	59.4
1940-41	48.2	61.4	95.5	32.0	58.1
1941-42	16.7	70.0	99.0	25.0	56.3
1942-43	45.2	70.1	101.5	26.5	58.1
1943-44	33.5	59.8	103.0	27.0	56.1
1944-45	29.7	59.9	97.0	26.5	55.3
1945-46	27.0	63.4	100.0	27.0	58.0
1946-47	27.6	63.5	100.5	27.0	58.3
1947-48	15.8	70.0	103.5	24.0	56.2
1948-49	16.9	64.7	100.0	18.0	54.5
1949-50	20.8	64.1	107.0	22.0	57.5
1950-51	11.5	72.4	102.0	23.0	59.6
1951-52	41.1	57.5	98.5	22.5	56.7
Average[2]	[3] 29.4	66.4	107.0	18.0	57.6

1/ Weather Bureau type evaporation pan.
2/ Annual average or range.
3/ 19-year average based on San Dimas Experimental Forest records.

THE SAN DIMAS EXPERIMENTAL FOREST

The San Dimas Experimental Forest covers 17,000 acres within the Angeles National Forest, and is situated on the southern slope of the San Gabriel Mountains in the San Dimas and Big Dalton drainages. Selection of the research area was based upon the following features: (1) It is representative of much chaparral-covered mountain land in southern California; (2) it is separated from the main San Gabriel Mountain mass by deep canyons which minimize the possibilities of underground water movement into the area; (3) the two major drainages contain a number of tributary watersheds of intermediate size, and many small watersheds, which can be studied; (4) the vegetation includes different chaparral associations as well as different ages of cover; and (5) the existence of San Dimas and Big Dalton dams, built and maintained by Los Angeles County Flood Control District, provides measuring controls for the major drainages.

Research Objectives

Watershed research on the San Dimas Experimental Forest, and related studies conducted elsewhere in southern California, have two broad objectives. The first is to determine how watersheds function: what happens to the precipitation, and how water and soil movement are influenced by conditions of vegetation, soil, geology, and topography. The second is to develop methods of watershed management that will ensure the maximum yield of clear, usable water with the minimum of flood runoff and soil erosion. Most research on the San Dimas area, thus far, has been directed toward the first objective.

Study of Watershed Functions

The following studies are designed to learn about watershed functions.

1. Climate--Climatic records, including air temperature, relative humidity, wind direction and velocity, and evaporation, have been collected at seven stations within the San Dimas Forest at altitudes ranging from 1,500 to 5,200 feet. Measurement of precipitation on the area was provided for originally by a network of 310 rain gages. Most of the gages were placed on contour trails. Supplementary studies were made to determine suspected errors in the rainfall sampling system. The results indicated that rain gages, tilted and oriented normal to watershed slopes, sampled the rainfall more accurately than the original network of vertical gages. Accordingly the first sampling system was replaced in 1950 with a network of 120 tilted gages. Fifteen gages in the new network are instruments which record both the amount and intensity of rainfall.

2. Streamflow--Measurements of runoff from the two major drainages are obtained from records of flow into San Dimas and Big Dalton reservoirs. These major watersheds have been divided into 10 tributary "intermediate watersheds" and contain two groups of small watersheds, the Bell and Fern series.

Each intermediate and small watershed contains a gaging station at its mouth. The gaging stations for the intermediate watersheds consist of three units--a 90-degree V-notch weir to measure low clear water flows; a steel San Dimas type flume to record ordinary storm flows that carry some debris; and a large concrete flume to record high flood flows. Two of the large flumes are Parshall type structures, one contains a step-type gaging section of U. S. Geological Survey design, and seven are San Dimas type flumes. Stream gaging stations for the small watersheds consist of a V-notch weir and a San Dimas flume. All stations are equipped with continuously recording instruments. Difficulties encountered in measuring debris-laden flows made it necessary to develop the San Dimas flume. This type of flume has proven satisfactory for the measurement of such flows.

3. Watershed Erosion--Measurements of the amount of material eroded from the major watersheds are obtained by periodic surveys of sediments deposited in San Dimas and Big Dalton reservoirs. Measurements of material eroded from the Bell and Fern small watersheds are made in concrete-lined basins at the mouth of each watershed.

4. Surface Runoff and Erosion--Studies of surface runoff and erosion on slopes, as differentiated from entire watersheds, are being made on 1/40-acre plots. Each plot is equipped to record runoff synchronously with rainfall, and to catch all eroded mater al.

The nine Fern plots are situated on a 50 percent slope at an elevation of 5,000 feet in a cover of live oak. The vegetation had been unburned for more than 50 years prior to 1938 when a fire swept over this area. Surface runoff and erosion had been negligible before the vegetation was burned, but both were increased markedly for three years following the fire. After that the re-growing cover of native plants again protected the soil, and surface runoff and erosion became negligible.

The nine Tanbark plots are situated on a 35 percent slope at an elevation of 2,800 feet in a dense chaparral cover unburned since 1919. There has been practically no surface runoff or erosion on these plots. The brush was removed from six of the plots in 1952 and replaced with grass. Runoff and erosion measurements are being continued to study the effects of the vegetation change. In 1952 three more plots were established in a Coulter pine plantation near the Tanbark chaparral plots.

5. Evapo-transpiration--Evaporation of water from vegetation and soil, including that transpired by the plants, is being studied in soil-filled tanks called lysimeters. The San Dimas lysimeter installation near Tanbark Flat consists of 26 concrete tanks, each 10.5 x 21 feet in area and 6 feet deep, with surface and bottom slopes of 5 percent. These large lysimeters are augmented by more than 100 smaller metal tanks for supplementary studies. All are filled with a uniform mixture of local soil. One large lysimeter is kept bare, and several species of bunchgrass are planted in two others. Groups of from two to five other lysimeters are occupied by pure stands of five shrubs and Coulter pine, all native to these mountains. Runoff and seepage are caught and measured in tanks set in a concrete tunnel underground. Electric water level transmitters permit the rates of runoff and seepage to be recorded on clock-driven charts. Soil moisture at various depths in the lysimeters is measured frequently with electrical soil moisture instruments.[2] The

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2/ The fiberglas electrical soil-moisture instrument, developed on the San Dimas Forest, consists of a soil unit buried permanently at the point where moisture measurement is required, and a portable meter to measure electrical resistances of elements within the soil unit. Soil moisture and temperature are determined from these measurements.

measurements make it possible to determine water movement into and through the soil as well as evaporative losses from the soil and plants growing in the lysimeters.

To study effects of unnatural soil drainage and restricted root development upon the growth of plants and their use of water in the large "confined" lysimeters, additional records of surface runoff and soil moisture are obtained from five "unconfined" lysimeters. The latter consist of pits $17\frac{1}{2}$ feet square and 7 feet, filled with lysimeter soil and planted to five of the species growing in the "confined" lysimeters.

6. <u>Disposition of Rainfall</u>--Studies were started in 1952 to determine the disposition of rainfall under covers of grass, brush, and pine. The work is being conducted on the 12 Tanbark runoff plots described above. ~~Two~~ Three series of electrical soil moisture units are installed in the center plot of each triplicate set, at regular depth intervals from $1\frac{1}{2}$ inches to bedrock which, in some places, is more than 16 feet below the surface. These units and other instruments make it possible to determine the total precipitation reaching the soil, the quantities of surface runoff, infiltration, and evapo-transpiration, and the amount of precipitation which percolates through the soil to the underlying rock. The results obtained here will aid in future investigations concerning the management or change of vegetation on entire watersheds.

7. <u>Physical Features</u>--Inventories and maps have been prepared of the vegetation, soil, geology, and topography of the Forest. Analysis of streamflow and erosion data for each of the Forest watersheds is evaluating the influence of these physical features, and the climate, upon water flow and soil movement.

<u>Study of Watershed Management</u>

Studies of watershed management include tests of the following improvement measures.

1. <u>Changes in Watershed Vegetation</u>--Studies of rainfall disposition and soil movement on slopes under several types of vegetation have been started on the runoff plots described above. Behavior of the Bell and Fern small watersheds is being observed for a period of years, after which the vegetation on some of them will be changed. Measurements of water yield, flood runoff, and soil movement from the treated watersheds will then be compared with similar measurements made on the watersheds left undisturbed. Vegetation on the Fern watersheds had been unburned for more than 50 years prior to 1938 when a fire swept over this area. Records obtained before and after this accidental treatment showed that storm runoff and erosion were increased greatly for three years after the fire. Vegetation on the Bell watersheds has not been burned since 1919.

2. <u>Management of Stream Bottom Vegetation</u>--It is known that alders, willows, sycamores, and other plants found in stream channels use much water. Complete removal of this vegetation would eliminate water use by the plants, but the loss of shade would increase evaporation from the water and soil. Studies are to be made to determine the species and amount of vegetation that will result in the minimum loss of water from stream bottoms and still provide

bank protection during high flows. Some of the studies in this investigation will be conducted in lysimeters. Others will require altering the vegetation in stream channels where records of streamflow can be compared for periods before and after treatment.

3. Engineering Improvements--Studies are to be made of the effects of small dams and retaining walls built in stream channels on total streamflow yield and flood peaks, as well as the stability of soil and rock material in the channels and on adjacent slopes. Effects of the engineering improvements can be determined by comparing hydrologic records from treated and untreated watersheds before and after the improvements are made.

Corollary Watershed Research

Other Forest Service watershed studies have been completed or are in progress elsewhere in southern California. Among the completed studies are: (a) erosion control methods for mountain roads, (b) the "first aid" seeding of burned watersheds, and (c) an appraisal of flood and erosion damages resulting from watershed fires. Now in progress are studies of soil movement on watershed slopes and of vegetation treatment methods designed to reduce this movement. These studies are being carried on in cooperation with the California Institute of Technology in laboratories of that institution, and on field plots in the Los Angeles River watersned.

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Watershed research conducted on the San Dimas Experimental Forest is designed to serve the interests of many agencies, local, State, and Federal, and all others that are concerned with the management of wildlands in southern California for the production of usable water and prevention of damaging floods. Since many of the findings have application in other places, the work of the San Dimas Forest has values transcending its local benefits.

ANNOTATED BIBLIOGRAPHY OF PUBLICATIONS ON PHASES OF WATERSHED MANAGEMENT RESEARCH ON THE SAN DIMAS EXPERIMENTAL FOREST

January 1, 1953

Precipitation

An analysis of precipitation measurements on mountain watersheds, H. G. Wilm, A. Z. Nelson, and H. C. Storey. June 1939. Monthly Weather Rev. 67: 163-172.

Analysis was made of precipitation measurements from gage systems on mountainous watersheds to determine reliability of computed rainfall averages and to decide if the original gage distribution provided accurate sampling of the watershed rain catch. The requirements for accuracy of averages were modified in inverse relation to size and importance of storms. A simple average of well-distributed gage readings will agree within close limits with rain catch computed from isohyetal maps.

Topographic influences on precipitation, H. Storey. 1939. Pacific Sci. Cong. 6th, Berkeley, Stanford, and San Francisco, California. Proc. 4: Soil Resources 985-993. July 1941.

Isohyetal maps show distribution of annual precipitation successively State-wide, then over Los Angeles County, and finally in detail on the San Dimas Experimental Forest. Variations in precipitation are explained by reference to topographic influences.

A comparative study of rain gages, H. C. Storey and E. L. Hamilton. 1943. Amer. Geophys. Union Trans. Pt. I: 133-141.

Rainfall was caught in several types of rain gages placed on hillsides exposed in three different directions. Gage catches were compared with the catch of rain on adjacent large concrete surfaces laid parallel to and at ground level. Standard rain gage catch was found to be significantly closer to that of the ground surface if the gage was tilted normal to that surface rather than being exposed vertically.

#-Publications marked with (#) were available for distribution on January 1, 1953.

Rainfall-measurement as influenced by storm-characteristics in southern California mountains, E. L. Hamilton. 1944. Amer. Geophys. Union Trans. Pt. III: 502-518.

Preliminary records indicated the need for supplementary research on rainfall characteristics and storm behavior. From observations of 173 storms which produced 251 inches of rain over a 7-year period, a representative sample of 60 storms was subjected to detailed study. Records from a novel instrument, a "vectopluviometer" or directional rotating rain gage, permitted the development of directional storm patterns and computation of the angle of inclination of rainfall from the vertical which could be correlated with wind velocity and rainfall intensity. The study indicated that southern California storms follow definite patterns which can readily be classified into groups having definite characteristics. The interpretation of these group characteristics is necessary to determine the proper distribution and exposure of rain gages on mountain watersheds to insure the accurate measurement of precipitation.

A comparison of vertical and tilted rain gages in estimating precipitation on mountain watersheds, H. C. Storey and H. G. Wilm. 1944. Amer. Geophys. Union Trans. Pt. IV: 518-523.

Precipitation on a 100-acre watershed within the San Dimas Experimental Forest was measured with a network of rain gages at 22 sites. The gages were paired at each location, one being installed vertically and the other tilted normal to the slope. Analysis of a 4-year record showed that the better measure of total rainfall on this steep mountainous watershed was obtained by the use of the tilted gages.

A system for the synchronization of hydrologic records, E. L. Hamilton. 1943. Amer. Geophys. Union Trans. Pt. II: 624-631.

Describes how recording instrument charts on the San Dimas Experimental Forest are kept chronologically in step with each other by electrical time impulses sent hourly by a clock at the Tanbark Flat Field Headquarters. Several widely distributed tipping-bucket rain gages also record synchronously by sending electric impulses over similar circuits to a central laboratory where, after amplification through relays, rainfall increments of 0.02 inch are recorded on a strip chart having a separate space for each gage.

The San Dimas tipping-bucket rain-gage mechanism, E. L. Hamilton. February 1947. Amer. Met. Soc. Bul. 28(2): 93-95.

Description of an inexpensive mechanism for the measurement of rainfall intensities. The unit can be installed in a standard 8-inch rain gage and the rainfall rates transmitted electrically to a suitable recorder. Featured are frictionless and non-corrodible electrical contacts.

The problem of sampling rainfall in mountainous areas, E. L. Hamilton. 1949. (In Proc. Berkeley Symposium on Mathematical Statistics and Probability held August 1945 and in January 1946.) p. 469-475. University of California Press.

On the San Dimas Experimental Forest in southern California an extensive distribution of 200 rain gages was made to determine variations in amount of rainfall on different slopes and at different altitudes in connection with watershed management research. Preliminary analyses indicated that although the arrangement of the sampling units was adequate, the technique of measuring rainfall might be subject to question. A device called the "equivalent facet" was selected as the basis for revising the rainfall-sampling network. In this system the placement of the rain gages was adapted to the terrain on an areal basis.

Rainfall interception by chaparral in California, E. L. Hamilton and P. B. Rowe. 1949. U. S. Dept. Agr., Forest Service, in cooperation with Calif. Dept. Nat. Resources, Div. Forestry. 43 p., 16 illustrations.

Determination of rainfall not reaching the soil, called interception loss, is important in the solution of water supply and flood control problems. Loss of rainfall through interception by shrub type vegetation was measured at three locations in California. On one area in the Sierra Nevada foothills in central California 81 percent of an average annual rainfall of 42 inches reached the soil as throughfall and drip from the brush cover, 14 percent reached the soil as flow down the stems, and 5 percent was lost before reaching the soil as direct evaporation from the vegetation. On another area in the same vicinity with a different type of brush cover, 62 percent of an average annual rainfall of 38 inches reached the soil as throughfall, 30 percent as stemflow, and 8 percent was lost by interception. In the San Gabriel Mountains of southern California, 81 percent of an average annual rainfall of 22 inches reached the soil as throughfall, 8 percent as stemflow, and 11 percent was lost by interception. Amounts of throughfall, stemflow, and interception loss varied directly with storm size. However, the proportion of interception loss varied inversely with storm size. An equation of interception loss for storms of more than 0.3 inch is given for each study area. The interception process through the course of characteristic storms is discussed.

San Dimas rainfall and wind velocity recorder, E. L. Hamilton and L. A. Andrews. 1951. Amer. Met. Soc. Bul. 32(1): 32-33.

A vertical drum waterstage recorder was modified for operation with an electromagnetically operated pen. It is suitable for recording electrical impulses induced by tipping bucket rain gages or anemometers. The recorder will run for 8 days, and 75 lineal feet of impulses can easily be recorded on a 12 x 18 inch standard chart at a speed of 4-1/2 inches an hour.

Shock resistant lucite graduate, E. L. Hamilton, L. F. Reimann, and L. A. Andrews. September 1952. California Forest and Range Experiment Station Misc. Paper No. 9, 2 p., 1 figure.

Describes the construction of a durable plastic graduate designed to measure rain gage catch.

Streamflow

Measurement of debris-laden streamflow with critical-depth flumes, H. G. Wilm, John S. Cotton, and H. C. Storey. September 1938, Amer. Soc. Civ. Engin. Trans. 1[illegible](9): 1[illegible]-1[illegible]8

Field experiments were conducted for the purpose of adapting existing gaging stations to measurement of loaded flows. Several types of flumes were tested including a modification of the Parshall flume, trapezoidal flumes, and rectangular flumes with sloping floors. Following these experiments, a control flume of the third type was developed functioning as a broad crested weir in which water depths are measured at a point downstream of the "critical" section. Supercritical water velocities kept the flume scoured clean, and it thus could be rated to give greater accuracy of loaded streamflow than other existing devices.

A nomograph for the integration of streamflow records, Paul B. Johnson October 1943. Civ. Engin. 13(10): 494-495

The conversion of streamflow rates to total volume of water for given periods of time was facilitated by a nomograph which also contained a means for the ready determination of the decimal point.

Velocity-head rod calibrated for measuring stream flow, H. G. Wilm and H. C. Storey. November 1944. Civ. Engin. 14(11): 475-476

The measuring stick described was developed to facilitate the gaging of small volumes of streamflow containing varying amounts of bed load and silt where standard measuring gages are not provided. It can be used even when the water carries considerable amounts of debris.

The San Dimas water-stage transmitter, E. A. Colman and E. L. Hamilton. June 1944. Civil Engin. 14(6): 257-258.

Description of water level indicating instrument designed by members of the Experimental Forest staff which has been used successfully on research installations for the measurement of liquid flow.

Instrument facilitates setting of weir zero values, Paul B. Johnson and Herbert C. Storey. November 1948. Civ. Engin. 18(11): 41-42

The instrument described in this paper was designed for rapid and easy determination of the zero value on 90-degree V-notch weirs. A similar instrument could be used for weirs of different angles. It is simple to make, rugged, highly accurate, and requires little skill to use.

Geology

Geology of the San Gabriel Mountains, California, and its relation to water distribution, H. C. Storey. 1948. U. S. Dept. Agr., Forest Service, in cooperation with Calif. Dept. Nat. Resources, Div. Forestry 19 p., 8 illustrations, colored map. (Separate maps available for distribution.)

Description of areal geology, structure, and history of the San Gabriel Mountains. Discussion of the manner in which geology influences the hydrology of a watershed from two viewpoints, (1) effect of land forms on the rainfall pattern, (2) the effect of structural fractures permitting water storage in rock formations, and the faults and dikes that determine the location of streams, springs, and underground basins.

<u>The dependence of field capacity upon the depth of wetting of field soils</u>, E. A. Colman. July 1944. Soil Sci. 58(1): 43-50.

Irrigation of field plots and subsequent soil moisture sampling is sometimes used to determine the field capacity, which is the maximum amount of moisture the soil can retain against drainage. This paper points out the errors which may arise from such determinations when based upon too shallow depths of penetration of the irrigation water.

<u>Some improvements in tensiometer design</u>, E. A. Colman, W. B. Hanawalt, and C. R. Burck. May 1946. Amer. Soc. Agron. Jour. 38(5): 455-458.

Description of a porous clay cup and manometer fittings for use in the study of water movement in the soil. Drawing of instrument.

<u>A laboratory study of lysimeter drainage under controlled soil moisture tension</u>, E. A. Colman. November 1946. Soil Sci. 62(5): 365-382.

A cylindrical column of soil 6 inches in diameter and 6 feet long was irrigated and drained four times, each time with a different moisture tension maintained at or beneath its base. The study showed it is possible to control seepage rate and the drained moisture content of a deep soil column by controlling the moisture tension maintained at the base of the soil.

<u>The place of electrical soil-moisture meters in hydrologic research</u>, E. A. Colman. December 1946. Amer. Geophys. Union Trans. 27(VI): 847-853.

Many kinds of hydrologic research can be facilitated by the use of direct reading electrical soil moisture meters. These meters can be used to measure accretions and losses of soil moisture and the direction and rate of soil-water movement, they can provide a means of controlling the time and amount of irrigation on crop land, and they can discern freezing and melting conditions of water in soil and snow. A meter has been developed by the California Forest and Range Experiment Station to meet these specifications.

<u>Manual of instructions for use of the fiberglas soil-moisture instrument</u>, E. A. Colman. October 1947. Revised June 1952. California Forest and Range Experiment Station. Multilithed. 20 p.

This manual gives a detailed description of the fiberglas and the ohmmeter units of the electrical soil-moisture instrument. The method of installation of the soil units, the method of using the ohmmeters, and the necessary steps in standardizing and calibrating the soil units are fully discussed.

<u>A laboratory procedure for determining the field capacity of soils</u>, E. A. Colman. April 1947. Soil Sci. 63(4): 277-283.

It was found that if small soil blocks were drained on a porous ceramic cell under a moisture tension of one-third atmosphere, the moisture retained in the blocks could be related empirically to the field capacity of the same soils determined under natural field conditions. A satisfactory degree of consistency was observed in the relationship between one-third atmosphere moisture percentage and field capacity. It is suggested that the procedure described may provide a convenient and rapid way of making an indirect determination of field capacity. Details of the design of the ceramic cell and moisture tension control equipment are given.

Soil surveying on wildlands: the problem and one solution, E. A. Colman. 1948. Jour. Forestry 46(10): 755-762.

Discussion of the difficulties involved in trying to make an intensive soil survey of a mountain watershed on the San Dimas Experimental Forest using the type of survey ordinarily conducted on agricultural lands. Description of a soil survey of the Angeles National Forest planned to classify and map wildland soils on the basis of their hydrologic characteristics.

The fiberglas electrical soil-moisture instrument, E. A. Colman and T. M. Hendrix. 1949. Soil Sci. 67(6): 425-438.

An instrument devised to measure soil moisture in place consists of a soil unit which includes a monel screen fiberglas cloth sandwich sensitive to soil moisture and a thermistor for temperature detection, and a meter unit which is a battery-powered alternating current ohmmeter. Relationships are indicated for (1) temperature-induced changes in resistance for various soils, (2) freezing and thawing in soils, and (3) moisture tensions. Soil moistures can be measured from pore-space saturation to well below the wilting point.

Calibration of fiberglas soil-moisture units, T. M. Hendrix and E. A. Colman. 1951. Soil Sci. 71(6): 419-427.

Units calibrated in field soil over a period of 15 months showed no indication of drift in relation between soil moisture content and soil unit resistance. Field and laboratory calibration are in good agreement when laboratory calibration is made in a natural soil core, whereas laboratory calibration made in granulated soil repacked to field apparent density does not agree with field calibration.

Ecology

The sample plot as a method of quantitative analysis of chaparral vegetation in southern California, Jerome S. Horton, October 1941. Ecology 22(4): 457-468.

In order to analyze quantitatively the density of vegetation occurring on a series of small chaparral-covered watersheds, 225 random milacre quadrats were measured. The data were segregated to show vegetative composition. Frequency distributions of vegetative densities were shown to be statistical curves other than normal. Size of plots had no significant influence on the results.

The wood rat as an ecological factor in southern California watersheds, Jerome S. Horton and John T. Wright. July 1944. Ecology 25(3): 341-351.

The wood rat is one of the most abundant rodents of the chaparral. With the exception of the heavy use of acorns at elevations above 4,500 feet the feeding habits of this animal do not exert any appreciable influence on chaparral cover because leaf and stem material, rather than seeds of the common chaparral shrubs, forms the bulk of its diet.

Stem surface area determination of nomograph, E. L. Hamilton. January 1949. Jour. Forestry 47(1): 57.

An alignment chart illustrated here cuts out many computations formerly needed for determination of the area of a vegetative stem.

Checklist of the vertebrate fauna of the San Dimas Experimental Forest, J. T. Wright and J. S. Horton, November 1951. California Forest and Range Experiment Station Misc. Paper No. 7. 15 p. Revision of 1946 mimeographed list.

The species comprising the vertebrate fauna of the San Dimas Experimental Forest are listed and very briefly discussed.

Trees and shrubs for erosion control in southern California mountains, Jerome S. Horton. 1949. U. S. Dept. Agr., Forest Service, in cooperation with Calif. Dept. Nat. Resources, Div. Forestry. 72 p.

The problem of erosion control planting in the mountains of southern California is discussed in this bulletin. Fifty-eight species of trees and shrubs are included and their place in erosion control outlined. A section is also included on methods of planting.

Effect of weed competition upon survival of planted pine and chaparral seedlings, J. S. Horton. June 1950. California Forest and Range Experiment Station Research Note No. 72. 6 p.

The effect of competition between annual plants and planted trees and shrubs was studied in 1944 on the San Dimas Experimental Forest in southern California. These plantings were made in an area adjacent to the San Dimas lysimeters to develop the proper method of establishing the desired vegetation. The study has shown that under conditions of summer drought, good survival of planted stock is dependent upon removal (at least during the first season) of competing annual grasses and herbs.

Plant Physiology

A rapid method of separating seed of chamise (Adenostoma fasciculatum) from the duff, E. C. Stone and J. Holt. January 1950. Ecology 31(1): 149.

In attempting to obtain large quantities of seed from the duff, various methods of separation by screening and floating were unsuccessful. A satisfactory procedure, making use of a small hand-operated "Clipper" seed separator, was worked out.

Water absorption from the atmosphere by plants growing in dry soil, E. C. Stone, F. W. Went, and C. L. Young. May 19, 1950. Science 111(2890): 546-548.

The ability of Coulter pine to survive long periods of drought on soils at or below the wilting point was investigated to determine the possibility of the plants taking up water from the atmosphere. A 2-year old Coulter pine seedling, growing in a sealed container to which no water had been added for 10 months, was sealed in a chamber which enclosed the vegetative portion of the plant and in which the initial humidity could be adjusted. Measurements with an Amico-Dunmore temperature-humidity sensing unit indicated a lowering of the humidity in the chamber from 98 to around 90 percent in 3 to 9 hours.

The effect of fire on the germination of the seed of Rhus ovata Wats, E. C. Stone and G. Juhren. 1951. Amer. Jour. Bot. 38(5): 368-372.

High temperature was found to be the factor responsible for fire-induced germination of seed of *Rhus ovata*. These temperatures rupture the second seed coat, which then allows water to reach the embryo causing the seed to germinate.

Evapo-Transpiration

The San Dimas lysimeters: instruments for evaluating the water economy of chaparral vegetation... Part 1--The lysimeter installation and research program. Part 2--The relative performance of four types of lysimeters, E. A. Colman and E. L. Hamilton. December 1947. California Forest and Range Experiment Station Research Note No. 47. 33 p.

The San Dimas lysimeters were established for the purpose of comparing the water economy of a number of chaparral plant species that are important in the management of southern California mountain watersheds. The installation includes five types of lysimeters and a climatic station located on an area of uniform topography. The same kind of soil has been used and uniformly placed in all the lysimeters in order to minimize soil variability. Rain, runoff, and seepage are measured, and weighing or periodic soil moisture sampling is used to study evaporative water losses. Comparisons of the soil water cycle, annual evapo-transpiration values, and yield of annual grass have been made between four types of lysimeters which are included in the San Dimas lysimeter installation. These lysimeters exhibit differences in depth, size, surface drainage, and seepage conditions. Some have been maintained bare, and some have supported stands of Bromus mollis.

Hydrology

Some aspects of watershed management in southern California, San Dimas Staff. April 1951. California Forest and Range Experiment Station Misc. Paper No. 1. 29 p.

Watershed management problems in southern California and the research program carried on by the California Forest and Range Experiment Station to aid in solving these problems are first discussed briefly. Second, the climate, geology, soils, and vegetation of the southern California mountains are described. Third, some of the results of the Station's hydrologic research are given.

Disposition of rainfall in two mountain areas of California, P. B. Rowe and E. A. Colman. December 1951. U. S. Dept. Agr. Tech. Bul. No. 1048. 84 p., 30 illus.

This publication reports a study seeking to evaluate and explain some of the hydrologic processes involved in the disposition of rainfall in two mountain areas. One area is near North Fork in the Sierra Nevada of central California, and one is in the San Dimas Experimental Forest in the San Gabriel Mountains of southern California.

The first part of the study was made on hillside plots in forest (ponderosa pine) and brush types of the two areas. These studies showed that annual burning of the vegetation cover, although reducing interception loss, did not appreciably affect total evaporation-transpiration loss. It did reduce the infiltration capacity of the soil, thereby increasing surface runoff. The reduced interception loss resulted in increased water yield (surface runoff plus seepage), but this increase was achieved by greatly increased surface runoff and erosion, and correspondingly reduced underground water yields. Removing the vegetation, trenching to prevent root intrusions, and maintaining a bare soil surface on the brush plots eliminated all interception and transpiration loss. Total evaporation loss was reduced but as in the case of annual burning, surface runoff and erosion was greatly increased.

During the long dry period of each summer, the bare soils lost appreciable quantities of water from all depths, but drying was slower and less complete in deep than in shallow soils. Total water yield was greatest from the plots with bare soil. However, underground yield was greatest from plots with natural vegetation.

The second part of the study was carried on in Monroe Canyon, a typical 875-acre brush-covered watershed of the San Dimas Experimental Forest. Average annual rainfall during the 2-year period of the study (1943-44 and 1944-45) was about 31.0 inches. Interception loss averaged about 2.4 inches per year and evaporation-transpiration, including riparian water loss, averaged 10.8 inches per year. Nearly 18.0 inches of rainfall was unaccounted for by the evaporative loss, but of this amount only about 4 inches appeared as streamflow. Thus more than three times as much water appears to have been yielded from the watershed as underground flow than as streamflow.

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Descriptive article illustrating experimental installations and giving general summaries of results during six years of operation.

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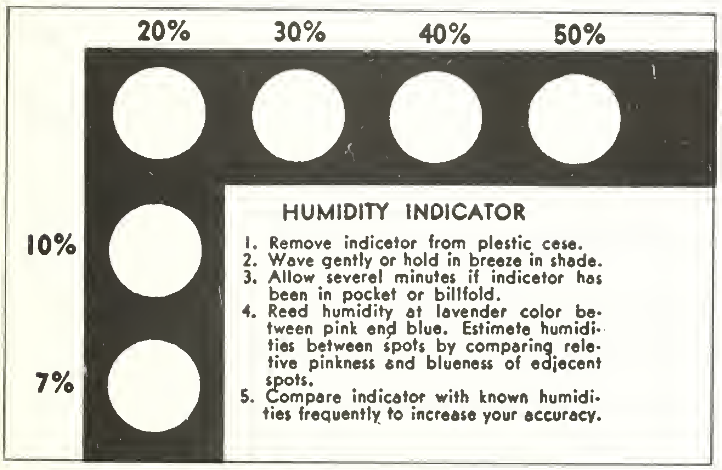
U. S. DEPARTMENT OF AGRICULTURE

MISCELLANEOUS
PAPER No. 12
MAY 5, 1953

A POCKET TYPE HUMIDITY INDICATOR FOR USE IN FIRE PREVENTION AND CONTROL

By
Clive M. Countryman

Humidity is often an indicator of the probability of fires starting and is an important element affecting the behavior of fires that do start. Knowledge of the relative humidity is thus important in both fire prevention and control activities. It is now possible to get a reasonably accurate estimate of relative humidity under field conditions with a pocket-sized humidity indicator designed by the Station's fire research staff.



Easy to handle and inexpensive, the indicator is in the form of a $2\frac{1}{2}$ by $3\frac{1}{2}$-inch card. The card is carried in a transparent plastic case which protects it from excess moisture, dirt and grease.

Six spots on the card are treated with cobalt chloride solutions, differing in concentration for each spot. The spots change from pink to blue as humidity decreases and the reverse when it increases. The color changes are not abrupt, but shade gradually from intense blue or pink through lighter shades and mixtures of these two colors.

When the relative humidity corresponds with any one of the six values shown, the color of the corresponding spot is lavender. If the humidity is higher than that shown for a spot, the color will be on the pink side of lavender; if lower, it will be on the blue side.

Relative humidity can usually be estimated from the card within 5 to 10 percent of actual humidity without other aids. Precision can be increased by practice in reading the card and associating color variations with known humidities.

Information on sources of supply may be had from California Forest and Range Experiment Station. For those interested in procuring from their own local sources, specifications for preparation of the solutions may be had on request to the Station.

The California Forest and Range Experiment Station is maintained at Berkeley in cooperation with the University of California.

Agriculture--Berkeley

SPECIFICATIONS FOR MAKING COBALT CHLORIDE HUMIDITY INDICATORS

The following specifications are intended to provide the essential information for those interested in making the cobalt chloride humidity indicators described in a paper released by the California Forest and Range Experiment Station1/.

Preparation of the Solutions

Solution concentration for the six humidity spots used on the card are given below:

Relative humidity	Grams of cobalt chloride per cc of water
7	0.0023795
10	0.0190360
20	0.0713850
30	0.1261135
40	0.1784625
50	0.2308115

Crystalline cobaltous chloride ($COCl_2 . 6H_2O$) of laboratory grade and distilled water should be used in making the solutions.

Selection of Paper

The solution concentrations were selected to give a lavender color reaction at the indicated humidity when used on 80-pound blotting paper of good quality. Other absorbent materials may be used; however, the color reactions will vary somewhat with the weight and absorbency of the impregnated material.

Application of the Solutions

The blotting paper should be at a very low moisture content, preferably oven dry, when the solution is applied. A small tube of glass, metal, or plastic, is most satisfactory for application of the solutions. Allow the tube to touch the paper so that the solution flows on, since considerable color variation often results if the solution is applied by drops. For large scale production, constant humidity and drying conditions during the manufacturing process are essential if exact uniformity among the indicators is desired.

1/ Countryman, C. M., A pocket type humidity indicator for use in fire prevention and control (Misc. Paper No. 12). Berkeley, California May 1953.

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MISCELLANEOUS PAPER No. 13
MAY 28, 1953

SUPPLEMENT TO CHECKLIST OF THE VERTEBRATE FAUNA OF SAN DIMAS EXPERIMENTAL FOREST

By John T. Wright and Jerome S. Horton

For the past several years H. L. Cogswell, University of California Department of Zoology, has been making intensive studies of the bird populations in the chaparral formation of the San Dimas Experimental Forest. During this period he has recorded many species not included in the publication "Checklist of the Vertebrate Fauna of San Dimas Experimental Forest," Miscellaneous Paper No. 7, November 1951. These species are listed below with brief notes as to their habitat and occurrence. No specimen of any of these species is included in the Experimental Forest collection.

The California Forest and Range Experiment Station is maintained by the Forest Service, U. S. Department of Agriculture, in cooperation with the University of California, Berkeley, California.

Agriculture--Berkeley

ADDITIONAL MAMMALS FOUND ON THE SAN DIMAS EXPERIMENTAL FOREST

RABBITS

Brush Rabbit (*Sylvilagus bachmani*)
Fairly common in chaparral.

ADDITIONAL BIRDS FOUND ON THE SAN DIMAS EXPERIMENTAL FOREST

DUCKS, etc.

Pintail (*Anas acuta*)
Migrant; Big Dalton Reservoir.

VULTURES, HAWKS, and EAGLES

Swainson Hawk (*Buteo swainsoni*)
Migrant.

OWLS

Pygmy Owl (*Glaucidium gnoma*)
Rare resident.

Long-eared Owl (*Asio otus wilsonianus*)
Occasional resident

SWIFTS and HUMMINGBIRDS

Vaux Swift (*Chaetura pelagica*)
Occasional migrant.

Black Swift (*Nephoecetes niger*)
Rare summer visitor; perhaps nesting in East Fork San Gabriel Canyon.

Costa Hummingbird (*Calypte costae*)
Abundant summer resident; open chamise-chaparral where black sage (*Salvia mellifera*) is abundant.

Rufous Hummingbird (*Selasphorus rufus*)
Common migrant.

Allen Hummingbird (*Selasphorus sasin*)
Occasional migrant.

Calliope Hummingbird (*Stellula calliope*)
Common migrant.

PERCHING BIRDS - FLYCATCHERS

Traill Flycatcher (*Epidonax traillii*)
Occasional migrant.

Wright Flycatcher (*Epidonax wrightii*)
Migrant.

Gray Flycatcher (*Epidonax Griseus*)
Occasional migrant.

Olive-sided Flycatcher (*Nuttallornis borealis*)
Common in summer; bigcone spruce and ponderosa pine forests.

SWALLOWS

Tree Swallow (*Iridoprocne bicolor*)
Fairly common migrant.

Barn Swallow (*Hirundo rustica erythrogaster*)
Occasional migrant.

WRENS

House Wren (*Troglodytes aedon*)
Common summer resident in woodlands.

THRUSHES, etc.

Swainson Thrush (*Hylocichla ustulata*)
Fairly common migrant, may nest in stream woodland.

WAXWINGS and SILKY FLYCATCHERS

Cedar Waxwing (*Bombycilla cedrorum*)
Occasional, sometimes common, winter visitor.

VIREOS

Solitary Vireo (*Vireo solitarius*)
Common summer visitor; bigcone spruce forest and oak-woodland.

WOOD WARBLERS

Calaveras Nashville Warbler (*Vermivora ruficapilla*)
Fairly common migrant.

Townsend Warbler (*Dendroica townsendii*)
Fairly common migrant.

Hermit Warbler (*Dendroica occidentalis*)
Fairly common migrant.

Tolmie Warbler (*Oporornis tolmiei*)
Occasional migrant.

FINCHES and SPARROWS

American Goldfinch (Spinus tristus)
Occasional summer visitor below 3,000 feet.

Green-tailed Towhee (Chlorura chlorura)
Occasional migrant.

Lark Sparrow (Chondestes grammacus)
Occasional summer visitor; open areas at low altitudes.

Rufous-crowned Sparrow (Aimophila ruficeps)
Fairly common in sparsely vegetated areas below 3,000 feet.

Chipping Sparrow (Spizella passerina)
Fairly common migrant.

Black-chinned Sparrow (Spizella atrogularis)
Common in summer; chamise-chaparral

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MISCELLANEOUS
PAPER No. 14
OCTOBER 16, 1953

A FIRE SEASON SEVERITY INDEX FOR CALIFORNIA NATIONAL FORESTS

By
C. M. Countryman and P. H. Intorf

When are the year to year variations in costs and accomplishments of a fire control organization due to variations in fire weather? When are the variations due to prevention and control action? To a combination of both? An index to the severity of fire weather by seasons can help answer these questions if the index separates the effects of weather on fires from the effects of prevention and control activities. This paper reports the results of an analysis made to determine such an index for California national forests.

Fire danger ratings compiled on the national forests were used as a measure of fire weather. The fire danger rating is determined daily on a scale of 0 to 100 for individual rating areas into which the national forests have been divided[1/]. The numerical rating is proportional to expected rates of forward spread of fire for observed conditions of wind velocity, temperature, humidity, and fuel moisture. The significance of a local fire danger observation to fire-control management is determined in part by comparing the observed daily rating with the long term mid-summer average for the rating area in which the observation is made. Making these daily comparisons is facilitated by application of a formula[1/] by which the degree of departure from mid-summer average danger is expressed as five qualitative danger classes: Low, medium, high, very high, and extreme.

1/ U. S. Forest Service. 1946. Fire Danger Rating Region 5. 9 pp. plus appendix.

The California Forest and Range Experiment Station is maintained by the Forest Service, U. S. Department of Agriculture, in cooperation with the University of California, Berkeley, California.

Agriculture--Berkeley

The study related the fire-danger rating to the number and size of fires, using data for 1,789 man-caused fires in 32 danger-rating areas in northern California, and 394 fires in 16 areas in southern California. The period of study was 1945 to 1952, and the data used were for the months of July, August, and September, when records were most complete and suppression forces near full strength.

Fire Danger and Number of Fires

Preliminary analysis showed that the number of fires was more closely related to the five danger classes than to the numerical rating. Accordingly, the average number of fires started per rating day[2] was computed for each danger class in each of the rating areas. To eliminate the effect of size of rating area in the final summation, the ratio of number of fires per rating day for each class to that of the medium class was computed. These ratios showed that the number of fires increased rapidly with increase in fire danger (table 1). For northern California 1.47 times as many fires occurred on days of extreme fire danger as on days of medium danger; for southern California 1.65 times as many.

Table 1. --Effect of fire danger on number of man-caused fires

Fire danger class	Ratio of number of fires per day to number in medium class: Northern California	Ratio of number of fires per day to number in medium class: Southern California
Low	.57	.27
Medium	1.00	1.00
High	1.22	1.33
Very high	1.34	1.49
Extreme	1.47	1.65

Fire Danger and Size of Fires

Because the fire danger rating is a rate of spread index, the size a fire will attain may be expected to increase as the numerical danger rating increases. In order to determine the relation between size of fire and the danger rating, an analysis was made of the acreage burned at different levels of fire danger. From this analysis curves were developed which showed that the average size of fires increases very rapidly with increase in numerical danger rating, the rate of increase being the greatest in southern California (table 2).

2/ A rating day was considered as one day in each Fire Danger Rating area. Thus, for the northern California study area there would be 32 rating days for each day of the fire season.

Table 2. --Average size of fire for specified fire danger indices

Fire danger rating	Northern California	Southern California
	---Acres---	
10	20	9
20	97	57
30	248	173
40	482	379
50	806	696
60	1 228	1140
70	1 753	1741
80	2386	2505
90	3 131	3453
100	3993	4601

Fire Season Severity Index for Rating Areas

To determine the severity of fire weather for a season, it is essential that the weather for each day be evaluated in terms of the number of fires and burned acreage most probable for the day's level of fire danger. It is thus necessary to assume that a constant fire-starting potential exists, and that the number of fires starting and the size each attains depend upon the weather alone.

The data given in tables 1 and 2 indicate the relative chance, or frequency, of fire occurrence and the average size of each fire that does occur on any day of given fire danger. The product of appropriate values from these tables is a relative measure of the area most likely to burn for a rating day, and the sum of these daily products for a season provides a measure of the severity of the season. Comparison with other seasons can readily be made if the length of period considered in each year is held the same.

For the danger rating areas covered in this analysis, the seasonal totals of probable acreage burned were too large to make the amount of variation between seasons readily apparent. To overcome this difficulty, the seasonal total for each area was divided by the average for the period of record. The resulting ratio was termed the "severity index" for the season (table 3).

There are wide differences in the severity indices both in magnitude and trend by seasons. This is sometimes true even for adjacent areas. Areas with similar severity tend to be grouped; but there appears to be no consistent relation in severity between areas, and the grouping varies in different seasons. Separately or in combination latitude, longitude, altitude,

Table 3.--Fire season severity indices for fire danger rating areas in California, 1945-1952

NORTHERN CALIFORNIA

Rating area	1945	1946	1947	1948	1949	1950	1951	1952
Lassen								
1	----	1.00	.37	.79	1.08	1.42	1.34	1.15
2	----	1.00	.93	.99	.74	1.25	1.08	1.13
3	----	.95	1.23	.75	1.09	.75	1.22	.48
4	----	1.05	1.05	.80	1.05	.98	1.09	.71
Mendocino								
1	1.35	.51	.87	.84	.92	1.32	1.19	.89
2	1.47	.91	.91	.71	.86	1.07	1.07	.96
3	1.37	.76	.76	.71	.83	1.29	1.30	1.27
5	.93	.78	1.00	.67	.62	1.47	1.53	1.63
Modoc								
1	----	----	----	.92	1.03	.76	1.28	1.02
2	----	----	----	.82	1.03	.70	1.40	.59
3	----	----	----	.92	1.03	.91	1.13	.94
4	----	----	----	.89	1.06	.93	1.10	.95
Plumas								
1	1.29	1.09	1.01	.78	.89	.94	1.00	.88
2	1.08	1.10	.87	.47	1.12	1.20	1.16	.62
3	.85	1.05	1.22	1.04	1.00	.68	1.16	.59
Sequoia								
1	.93	.69	.83	1.23	1.23	1.12	.97	.66
2	.76	.80	1.18	1.28	.74	1.12	1.11	.77
4	----	.55	1.03	.81	1.00	1.17	1.44	.73
5	----	2.21	1.00	.69	.62	.72	.38	.83
Shasta								
1	.90	.95	1.01	.75	1.15	1.13	1.10	----
2	1.24	1.11	.77	.90	1.05	.96	1.00	----
3A	1.27	.77	.76	.64	1.07	1.25	1.23	----
4	1.49	1.18	.73	.76	1.08	.77	.99	----
5	----	1.00	.92	.95	1.13	.83	1.17	----
6	----	1.41	1.10	1.01	.89	.58	1.03	----
7	1.06	.84	.61	.69	.70	1.08	2.02	----

Table 3. --(continued)

NORTHERN CALIFORNIA

Rating area	1945	1946	1947	1948	1949	1950	1951	1952
Stanislaus								
1	.71	.99	1.10	.98	1.04	1.14	1.03	.50
2	.74	1.45	.61	.95	.75	1.45	1.06	.34
Tahoe								
1	1.43	1.07	.78	.62	.89	1.07	1.14	.90
2	.93	1.28	1.39	.70	.82	.83	1.06	.50
3	.66	1.45	1.31	.64	1.24	.50	1.27	.44

SOUTHERN CALIFORNIA

Rating area	1945	1946	1947	1948	1949	1950	1951	1952
Los Padres								
1	.81	.88	.98	1.19	.85	.94	1.35	.79
2	1.29	.61	.82	1.21	.97	1.20	.89	.81
3	1.93	.75	.81	1.29	.67	.77	.78	.63
4	1.31	.81	.81	----	.89	1.01	1.16	.63
4A	1.97	.69	1.65	1.43	.40	.53	.34	.55
5	----	----	.32	1.04	.89	1.29	1.45	.58
6	1.41	.63	.85	1.19	.99	.58	.94	.69
7	1.92	.91	1.12	.89	.82	.72	.63	.79
8	1.01	.61	.17	1.06	.89	1.34	1.91	1.25
9	1.49	1.04	.61	1.16	1.00	.64	1.07	.81
San Bernardino								
1	1.14	.73	.88	2.01	.74	.70	.81	.79
2	.95	.93	1.08	1.39	.79	.99	.87	.71
3	1.46	.74	.87	1.10	.84	.95	1.04	.87
4	1.51	.49	.90	1.46	.88	.80	.96	.94
5	1.67	.45	.94	1.56	.64	.94	.80	1.61
7	.87	.57	.94	1.74	1.07	.82	.99	.75

or general aspect appear to control the grouping for each season. For example, in 1945 the severity of fire season for rating areas in the southern Sierra Nevada and east slope of the Sierra Nevada tended to be low. Low elevations in the coastal regions and the northern Sierra Nevada had high severity that year. In 1947 the east slope of the Sierra Nevada had severe conditions, but low to moderate severity occurred in the coastal regions and in southern California. In 1948 most of northern California had low severity, while in southern California the severity was high.

The reason for these irregularities is not apparent from the data available in this study. It is probable that the tendency of the areas to vary in their grouping from year to year is the result of large-scale climatic variations.

Severity Index for Combined Areas

The use of the data in table 1 for computing severity indices assumes an equal number of fires starting in all areas. Indices computed on this assumption are valid for comparisons of seasons for any given area or for comparing relative trends between areas. Average fire occurrence per rating day, however, varies widely among the rating areas. The indices in table 3 thus cannot be added directly to obtain an index for combined areas, since a change in the severity index for an area of high fire occurrence has a relatively larger effect on the probable number of fires and acreage burned than does the same change in severity index for an area of low fire occurrence.

To provide an overall severity index the indices in table 3 were weighted by the fire occurrence per rating day for the area. The averages of the weighted indices were then obtained for each season to give a severity index for the combined areas (table 4). For northern California 1945 was the most severe year for the period; the probable burned acreage was 1.17 times the average. In southern California a severity index of 1.42 indicated that 1948 was the most severe year.

Table 4. --Relative severity of fire seasons for California national forests, 1945-1952

Year	Northern California	Southern California
1945	1.17	1.38
1946	1.06	.72
1947	.98	.89
1948	.77	1.42
1949	.96	.85
1950	.96	.88
1951	1.09	.96
1952	.76	.87

In making local applications of this study, it should be remembered that the relation between size of fire and danger rating illustrated in table 2 is based on the average size of fire. Because the data included many very small fires, the potential fire size for any given danger rating is much greater than the average shown in the table. Table 2 shows, then, that as the danger increases, more and more fires that start tend to become large fires. Furthermore, the number of fires starting also becomes greater, as shown in table 1. The potential fire load thus becomes acute with increasing rapidity as the danger increases. This further emphasizes both the need for greater preventive and preparedness effort when the danger rises and the need for all-out attack on fires that do start.

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MAJOR BRUSHLAND AREAS OF THE COAST RANGES AND SIERRA-CASCADE FOOTHILLS IN CALIFORNIA

By A. E. Wieslander and Clark H. Gleason

There are extensive areas in California in which the presence of woody vegetation poses problems of land management. The woody vegetation ranges in size from trees to low bushes that grow in stands dense enough to shade out herbaceous ground cover or prevent ready access to the land. Such areas are commonly called "brushland." The problems of managing brushland affect, among others, graziers who want to increase the value of forage for livestock; wildlife managers who want to improve the habitat for wild game; fire control agencies who seek more effective controls for wildfire; and water users who want to maintain the type of watershed plant cover that is best for regulating streamflow and controlling soil erosion. Solution of these problems for the best interests of the greatest number of people is an important challenge in this State.

Because of the widespread interest in these brushland areas, the California Forest and Range Experiment Station is frequently asked about their location and extent, and also the kinds of woody vegetation which cover them. Accordingly, a map showing the principal brushland areas has been prepared from Forest Survey data.1/ It shows the extent of brushland cover types below the belt of commercial timber in the Coast Ranges and Sierra Nevada-Cascade foothills. Excluded are the shrub types on areas dominated by Great Basin sagebrush east of the Sierra-Cascade Mountains and on the desert lands in the southeastern part of the State. This paper tells how the map was prepared and how the brushland acreages were determined; it also describes the cover types shown on the map.

1/ Wieslander, A. E., and Herbert A. Jensen. Forest areas, timber volumes, and vegetation types in California. California Forest and Range Experiment Station, Forest Survey Release No. 4, 66 pp., March 1, 1946.

The California Forest and Range Experiment Station is maintained at Berkeley in cooperation with the University of California

Procedure

The brushland areas map was generalized from the map "Vegetation Types of California, January 1, 1945," which was prepared by the Forest Survey Division of this Station and published on a scale of 1:1,000,000.[2] Steps in preparing the 1945 map and the current generalization were as follows:

1. All cover types were delineated on air photos to a minimum area of 500 acres.

2. The types were transferred to maps of 1:125,000 scale (approximately 1 inch = 2 miles) to a minimum area of 500 acres; acreages were measured by dot-counting on these maps.

3. The types were then generalized on the state map of 1:1,000,000 scale (approximately 1 inch = 16 miles) to a minimum area of 2,500 acres. This is the vegetation type map of 1945.

4. On the vegetation type map of 1945, areas were outlined in which the following 5 cover types are dominant: Woodland, woodland-grass, chaparral, minor conifers, and coastal sagebrush.

5. To make the map of brushland areas the two woodland types and the three chaparral and associated types were shown in two groups, also on a scale of 1:1,000,000.[3] Figure 1 is a photographic reduction of this map.

Brushland Acreage

Excluding areas suitable for growing timber, the Coast Ranges and Sierra-Cascade foothills contain a total of 20 million acres on which woody vegetation introduces more or less of a problem in land management.[4] Of this total, 9 million acres are woodland types, and 11 million acres are chaparral and associated types. The brushland acreage is found in five cover types, as follows:

2/ Blue-line prints of the vegetation type map can be obtained from the U. S. Forest Service, 630 Sansome Street, San Francisco 11, at $1.00 each. Make check or money order payable to Treasurer of the United States.

3/ Blue-line prints of the full-scale brushland areas map can also be obtained from the Forest Service, at $1.00 each.

4/ Wieslander and Jensen, table 1, op. cit. Acreage computed from table 1 by subtracting the area of each type on sites classified as suitable for growing timber.

Type	Million acres	
Woodland	1.5	
Woodland-grass	7.5	
Total woodland types		9.0
Chaparral	8.5	
Minor conifers	.5	
Coastal sagebrush	2.0	
Total chaparral types		11.0
All brushland types		20.0

Owing to generalizations made after the acreages were determined, some brushland areas will be found outside the areas shown on the accompanying map (fig. 1). Also owing to the generalizations, the areas mapped embrace some cover types, such as grassland, in which there is no woody vegetation. The generalizations do not affect the overall accuracy of the acreage determinations.

Woodland Types

The woodland and woodland-grass types are characterized by hardwood trees, often in association with Digger pine. Grass is the ground cover in extensive areas. The woodland, which covers about 1.5 million acres, includes relatively dense stands of trees alone (fig. 2), or mixtures of trees and shrubs commonly called woodland-chaparral (fig. 3). The hardwood trees are of several species, mainly interior live oak, coast live oak, blue oak, Oregon white oak, canyon oak, California laurel, and madrone. Most of the canyon oak stands are restricted to steep, rocky slopes. The woodland-grass, which covers about 7.5 million acres, includes relatively open stands of trees in association with grass alone (fig. 4) or mixtures of shrubs and grass (fig. 5). Included in the woodland-grass type are pure and mixed stands of such hardwoods as blue, Oregon white, valley, interior live, and coast live oaks. Shrubs such as wedgeleaf ceanothus, common and whiteleaf manzanita, California coffeeberry, and poison oak are common in much of the type. The grasses and associated herbaceous plants are mainly annuals.

In the woodland-grass type are substantial areas without shrubby vegetation. In such areas the woody vegetation consists of scattered, open-crowned blue or valley oak trees that shade out relatively little of the herbaceous ground cover (fig. 4). Just how much of the type as mapped is characterized by open stands of this kind is not accurately known. Such a determination was made, however, for a fairly large body of the woodland-grass type in connection with a land use study covering six counties east of the Sacramento River.5/ Of 660,000 acres mapped in the six-county area, nearly 30 percent was found to have practically no shrubby growth that would interfere with grazing or other land uses.

Chaparral and Associated Types

Chaparral, minor conifers, and coastal sagebrush make up the second broad class of brushland. In these types the plants are characteristically crowded together, and little or no grass grows under their closed canopy. The chaparral (fig. 6) covers about 8.5 million acres. It consists of relatively dense stands of shrubs typically 6 to 8 feet tall, of such species as chamise, manzanita, ceanothus, and scrub oaks. The minor conifers (fig. 7), which cover 0.5 million acres usually intermingled with chaparral, are trees such as knobcone pine, Coulter pine, and scrub cypresses. The coastal sagebrush (fig. 8), which occupies about 2.0 million acres, consists of bushes 3 to 5 feet tall, characterized by such species as black sage, white sage, California sagebrush, California buckwheat, and coyote brush; most of this type also occurs adjacent to or intermingled with the chaparral.

The chaparral and associated minor conifer types, in contrast with the woodland types, almost everywhere are dense enough to restrict land uses such as grazing and hunting. On the other hand, coastal sagebrush is less troublesome in this respect because of its smaller stature and more open growth habit (fig. 8). It is chiefly in the chaparral, minor conifer, coastal sagebrush, and dense woodland types that efforts are being made to substitute for the woody vegetation some other type of cover that will facilitate land use and management, yet give an equal or better degree of watershed protection.

The brushland areas map, then, shows the gross acreage and the character of cover types which create problems in the use and management of wild lands below the commercial timber belt in California, excluding the sagebrush areas east of the Sierra-Cascade Mountains and the desert lands in the southeastern part of the State. The proportion of these brushland areas which can be improved with respect to their plant cover remains to be determined.

5/ Weeks, David; A. E. Wieslander, H. R. Josephson, and C. L. Hill. Land utilization in the northern Sierra Nevada. University of California Agric. Expt. Sta. Special publication of the Giannini Foundation of Agricultural Economics, Berkeley, 127 pp., illus., 1943.

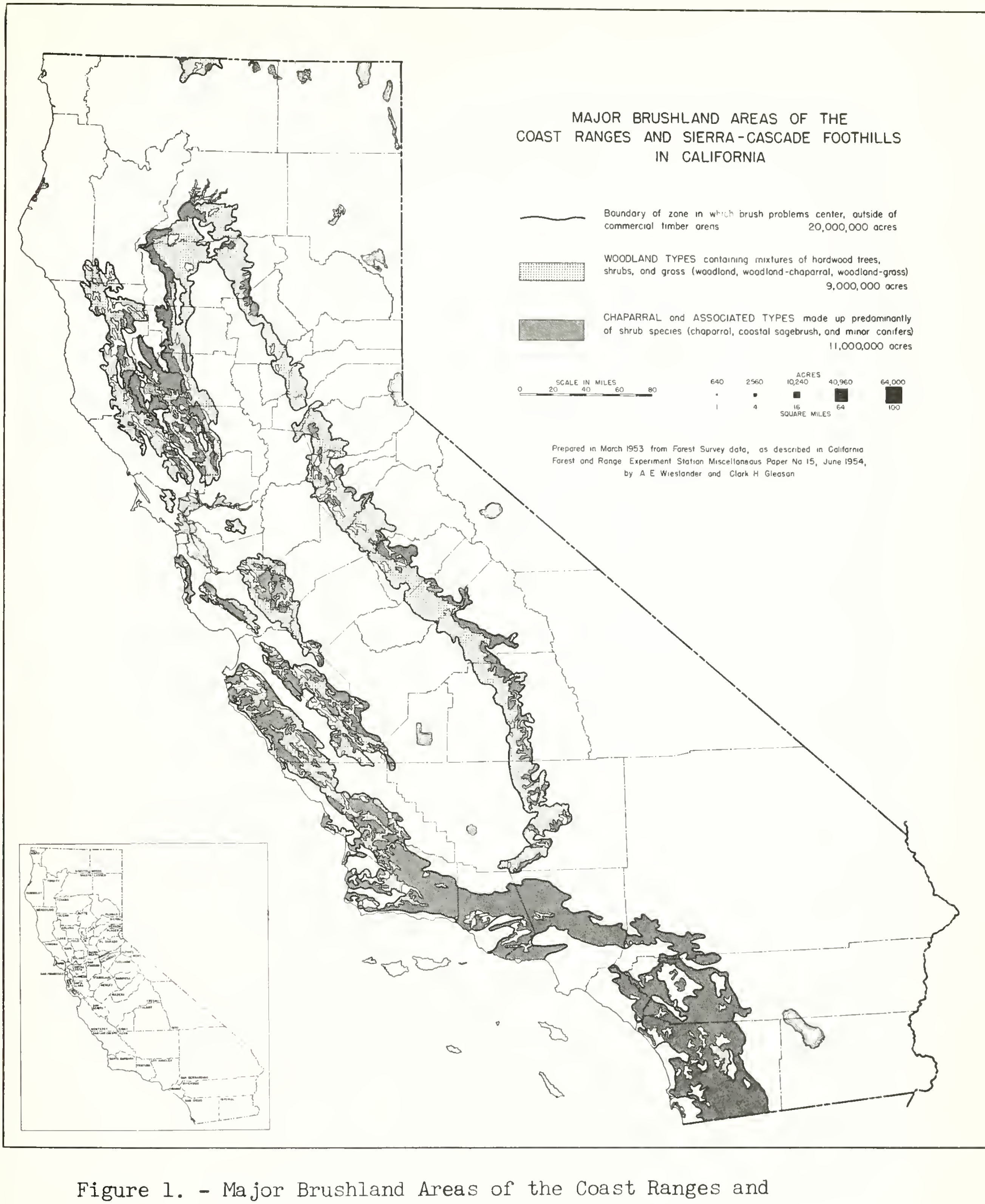

Figure 1. - Major Brushland Areas of the Coast Ranges and Sierra-Cascade Foothills in California.

Figure 2. - Woodland type of interior live oak in association with blue oak and Digger pine.

Figure 3. - Woodland type of blue oak and Digger pine in association with whiteleaf manzanita, wedgeleaf ceanothus and poison oak.

Figure 4. - Woodland-grass type of blue oak in association with annual grasses.

Figure 5. - Woodland-grass type of blue oak and Digger pine in association with whiteleaf manzanita, wedgeleaf ceanothus, and annual grasses.

Figure 6. - Chaparral type of chamise and manzanita.

Figure 7. - Minor conifer type of Sargent cypress.

Figure 8. - Coastal sagebrush type of California sagebrush, white sage and wild buckwheat.

UNIT AREA CONTROL - - -
ITS DEVELOPMENT AND APPLICATION

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CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
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The California Forest and Range Experiment Station is maintained by the Forest Service, U. S. Department of Agriculture, at Berkeley, California, in cooperation with the University of California.

Agriculture - Berkeley

UNIT AREA CONTROL - ITS DEVELOPMENT AND APPLICATION [1]

William E. Hallin

Definition of Unit Area Control

The development of unit area control was the culmination of a lifetime of work by Duncan Dunning. It is a silvicultural concept in which the essential characteristic is "detailed control of stocking on small areas." The basic idea is not new. In some localities it has been referred to as forestry by the acre.

"Unit area" and "control" -- the two parts of the term -- are the keys to understanding this concept. "Unit area" was selected because silviculture must fit stand conditions that are natural units. Most forests are composed of homogeneous stand units, or unit areas, varying in size from a fraction of an acre to many acres. Characteristics commonly determining the homogeneity of these unit areas are: age class, species composition, stocking, and presence or absence of seed trees.

"Control" was selected because it most aptly describes the aim of silvicultural treatments applied to the unit areas. Control of the ground by a desirable or valuable tree species rather than by brush or inferior tree species is of first importance. Also, control means continuously maintaining adequate stocking of desirable species of trees that are growing at rates commensurate with the site. Silvicultural treatments applied at the proper time are the means by which the forester controls the stand.

I wish to emphasize these two points: (1) Forest stands are made up of unit areas and (2) the forester controls his stand by applying silvicultural treatments.

Unit area control is in sharp contrast to the widely used forms of tree selection. Silviculture is applied according to the needs and conditions of each unit area of the stand rather than tree by tree according to generalized rules. An improvement cut by individual tree selection may, however, be appropriate for unit areas of young age class of some species before the final harvest cut.

Unit area control as a term was first used in connection with a cutting trial in a sugar pine-white fir forest; consequently many

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1/ Paper presented at the Annual Meeting of Columbia River Section Society of American Foresters at Portland, April 18, 1953.

California foresters first thought the term referred merely to the technique used in sugar pine management. This is not the case; applying silviculture by unit areas is appropriate and desirable for other major types as well.

Large-scale trial and demonstration of these applications are under way in ponderosa pine at the Blacks Mountain Experimental Forest and in a mixed conifer forest at the Stanislaus Experimental Forest. At both places small-scale studies are being carried on to implement and improve the application of unit area control.

Basis of Unit Area Control

Thirty years of research in the ponderosa pine and mixed conifer forests of the Sierra of California by Dunning and his associates have shown that previous methods of silviculture were not providing adequate restocking of pine. Analysis of records indicated a new approach was necessary. From this work, new procedures that gave most promise of success were formulated by Duncan Dunning. These procedures are techniques for applying unit area control in the ponderosa pine and mixed conifer forests.

What the forester does in managing his stand is to analyze (1) the objectives of the land manager or owner, (2) the silvical characteristics of the species, and (3) the condition of the stand when treatment starts, in order to select and apply the appropriate treatment.

Objectives of Management

Obviously what the land manager wants is the first controlling factor in determining what is done to the forest. The land manager must decide the species desired, the acceptable degree of stocking, the size and kind of product desired, and make the other customary managerial decisions.

Customarily in the ponderosa pine or mixed conifer types a primary objective of land managers is to grow large size ponderosa or sugar pine peeler logs or sawlogs. If sustained production with a growth rate commensurate with the site capacity is desired, conversion of the unmanaged stand to a regulated stand -- a forest with each age class through rotation or harvesting age uniformly represented, and adequately stocked -- is an essential objective.

Silvical Characteristics

Some of the important silvical characteristics of ponderosa and sugar pine that affect its management are: (1) They are intolerant species and grow best in even-aged groups. (2) They germinate best on bare mineral soil. (3) If pine starts free of competition, its initial growth is rapid, and it usually is able to compete successfully with fir, brush, and other vegetation that may subsequently become established. (4) For best growth, thinnings and cleanings are usually necessary. (5) Pine seeds are the preferred food of numerous rodents commonly found in our forests. (6) Pine does not prune itself of branches naturally during practical rotation periods.

As a result of characteristics (1) and (2), ponderosa and sugar pine do not readily establish themselves under brush and white fir. Where they have become established under brush or white fir, they do not develop properly unless released from this competition.

Site quality, through its effect on growth rates, has an important effect on acceptable stocking, length of rotations, and final yield.

Condition of the Stand -- Condition Classes

Ponderosa and sugar pine stands when considered by large areas are all-aged; however, when the forest is examined closely the trees are seen to occur in even-aged groups, usually small in size and homogeneous in respect to stocking, species, and other characteristics. Dunning has called these groups condition classes.

The objects of a classification by condition classes are: (1) To subdivide the forest or working circle into natural units sufficiently small and homogeneous for practical, uniform treatments such as harvest cutting, regeneration, and stand improvement. (2) To determine (a) which unit areas have existing stands adequate to carry as growing stock and, if they do, whether or not they should be subjected to an improvement cut, and (b) which unit areas have stands that should be clearcut and the unit regenerated. (3) To provide the basis for the cutting plan, the cutting budgets, the allowable cut, and other steps in a working plan that is most likely to accomplish stand regulation in the conversion period.

The basis for a condition classification is the prevailing, naturally occurring group stand structure. Dominant trees are used as indicators in condition classification because they make up more than 80 percent of the stand in board foot volume, but require counting or considering only about 40 percent of the stand in numbers of trees. The criteria for recognizing and classifying condition classes are age, species, degree of stocking relative to the stand aimed for in regulation, and -- for unit areas needing regeneration -- the presence or absence of seed trees and the presence or absence of brush or other vegetation needing eradication.

The age classes we have commonly used for the overstory are: (1) Overmature -- 300 years plus -- Dunning's tree class 5 or Keen's tree class 4; (2) mature -- 150 to 300 years -- Dunning's tree classes 3 and 4 or Keen's tree class 3; (3) immature -- 75 to 150 years -- Dunning's tree classes 1, 2, and 6, or Keen's tree class 2. Age classes commonly used for the understory are: (1) Young -- 25 to 75 years -- usually poles 4 to 12 inches diameter breast high (d.b.h.); (2) seedlings and saplings -- 0 to 25 years -- usually trees less than 4 inches d.b.h.

This age class breakdown has been adequate for deciding on the appropriate treatment. In preparing management plans and regulating the cut, however, it has been found desirable to have a greater breakdown of age classes for those ages below rotation age.

The species classification of a unit area is based on the relative number of dominants. If the most desirable species makes up one-third or more of the dominants, the unit area is designated as that species. If the most desired species makes up less than one-third of the dominants, the next most desirable species is considered; and so on down the list of species in their order of desirability. Although this species designation is for the purpose of classifying the unit area at the time of inventory or treatment, it commonly indicates the species to be favored on the particular unit area for the conversion period. With favorable conditions, however, the forester may treat some unit areas so as to change the species to more valuable ones. Although species consideration is not a problem on much of the ponderosa pine type, less desirable species occur and present a problem on some unit areas in most localities.

Stocking is rated as adequate or inadequate on the basis of a minimum stocking that is acceptable to the land manager. On our Blacks Mountain Experimental Forest in the ponderosa pine type we ordinarily use 25 percent stocking as the minimum. The minimum size unit that will be segregated must be decided upon by the land manager also. One-fifth acre is the minimum sized unit area which we try to regenerate, although for practical operating reasons one-fifth acre may sometimes be too small.

Foresters often ask what should be the minimum, optimum, and maximum sized unit areas. Nature has already established the present sizes of unit areas. The forester, of course, can change the size of the unit areas by silvicultural treatments. But during the early stages of converting the wild forest to a managed one, he can make very few such changes. It is possible, for example, to cut and regenerate a small mature unit area at the same time an adjacent overmature unit area is cut and regenerated, thus making one unit area of a more desirable size. In practice, however, the lack of adequate young components in the stand usually makes this undesirable. If unit areas are larger than desired they can be subdivided and the parts cut and regenerated at different times. In California pine stands, unit areas over five acres in size are not common; consequently we have not had to set a maximum size in our pine stands.

Seed trees are rated as adequate or inadequate for old or mature unit areas without adequate advance growth. Seed trees should be distributed around the border of the unit area to be regenerated. The number and size required varies with the species.

Shrub or other vegetation requiring eradication is rated as present or absent on unit areas needing regeneration.

Recognition of condition classes is not unduly complicated when it is viewed in terms of these few criteria. For any specific unit area the following questions should be answered: (1) What is the age class of the overstory? (2) What is the species composition? (3) For immature and mature age classes, is the stocking acceptable to carry as a reserve? (4) Is an understory present? (5) What is the species composition of the understory? (6) Is the stocking of the understory adequate? (7) If the understory is inadequately stocked or absent are there adequate seed trees? (8) If the understory is inadequate or absent do shrubs or other competing vegetation need eradication?

Treatments

In the application of unit area control each unit area of a specific condition class is given its appropriate cutting and all other necessary treatments at the proper time. I wish to emphasize the importance of applying all treatments. The immediate objective is to keep control of the ground with trees. As previously mentioned, the long-time objective is to convert the forest into a regulated stand with each class through rotation age uniformly represented as even-aged groups, or unit areas with adequate stocking and proper growing conditions. This means even-aged management. Ultimately, of course, all unit areas will be harvested and regenerated when they reach rotation age. Timing is especially important in securing either natural or artificial reproduction. Once an area has been prepared for reproduction, it should be restocked at once, otherwise brush and other competing vegetation will invade and rapidly take control of the ground. Hence, it is vital that planting stock be available when regeneration cuts are planned, either for planting the entire area or for fill-in planting where natural reproduction fails. The main initial treatments to be applied are:

Cutting for natural restocking is carried on in unit areas of overmature condition classes with inadequate advance growth, with suitable seed trees present, and during a year of a good seed crop. These units are clearcut, but seed trees are left around the border of each unit. Rodents are controlled with lethal bait. Slash and brush are piled and burned. Competing vegetation is eradicated, and the bare mineral soil exposed as a seedbed. If natural regeneration fails the unit area is planted at once before brush and other vegetation invades it.

Cutting for artificial restocking is carried out in the unit areas of overmature condition classes with inadequate advance growth, but with no suitable seed trees or no seed crop in sight. These condition classes are clearcut. Slash is piled and burned. Competing vegetation is eradicated. Because of the infrequency of good seed crops, a high proportion of the overmature classes may need to be regenerated by artifical means.

Cutting for release is carried on in unit areas of overmature classes with adequate advance growth. The overstory is clearcut to release young growth; cutting is followed up with pruning, thinning, and other stand improvement measures.

Improvement cuts are made in young but merchantable stands (immature and mature age classes). The occasional old, malformed, or defective trees are removed to improve the quality and vigor of the stand. At this point it is well to point out that there is distinction between an intermediate harvest cutting and a final harvest cutting. Even though the final harvest cutting is in some form of clearcutting, any intermediate harvesting or improvement cutting must be some form of individual tree selection.

Risk Cutting

How does sanitation-salvage, or risk cutting, tie in to unit area control? Where risk trees can be readily recognized and the proportion of them is small, a risk cut the first time around is desirable. Under these conditions, by removing a low volume per acre the working circle or forest property can be rapidly cut over and the stand protected from serious insect loss. This should be followed by silvicultural treatments as indicated by the needs of the stand. In unit areas for which the final harvesting is deferred until later cutting cycles the risk trees should, of course, be removed when nearby unit areas are harvested.

In species and types where risk trees cannot be readily recognized or when the proportion of risk trees is large, the first cut should be based on silvicultural objectives other than sanitation-salvage.

Application of Unit Area Control

I will now briefly discuss some of the problems in the application of unit area control.

Inventories and Management Plans

Adequate inventories and preparation of suitable management plans are desirable and necessary with any method of cutting if a continuous forestry enterprise is the objective of the land owner. Unit area control can be started without inventories, as can any other type of cutting. On any forest working circle, the desired progress toward a regulated stand depends on an adequate inventory and management plan. The application of unit area control perhaps makes the need more obvious.

Adequate reserves for short cutting cycles are maintained by deferring the final harvesting on some unit areas. A knowledge of the area and volume in each condition class is necessary to make the best decision on the amount of reserve to carry and to decide which unit areas to harvest now and which ones later. These decisions can be made on the basis of a general knowledge of conditions for the working circle. However, in order to make adequate progress towards a regulated stand, an adequate inventory cannot long be delayed.

The area and volume for each condition class can be estimated by customary sampling procedures. In the more open types, such as many ponderosa pine stands, aerial photos can be used for area determination, and volumes can be determined from sample plots within the different condition classes. Areas can also be determined by the line-transect method.

Calculating the allowable cut and preparing the cutting plan are simplified with an inventory by condition classes. The deficiencies or excesses in the different age classes are readily shown. By using a combination of area and volume regulation, the condition classes can be sorted into their proper place in the cutting plan in order to provide for a sustained cut and progression toward a regulated stand. The younger age classes with or without an overstory are allocated to cutting cycles at the end of the rotation and the overmature age class to the first part of the rotation. The mature and immature age classes are fitted in between. With this type of picture, priorities of cut can readily be set up. Because condition classes are usually even-aged, conventional yield tables can be used for predicting growth.

Short cutting cycles are desirable in order to maintain proper control of the stand. In converting virgin old-growth stands to a regulated condition, the large volume of overmature trees appears to present somewhat of a problem if initial cutting cycles are to be kept short. This can be quite satisfactorily handled by deferring the final harvest on some of the overmature unit areas. The analysis of stand structure by condition classes will give the first indication of kinds of condition classes on which the final harvest should be deferred. If during certain periods planting is not feasible for one reason or another, cutting of overmature unit areas needing artificial regeneration can be deferred until such time as planting or seeding can be carried out.

Overmature condition classes vary in age from 300 to 600 or 700 years. Usually the decision on whether to cut or defer a unit area will be based on its relative thriftiness. The older and more decadent unit areas will be cut now, and the more thrifty and less decadent ones cut in a later cutting cycle. The proportion of risk trees in a unit area also is a guide. Unit areas with a large percentage of risk trees should be cut rather than deferred. Risk trees should be removed from the unit areas on which final harvest has been deferred.

On the Blacks Mountain Experimental Forest release of poles was given first priority after risk trees had been cut. As a result more than two-thirds of the pole stand had been released at the time of the inventory in 1949. Since then the overwood has been removed from most of the remaining unreleased pole stands. Consequently most of our present cuts in overmature unit areas are coming from unit areas with a seedling and sapling understory or from areas needing regeneration. Therefore the condition of the overstory is the main controlling factor in selecting unit areas for cutting. In order to provide for a cut in each compartment in each 20-year cutting cycle, we have set up 8,000 board feet per acre as the desired reserve after our current cuttings. Although the reserve has fallen below this on some compartments because of a preponderance of very old condition classes, on most compartments we have had no difficulty in keeping a heavier reserve. The original volume averaged about 18,000 board feet per acre. All compartments now being cut have been cut over once or twice in the past.

Marking

The complexity of the forest prevents drawing up hard and fast cutting or marking rules that will cover all situations encountered in the forest. Consequently marking rules should be in the nature of guides only, and emphasis should be on objectives. The marker should use his silvicultural knowledge and his ingenuity in order to best meet the objectives rather than slavishly following detailed rules.

During marking some kind of mapping is desirable in order to locate areas where subsequent work such as rodent control, site preparation, and planting is to be done. A high degree of accuracy is not required because the main purpose of the map is to identify the areas so that they can be readily found.

Regeneration

Regeneration quite often is the most critical problem facing the forester. If his efforts to secure prompt restocking fail, his forestry enterprise will, of course, ultimately fail. If artificial methods are necessary, regeneration can be one of the most costly phases of forestry. This is the most compelling reason to take advantage of means of securing natural regeneration whenever possible.

When seed years are infrequent, as they commonly are in ponderosa pine, some means of artificial regeneration are necessary. Insofar as is practical, then, regeneration cuts should be made during years of a good seed crop. Unless there are units of the working circle with a concentration of unit areas needing regeneration it is not practical to save up areas for regeneration cutting in seed years. Consequently the usual procedure would be to have a regular planned program for regeneration cutting and secure regeneration by natural means during seed years and by artificial means in other years.

I would like again to emphasize the importance of timing for natural reproduction; cutting, slash disposal, eradication of competing vegetation, and rodent control must be completed before seed fall.

Various types of so-called brush rakes or tractors have been quite successful in site preparation. In order to keep costs low highly skilled operators are essential.

Why not cut and then wait for a seed crop? In most areas brush and other vegetation would reinvade. The advantage of freshly exposed seedbeds would be lost.

Logging

Basically logging is the same as with other types of cutting. However, a large part of the cutting consists of complete removal of the overwood to release poles, seedlings, and saplings. Consequently an adequate logging plan and careful supervision to prevent logging damage are essential.

One last caution in the application of unit area control. Most timber types are relatively uniform throughout their range. Within that range, however, there will be local differnces in such things as climate, subordinate vegetation, and rodent population. A fundamental principle of unit area control is that treatments must fit stand needs or requirements. Therefore you must consider your own stand conditions when adopting or adapting silvicultural treatments that are successful elsewhere.

Summary

1. Forest stands break down in small homogeneous stand units -- unit areas.

2. The forester keeps desirable tree species in control of the ground by means of silvicultural treatment.

3. What the forester does in managing his stand depends on (a) objectives of the land manager, (b) silvical characteristics of the species, (c) condition of the stand when treatment starts and (d) treatments required to obtain the desired results -- all the treatments and at the proper time.

4. Intolerant species grow best in even-aged groups, consequently even-aged management is desired.

5. In stands predominantly overmature in character, adequate reserves for short cutting cycles are maintained by deferring the final harvesting of some overmature unit areas.

Stripped to essentials, unit area control is, with due consideration of the silvical characteristics of trees, the common sense application of silviculture to the individual unit areas of the forest stand.

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ETHYLENE DIBROMIDE SPRAYS FOR CONTROLLING BARK BEETLES IN CALIFORNIA

By G. L. Downing, Entomologist

Ethylene dibromide has been found effective for controlling bark beetles in California. Originally perfected as a control measure for the Black Hills beetle in Colorado,1/ penetrating oil solutions containing ethylene dibromide have been found highly effective against other species with similar habits. The principal advantage of penetrating oil sprays is that they can be used instead of burning in areas of high fire hazard. Although several mixtures are effective when properly applied, the most satisfactory mixture is ethylene dibromide in diesel oil. This insecticide is recommended to control the western pine beetle, mountain pine beetle, Jeffrey pine beetle, California flatheaded borer, and, occasionally, pine engravers in any of the various host trees in which broods of these beetles occur.

Spray Equipment

The type of equipment needed to apply ethylene dibromide spray depends upon the size of the control job. When only a few trees are to be treated, ordinary garden sprinkling cans with showerhead-type nozzles are satisfactory. When large concentrations of trees are to be treated, it is sometimes advantageous to use power sprayers, such as a Bean slip-on unit or Pacific Marine slip-on unit. Best results are obtained with power equipment capable of maintaining pressure at the nozzle of 10 to 15 pounds per square inch. This avoids creating a mist, which will usually drift away, or causing the spray to bounce off at higher pressures. Spray nozzles on power units should be of a type that allow for large volume at low pressure. A showerhead can be adapted for this purpose.

Treating Procedure

The treatment includes three steps:

1. Prepare the spray.--Mix the ethylene dibromide and diesel oil in a suitable container at the rate of one pint of 85 percent concentrate to 5 gallons of diesel. Pour the concentrate into the container first, then add the oil. Fifty-gallon drums are handy mixing tanks and when equipped with spigots are easy to fill spray cans from.

1/ C. L. Massey, R. D. Chisholm, and N. D. Wygant. Ethylene dibromide for control of Black Hills beetle. Jour. Econ. Ent. 45(5): 861-862, 1952.

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Agriculture--Berkeley

2. Prepare the tree.--Fell and limb the tree, and buck the infested section of the trunk into lengths that can be rolled.

3. Apply the spray.--Thoroughly drench the top portion of each log until the insecticide puddles in the bark crevices. Allow the spray to soak into the bark, then roll the log so that an untreated area is on top and repeat the process. Continue treating and rolling until all of the outer surface has been covered. This usually requires three to four turns of the log. Special care should be exercised to avoid missing any areas, especially along the sides of the log as it is rolled. Treating should not be attempted when the bark is wet.

Rate of Application

The amount of spray required to treat an infested tree properly varies. Ordinarily one application is enough. Large trees, however, require greater volumes than do small ones. As a rule of thumb, the following may be used as a guide in determining quantities needed for ponderosa pine:

Diameter breast high, inches	Gallons of spray
12	6-8
18	8-10
24	15
30	25

When treating other tree species with thinner bark, less spray will be required; thicker barked species may require more.

Sources of Supply

Ethylene dibromide is sold under several trade names. Two commercial products which contain 85 percent concentrations are Dowfume W-85, manufactured by the Dow Chemical Company, and Bromofume-85, produced by Eston Chemicals Division. Both are obtainable through insecticide distributing houses. Some California sources are:

California Spray Chemical Corp., Richmond, California

Eston Chemicals Division, American Potash & Chemical Corp., 3100 E. 26th Street, Los Angeles 23, California

Neil A. Maclean, 470 Eighth Street, San Francisco 3, California

The Dow Chemical Co., 350 Sansome Street, San Francisco 4, California

The cost of ethylene dibromide sprays, when mixed with diesel oil at the rate described above, is about 30 cents per gallon at current prices.

In order that the information in our publications may be more intelligible it is sometimes necessary to use trade names of products or equipment rather than complicated descriptive or chemical identifications. In so doing it is unavoidable in some cases that similar products which are on the market under other trade names may not be cited. No endorsement of named products is intended nor is criticism implied of similar products which are not mentioned.

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INSECT DAMAGE TO THE 1954 CROP OF DOUGLAS-FIR AND SUGAR PINE CONES AND SEEDS IN NORTHERN CALIFORNIA

By Ralph C. Hall, Entomologist

Insects have destroyed four-fifths of the 1954 seed crop of Douglas-fir and a very high percentage of sugar pine seed in northern California. Evidence of this loss was obtained from a study conducted by the California Forest and Range Experiment Station in cooperation with the administrative branch of the Forest Service.

Lack of satisfactory regeneration has frequently been observed in Douglas-fir and sugar pine cutting areas despite an abundant crop of cones. Occasionally, lack of seed during a good cone-crop year may be caused by adverse weather conditions, such as freezing temperatures in the early stages of cone development. But generally speaking the failure of a cone to produce sound seeds can be directly traced to insects. The insects may cause failure of a seed crop by eating the seeds or by destroying the flowers or immature cones.

In Douglas-fir, many different insects attack cones and seeds. Among the more important are the Douglas-fir cone moth (Barbara colfaxiana Kearf.), the Douglas-fir chalcid (Megastigmus spermotrophus Wachtl), the fir dioryctria (Dioryctria abietella (D. & S.)), and the fir cone geometrid (Eupithecia togata spermaphaga (Dyar)). In sugar pine, the principal destructive insect is the sugar-pine cone beetle (Conophthorus lambertianae Hopk.).

Since practically no information is available in California as to the amount of damage caused by these insects, a survey of damage to Douglas-fir and sugar pine seed was undertaken by the Station's Division of Forest Insect Research and several national forests in California during the 1954 field season. The purpose was to determine the amount of damage and the insects associated with damage to Douglas-fir. In sugar pine, the insect responsible was well known, so only damage was surveyed.

Cone and Seed Damage in Douglas-fir

In Douglas-fir, sampling procedure was designed to determine both the amount of damage and the associated insects. This survey was conducted in the following manner:

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Samples of cones were collected at weekly intervals by the District Rangers on the Orleans District of the Six Rivers National Forest and the Happy Camp District of the Shasta-Trinity National Forest. These collections started in early June and continued until early September, and were made from freshly felled trees. Approximately 100 cones were collected in each sample and were forwarded to the Hat Creek Field Laboratory, where they were sampled for damage and then placed in rearing cages to collect any insects that might emerge. Also, early in September collections were sent in from all national forests where Douglas-fir is a major timber species. These included collections from the Shasta-Trinity, the Mendocino, and the Lassen National Forests, and additional collections from the Six Rivers and the Klamath.

Rearing records are not complete; therefore, only the damage is reported here. An analysis of the samples from the Klamath National Forest showed 97.8 of the seed destroyed; from the Six Rivers, 91.6 destroyed; from the Mendocino, 87.7 destroyed; from the Shasta-Trinity, 71.6; and from the Lassen, 53.2. The average for all forests sampled was 82.2 of the 1954 seed crop destroyed. Cone production was light in northern California as a whole; therefore we can expect very poor regeneration on most of these national forests.

Cone and Seed Damage in Sugar Pine

The sugar-pine cone beetle bores into the stalk of sugar pine cones early in the spring of the second year of cone development. The beetle then extends the gallery through the axis of the cone, where eggs are laid, and the resulting larval broods mine out the interior of the cone. Such cones are classified as "aborted", since they usually fail to grow in length or diameter after attack.[1/]

Damage to sugar pine cones and seeds was sampled on six national forests in northern California by a random selection of a sugar pine nearest to the starting corner on permanent sample plots surveyed during the late fall season. The sampling consisted of counting all the aborted and good cones on the ground, plus those good cones still on the trees.

Records at the Stanislaus Experimental Forest showed the total cone production to be about double the 1948 crop, about half the bumper crop of 1952, and about 40 times the crop produced in 1953.

1/ Miller, J. M. 1915. Cone Beetles: Injury to sugar pine and western pine, U. S. Dept. Agr. Bul. 243, 12 pp., illus.

Damage to the 1954 cone crop throughout northern California was spotty in local areas, ranging from light to very heavy. One tree sampled on the Stanislaus National Forest had 529 cones destroyed out of a total of 551 cones produced; another sample tree on the Lassen National Forest had the total crop of 264 cones destroyed.

It takes two years for sugar pine cones to mature. The average production of 1-year-old cones in northern California in the spring of 1954 was estimated at 71 per tree (table 2). This represents a very good cone crop. At the end of the summer of 1954, only 18 viable mature cones per tree were left after heavy damage by insects. The number left indicates that, even with a loss of 75 percent of the crop from insects, there still was a fair crop of cones as an average for northern California. In certain critical areas, however, where cutting was done for regeneration of sugar pine, the seed crop was essentially a failure.

Table 1.--Insect-caused damage to Douglas-fir cones and seeds, northern California, 1954

National forest and location	Percent of seed crop destroyed	Number of seed sampled
Six Rivers N. F.		
Upper Bee Creek	91.8	541
Orleans	91.4	445
Average or total	91.6	986
Klamath N. F.		
Happy Camp	99.1	572
Elk Creek	96.4	506
Average or total	97.8	1,078
Mendocino N. F.		
Ball Mountain	89.1	490
Log Springs	86.4	522
Average or total	87.7	1,012
Shasta-Trinity N. F.		
Wildwood	70.4	486
Parker Creek	77.2	382
Pondosa	67.2	498
Average or total	71.6	1,366
Lassen N. F.		
Hat Creek	53.2	474
All five national forests	82.2	4,916

Table 2.--Damage to sugar pine cones, caused by the sugar-pine cone beetle, northern California, 1954

National forest	Trees sampled	Cones in sample			Aborted cones
		Good	Aborted	Total	
	No.	No.	No.	No.	Pct.
Lassen	18	348	779	1,127	69.1
Stanislaus	23	242	1,386	1,628	85.4
Plumas	7	31	396	427	92.7
Mendocino	7	286	288	574	50.1
Shasta-Trinity	5	79	37	116	31.8
Klamath	5	156	558	714	78.1
Total	65	1,142	3,444	4,586	75.1

Average production of one-year cones per tree - - - - - - - - 71
Average production of viable two-year cones per tree - - - 18