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IRRIGATION REQUIREMENTS OF THE ARID AND SEMIARID LANDS OF THE PACIFIC SLOPE BASINS

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CONTENTS

INTRODUCTION

This is the fifth and final report of a series dealing with the irrigation requirements of crops in the arid and semiarid lands of Western States (*17, 18, 21, 22*).[1]

The term "irrigation requirement of arable land" is used for the quantity of irrigation water required for profitable crop production under the prevailing climatic and physical conditions. The "water requirement" is the total quantity of water required by crops for normal growth under field conditions. The water required is disposed of by transpiration from the plant, evaporation from the soil, deep percolation, and other unavoidable losses.

[1] Italic numbers in parentheses refer to Literature Cited, p. 44.

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The water requirement is applicable to individual crops grown (relatively small tracts and includes soil moisture and rainfall in adc tion to the irrigation requirement. Both requirements are measur in acre-feet of water per acre.

It is estimated that with proper storage of flood waters and nece sary improvements in irrigation practices ample water will be ava able to satisfy the requirements of three times the total area no irrigated in all the Western States.

Much of the investigational work on field crops summarized this bulletin was carried on in cooperation with the Department Public Works of the State of California and the division of irrigati investigations and practice of the University of California. Tl statistical data on irrigation of semitropical fruits and nuts in southe California were obtained mainly from studies conducted by tl agricultural extension service of the University of California ar the United States Department of Agriculture, cooperating.

THE PACIFIC SLOPE BASINS

This report covers all the territory in an east and west directi between the crest of the Sierra Nevada Range and the Pacific Ocea and in a north and south direction all the territory between the wate sheds of the Columbia and Colorado Rivers (fig. 1). It includes of California with the exception of Modoc, Lassen, Inyo, and Mo counties occupying the high tablelands east of the Sierras, the easte portion of San Bernardino County and the deltaic plains of Imperi County in the southeast which depend for a water supply on tl Colorado River. In Oregon it includes Klamath, Jackson, Josephin Curry, Douglas and Coos Counties, located in the southwestern corn of the State bordering on California and drained chiefly by tl Umpqua, Rogue, and Klamath Rivers and their tributaries. Tl area of the Pacific slope covered in the two States is in round numbe 90,000,000 acres of which 4,225,000 acres are irrigated. Includi nonirrigated tracts, 5,500,000 acres are producing crops. The relati smallness of the cropped area is due mainly to the rugged and mou tainous character of the land and to a smaller extent to the prevaili custom of summer fallowing dry-farmed lands. Including the summe fallowed and other cultivable and occasionally cropped lands ov 8,000,000 acres are used for the production of crops.

As related to drainage and stream flow, the Great Valley of Ca fornia is separated into three more or less distinct parts known as tl Sacramento, San Joaquin, and Tulare Valleys. About 31 percent the total arable land lies north of the Golden Gate and San Francis Bay, and is traversed by the Sacramento River. The remaining percent lies south of the Bay and is traversed by the San Joaqu River. Tulare Valley occupies the extreme southern portion and i watershed is drained chiefly by Kern River and its tributaries. I chief peculiarity is that in low or normal stream flow it has no outl to the ocean, the run-off from its watershed being evaporated shallow marshes and lakes, of which Tulare Lake is the largest. I asmuch, however, as high flood waters have spilled over into tl San Joaquin Basin to the north, it is customary to consider Tula Valley as part of the San Joaquin Valley, and in this report it is regarded. Each of the main rivers of the interior plain, viz, tl

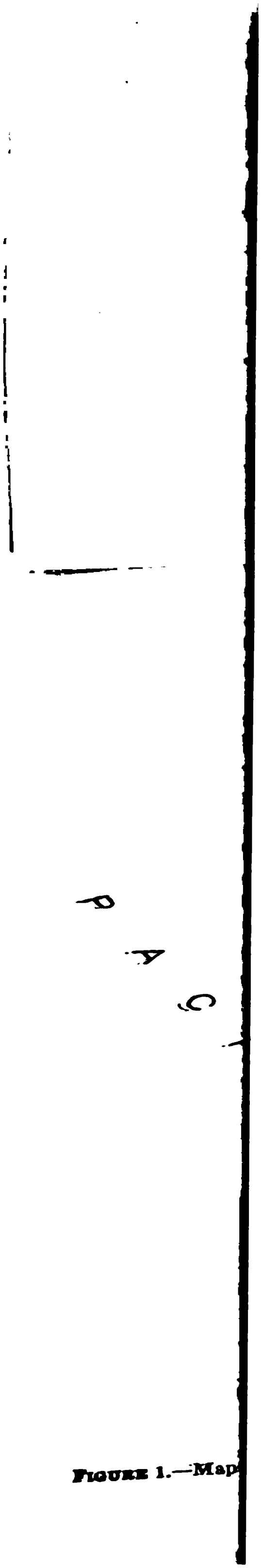

FIGURE 1.—Map

Sacramento, San Joaquin, and Kern, not only drains the arable land of its respective basin but an additional area of rugged, nontillable mountain land, part of which is forested.

The altitude of the greater part of the arable lands of the Pacific slope basins comprising the floor of the great valley and of the smaller valleys west of the Coast Range and south of Tehachapi Pass is less than 500 feet above sea level. The elevations of the rim of the great valley range from several hundred to several thousand feet above sea level. The elevation of Rogue River Valley, Oreg., is about 1,500 feet and that of the Klamath Lake district, Oreg., about 4,100 feet above sea level. As a rule, the uncultivated lands are high, ranging from low brush-covered or timbered hills to elevated tablelands and lofty mountain ranges.

SOILS OF THE PACIFIC SLOPE BASINS [3]

The soils of the Pacific slope basins with adjacent hill and coastal-plain areas represent a wide range in environmental conditions of climate, topography, parent materials, and stage of development. These are reflected in extreme differences in color, organic-matter content, physical character of soil profile, and degree of leaching or accumulation of soluble materials, some of which have fertilizing or ameliorating value, and some of which are detrimental.

From the standpoint of geographical distribution and convenience they may be designated as the soils of the Oregon basins, the Great Valley of California, the coastal valleys of California, and the coastal plain and local inclosed valley basins of the extreme southern California coastal region. On the basis of soil characteristics as reflected in the soil profile they fall into three principal major soil groups. These are:

(1) The unweathered alluvial soils represented by the Hanford, Yolo, Foster, and other series.

(2) The weathered soils developed on unconsolidated materials represented by the Redding, San Joaquin, Madera, Gridley, Farwell, and other series.

(3) The weathered soils developed on consolidated rocks represented by the Aiken, Sierra, Holland, and other series.

The first group consists of recent alluvial deposits in which the time element since deposition has not been sufficient to promote consistent physical or chemical changes in the soil material. They are usually deep, friable, and productive, and the subsoils consist of variably textured stratified sediments. Some of these are still in process of accumulation, and low-lying areas are subject to overflow during flood periods where not protected by levees. In chemical and mineralogical character they are dominated by that of the parent geological materials.

The second group represents progressive stages in weathering of the older sedimentary deposits of the valleys. They are characterized by slightly to greatly compacted subsoils which contain accumulated clay and colloidal materials and chemical compounds formed by leaching of the surface soils and downward migration of the finer physical particles, and in the more advanced stages of development by iron

[3] The material in this section was prepared by Macy H. Lapham, senior soil scientist, Bureau of Chemistry and Soils, U.S. Department of Agriculture.

and silica or lime-cemented hardpans. They occupy stream and coastal terraces and the more elevated valley plains now entrenched by streams and undergoing erosion. They are approaching or have acquired a condition of stability in which they have become adjusted to environmental conditions of climate and native vegetation and in which the character of parent geological materials becomes less evident and less dominant with advance of maturity.

The third group has been developed on the sandstone, shale, granitic, and volcanic bedrocks. They occupy hilly and mountainous areas which are susceptible of irrigation only in sections of more favorable topography and water supply. In stage of development and character of subsoils they represent only moderately mature conditions since removal of weathered soil materials by erosion tends to keep pace with the processes of weathering and soil development.

The next characteristic soils of the Oregon basins are those of the Rogue River Valley, occupying a valley trough in the Klamath Mountains west of the Cascade Range, and the soils of the Klamath Basin east of the Cascades. The soils of the Rogue River Valley Basin are developed mainly by weathering in place of old alluvial deposits having their source predominantly in basaltic and similar igneous rocks with admixture of materials derived from shales, sandstones, and granitic rocks, and are of brown to black color. In texture they range mainly from loam to heavy clay loam or clay. The heavier textured types have pronounced adobe structure under which the soils contain a high content of colloidal clay, are highly absorptive of moisture, and plastic, and when dry check and crack into blocks, irregular clods, and granules. The soils of the valley slopes are usually well drained and productive where not too shallow but areas occur in which bedrock has been only thinly mantled with soil material. The flatter valley areas are underlain by compacted and moderately heavy to heavy textured subsoils which frequently contain accumulations of lime. They are productive under irrigation except for areas in which impervious cemented hardpan has been formed and in which orchard plantings have proved unsuccessful.

The Klamath Basin soils occur under less favorable climatic and drainage conditions, are derived in part from siliceous lake-basin and volcanic materials, and include areas of organic peat deposits and highly colloidal lake-basin accumulations.

The soils of the great interior valley trough or basin of California embracing the Sacramento and the San Joaquin Valleys are predominantly weathered from several series of old sedimentary deposits having their sources in a wide range of rocks. The more maturely developed of these are of brown to red color and are underlain by cemented hardpan layers or by compacted and relatively impervious substrata. The so-called red hardpan lands are represented by the soils of the Redding and the San Joaquin series, the latter occurring at intervals on the east side of the valley from the northern extremity to the southern San Joaquin portion. They are of secondary importance from the standpoint of irrigated agriculture and are utilized mainly for dry-farming and pasture. The brown soils having compacted and irregularly or intermittently developed hardpan are better adapted to irrigation and are more productive. They are typically represented by the Gridley, Farwell, and Madera series of soils, with which are associated areas of soils of heavy texture represented by the

Stockton and related series of soils. This group of soils has been developed under an environment of less well developed drainage. The Farwell, Madera, and Stockton soils have subsoils characterized by seams, lenses, and mottlings of lime accumulation which in the Stockton soil may form cemented lenses or plates. In the central and southern parts of the interior valley, as the rainfall decreases the soils are less thoroughly leached, and accumulated lime carbonate becomes a dominant characteristic of the soil profile, the soils finally giving way to the lighter-colored grayish and highly calcareous soils of the Fresno, Pond, Delano, and associated soils of the southern San Joaquin Valley.

The flatter areas of the San Joaquin delta region and of the valley floor and overflow basins are occupied by extensive areas of peat and dark-colored peaty loams and by heavy-textured soils of the Sacramento, Merced, and Tulare series which have been developed on sediments deposited in sluggish water or inclosed lake or overflow basins. With the exception of the peat they are calcareous or have calcareous subsoils.

The areas of the older or more maturely developed soils are interrupted at intervals by narrow to broad deltalike deposits of unweathered recent alluvial materials occupying flood plains and alluvial fans built up by the streams tributary to the valley. The larger of these have their sources in the Sierra Nevada and enter the valley from the east where the built-up areas of higher alluvial soils are most extensive and have pushed the valley trough west of its normal geographical center. The soils deposited by the larger of these streams heading back in the granitic core of the Sierras are deep, friable, and predominantly brown in color. They are represented by the Hanford series with which are associated darker, dull grayish brown soils of the Foster series occupying the flatter less well-drained areas.

The recent alluvial soils of the west side of the valley are derived mainly from shales and sandstones. Those of the central and northern parts of the valley are mainly brown soils of the Yolo series; those of the southern part occur under arid conditions and are predominantly the grayer calcareous soils of the Panoche and related series. The Yolo and Hanford soils, with the Columbia soils occupying the immediate flood plain of the Sacramento River, comprise the most widespread and important alluvial soils of the State. The Yolo soils average somewhat heavier in texture than the other series.

The soils of the marginal foothills on the east side of the valley consist mainly of the red Aiken soils weathered in place on basaltic and andesitic rocks, and of the pale-red to brownish-red Sierra soils and the brown soils of the Holland series developed on granitic rocks. The Aiken soils are of medium to heavy texture but granular and friable. The Sierra and the Holland soils are of sandy loam to loam texture, of lower water holding capacity and somewhat earlier in plant production.

The soils of the coastal valleys are predominantly medium to heavy in texture. The unweathered soils of the northern valleys are represented mainly by the brown Yolo soils and the darker-colored Dublin soils. Associated with these are older soils developed by weathering of similar materials. With decrease in rainfall southward, leaching of the soil materials is diminished, the subsoils, and in some cases the surface soils as well, contain accumulated or unleached lime, the organic matter content is diminished, and the soils tend to become lighter in color. In the immediate proximity to the coast, however, under influence of cool uniform temperature and frequent fogs, evaporation of moisture and decomposition of organic matter are retarded and the soils are darker in color and sometimes acid in reaction.

The main valley basin of southern California embracing the San Fernando-San Gabriel-San Bernardino Valleys and contiguous valley areas are occupied mainly by the recent soils of the Hanford series and by older soils developed by weathering of similar materials. These range from the brown, partly weathered soils of the Greenfield and the Ramona series to the more maturely weathered red soils of the Placentia series.

The coastal areas and local valley basins occuring at intervals southward to the international boundary of Mexico are occupied by a large number of soils, frequently covering small individual areas and occurring in complex associations. The soils adjacent to the coast are mainly developed on uplifted old marine deposits, and are predominantly underlain by tough, waxy impervious subsoils or cemented hardpan and substrata. The friable surface soils are usually shallow and large areas are unfavorable to irrigated agriculture. Local areas, however, of more favorable character or with unusually favorable environment as regards temperature, frost, and water supply, have become intensively developed and of high value. Soil conditions in the river valleys and structural valley basins find their counterpart in the interior and coastal valleys in the more northern and central parts of the State.

For further information regarding soils of the areas discussed in this report the reader is referred to the various reports on soil surveys in California and Oregon by the Bureau of Chemistry and Soils.

CLIMATIC CONDITIONS

The climate of the Pacific slope is divided into two distinct periods—wet and dry—the former occurring during the short, cool months in the fall and early spring, when plant life is dormant, and the latter during the warmer months. The seasonal precipitation varies greatly, increasing from 2 or 3 inches in the southern desert areas to seasonal totals of 100 inches or more along California's northwestern coast. Rainfall is deficient throughout the fertile interior valleys and along the slope of the coastal plains, the greater part of the area receiving less than 20 inches annually, with one third of the area receiving less than 10 inches. This small precipitation, coupled with the time of year in which it occurs, is incapable of providing sufficient moisture to insure profitable cropping. Agriculture on the Pacific slope must, therefore, depend upon irrigation for crop production.

Other important factors are temperatures and frost-free periods. Data pertaining to these three elements of climate have been compiled from the records of the Weather Bureau (*30*) for 12 typical localities and are summarized graphically in figures 2 and 3.

Summer temperatures in the interior valleys are higher than those found nearer the ocean as the thousand-mile coast line of California modifies the coastal climate to an equable temperature freer from the extremes of heat found farther inland. Use of water by plants, disposed of by transpiration, is affected by numerous factors of which

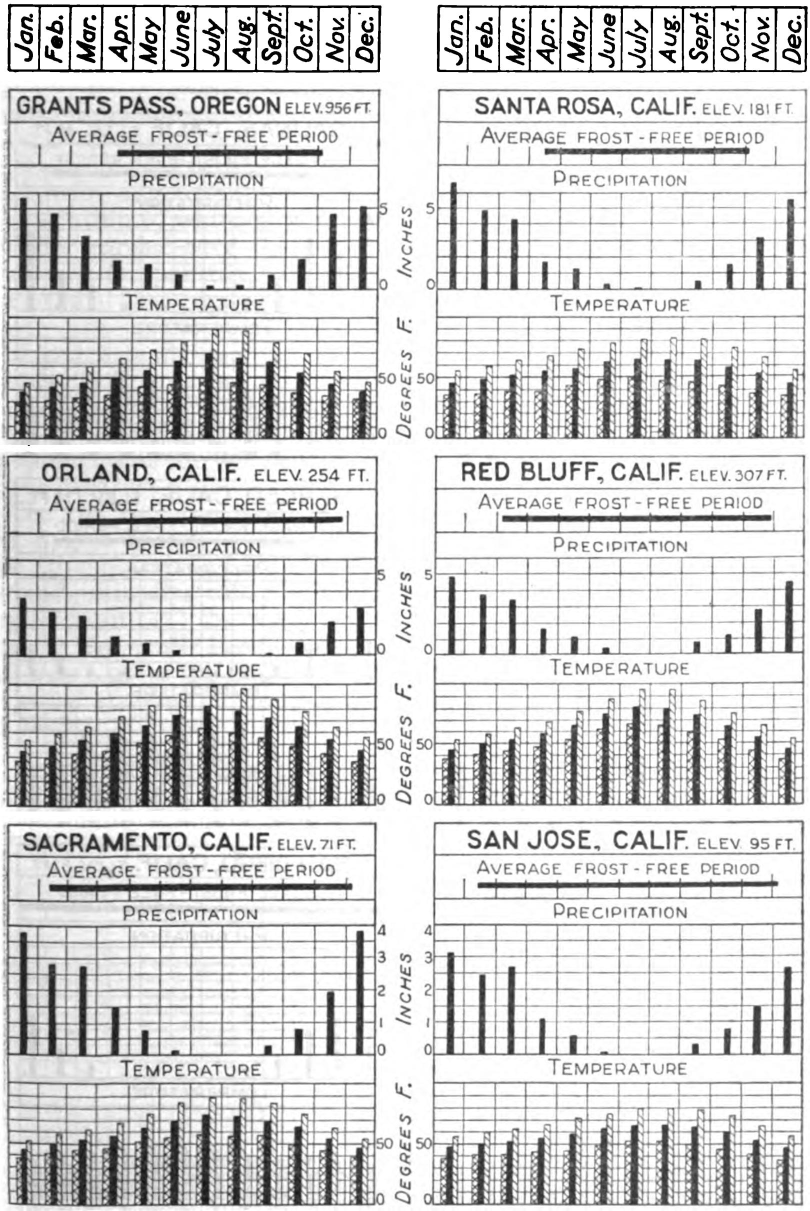

FIGURE 2.—Condensed climatology of typical stations in Oregon and California, showing average frost-free period, mean monthly precipitation, mean maximum temperatures (single-lined bars), mean minimum temperatures (double-lined bars) and mean temperatures (solid bars).

temperature is one of the most important. Crops grown in the coastal areas require less water than those grown in the interior.

The frost-free period in the agricultural districts is generally long in comparison with those of other Western States. Snowfall is abundant in the mountain districts, providing storage for summer

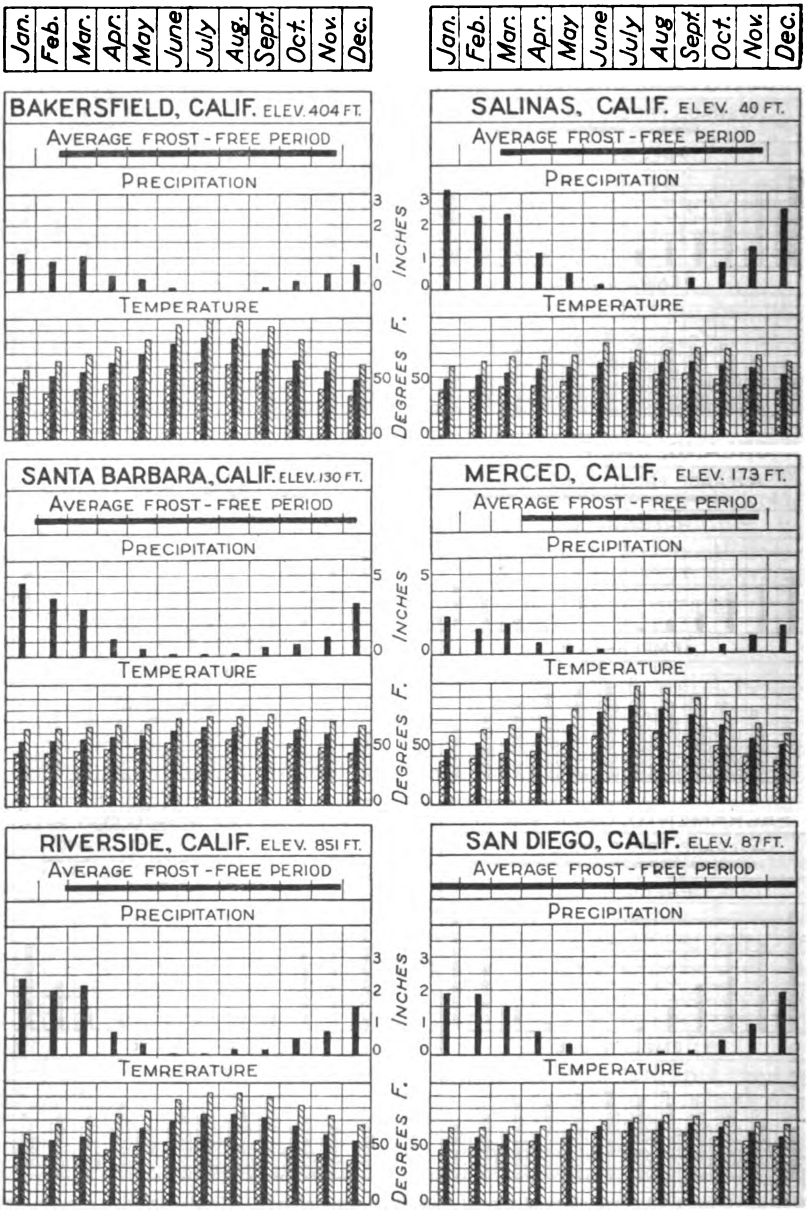

FIGURE 3.—Condensed climatology of typical stations in California, showing average frost-free period, mean monthly precipitation, mean maximum temperatures (single-lined bars), mean minimum temperatures (double-lined bars), and mean temperatures (solid bars).

stream flow, but is of rare occurrence in California's valleys. Evaporation in summer is higher in the interior than along the coast and because of the long period of warm weather the total loss of moisture by this means is considerable. Farming communities are learning from year to year to adapt more skillfully and scientifically the crops grown and the type of farming followed to the climatic conditions.

RIVER BASINS AND WATER RESOURCES

The water supply of the territory considered is by far its most valuable natural asset, and its wise administration and economical use impose upon communities their greatest public responsibility. Other natural resources, such as grasses, forests, minerals, and soils, may be conserved for future generations, but water to be of value must be used from day to day as it is available. The nearest approach to conservation of water is where it is impounded in reservoirs for short periods, spread over the surface of land to replenish underground basins, or temporarily withheld by soil coverings.

Perhaps the greatest difficulty to be overcome in dealing with water supplies for irrigation results from the fact that the precipitation and stream flow are not distributed proportionately with demands. Large areas of fertile arable land have little available water, while abundant water supplies exist in localities possessing limited areas of arable land. How to transfer the excess waters of one basin to supplement the deficiency in some other more distant basin is one of the greatest problems confronting the residents of the Pacific slope.

The 100 or more river basins in this report may be grouped into five major basins. These are: (1) the Rogue, Klamath, Umpqua and adjacent river basins in southwest Oregon and northwest California hereinafter called the northern group of basins, (2) the Sacramento Basin, (3) the San Joaquin Basin, (4) the San Francisco Basin and (5) the south Pacific Basins.

Table 1 gives the maximum, minimum, and mean discharges of the principal streams in the various basins for periods ranging from 11 to 34 years. Figure 4 shows the mean monthly flow of typical streams.

TABLE 1.—*Discharge of typical streams of the Pacific slope* [1]

River	Station	Years of record	Water-shed area	Annual discharge		
				Maximum	Minimum	Mean
		Number	*Square miles*	*Acre-feet*	*Acre-feet*	*Acre-feet*
American	Fairoaks, Calif.	24	1,910	5,710,000	530,000	2,710,000
Calaveras	Jenny Lind, Calif.	22	395	675,000	31,300	203,000
Eel	Scotia, Calif.	18		8,590,000	814,000	4,280,000
Feather	Oroville, Calif.	28	3,640	9,340,000	1,190,000	4,630,000
Fresno	Knowles, Calif.	14	132	132,000	13,200	59,700
Kaweah	Three Rivers, Calif.	26	520	1,090,000	102,000	400,000
Kern	Bakersfield, Calif.	27	2,345	2,460,000	191,000	743,000
Kings	Piedra, Calif.	34	1,700	3,860,000	392,000	1,710,000
Merced	Pohono Bridge, Calif.	14		608,000	157,000	404,000
Mokelumne	Clements, Calif.	25	631	1,670,000	182,000	770,000
Pit	Ydalpom, Calif.	18	5,260	4,670,000	1,860,000	3,030,000
Sacramento	Red Bluff, Calif.	25	9,300	15,400,000	2,970,000	8,200,000
San Gabriel	Azusa, Calif.	27	214	410,000	23,700	134,000
San Joaquin	Newman, Calif.	18		4,780,000	198,000	1,720,000
Santa Ana	Prado, Calif.	11		305,000	66,000	125,000
Stanislaus	Knights Ferry, Calif.	16	972	1,580,000	250,000	965,000
Trinity	Lewiston, Calif.	19	724	2,150,000	266,000	1,090,000
Tuolumne	Hetch Hetchy, Calif.	15		936,000	374,000	665,000
Yuba	Smartville, Calif.	27	1,220	4,460,000	443,000	2,300,000
Klamath	Spencer Bridge, Oreg.	19	4,000	1,970,000	648,000	1,230,000
Rogue	Raygold, Oreg.	25	2,020	3,030,000	1,100,000	2,040,000
Umpqua	Elkton, Oreg.	21	3,680	8,770,000	2,870,000	5,180,000

[1] From Geological Survey, U.S. Department of the Interior.

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NORTHERN GROUP OF BASINS

The northern group of basins includes an area of approximate 20,000,000 acres drained by the Umpqua, Klamath, Rogue, Eel, ar Russian Rivers and other smaller streams. This vast area is, f the most part, rough and mountainous, densely covered with ma nificent conifers where the precipitation is ample, and having a mo scattered stand where the precipitation is deficient or other unfavo able conditions prevail. The comparatively small area of tillab land—totaling about 1,000,000 acres—is confined chiefly to delta lake bottoms, and narrow valleys bordering streams. The wat supply is abundant but, save for the generation of power for whi there are many excellent opportunities, only a small part can be us for agricultural purposes, and, wi the exception of a part of the flc of Trinity River, there is no feasib means of conveying a part of t excess waters to other basins havi larger areas of arable land. T precipitation ranges from 13 inch per annum at Klamath Falls, Ore to over 100 inches at the headwate of some of the streams, and probab averages about 35 inches. Exce on the mountain peaks and oth high regions, precipitation is in t form of rain rather than snow, a there is little rain in summer. T heavy winter rainstorms produ the floods.

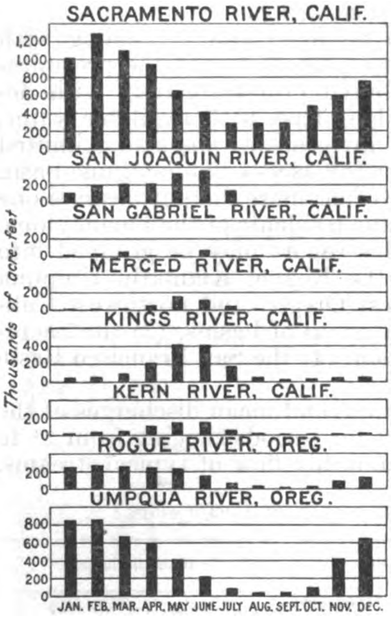

FIGURE 4.—Mean monthly flow of typical streams in the Pacific slope basins.

The mean annual run-off from th group of basins is, in round numbe 40,000,000 acre-feet. In gener Klamath River and its tributari including Trinity River, supply percent of the total, Eel Riv furnishes 15, Umpqua River 1 Smith River 9, Rogue River 5, a Russian River 4. On account the relative smallness of the contributing areas, the melting of snc at the higher elevations causes little increase in run-off.

SACRAMENTO BASIN

The Sacramento Basin has a much larger area of fertile tillab land then the northern basins, a more favorable climate for the pr duction of crops, and better transportation facilities. The grc agricultural area comprises 6,435,000 acres of valley floor, footh area, mountain valley, and the Sacramento-San Joaquin delta, which 4,266,000 acres are classed as irrigable (*11*).

The nontillable portion of the basin occupies the mountain slop and extends to the crest of the Sierras on the east and to the crest the Coast Range on the west. Its chief agricultural value lies in i timber, pasturage, and water-catchment areas. The precipitation variable in both form and amount. On the floor of the Secramen

Valley and around its rim it occurs as rain during the late fall, winter, and early spring months. Little rain falls during the crop-growing season from April 1 to October 1. On the higher elevations the precipitation occurs during the winter months, chiefly as snow. Valley lands receive an average of about 20 inches of rainfall per annum and mountain lands from 30 to 88 inches of precipitation in the form of rain and snow. The estimated mean annual run-off from the basin (*9*) is 25,199,500 acre-feet of which Feather River furnished 21 percent, Pit River 17, American River 13, Yuba River 11, McCloud River 6 and Cottonwood Creek 4, the remaining 28 percent being furnished by smaller tributaries of the Sacramento River. A characteristic of the flow of the Sacramento River and of each of its main tributaries is that high water occurs early in the year, the months of greatest discharge being February, March, April, and May.

SAN JOAQUIN BASIN

The San Joaquin Basin has more land than the Sacramento Basin, while the water supply is less than half as much. The extent of arable land is 8,219,000 acres, of which 5,704,000 acres are irrigable. The mean run-off over a 40-year period is 11,980,000 acre-feet (*9*). The precipitation also is much less. The valley and low foothill areas have an average rainfall of about 10 inches per annum. The remainder is mountain land with larger average precipitations at the higher elevations. The run-off from the San Joaquin Basin comes mainly from the high Sierras between Calaveras County on the north and Kern County on the south. San Joaquin and Tuolumne Rivers each furnish 17 percent of the total run-off, Kings River 16, Merced River 9, Mokelumne River 7, and Kern River 6; the remaining 28 percent of the total run-off being furnished by the smaller tributaries of San Joaquin River.

SAN FRANCISCO BASIN

The San Francisco Basin is the smallest of the basin groups. It comprises 1,420,000 acres and is drained by a number of small streams, which empty into San Francisco Bay. The average annual precipitation, which occurs in winter in the form of rain, is 23 inches near sea level, and somewhat greater on the higher areas of the Coast Range. The mean annual run-off from the basin is 825,300 acre-feet, the greater part of which occurs during the months of January, February, and March, following the winter rains. The larger streams of the basin, from larger to smaller in the order named, are Alameda Creek, Napa River, Coyote River, Petaluma Creek, Mount Diablo Creek, and Los Gatos Creek, with average annual run-offs ranging from 141,000 to 69,000 acre-feet. Taking into consideration the increasing demands for water from the growing urban areas and the 360,000 acres of arable land, the water supply is deficient even though every available storage site is utilized.

SOUTH PACIFIC BASINS

The south Pacific group of basins comprises the coastal watersheds from the San Francisco drainage area on the north to that of the Colorado River on the southeast. The total area drained comprises 8,697,000 acres, of which about 2,616,000 acres are classified as arable lands. Here, also, even with every available reservoir site utilized, there would not be sufficient water to meet the irrigation requirements, and, with the exception of supplies from the Colorado River, there is no feasible means by which water can be brought into this group of basins from outside sources. The precipitation, which is derived almost wholly from rainfall, occurs during the winter months and is generally inadequate for crop production. The mean annual rainfall at Salinas is 14 inches, at Santa Barbara 18.5, at Los Angeles 15.2, at San Diego 10.3, and at Riverside 10.9. The precipitation on the higher areas is somewhat greater. At Mount Wilson it is 33.9 inches and at Squirrel Inn, in the San Bernardino Mountains, it is 37.4 inches per annum. The total mean annual run-off is 3,441,800 acre-feet made up of the discharges of a number of relatively small streams of which Salinas River with its tributaries is the largest. The mean annual discharge of this stream is 961,900 acre-feet, or 28 percent of the total. The Santa Ana River is second—discharging 253,400 acre-feet, or 7 percent. The Soquel Creek group, Pajaro River, San Luis Obispo Creek group, and Santa Clara, Santa Maria, and Santa Inez Rivers, have average annual discharges ranging from 279,900 to 205,500 acre-feet.

The mean annual run-off from the five groups of basins described totals 81,797,900 acre-feet, and the net irrigable area is nearly 14,000,000 acres. It is evident from these figures that the stream flow would be ample to meet all agricultural and other demands for water provided it could be properly conserved and conveyed to the places where it is needed. It is probable that one half of the water supply, if made available, would satisfy all reasonable demands. The northern basin has 40, the Sacramento Basin 5.9, the San Joaquin Basin 2.1, the San Francisco Basin 2.3, and the south Pacific basin 1.3 acre-feet of water to each acre of irrigable land. In the first two basins there are large excess supplies of water, but in the third, fourth, and fifth shortages occur. Little water can be conveyed out of the northern group of basins and little or none out of the San Francisco Basin. Furthermore no appreciable quantity of water from other basins can be conveyed into the south Pacific group of basins. The Department of Public Works of the State of California, however, has formulated a plan by which excess waters of the Sacramento Basin can be conveyed to the San Joaquin Basin. If it were feasible to transfer annually 10,000,000 acre-feet of flood waters from the Sacramento Basin to the more arid lands of the San Joaquin Basin it would solve the overflow problem of the former basin and give an adequate supply to the latter. Under this plan 10,000,000 acres of fertile land in the great central plain of California would be provided with a dependable water supply for irrigation.

The quantity of water which can be transferred annually from the Sacramento Basin to the San Joaquin Basin will depend to a large extent on the storage facilities in the former basin. Sites aggregating a storage capacity (*9*) of 7,743,000 acre-feet available for irrigation in 10 reservoirs have been surveyed in the Sacramento Valley.

IRRIGATION PRACTICE

Irrigation practice in the Pacific slope basins has been characterized by the success attained along four general lines. These are (1) the organization of irrigation enterprises; (2) pumping water from underground basins; (3) using concrete pipe in farm and orchard irrigation; and (4) combining the storage of water for irrigation with hydro-electric development.

IRRIGATION ENTERPRISES IN CALIFORNIA

Irrigation-district, mutual-company, and commercial-company enterprises together embrace 58 percent of the irrigated area of California (*31*). The irrigation district is the outstanding type of organization, with 34 percent of the irrigated area, and the mutual company is second, with 18 percent. Individual and partnership enterprises cover 37 percent of the State's irrigated area, this high ratio being largely because of the extensive installation of pumping plants.

The organization of irrigation districts on the Pacific slope originated in an effort to provide suitable means for the conversion of dry farms into smaller irrigated holdings. Its purpose was to place in the hands of those owning the land the management and control of the irrigation system, and provide a method for securing funds to construct and operate works too costly for an individual or a small group of individuals to undertake. Its chief benefit lies in uniting in one organization all the people of an agricultural community so that each one contributes his just share toward the expense of the enterprise, has a voice in its management, and shares in its benefits.

An analysis of the available data on the cost of water in California, compiled cooperatively in 1930 by the Bureau of Agricultural Engineering, the University of California, and the California State Department of Public Works, (*8*) indicates that the three leading types of irrigation organization have, in the aggregate, an important influence upon the quantities of water used in irrigation. This is due partly to the fact that so many of them engage in pumping, and partly to the widespread practice of charging tolls based upon the quantity of water delivered.

Of the 71 irrigation districts reported, 28 pumped 100 percent of their water supplies and 10 pumped parts of such supplies, the lifts ranging from 5 to 400 feet, while 43 charged tolls for water in addition to the annual assessment. Of the districts charging tolls, only 6 reported deliveries of more than 2 acre-feet per acre in 1929, while 34 reported that the water supply was ample for the acreage irrigated in that year.

The mutual company is particularly important in southern California. Nearly all of the leading companies in that section of the State and many of those in northern and central California depend wholly or partly upon pumped water. A number of the companies charge a quantitative rate for water, which either supplements the stock assessment or supersedes it entirely. The value of water in southern California is very high and on the whole wasteful practices are exceptional.

The rate schedules of the commercial companies are mainly quantitative rather than flat charges per acre. Only 6 of the 34 companies reported in the cost study derive their water supplies by pumping, and all of these are in southern California. Most of the companies reported water deliveries of less than 2.5 acre-feet per acre, the larger quantities generally being for rice irrigation. Wasteful uses exist, but the decreasing supply of unappropriated water, the high capital costs, and frequently the high cost of operation, effectively prevent the extension of wasteful practices.

PUMPING WATER FROM UNDERGROUND BASINS

In 1930 there were 46,737 pumped wells in California, having an aggregate capacity of 24,266,000 gallons per minute, with a capital investment of about $240,000,000. During the previous decade the number of plants had more than doubled and the investment had trebled. This was due in part to a series of dry years with a resulting decrease in surface run-off and an extension of the farming area dependent upon irrigation for crop production.

During the 1920–29 decade the quantity of water derived from underground sources in California steadily increased, resulting in a general lowering of the water table, with threatened exhaustion of the supply in many districts. In 1919 the average depth to ground water in the State was 42 feet but 10 years later it was 53 feet. In Santa Clara County, with only a small increase in the number of pumped wells, the average ground-water level dropped from 56 to 100 feet. Average drops of 29 feet in Santa Barbara County, 26 feet in Los Angeles County, and 19 feet in Orange County are recorded (*31*).

Such a general lowering of the water table results in ever increasing expense to the grower for pumping, until crop returns no longer show profits. This point arrives sooner with some crops than with others.

In California about 1,500,000 acres are irrigated by pumping from wells. The cost of pumping, which includes the cost of power, attendance, interest, taxes, insurance, and repairs, varies within rather wide limits. In 1922 and 1923 a number of these costs were determined on farms in the Sacramento and San Joaquin Valleys (*8*) where it was found that the average cost of pumping an acre-foot of water per foot of lift was 18.7 cents. At this rate the increased cost of raising water an additional 12 feet is $3,000,000 per annum.

To counteract this an attempt is being made partly to replenish basins in which the lift is approaching the limit of economic pumping. This is called "water spreading" and consists in applying flood or waste water to the surface of porous soils and subsoils in such a way that it will pass through the porous material and increase the ground-water supply. As a further aid to replenishment, reservoirs have been built and other reservoir sites have been surveyed with the object of using stored water mainly to raise the level and increase the volume of underground water.

A number of such spreading grounds are now maintained on the detrital cones at the mouths of various canyons in the San Bernandino Mountains where flood waters are allowed to percolate into the underground basins to be recovered by pumping at lower levels as needed. This method of storage has distinct advantages over surface storage both in cost and capacity as also in preventing evaporation losses. The practice of water spreading is increasing and the demand for information regarding methods of spreading and rates of percolation under different conditions has led to important studies by the Bureau of Agricultural Engineering of these problems.

USE OF CONCRETE PIPE IN IRRIGATION

In many irrigated districts only about one half of the water diverted is serving a useful purpose in the production of crops. It is mainly to decrease this serious loss that in California earth ditches are being replaced by concrete pipes.

As has been stated elsewhere (*19, p. 395*):

> By this substitution the farmer saves valuable water, spreads it more uniformly over the surfaces of fields, lessens the work of applying it, prevents the growth of weeds on ditch banks, removes a barrier to transportation, prevents the water-logging of soil, and salvages fertile land for cropping.

The census (*31*) reports the mileage of concrete irrigation pipe installed in California as close to 10,000 miles, mostly of diameters of 12 inches or less.

COMBINING THE STORAGE OF WATER FOR IRRIGATION WITH HYDROELECTRIC DEVELOPMENT

Frequently a stream can be made to serve two purposes. As a stream descends from the high mountains electrical energy can be developed before the water reaches the intakes of the farmers' canals. Also, when the flood flow of mountain streams is retained temporarily in reservoirs, it regulates the flow to both power plants and irrigation enterprises, greatly extends its useful period, and increases the profits of both industries. These conditions prevail in most of the Pacific slope basins.

The greater part of the run-off of the San Joaquin, Sacramento, and northern basins comes from elevations of 3,000 to 7,000 feet, and in the lower catchment areas of the Coast Range, which feed the streams of the San Francisco and south Pacific basins, there are natural reservoir sites that can be utilized for the development of power and also for irrigation. Considerable progress has already been made in storing water for this twofold purpose.

Two plans of great magnitude formulated for combinations of this sort may be mentioned. The first pertains to the proposed development at Kennett, Shasta County, Calif., consisting of a dam which will impound 2,940,000 acre-feet of water, and a power plant of 275,000 kilovolt-amperes capacity (*11*). The second is the Boulder Dam on the Colorado River, which will create a reservoir of 30,500,000 acre-feet capacity, a part of which will be made available to residents of the south Pacific basins.

CROPS GROWN UNDER IRRIGATION

Prior to 1850 irrigation was not practiced in the Pacific slope basins and crop production was confined mainly to raising cereals and wild hay on the fertile lands along stream bottoms. Crop production without irrigation reached its maximum in 1885, the area farmed being determined by the amount and distribution of rainfall. Only crops of low water requirement could be successfully raised. The demand for agricultural products was therefore supplied by dry farming and little or no attention was paid to irrigation. As settlement continued and the demand for agricultural products increased, a few farmers increased their production by practicing a crude method of irrigation. Such irrigation was by individual effort of the owner as water was plentiful and easily diverted from the neighboring stream. In this way some farms became more productive than others, but the majority depended on the scanty rainfall.

When the demand for agricultural products exceeded the capacity for production by dry-farming, better methods and more intensive farming were employed. Individual irrigation enterprise had demonstrated the benefits of this practice with the result that the irrigated land in California has increased from a small area in 1870 to 4,746,000 acres in 1929.

Many changes in agriculture have occurred since the beginning of irrigation, particularly during the last 2 decades. Weeks (*14*) showed that although the total cropped area harvested increased only 15 percent between 1909 and 1929 the acreage in subtropical fruits had increased 143 percent, in Temperate Zone fruits 159, in vegetables 203, and in miscellaneous field crops 66 percent. In making this shift of crops there was necessarily a loss in acreage of those crops grown under earlier conditions. Thus, hays and forage lost 22 percent of their acreage, while cereals lost 6.

On account of economic conditions and changes in price levels, differences in acreage of different crops occur from year to year. In years of high prices large acreages in high-priced crops are planted with hopes of making large profits. Yearly shifts from one crop to another can be easily made with annuals as production becomes no longer profitable or another high-priced crop seems more favorable. With perennials such as fruits or nuts that do not come into production quickly, the high prices which have led to their planting may have vanished before crop yields are available. In this case the grower holds on in the hope high prices will return, since he cannot readily change from one crop to another. Citrus fruits, grapes, avocados, deciduous fruits, and walnuts, are in this class and there has been a steady increase in acreage of these crops during the past 25 years.

Rice and cotton first made their appearance commercially in California about 20 years ago. The acreage of rice increased to a maximum of 162,000 acres but had decreased to 125,000 in 1931. It is grown mainly on the heavy soils in the Sacramento Valley, with a few thousand acres in Merced County and a small amount in the Imperial Valley. Cotton acreage continued to increase until 1929, when there was a total of 309,000 acres harvested in the State, although there has since been a marked decrease in acreage because of low prices. The greater portion of this acreage lies in the six most southerly counties of the San Joaquin Valley, which have shown a great increase in cotton yield in recent years. In 1924 the Imperial Valley produced 80,000 acres of cotton which decreased to less than 10,000 in 1930. Cotton acreage in the San Joaquin Valley increased from 2,500 acres in 1922 to 250,000 in 1929.

The principal crops grown in southwestern Oregon are hay and forage, cereals, and deciduous fruits. The eastern portion of this area has a rather high altitude and short growing season which is best suited for production of hay and forage crops. In the western portion the soil, climate, and water supply are more suitable for growth of deciduous fruits and hay crops.

RELATION OF WATER APPLIED TO CROP YIELD

Investigations have been carried on for a number of years by the Bureau of Agricultural Engineering [3] either independently or in cooperation with other agencies, in several localities in Oregon and Cali-

[3] The studies were made first under the Office of Experiment Stations and later under the Bureau of Public Roads, before the Bureau of Agricultural Engineering was established.

fornia to determine the relation of water applied to crop yield. These experiments are generally conducted on duplicate or triplicate plots under similar conditions of soil, temperature, sunshine, and rainfall. Measured quantities of water are applied to the different plots. One plot or set of plots is frequently left unirrigated as a check plot so that the full effect of irrigation on the crop yield may be noted. As nearly as possible plots having similar soils are selected.

Under these conditions the relation of water applied to the crop yield and the quantity of water which produces the best crop may be determined. This relationship is more easily established with some crops than with others and for various reasons it will be found that the ratio of pounds of water received by the crop to pounds of yield show rather wide variations. In experiments of this nature only the irrigation water and the rainfall were measured. More recent experiments take into account soil moisture throughout the period of observation and thus gain or loss of moisture in the soil throughout the growing period is determined.

By growing plants in duplicate or triplicate the inaccuracies due to factors which affect plant growth are minimized and better records are possible. Application of more water generally results in increasing crop yield up to a certain limit with certain crops, but beyond this limit there is a decrease in crop yield. This has been found to be especially true with field crops but not necessarily so with fruits or nuts.

The results shown graphically in figures 5 and 6 have been selected from data given in tables 6 to 11 and include alfalfa, silage corn, rice, wheat, oats, barley, and cotton.

WATER REQUIREMENTS OF CROPS

EXPERIMENTS WITH ALFALFA

During the years 1913 and 1914 measurements were made on a number of farms in different localities to determine the most economical duty of water for alfalfa grown in the Sacramento Valley. These farms ranged in size from 3 to 76 acres, with soils of silt loam or clay loam. Rainfall during the growing season is generally small as the heaviest rains occur during the early spring months. The spring rains, however, store water in the soil for later use, and in this bulletin water used by field crops grown in the Sacramento and San Joaquin Valleys, as tabulated in tables 9 to 11, inclusive, includes irrigation water applied as well as rainfall occurring between January 1 and September 30. No rainfall has been added to soil moisture used by crops grown in tanks, as early spring rains would not greatly change soil-moisture conditions in tanks having high water tables.

Rainfall on farms studied varied in the different localities from 0.44 to 1.54 feet and the number of irrigations ranged from 2 to 15, differing with the soil and irrigation management. Analysis of the data abstracted from Bulletin No. 3, Department of Engineering, State of California (4), in table 9, shows that of the 83 farms reported 12 receiving amounts of water averaging 3.23 acre-feet produced less than 4 tons of hay per acre; 38 receiving amounts averaging 4.43 acre-feet produced from 4 to 6 tons; 13 receiving amounts averaging 5.20 acre-feet produced from 6 to 7 tons; 11 receiving amounts averaging 4.12 acre-feet produced from 7 to 8 tons; and 9 receiving

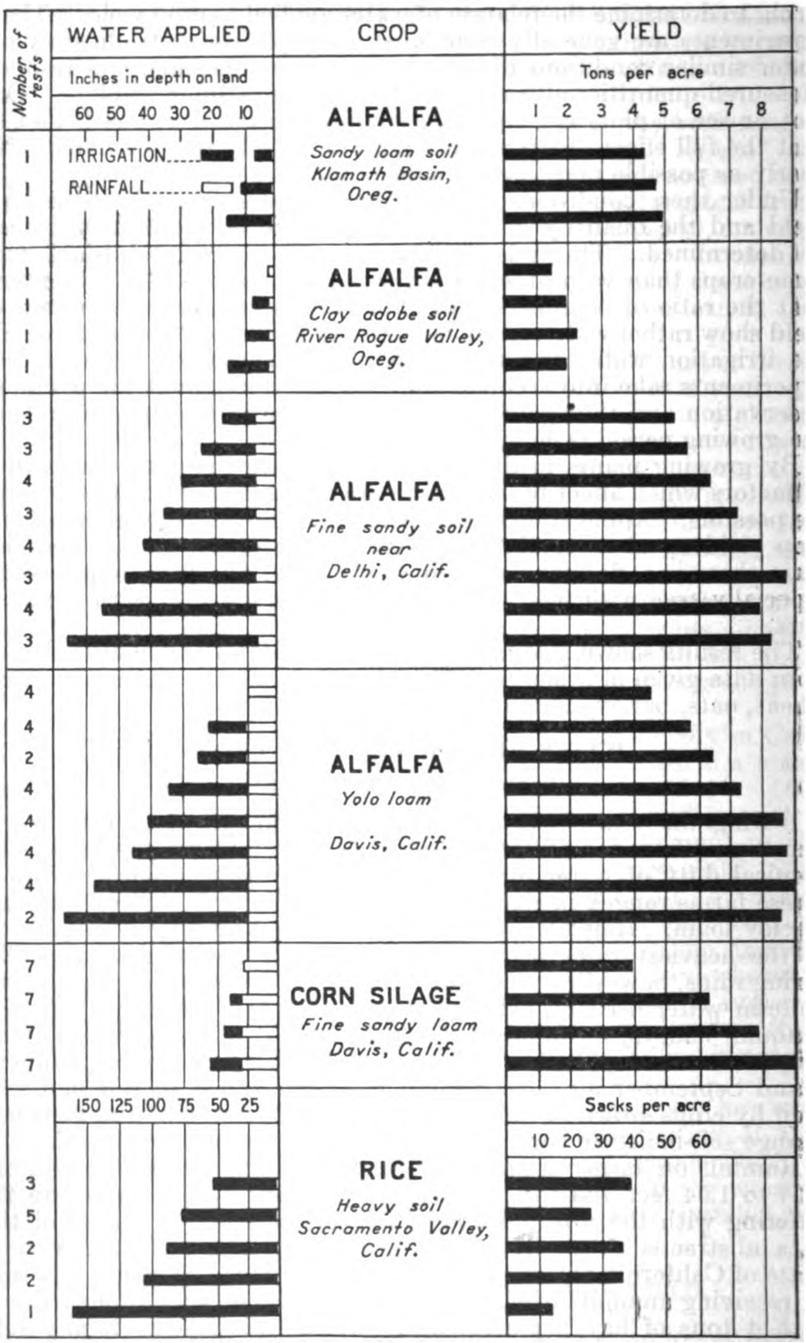

FIGURE 5.—Relation between quantity of water applied and crop yields of alfalfa, silage corn, and rice, as determined by plot experiments at various places in Oregon and California.

amounts averaging 4.19 acre-feet produced more than 8 tons per acre. The amounts of water received were inclusive of rainfall. The results obtained on these 83 tracts indicated further that those receiving less than 2 acre-feet of irrigation water (not including rain-

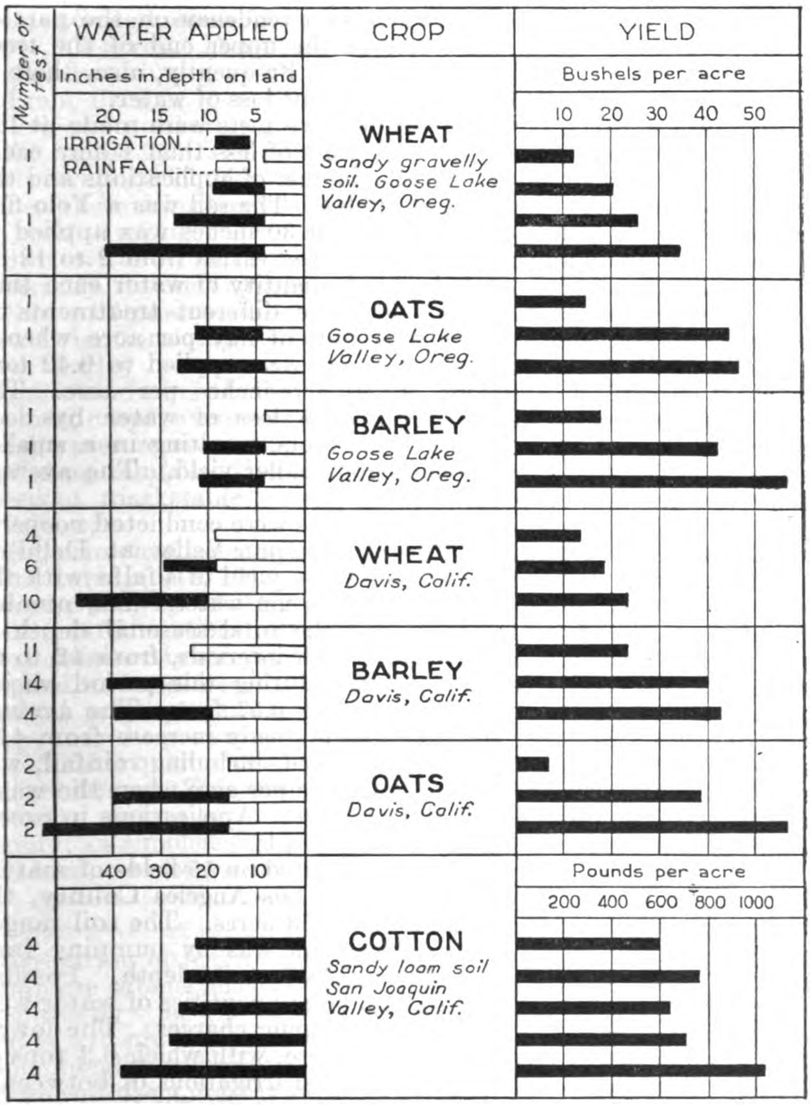

FIGURE 6.—Relation between quantity of water applied and crop yields of wheat, oats, barley, and cotton as determined by plot experiments at various places in Oregon and California.

fall) did not produce satisfactory yields and that, on the other hand, irrigation water in excess of 4 acre-feet per acre usually did not increase the yield. It was concluded that generally in the upper Sacramento Valley the most satisfactory yields result from applications of irrigation water amounting to about 3 acre-feet per acre which, with the normal rainfall, gives a total of a little more th 4 acre-feet per acre.

These studies differ from plot experiments in that water appli to large areas is not under as good control and cannot be used carefully and economically as on small plots where the observer c give it better attention. Often there is a tendency on the part irrigators to apply too much water at the upper end of the tra irrigated and too little at the lower end. Frequently, also, there a disposition to overirrigate, with a resultant loss of water.

From 1918 to 1925, inclusive, cooperative tests were made at t University Farm at Davis, Calif., on plots of less than 1 acre eac to determine the effect of varying the number of applications and t depth of water applied on yield of alfalfa. The soil was a Yolo fi sandy loam. The total seasonal depth of 30 inches was applied each plot, but the number of irrigations was varied from 2 to 12 applying different fractions of the total quantity of water each ti (table 9). The average yields under the different treatments i creased quite consistently from 8.24 tons of hay per acre when irrigations of 15 acre-inches per acre each were applied to 9.42 to per acre with 12 applications of 2½ acre-inches per acre. T heavier applications probably resulted in loss of water by de percolation beyond the reach of plant roots, resulting in a smal consumptive use and a correspondingly smaller yield. The avera rainfall amounted to 0.73 foot.

During 1922, 1923, and 1924 experiments were conducted coope tively (table 10 and fig. 5) in the San Joaquin Valley at Delhi plots of about 1 acre each to determine the yield of alfalfa with t application of different quantities of irrigation water. The numb of irrigations varied from 3 to 6, and the total seasonal depth water applied increased, with 6- to 12-inch intervals, from 12 to acre-inches per acre. Effective rainfall during this period vari from 0.31 to 0.76 foot in depth, averaging 0.57 foot. The avera yield for the 3-year experiment showed a steady increase from 4. tons per acre when the total water received, including rainfall, w less than 1.5 acre-feet per acre to 8.27 tons per acre when the wa received averaged about 4 acre-feet per acre. Applications in exc of this amount produced slightly smaller yields.

During 1931 irrigation water was measured on 15 fields of matu alfalfa grown in the Antelope Valley in Los Angeles County, t different fields ranging in size from 4 to 153 acres. The soil rang from sand to fine sandy loam. Irrigation was by pumping fr individual wells ranging from 50 to 129 feet in depth. Possib because of the sandy nature of the soil large quantities of water we used in spite of high lifts and heavy pumping charges. The low quantity applied was 1.19 acre-feet per acre, with which 6.3 tons alfalfa hay were produced. Total seasonal irrigations of between and 5 acre-feet per acre produced on an average 6.9 tons of ha between 5 and 6 acre-feet the yield was 6.3 tons; 6 to 7 acre-fe produced 5.6 tons. These results indicate that the application excessive quantities of water in the irrigation of alfalfa tends reduce yields and represents wasteful irrigation. Because of the lo growing season in this locality and storage of spring rains in the s the entire seasonal rainfall of 0.71 foot in depth has been added irrigation water applied to arrive at the total water received by the crop (table 12).

EXPERIMENTS WITH CEREALS

The cereals grown in the Pacific slope basins, in the order of acreage cropped, are barley, wheat, oats, sorghums, rice, and corn. The total acreage used for these crops in California comprises over 2,000,000 acres. Except for rice the water requirements of the various grains do not vary widely.

From 1910 to 1916, inclusive, cooperative experiments were made in irrigation of barley grown on plots at the University Farm, Davis, Calif. (table 9). The soil was a Yolo fine sandy loam. Barley is an early crop which derives most of its moisture from winter rains. When these rains amount to from 15 to 18 inches and are distributed in such a manner as to be of value to crop growth, barley may be grown without supplementary irrigation. If rainfall is deficient, especially during the later spring months, one irrigation of 4 to 6 inches will produce a satisfactory crop, or if the season is very dry two irrigations may be necessary. During the period when tests with barley were being made early spring rainfall showed wide variations during the different years of the experiment. In general the best crops, averaging 45 bushels per acre, were obtained when the total water received amounted to from 1.5 to 2.0 acre-feet per acre, including rainfall. Usually when less than 0.83 foot of moisture was received marketable returns were too small to pay for the labor involved.

Experiments were also made in irrigation of wheat at the Davis farm during 1912, 1913, and 1914, to determine the most economical use of water by wheat grown in plots. A number of these plots received no irrigation, resulting in a very low yield. The best yields were obtained in the year of lowest rainfall by means of two irrigations applied at times when the soil was in greatest need of moisture. In general small grains are low in water requirement and satisfactory crops may be grown without irrigation provided precipitation occurs in sufficient quantities and at proper intervals to provide the necessary soil moisture. This practice is not generally followed in California, however, except on marginal lands of low value without a water supply, as supplementary irrigation if applied at the proper time, will increase crop yields.

EXPERIMENTS WITH RICE

Irrigation of rice differs from the irrigation of other crops in that complete submergence of the rice field to a depth of from 6 to 8 inches is necessary for the best production. Therefore, only heavy soils which will prevent rapid downward movement of water may be used economically for irrigated rice, and it is probable that imperviousness of the soil has a greater effect in promoting a high duty than all other factors combined. Clay, clay adobe, and adobe soils are generally adapted to rice growing.

The period of submergence begins with the planting of the crop and continues until about 2 weeks before harvest, allowing the soil sufficient time to dry out and become firm enough to support the weight of harvesting machinery. The drainage of rice fields before harvesting requires complete drainage systems to carry away the ponded water as well as to prevent the rise of ground water too clo: to the soil surface thus keeping the land dry in the spring and read for seeding.

Other factors in the use of water by rice are length of growir season, evaporation from water surfaces, alkali removal from the soi and prevention of early growths of water grass and other weeds, all ‹ which increase the quantity of water used. Evaporation during tl growing season is an item of considerable importance and is the or under the least control. It has been estimated (2) that the water lo: by evaporation amounts to about one third of the total applied.

Experiments were conducted cooperatively (table 9) during 191 and 1917 to determine the net use of water by rice in the Sacrament Valley. Of 30 farms, ranging in size up to more than 2,000 acres, 1 produced an average of 38 sacks of 100 pounds each per acre with tl net use of about 5 acre-feet of water. The soils of these farms we: mostly clay and clay adobe. The use of more water on these soi resulted in a decrease in yield. On the more pervious loam soils, for farms had an average use of water of 10.7 acre-feet per acre with a average yield of 27.5 sacks of rice. It appears, therefore, that impe vious soils are best for rice production and that on such an average ‹ 5 acre-feet per acre is the most economical net use of water.

EXPERIMENTS WITH COTTON

Experiments to determine the use of water by cotton were made b the University of California Agricultural Experiment Station at tl United States Cotton Field Station at Shafter, in southern San Jo: quin Valley, during the years 1926 to 1930, inclusive (6). The princip: factors in growing cotton are climate, soil, cultural practices, an irrigation. The growing season must be both long and warm and tl soil should be able to absorb water freely. Frequent cultivations a1 necessary to keep down growths of weeds which use large quantiti of water. In the arid and semiarid valleys of California cotton cann be grown without irrigation. In the cotton-growing districts of tl San Joaquin and Imperial Valleys rainfall is too small and occurs : the wrong time of year to be of value, hence the necessary soil moistu: must be maintained by irrigation (table 10). A preirrigation ‹ about 6 acre-inches per acre is recommended as moisture applied : this time is of great value to plant development. The soil should l moist to the depth of the root zone at all times to encourage prop root growth. Cotton is sensitive to irrigation; it quickly shows tl effect of either drought or the addition of moisture.

At the experimental station at Shafter cotton was grown on plo of Delano sandy loam which was fairly uniform to a depth of 5 fee The size of plots was 16 by 90 feet, and four rows of cotton 4 feet apa: were planted in each plot, the plants being 12 inches apart in the ro The irrigation treatments given different groups of plots during eac of the 4 years of the experiment were: Irrigation when (1) the moistu: content fell to about 7 percent, (2) when plants wilted at 4 p.m (3) when plants wilted at 9 a.m., (4) to provide high moisture conte early in the season and low moisture content late in the season, an (5) to provide low moisture content early in the season and hig moisture content late in the season. From 5 to 9 replications we: made of each treatment and the results from these replications ha been averaged in table 2, in which the experiments are listed for each year in the same order as the number of the treatment. All plots except those receiving treatment no. 5 include a preseason irrigation of 6 acre-inches per acre before planting. All irrigation was by flooding. Each year the best yield was obtained from treatment no. 1 and the poorest yield was obtained under treatment no. 3. The 4-year averages of yields and water applied, including preseason irrigations and rainfall, are given in table 2.

TABLE 2.—*Summary of water applied and yield of cotton grown under different irrigation treatments* [1]

Treatment no.	Irrigations	Water applied per acre including rainfall	Yield per acre
	Number	*Acre-feet*	*Bales*
1	7	3.46	2.06
2	4	2.31	1.53
3	3	2.12	1.20
4	5	2.57	1.39
5	5	2.42	1.26

[1] Average of 4 years' experiments.

TANK EXPERIMENTS WITH VEGETABLES IN THE SACRAMENTO-SAN JOAQUIN DELTA

Experiments in the use of water by vegetables grown on both sedimentary and peat soils in the Sacramento-San Joaquin delta made cooperatively by the Bureau of Agricultural Engineering and the State of California Department of Public Works, Division of Water Resources, were begun in 1924 and are still in progress (table 11). The land lies at or below tide level, enclosed in diked districts in which the high ground water fluctuates within the limits of the root zone, making it well adapted to the subirrigation method. Roughly, from 40 to 45 percent of the crops in the area are grown on peat soil. The scope of the investigation included the determination of the use of water on individual tracts or islands measured as a unit, measurement of the net quantity of water applied to individual crops on selected fields, and determination of consumptive use of water by the principal delta crops grown in tanks. The most satisfactory determination of use of water by crops grown on a large area as a unit was conducted on about 22,000 acres of Reclamation District No. 999. The soil in this district is sedimentary and is well adapted to the growth of deciduous fruits, alfalfa, sugar beets, asparagus, and vegetables. The net use of water by crops was determined as the difference in the quantities pumped or siphoned onto the land for irrigation and that pumped out of the district as drainage. The results indicate that the net seasonal consumptive use of water for the crops grown on the sedimentary land of this district is 2 acre-feet per acre.

Measurements of the use of water on large areas of peat land proved unsatisfactory because of nonmeasurable quantities of upward seepage or movement of water into the area investigated, and the same held true for individual farms. Measurements made under such conditions are inconclusive. The tank method of measuring the use of water by crops was therefore used for peat soils and to some extent for sedimentary soils.

The principal crops grown on peat soils are asparagus, corn, gra and potatoes. Under field conditions crop demand for moisture satisfied by artificial regulation of the ground-water level. Watei pumped over the river levees into large ditches from which it is lift into shallow "spud" ditches by booster pumps. To lower the grou water the process is reversed and water is pumped out of the ditcl back to the river. As the peat soil is exceedingly porous the wa table falls quickly and the peat is easily and rapidly drained.

In these experiments water tables were maintained in the tank s either at a fixed depth to determine the optimum depth, or by causi the water level in the tank to fluctuate uniformly with that in t adjoining field. In the experiments hereinafter referred to, eitl condition may have been followed. All tank experiments were ma during the growing season and the use of water as determined d(not include rainfall.

ASPARAGUS

For several years tank experiments have been made with a varie of delta crops, of which asparagus is one of the most important. 36 tank experiments with asparagus grown in peat soil, conduct during 1929, 1930, and 1931, the average use of water was 2.79 ac feet per acre and the corresponding average yield per acre was 5. tons of spears. In these experiments 12 tanks had a water table feet below the soil surface, 12 had a 3-foot water table, and 12 had 4-foot water table. There does not seem to be any direct relati between depth to water and crop yield, the average yield for t 2-foot and that when the water was at the 4-foot levels being neai the same. For quantities of water used at the different depths water table, however, the consumptive use was 37 percent great with the upper level than with the lower. A part of this differen was undoubtedly due to greater evaporation as more moisture w held in the surface soil when the water level was high.

POTATOES

In 1925 potatoes were grown in peat soil in tanks. The water tal in the tanks stood at about 2 feet below the soil surface at the begi ning of the season, was raised to about the 1-foot level during mi season, and allowed to fall below the 2-foot level at the close of t season. Four of the tanks were covered in such a manner as to pı vent evaporation loss from the soil without interfering with the ra of transpiration. All tanks showed a close relation between use water and yield of crop. The average use as determined by 12 exp(iments was 1.49 acre-feet of water per acre, with an average yield 23,000 pounds of potatoes.

CORN

During 1926 and 1927 tank tests were made of corn grown on pe soil to determine the use of water by this crop. The water tables the various tanks were maintained at depths of 1 foot and 2 feet frc the ground surface. If the water table is fixed throughout the gro ing season, probably little harm is done to ordinary vegetable cro by high ground water; but if the water table is raised during midseas above the limit of depth to which the roots have previously penetrat(

they will be drowned and the crop will be damaged. In the tests with corn the water table was kept at one level during the growing season. Twenty-one tests were made in which the relationship of the quantity of water used by the crop to the yield of ears of corn was determined. The average use of water from these tests was 3.38 acre-feet per acre and the corresponding yield was 11,770 pounds of ear corn. This is the largest quantity of water used by any crop tested in these experiments, and is much more than corn ordinarily uses under field conditions in other localities. There seems to be a definite use-yield relation for this crop, but it seems to be less striking than that found in experiments with other crops.

BARLEY

During 1930 experiments were conducted on the water requirement for barley grown in peat soil in tanks. There was found to be a definite relationship between the quantity of water used by the crop and the yield. Out of 19 tests two tanks used less than 1 acre-foot of water in producing a crop of 23 sacks of 100 pounds each per acre. With the increase in the quantity of water used there was a corresponding increase in the yield up to the limits of the experiment; thus, 37 sacks of grain were produced when from 1.0 to 1.5 acre-feet of water was used; 84 sacks when the use was between 1.5 and 2.0 acre-feet per acre, and 126 sacks when the water use amounted to between 2.0 and 2.5 acre-feet per acre. The average use of water for all the barley experiments of that year was 1.65 acre-feet per acre.

MISCELLANEOUS TANK EXPERIMENTS

Experiments were also carried on to determine the average use of water by other delta crops, as follows: Measurements of the water used by celery averaged 1.07 acre-feet of water per acre in 7 tank experiments; 8 tests for onions showed an average use of 1.35 acre-feet per acre, and with 32 tests with sugar beets the average use of water was determined to be 2.71 acre-feet per acre. The seven varieties of crops referred to herein, viz., asparagus, potatoes, corn, barley, celery, onions, and sugar beets, are those most extensively raised in the delta region and from these experiments it has been estimated that the weighted average seasonal use of water by crops grown on peat soils is slightly over 2 acre-feet per acre.

EXPERIMENTS WITH PEAR TREES

Cooperative experiments have been conducted in the Rogue River Valley, Oreg., by the Bureau of Agricultural Engineering and the Oregon State Agricultural Experiment Station during 1930, 1931, and 1932 to determine the quantity of water used by mature pear trees grown in silty clay loam and clay adobe soils. Twenty-eight measurements of use of water by the trees and the corresponding yields are given in table 6. The trees were fully matured, being either 22 or 27 years old except in four tests where the age was 16 years. The number of irrigations varied from 1 to 7 with different treatments, and the total depth of irrigation water applied ranged from 0.32 to 2.02 acre-feet per acre. Rainfall included is that which fell during the growing season from March 1 to October 31.

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It is sometimes difficult to determine the effect that the quantity of water applied has on orchard yield as many factors enter into the problem, such as climatic conditions, damage by pests, fertility of the soil, pruning, variety of fruit produced, and soil on which it is grown. Any one or all of these factors may influence the amount and quality of the fruit produced and in some cases may have more effect than variations in the quantity of water applied. In these experiments, however, and overlooking other factors, there appears to be some relation between the quantity of water, including rainfall, applied to the trees and the fruit crop that the trees produce. Of the 28 tests made during a 3-year period the best average yields were made in seven tests in which the total water applied, including rainfall, was between 1.25 and 1.50 acre-feet per acre. Increasing the quantity to 2 acre-feet per acre did not result in any increase in the tree yield.

USE OF WATER BY CITRUS TREES

As previously mentioned, many factors affect the yield and quality of orchard products, and this statement is even more applicable with respect to citrus and other subtropical fruits in southern California than it is for the hardier deciduous fruits. Such factors are (1) climate, soil type, and age and variety of trees, all of which are beyond the control of the grower, and (2) cultivation, pest control, pruning, fertilizing, growing of cover crops, and the amount of irrigation and the time of its application, which are under the grower's control. In addition to the irrigation water applied and its distribution throughout the season all these factors, under control or otherwise, influence the crop yield and therefore it is difficult to determine the effect of irrigation alone in comparison with the combined effects of all other influences.

In southern California climate may be classified as coastal, intermediate, and interior. In the coastal climate strong ocean influence is manifest; the intermediate climate is found back from the coast but not remote from all ocean modifying influences, and the interior climate is remote from the coast and all ocean influences. The atmosphere along the coast contains more moisture than is found in the interior and, moreover, is cooler in summer. Crops grown in the coastal area, therefore, can mature with less irrigation water than can those of the interior. This is shown in table 3 which contains a summary of the use of water by subtropical fruits and nuts in Los Angeles, Riverside, San Diego, Orange, and Tulare Counties. These records are given in greater detail in tables 13 and 14. They were kept by individual growers under the supervision of the Agricultural Extension Service of the University of California and the immediate direction of the county farm advisor. Although in some cases too much and in other cases too little water was applied, the average is probably not much in excess of the water requirements of the crops. The use of water in southern California is normally restricted by its scarcity and cost; hence little water is wasted through over irrigation.

TABLE 3.—*Average seasonal use of water and crop yields of subtropical fruits and nuts in southern California* [1]

County	Crop	Year of record	Tracts of record	Rainfall [2]	Irrigation per acre	Yield per acre	Climatic location [4]
			Number	*Feet*	*Acre-feet*		
Orange	Valencia oranges	1929	71	0.83	1.71	285 packed boxes [3]	Coastal.
Do	do	1930	63	1.08	1.60	151 packed boxes [3]	Do.
Do	do	1931	57	.93	1.66	254 packed boxes [3]	Do.
Los Angeles	do	1931	20	1.12	1.79	223 packed boxes [3]	Intermediate.
San Diego	Washington navel oranges.	1923–25	6	.88	1.81	247 field boxes [3]	Do.
Tulare	do	1928	14	.65	2.37	119 packed boxes	Interior.
Do	do	1929	18	.56	2.59	87 packed boxes	Do.
Do	do	1930	24	.44	2.70	171 packed boxes	Do.
Los Angeles	do	1931	20	1.11	1.94	314 packed boxes	Intermediate.
San Diego	Lemons	1923–25	9	.88	1.66	423 field boxes	Do.
Orange	do	1929	9	.83	1.27	169 hundredweight	Coastal.
Do	do	1930	16	1.03	1.22	113 hundredweight	Do.
Do	do	1931	14	.90	1.37	172 hundredweight	Do.
Los Angeles	do	1931	20	1.16	1.74	287 packed boxes	Intermediate.
Orange	Avocados	1930 [5]	10	.94	1.41	865 pounds	Coastal.
Do	do	1931 [6]	18	.94	1.64	3,560 pounds	Do.
Kern	Grapes	1930	11	.37	3.21	5.35 green tons	Interior.
Orange	Walnuts	1930	23	1.09	1.93	1,128 pounds	Coastal.
Do	do	1931	18	.89	1.85	1,018 pounds	Do.
Los Angeles	do	1927	3	1.36	1.25	285 pounds	Do.
Do	do	1927	17	1.88	1.29	1,703 pounds	Intermediate.
Do	do	1927	2	2.06	2.31	1,791 pounds	Interior.
Do	do	1928	4	1.11	1.54	899 pounds	Coastal.
Do	do	1928	19	1.06	1.47	623 pounds	Intermediate.
Do	do	1928	2	1.19	1.77	980 pounds	Interior.
Do	do	1929	5	.87	2.07	1,734 pounds	Coastal.
Do	do	1929	22	.72	1.66	1,147 pounds	Intermediate.
Do	do	1929	5	.99	2.39	972 pounds	Interior.
Do	do	1930	5	.87	1.90	989 pounds	Coastal.
Do	do	1930	19	1.14	1.43	622 pounds	Intermediate.
Do	do	1930	11	1.15	2.00	726 pounds	Interior.
Do	do	1931	4	.98	1.76	1,083 pounds	Coastal.
Do	do	1931	15	.96	1.55	1,182 pounds	Intermediate.
Do	do	1931	8	1.12	1.56	884 pounds	Interior.

[1] From records of farm advisers, except in San Diego County.
[2] In all localities except Kern County the rainfall is the amount from Oct. 1 of the preceding season to Sept. 30 of the current year. In Kern County rainfall is computed from Jan. 1 to Sept. 30.
[3] Packed boxes of oranges are computed on a basis of 72 pounds of fruit per box; field boxes of oranges weigh between 45 and 50 pounds; and field boxes of lemons 55 to 60 pounds. All packed boxes include culls on a packed-box basis.
[4] Coastal climate is one where strong ocean influence is manifest. Intermediate climate is one back from the coast but not remote from all ocean modifying factors. Interior climate is one remote from modifying ocean influences.
[5] 1930 was a low-crop year for avocados.
[6] 1931 was a normal-crop year for avocados.

Records of water applied and yields obtained during a 5-year period on a group of Valencia orange groves in the coastal area indicate that the more conservative group of growers, who used medium irrigations, ranging from 16 to 19 acre-inches per acre, produced the largest yields. The group applying less water produced the lowest yield, while the one that applied 31 acre-inches per acre had less fruit than the conservative group. For lemons raised in this area the use of over 18 acre-inches per acre is considered excessive.

The irrigation water as shown in column 6 of table 3, will be found to agree very closely with suggestions by Vaile (*32*) for irrigation of citrus in California in coastal, intermediate, and interior climatic areas as shown in table 4.

TABLE 4.—*Designation of classes in irrigation (32)*

Class	Acre-inches applied per season		
	Coastal	Intermediate	Interio
Light	Under 14	Under 16.5	Under 19.
Moderate	14–17.9	16.5–21.4	19–24.9.
Usual	18–21.9	21.5–26.4	25–30.9.
Heavy	22–25.9	26.5–31.4	31–36.9.
Very heavy	26 and over	31.5 and over	37 and over

USE OF WATER BY WALNUT TREES

Walnut growing is an important industry in California, particul in the southern part of the State where walnut groves exist side side with citrus. The trees are larger in size than citrus, each containing 20 to 25, whereas an acre of orange trees numbers ab 90, but the water requirement is nearly the same for each. Tabl shows the use of water and crop yield on walnut groves in south California. These records do not indicate that there is any spe relation between the quantity of water applied and walnut y except that the group of walnut groves using an average quantit water produced the best yield in point of quantity and quality. use of 22 acre-inches of irrigation is about normal for mature wal trees grown in the coastal area when the rainfall is about 12 inches.

The greatest water requirement occurs in July and Aug but adequate moisture at all times is necessary for the best c production.

CONDITIONS INFLUENCING THE QUANTITY OF IRRIGATION WA REQUIRED

Conditions affecting the use of water by crops on irrigated la should be considered if economical irrigation is to be assured. So of the principal factors affecting the use of water are (1) phys conditions, (2) farm management, (3) economic conditions, results of investigations and (5) character of distribution works methods of applying water. A sixth factor is the duty of wate affected by State, community, and corporate regulations whic discussed elsewhere (p. 31).

PHYSICAL CONDITIONS

Physical conditions affecting the irrigation requirement of cr include soil, topography, climate, and water supply. Most of irrigated land of the Pacific slope is found in fertile valleys of allu formation of great depth, having broad undulating slopes wh require less land preparation for irrigation than do many other i gated districts of the Western States. Soils in arid and semi regions are generally well supplied with mineral plant food, because of low rainfall and a resulting lack of vegetation they deficient in decayed vegetable matter, which is necessary continued production as an addition of humus to the soil incre its water retentiveness and helps to reduce irrigation requirem In general the light alluvial soils not only require a minimum preparation for the distribution of water, but they also take water readily and retain a sufficient quantity in the pore spaces for plant use. The loams and fine sandy loams are better in this respect than clays and adobe soils or sands and gravels. In the heavier soils the pore spaces are finer and plant roots have greater difficulty in obtaining plant nutriment held in close association with the finer soil particles, while the sandy-gravelly soils allow water to percolate rapidly beyond the root zone.

On much of the arable land in the interior valleys not affected by coastal climatic influence, the long growing period, intense sunshine, high temperatures, and great evaporation tend to a large water requirement. Rainfall occurs during the winter months, causing high run-off stages during a period when the water is least used for irrigation and storage of water from mountain streams is necessary to conserve the water supply for summer use. The cost of stored water, offset to some extent by the sale of power developed as a result of storage, is generally, but not always, within the limit of permissible cost to the irrigator. Storage of water, either for irrigation alone or for combined irrigation and power, is an economical way of extending the acreage of irrigated lands.

For flood water held in check in the mountains of southern California, where stream gradients are steep and reservoir capacities are small, the unit cost of an acre-foot of storage capacity is beyond the means of the farmer or orchardist. In many sections water stored underground is the source of supply for irrigation and domestic uses and in districts where flood-control reservoirs of small capacities are utilized the water retained in them is released and re-stored underground by means of spreading grounds. In this way the small flood-storage reservoirs may be filled again and again in the rainy season and the water made available for irrigation by pumping.

FARM MANAGEMENT

As previously stated, the soils of the valleys of the Pacific slope are generally lacking in an adequate amount of humus although high in mineral plant food. Maintenance of soil fertility is essential for continued production. In the irrigated areas where forage, grains, cereals, and vegetables are the principal crops, fertility is maintained by rotation and diversification of crops. In the southern area devoted to the production of subtropical fruits and nuts rotation is not feasible because of the long life period of the orchard growth, and fertility is maintained by applications of fertilizers and growth of winter cover crops between the tree rows. The extensive use of cover crops has been practiced only in recent years. Two classes of cover crop are in use, a leguminous cover-crop plant, either *Melilotus indica* or vetch or a nonleguminous plant of which mustard is the outstanding crop. These are planted in the fall, allowed to grow during the rainy winter months and plowed under as green manure in February or March. If allowed to grow later in the spring the crop will be in competition with the tree growth for soil moisture and will increase the water requirement of the orchard. Summer cover crops should seldom be used as at this time of year the water requirement of plants is at a maximum and unless the water cost is low the value of the green manure produced will be less than the value of the water consumed.

ECONOMIC CONDITIONS

The cost of water is an important item in the total cost of produci a crop and improvements in farm management, irrigation practi basis of paying for water, or method of delivery that will lower t ultimate use by the crop will tend to increase profits. When water sold at a flat rate or on an acreage basis there is little or no incenti to economical use. On the other hand, when water is sold on a u basis and the user is charged for each additional acre-foot, any sa ing made in the water cost increases the farm profit. The amount water available to plants is always less than that applied, since it impossible to prevent all waste. In many cases the amount of tl waste cannot be reduced, within reasonable cost, below 30, and some cases below 50 percent, of the total applied. Some is lo through surface run-off, evaporation, and deep percolation. Wi the exception of surface run-off these losses are included in "p missible waste" (*23*), which varies with the extent of preparation the land that is to receive water, efficiency of the farm distributi system in prevention of losses by seepage, and improvements irrigation practice.

RESULTS OF INVESTIGATIONS BY VARIOUS AGENCIES

Experimental studies regarding the economical use of water crops conducted by the United States Department of Agricultu the agricultural experiment stations, and other agencies have do much to improve irrigation practice and promote a more economi use of water. These studies have made possible a knowledge of t water requirements of most crops grown under irrigation and ha provided a foundation for planning monthly and seasonal diversi rates and the proper canal capacities for new irrigation enterpris Not only has there been assembled a fund of scientific informati concerning total seasonal water requirement, time of water applic tion, transpiration of crops, evaporation from soils and water, a results of soil studies and surveys, but a fuller knowledge has be gained of the carrying capacities of canals, flumes, and pipe lines, a of transmission losses, and return flow. These data are available f use by administrators, courts, and engineers who are concerned wi irrigation problems and are being used with increasing frequen For a number of years new irrigation projects and improvements those already in operation have been based upon these data and wa adjudications are determined in the light of expert testimony.

CHARACTER OF DISTRIBUTION WORKS AND METHODS OF APPLYING WATER

In the early days of irrigation, when canals and distribution syste were built by individual or cooperative effort and water was plenti and easily diverted from the stream to the land on which it was us little attempt was made to economize in the use of water on the fa or to prevent transmission losses in the canals. As water beca scarcer and new and more valuable enterprises were constructed mutual effort or under irrigation-district laws, engineers began effect savings of water by preventing transmission losses where p sible, and farmers constructed better planned and more perman farm distribution systems. These changes were effected on o established farms only after the profits from irrigation made such i provements possible. Engineers led the way by permanent construction on the larger projects and were followed by individual farmers as means permitted.

The water-saving program carried out under the general direction of the irrigation district or mutual company was confined principally to storage of flood flow and the prevention of transmission losses by means of canal linings. A third factor in water saving was the installation of devices to measure water deliveries to farms. Weirs came into general use with construction of larger projects and resulted in water saving by measuring the proper quantities to each irrigator, thus doing away with the practice of guessing at water deliveries. As water became more valuable and economic conditions permitted farm-distribution systems were changed from earthen head ditches to ditches lined with concrete and to the installation of underground pipe systems with risers located at intervals to supply water to furrows or basins. Better methods of distribution and soil requirements, changes in methods of applying water also are employed. As the farmer becomes better acquainted with irrigation methods and better able to afford improvements permanent distribution systems are installed.

DUTY OF WATER AS AFFECTED BY STATE, COMMUNITY, AND CORPORATE REGULATIONS [4]

The four preceding bulletins of this series have brought out in some detail the relationships between public and corporate regulations and the irrigation requirements of lands in the several Western States, excepting California, and the principles there discussed apply in large measure to California as well. However, the extensive irrigation development of that State, which in 1929 included one fourth of the irrigated land of the West (*31*), has been marked by certain acute institutional problems which bear directly upon the State's irrigation requirements.

CONFLICT OF RIPARIAN AND APPROPRIATION RIGHTS

In no other of the Western States has the riparian versus appropriation-rights controversy been productive of so much litigation or have riparian rights been so completely recognized as in California. The doctrine of appropriation "grew up during the early occupancy by the miners of the public domain in the Western States" and became established as a doctrine of the California courts by several decisions in cases which, however, "were between parties not holding title to any land along the streams" (*15*). In 1886, in the first major controversy between appropriators and riparian owners to reach the California Supreme Court—*Lux* v. *Haggin* [5]—the court adopted the common-law doctrine of riparian rights, modified to the extent that each riparian owner's use for irrigation must be a reasonable use as against all other riparian owners. The courts of that State have adhered consistently to this doctrine. As recently as 1926 it was held that riparian rights attached to the entire flow of San Joaquin River, where the entire flow was needed to fill sloughs and make possible

[4] The material in this section was prepared by Wells A. Hutchins, irrigation economist, Bureau of Agricultural Engineering.
[5] 69 Cal. 255, 10 Pac. 674.

the irrigation of riparian land without the installation of expensiv improvements.[6] The decision turned on the question of protectin vested rights, and not upon the character of irrigation use, whic clearly was a wasteful use. A constitutional amendment designed t prevent riparian owners from using water wastefully was passe 2 years later, but has not yet been passed upon by the higher court

Thus the appropriation and riparian doctrines exist side by side i California. Legally, riparian rights are very important. Economi cally, only 7.5 percent of the State's area irrigated in 1929 claime riparian rights from streams (*31*). The economic importance of th riparian doctrine in California may be said to lie principally in th restrictions it imposes upon the operation of the doctrine of appro priation, rather than in the amount or kind of development actuall based upon riparian ownership. The fact that so much developmen has been permitted to take place on nonriparian lands has been du in no small degree to the neglect or indifference on the part of riparia owners in protecting their rights from loss by prescription. I recent years, however, they appear to have been better informed an more on guard; and it is stated that in certain localities riparia values have come to include a "hold-up" element.

In contrast with the California decisions, which have reiterated an extended the riparian doctrine, the trend of the Oregon decisions ha been to restrict its operation and to limit the riparian owner t beneficial use. Where riparian rights are unrestricted, there i obviously little incentive to use water economically; as against non riparian irrigators, the riparian proprietor may make as lavish a us as he chooses. This does not mean that the irrigation of all riparia lands is uneconomical. There are wide differences in the characte of such use. It does mean that the doctrine does not encourag economy in irrigation.

A saving feature of this situation has been that riparian land necessarily border a stream and do not extend beyond the watershed consequently in the typical situation much of the water applied t such lands in excess of crop requirements returns to the stream fro which it is diverted. Of course upper diversions are denied access t whatever surplus there may be; and if the riparian lands are locate along the lower reaches of the stream, the surplus above the actua requirements of such lands benefits nobody.

THE UNDERGROUND WATER SITUATION

Nearly one third of the lands irrigated in California in 1929 wer reported as deriving their water supplies from wells (*31*). Thi represented a large increase above the area so irrigated in 1919. Th unrestricted installation of pumping plants in certain areas, couple with a cycle of low precipitation and run-off, has led to such seriou lowering of the underground water table that pumping costs in som cases have become almost prohibitive. The State engineer (*11 p. 100*) has stated, in referring to upper San Joaquin Valley, that–

> * * * quality of land, rather than adequacy of supplies, has been the facto controlling irrigation development of this type, and the result in many localiti has been a net draft in excess of the average seasonal replenishment. Little o no consideration has been given in the development of these areas to the poss

[6] *Herminghaus et al.* v. *Southern California Edison Co. et al.*, 200 Cal. 1, 252 Pac. 607.

bility of systematic artificial replenishment of the ground-water reservoirs. * * * the result has been a depletion of ground-water storage, which is indicated by a continuously receding water table (*11, p. 147*).

Referring to Santa Clara Valley (*11, p. 185–186*):

There has been a lowering over the past 15 years of 64.5 feet in the general level of ground water in this area. As practically all the irrigation and domestic water used in the valley is pumped from underground sources, there is great public concern over this situation, due to the increased costs of pumping and the possibility of invasion of saline water from San Francisco Bay.

The same situation exists in greater or less degree, in other important areas of the State.

In California owners of land overlying common strata of percolating water have paramount rights to its use but are limited to such quantities as are reasonably necessary for beneficial use on the overlying lands, and appropriators may take the surplus for use on distant lands. This doctrine, therefore, in contrast with the doctrine of riparian rights to surface streams, imposes a measure of economical use. However, as between overlying landowners, there is no priority of use, with the result that each person in an area overlying an underground-water basin who installs a pumping plant for the irrigation of his farm is required to share the supply with all other operators in such area, however extensive their holdings may be with respect to the available water supply and at whatever subsequent time they may choose to exercise their correlative rights. The pumping-plant operator has no security against the practical destruction of his water right by overdevelopment, such as would be afforded under an administrative control of underground-water supplies based upon priority of appropriation and use. In some sections of California the draft upon the underground supply exceeds the replenishment that would have been effected during the past 20- and even 40-year periods, including both wet and dry cycles (*11*).

Use of underground water in irrigation is seldom wasteful; a most effective brake upon waste is the cost of pumping. On the whole the utilization of underground reservoirs should result in economical and beneficial irrigation practice, provided public control is exercised over priorities to underground water rights, or over the installation and use of pumping equipment; or provided that adequate replenishment of underground water supplies is effected by natural run-off, extensive surface irrigation, or recharge with water imported from other areas.

THE CALIFORNIA STATE WATER PLAN

"California's problem is twofold, involving first the conservation and utilization of its water resources, and second the control of floods" (*11*). In three large and important areas the problem of water shortage has become acute and requires immediate attention. In the Sacramento-San Joaquin delta and the upper bay industrial region the shortage has been accompanied by invasion of saline water; in upper San Joaquin Valley some 400,000 acres of developed land are menaced by shortage, aggravated in large measure by overdrafts upon the underground supply; in Santa Ana River Basin and other parts of the south coastal basin there have been heavy overdrafts upon surface and underground supplies for both metropolitan and agricultural purposes. In addition to these major problems, other areas are affected in greater or less degree.

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Recognition of this situation has led to much work during the past decade in developing a coordinated plan for conservation and orderly utilization of California's water resources.

The works involved in regulating streams by storage and in transporting water from one section of the State to another are of great magnitude and will cost several hundred million dollars. One of the two main purposes of the plan is to remedy deficiencies in certain sections of the State by salvaging local wastes and by importing supplies from other sections where the natural water resources are more abundant. A significant item is the purchase and extinguishment of early riparian rights to a great quantity of water appurtenant to a large area of grass and pasture lands—a relatively unimportant purpose—in order that such waters may be stored and used for more valuable purposes. Clearly, uneconomical practices have no place in a plan of orderly utilization of the State's great natural resources.

The engineering features have been described in considerable detail in various publications of the State; the irrigation requirements of various sections of the State have been carefully analyzed; and the legal, economic, and financial features have been studied and debated. The project has not yet been financed, except in case of the Metropolitan Water District of Southern California; and the legal, political, and human elements appear to offer many difficulties. Not the least troublesome question is that arising from the riparian-rights situation. As stated by the State engineer, the controversy between the riparian and appropriation doctrines "has been long and bitter and is still extant. It adds to the uncertainty and cost of any water development in the State and is a serious obstacle in the way of a major State plan of development" (*11*).

THE RECLAMATION OF ARABLE LANDS AND MONTHLY AND SEASONAL NET IRRIGATION REQUIREMENTS

During the last 50 years the increase in the number of irrigated farms on the Pacific slope has resulted in the use of practically all available summer stream flow, and further extension is not possible without additional storage of flood waters or transportation of water from a drainage basin having a surplus flood flow to another basin in which there is a deficiency. Construction of dams to store water which would otherwise be wasted has resulted in providing a total storage capacity in California and southwestern Oregon of nearly 4,000,000 acre-feet (*31*). In recent years the building of high dams has provided not only additional supplies for agriculture but also a double use of the water through the development of power at the dam site. Such development enables irrigation districts sponsoring construction to pay a part of the construction costs by sale of power in addition to providing electrical service to residents. Power generated at the Exchequer Dam of the Merced Irrigation District returned an income to the district in 1927 of $569,815 and only a little less was paid the Turlock Irrigation District for electrical energy developed at the Don Pedro Dam (*3*). Sometimes there is a tendency on the part of directors of irrigation districts to allow stored water to be used for power that should be held for the irrigation of crops and this tendency should be guarded against.

Recovery and economical use of underground water for irrigation plays a large part in the development of agricultural lands and particularly so in many districts in California. Recovery is brought about by different methods, of which pumping from wells is of the utmost importance, while land drainage and return flow are responsible for augmented summer flow in depleted streams. Approximately 1,453,000 acres, or 70 percent of the acreage so irrigated in the Western States, are irrigated in California by water pumped from wells. Water pumped from individual wells directly upon the land irrigated is generally put to the highest possible use—(1) because there is no transmission loss before reaching the farm as in gravity diversions, and (2) because of cost of pumping. Each additional foot of lift and each acre-foot of water pumped increases the cost of irrigation and lessens the farmer's profit. Farmers sometimes try to obtain better yields by applying greater quantities of water than are necessary to obtain the best crops. Excess water applied to land irrigated by pumping returns to the underground basin from which it was drawn and the ultimate loss of water is small as it may be reused later. Water diverted from streams into canals and delivered to irrigated farms suffers loss in transmission through unlined canals and further losses occur after delivery. Preventable water losses are caused by overirrigation, poorly prepared land, and lack of proper farm distributaries.

"Return flow" is the water returning to a stream through drainage canals and by seepage along stream banks. It is generally stated as a percentage of the total diversion and represents the unconsumed portion of water applied to an irrigated area.

The amount of return flow depends upon a number of factors, chief of which are quantity of water diverted, porosity of soil irrigated and through which the ground water has to travel, and length of time the district has been irrigated. Porosity of soil and gradient of the underground-water table determines the rate at which underground water may travel and the time in which the initial return flow will appear in the parent stream. The first return may be slow to appear, but year by year, as the irrigated area is extended and the underground basins become filled with water, the amount returning to stream channels increases. This return flow then becomes available for reuse and may be stored, diverted for irrigation of additional lands along the lower reaches in the same drainage basin, or made to provide underground water for irrigation by pumping.

Measurements of return flow, made for a number of years in the Sacramento and San Joaquin Valleys by the State engineer's office, show considerable variation from year to year in both streams. The Sacramento River shows the highest rate of recovery, equal to 50 percent of the diversions for a 5-year period. The average return for the San Joaquin Valley was 32 percent for the same period of years. The reason for the difference in recovery in the two drainage basins is not altogether clear, but some use of underground water for irrigation by pumping in the San Joaquin Valley may be responsible in part. (*29*).

From the foregoing discussions it is evident that on the Pacific slope, as in other western drainage basins, there is an unequal division of arable land and available water. The main agricultural producing areas in the basin are the Rogue River and Klamath Lake Basins in Oregon, the Sacramento and San Joaquin Valleys in central California, and the citrus-growing districts in southern California. All these areas are now irrigated to the full extent of the present water supply, and any further extension in irrigation must come mainly from additional storage in mountain reservoirs and diversion of flood water from the winter flow of streams in which there is a surplus to other areas in which there is a shortage of water. An additional means of increasing the quantity of water that may be used is the reclamation and reuse for irrigation of municipal and industrial wastes which now pass into the ocean. This has been estimated as 155,000 acre-feet per year in the Los Angeles district alone (*13*).

The total mean annual stream flow of the groups of drainage basins heretofore described amounts to 81,797,900 acre-feet and the extent of arable land therein is approximately 14,000,000 acres, of which 4,225,000 acres are now under irrigation. It is evident therefore that the total annual water supply from all basins exceeds the irrigation requirement of lands which may ultimately be brought under irrigation. Moreover, it seems probable that all of the water supply, particularly in the northwesterly portion of the Pacific slope, may not be made available for irrigation owing to the lack of adjoining agricultural land and difficulties in the way of conveying the surplus to other basins.

In table 5, summarizing the monthly and seasonal net irrigation requirements of the various subdivisions of the Pacific slope no allowance is made for rainfall or for any losses in transmission or distribution other than permissible waste. The net irrigation requirement should not be confused with the quantities listed as irrigation use in tables 6 to 14 in the Appendix, the latter being the quantities actually applied in irrigation. In plot experiments the depth of irrigation was arbitrarily varied from too little moisture to too much in an attempt to discover the proper quantity for the best and most profitable production. In application of water to farms by the individual owners the quantity nearly always exceeds the irrigation requirement. Table 5 has been prepared in anticipation of the time when agriculture will require an extension of area, when water will be scarcer and more valuable than at present, and when knowledge s more generally available regarding soil moisture conditions and the rrigation requirements of crops.

Table 5.—*Monthly and seasonal net irrigation requirements of the various subdivisions of the Pacific slope*

Division No.	Division	Portion of total seasonal net irrigation required in—												Seasonal net irrigation requirement per acre
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
		Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Acre-feet*
	Oregon:													
1	Umpqua, Coquill, and lower Rogue River basins	-----	-----	-----	4	12	20	30	30	4	-----	-----	-----	0.85
2	Upper Rogue River Basin	-----	-----	2	8	18	25	25	18	4	-----	-----	-----	1.50
	Oregon and California:													
3	Klamath Lake and River Basins	-----	-----	-----	4	20	25	30	18	3	-----	-----	-----	2.00
	California:													
4	Pacific slope in northwestern California	-----	-----	-----	10	20	20	20	17	11	2	-----	-----	1.40

TABLE 5.—*Monthly and seasonal net irrigation requirements of the various subdivisions of the Pacific slope*—Continued

Division No.	Division	Portion of total seasonal net irrigation required in—												Seasonal net irrigation requirement per acre
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
	California—Continued.	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Acre-feet*
5	Pit River drainage basin	-----	-----	-----	3	14	24	26	21	12	-----	-----	-----	1.60
6	Feather, Yuba, and American River Basins	-----	-----	2	2	15	20	22	20	13	5	1	-----	1.50
7	Sacramento Valley	-----	-----	1	5	16	20	22	20	12	4	-----	-----	2.10
8	Sacramento-San Joaquin delta	-----	-----	-----	-----	8	22	30	25	15	-----	-----	-----	2.00
9	San Francisco Bay Basin	-----	-----	4	6	15	20	15	15	14	9	2	-----	1.50
10	Salinas River Basin	-----	-----	2	12	18	20	20	16	10	2	-----	-----	1.70
11	Santa Maria, Santa Inez and Santa Clara River Basins	2	2	2	5	12	16	20	16	13	8	2	2	1.60
12	San Joaquin Valley	-----	2	5	11	17	18	18	15	10	4	-----	-----	2.30
13	Western slope of the Sierras, east of San Joaquin Valley	-----	1	3	10	16	18	18	16	11	6	1	-----	1.70
14	Eastern slope of the Coast Range west of San Joaquin Valley	-----	2	5	11	17	18	18	15	10	4	-----	-----	1.80
15	Antelope and Victor Valleys	-----	-----	3	10	16	18	20	18	10	5	-----	-----	1.90
16	Los Angeles, San Gabriel, and lower Santa Ana River Basins	3	3	3	7	12	14	15	14	12	9	5	3	1.70
17	Upper Santa Ana River Valley	2	2	3	7	13	15	16	15	13	8	4	2	1.80
18	San Diego County	2	2	3	7	13	14	15	14	13	10	5	2	1.40

MONTHLY AND SEASONAL NET IRRIGATION REQUIREMENTS OF SEPARATE SUBDIVISIONS

As indicated in figure 1 and table 5, the irrigable lands of the Pacific slope basins have been separated into 18 subdivisions based, for the most part, on the average seasonal quantity of delivered irrigation water needed for crop growth. As concerns California lands included in this report, this subdivision follows somewhat closely the order laid down by a committee of four of which the senior author was a member. The findings of this committee were published by the State of California in 1923 (*10*).

In groupings of this kind the primary considerations are climate, crops and the scarcity and value of water. Aside from other factors, lands which receive annually less than 10 inches of winter rainfall require more irrigation water than those receiving 20 inches. Likewise the seasonal water requirement of rice is more than double that of fruit trees. So too in localities having a limited water supply of high value coupled with a pressing demand for water, preventive water wastes are reduced to a minimum. The necessity of these and other considerations will become more apparent by briefly reviewing the conditions prevalent in each of the subdivisions.

DIVISION 1

In division 1, which comprises Coos, Curry, Douglas Counties, and part of Josephine County, Oreg., the annual precipitation varies from 35 to 85 inches and there would be no need for supplemental irrigation if the precipitation were more evenly distributed. The dry summer season which prevails farther south extends into this section and no matter how moist the soil may be at planting, certain crops produce better yields when watered artificially. At present less than 1 percent of the land is irrigated but as farming is extended this percentage is likely to increase. By reason of the heavy winter rainfall and the short duration of the irrigation season, it is believed that an average seasonal allotment of 0.85 acre-foot of water per acre will suffice for the needs of crops grown in this locality, this quantity to be used chiefly during the months of July and August.

DIVISION 2

The area included in this small division is contained in Jackson and Josephine Counties of Oregon located in the central part of the Rogue River Basin. The normal annual precipitation at Medford, the county seat of Jackson County, is 18.08 inches. The normal precipitation at Grants Pass, the county seat of Josephine County, is 29.59 inches. Little rain falls at either station during the crop-growing season and such crops as alfalfa and deciduous fruit require supplemental irrigation for their proper development. The elevation of the irrigable area ranges from 1,000 to 1,500 feet and the soils range from porous agate gravelly loam, through the sandy loams, to the impervious Olympic clay adobe.

The crops grown may be roughly classified into three groups of nearly equal acreage: (1) Forage crops, including alfalfa; (2) deciduous orchards and vegetables; and (3) cereals. The average net seasonal irrigation requirement of the division is fixed at 1.5 acre-feet per acre with a monthly apportionment, as given in table 5, based on partial control of flood flow by storage.

DIVISION 3

The irrigable areas of the upper Klamath Basin are located chiefly in Klamath County, Oreg., and Siskiyou and Modoc Counties, Calif. The Federal Government has established an irrigation project in this area covering 176,517 acres at a cost for construction of $5,751,764 (*24*). The engineering works include 956,000 acre-feet of storage capacity, 224 miles of open drains, and several hundred miles of main and secondary canals.

The average elevation of the irrigable area is 4,100 feet above sea level, the climate is arid and the length of the irrigation season seldom exceeds 130 days. The principal crop raised is alfalfa, while small grains rank second with a relatively small acreage in potatoes and other vegetables, the average seasonal crop values averaging about $40 an acre.

The average net seasonal use of water before drainage systems were installed was low, chiefly because of a high water table over much of the area. With the completion of drainage channels and the lowering of the ground water, the irrigation requirements will be greater and an average of 2 acre-feet per acre per season has been allocated to the irrigable lands in anticipation of efficient drainage protection.

DIVISION 4

Division 4 extends from the southern limits of southwestern Oregon along the north coast in California as far south as the basin of San Francisco Bay and includes the lower Klamath Basin, the Eel and Russian River Basins, and other smaller basins. Thus far irrigation has not been practiced extensively in this section, mainly because of the relatively high rainfall and the prevalence of fogs near the coast. The average precipitation is greater than that of Iowa and, if it were as favorably distributed for crop production, there would be little or no need for a supplemental supply. The rains occur, however, principally in the colder season, and as more farms are established and more intensive farming practiced, the need for irrigation will increase. About 300,000 acres of arable land may be irrigated when economic conditions justify the expenditure of providing a water supply. Water is abundant and the cost of irrigation works would be moderate, but the conditions do not warrant large expenditures in providing impervious channels to convey water. Accordingly a rather liberal allowance has been made in allotting irrigation water, the average being placed at 1.4 acre-feet per acre.

DIVISION 5

Scattered over a wide expanse of mountainous and untillable land in northeastern California are to be found irrigable stream valley lands and old lake beds at elevations of 2,000 to 5,000 feet. This district extends from the Klamath River Basin on the west to the Nevada State line on the east, and as far south as the foothills of the Sacramento River Basin. It includes the headwaters of such streams as the Sacramento, Pit, McCloud, and Fall.

In 1929 approximately 150,000 acres were irrigated in a crude fashion and any substantial increase in irrigated land will involve storage of part of the winter rains. Most of the arable land receives an annual precipitation insufficient for satisfactory dry-land crops, and a larger utilization of the agricultural resources depends on irrigation. Successful irrigation, in turn depends on better control of the flood waters and more economical use of water. Conditions in this division resemble those of division 4 in that a strict adherence to the water requirement of the crops grown in allotting water for irrigation would injuriously affect the growers.

The growing season is short and the crops that can be raised successfully are confined mainly to forage and cereals. The returns from these are small and farmers cannot afford to expend much money or labor in lessening preventive waste of water. Besides, much of the waste water returns to stream channels and is subject to reuse. For the reasons given, the irrigation requirement has been estimated at 1.6 acre-feet per acre, although this is more than the crops require when precipitation is included.

DIVISION 6

Division 6 includes all of the irrigable lands located in that part of the Sacramento River Basin above the valley floor along the Sierra foothills and as far north as division 5. For the most part its physical conditions are well adapted to fruit raising, with some citrus and the less hardy deciduous fruit trees at the lower, and the hardier deciduous trees at the higher elevations.

The chief obstacle to future irrigation development under community enterprises lies in the fact that the tracts of irrigable lands are relatively small and widely scattered. They are also more or less cut up by ridges and ravines and frequently are covered with brush and dwarf oak at the lower elevations and with pines and firs at the higher. Moreover, there are usually large blocks of nontillable land surrounding each parcel of irrigable land, causing added expense in providing water.

The climate, especially the rainfall, is so varied as to cause corresponding variations in irrigation requirements. A net seasonal quantity of 1 acre-foot per acre is as adequate in some parts as 2 acre-feet per acre are in others. Accordingly, the average has been estimated to be 1.5 acre-feet per acre.

DIVISION 7

The floor of Sacramento Valley, including the low foothill areas, comprises an area of over 3,000,000 acres of farming lands of which about 85 percent is irrigable. The water supply, if properly controlled and equitably allotted, is ample for the needs of the crops which may be grown, there being in years of normal run-off 6 to 7 acre-feet for each irrigable acre.

Rice growing on a commercial scale began in this valley in 1912 and reached its maximum in 1920, when 162,000 acres were devoted to this crop. For the past decade acreage, returns, and profits have decreased.

In estimating the irrigation requirement of Sacramento Valley lands, the custom has been to place it high enough to allow for the high seasonal use required by rice. In the judgment of the authors too large an allowance has been made for this purpose. While limited areas of heavy adobe soils in certain localities are well adapted to the production of rice, it is questionable if the area devoted to this crop will be much extended in the future. As progress is made in irrigation and as the value of water increases, it will be found unprofitable to use 7 to 10 acre-feet per acre in growing rice on fertile loam soils, when much larger returns can be had by using the same quantity of water on 3 or more acres planted to more profitable crops. Largely for this reason the average irrigation requirement of the Sacramento Valley lands has been placed at 2.1 acre-feet per acre.

DIVISION 8

Division 8 includes the deltaic area of about 421,000 acres formed at the confluence of the San Joaquin and Sacramento Rivers in California. The central part of this area, comprising about 43 percent of the total, is a peat formation composed chiefly of decayed organic matter with its surface slightly below tide level. The balance is a sedimentary formation composed of river sediment and organic matter with its surface slightly above sea level. Both formations are subdivided into 100 or more tracts by natural sloughs, old river channels, artificial channels, and levees. The moisture content of the root zone is regulated and maintained by a proper control of the ground-water level. The object in applying water in irrigation is to raise the ground-water level rather than to wet the surface since sub-irrigation methods are employed throughout. Under such methods irrigation and drainage systems are closely combined, the first being used to raise the ground-water level and the second to lower it in order to adjust the moisture content to the requirements of the plants grown and their stages of growth.

Experiments carried on by the Bureau of Agricultural Engineering in cooperation with State agencies for several years point to the conclusion that the average seasonal irrigation requirement of this area is 2 acre-feet per acre.

DIVISION 9

Included in division 9 are the irrigable lands of the San Francisco Bay Basin, exclusive of the Sacramento-San Joaquin delta lands. The yearly rainfall, which occurs mainly during the colder months, ranges from about 15 to 25 inches over the arable portion, with considerably larger amounts at higher elevations of the Coast Range. Compared with the Sacramento Valley, which has as high an annual rainfall, the irrigation requirement is lower by reason of much lower summer temperatures, the presence of fogs, and less evaporation. The unirrigated arable areas are devoted mainly to small grains cut for hay and the irrigated areas to fruits, nuts, grapes, and vegetables. As irrigation is extended, more of the dry-farmed lands, which now raise grain for fodder, will be converted into irrigated fruit orchards, vineyards, and vegetable farms. The irrigation requirement is medium or low for all three classes of products, and it is believed that an average irrigation requirement of 1.5 acre-feet per acre will suffice for the entire division.

DIVISION 10

The irrigable lands of the Salinas River Basin and other smaller contiguous valleys are included in division 10.

The climate is similar to that of the San Francisco Bay Basin but with less rain, more evaporation, and a higher wind movement. The average annual rainfall over the irrigated portion is slightly below 15 inches, with trade winds entering the valley from Monterey Bay, thus increasing the evaporation.

The crops, dry-farmed and irrigated in the order of acreage, are small grains cut for hay, alfalfa, barley and wheat harvested for grain, beans, sugarbeets, lettuce, deciduous fruits and grapes.

Only about 30 percent of the arable lands are irrigated and the irrigation requirement of the future will depend to a considerable extent on the crops grown. In anticipation of a relatively larger acreage being devoted to alfalfa in the near future, the average net seasonal irrigation requirement has been placed at 1.7 acre-feet per acre.

DIVISION 11

Division 11 includes the irrigable lands of the counties of San Luis Obispo, Santa Barbara, and Ventura, located between the summit of the Coast Range and the Pacific Ocean. Coastal plains constitute the greater part of the irrigable area. The normal rainfall along the coast varies from 16 inches at Ventura to 21 inches at San Luis Obispo with moderate temperatures throughout the year. The larger part of the arable area is farmed dry, bringing in small seasonal retur from small grains harvested for grain or cut for hay. Beans, sm grains cut for hay, and fruit are extensively grown in Santa Barba and Ventura Counties. Conditions throughout all three counties a favorable for the production of orchard fruits and grapes. The co bination of scarcity of water and high water requirement of alfalfa a likely to limit the production of alfalfa. A bean crop, on the oth hand, has a low water requirement, and conditions being favorable f its growth it is reasonably certain to continue to be a leading s product. Orchard fruits, sugar beets, and vegetables require mediu quantities of water.

Assuming, therefore, that alfalfa does not exceed a third or four rank in irrigated acreage, an average irrigation requirement of 1 acre-feet per acre for the division would supply enough water nourish the crops likely to be produced.

DIVISION 12

San Joaquin Valley contains the largest single body of arable la considered in this report. The percentage which can be irrigat depends on factors difficult of determination. As stated elsewhe the normal run-off, if controlled and evenly distributed over the n irrigable land, would give to each acre a gross quantity of about 2 acre-feet annually. It is not feasible, however, to utilize all the ru off for lack of storage sites and other reasons. High evaporati losses from both soil and water in addition to those which occur transmission of large quantities of water over long distances w reduce considerably the gross quantity available. The net seasor irrigation requirement is estimated to be 2.3 acre-feet per acre, a unless large quantities of the excess waters of the Sacramento Riv Basin are transported to the arable lands of the San Joaquin Valle a large percentage of the latter cannot be irrigated.

In a report issued by the Department of Public Works of the Sta of California in 1923 (*10*) the average irrigation requirement of t arable lands of the San Joaquin Valley was estimated to be 2 ac feet per acre and that of the Sacramento Valley 2.25 acre-feet per ac

Aside from the question of variation in the water requirement crops, the southern portion of the great central plain is more a than the northern, with a somewhat greater evaporation. In gene terms the southern portion receives a normal rainfall of 10 inches p annum and the northern 20 inches.

In 1929 the San Joaquin Valley produced 44 percent of the alfa grown in California. It requires about 3 acre-feet per acre per seas for alfalfa in this locality and as long as sufficient water is availab this crop is reasonably certain to continue to occupy a promine place in crop production.

The average net use of water for the entire valley has according been estimated to be 2.3 acre-feet per acre in order to continue, desirable, the present relative acreages in the crops and types farming which have been established.

DIVISION 13

The arable lands located on the western slope of the Sierras ea of San Joaquin Valley, and also those on the northern slope of t Tehachapi Mountains, are in relatively small detached areas diffic to reclaim by irrigation and lacking in transportation facilities. These obstacles might be overcome if the water supply were more abundant, but with a water shortage for lower and smoother lands more favorably located in the floor of the San Joaquin Valley, it is not likely that foothill irrigation will ever attain large proportions. The locality is well adapted to the raising of fruit and this product bids fair to continue the lead it has attained.

On this basis the average irrigation requirement for division 13 has been estimated to be 1.7 acre-feet per acre.

DIVISION 14

Division 14 includes the eastern slope of the Coast Range foothills located west of San Joaquin Valley. Compared with the Sierra foothills, located east of the same valley, the arable lands are in larger units with more uniform surface relief but water is more scarce and the climate more arid. For the limited area which can be irrigated the net duty of water is estimated to be 1.8 acre-feet per acre.

DIVISION 15

Division 15 includes Antelope and Victor Valleys, which form a small part of the Mohave Desert. Both summer temperature and rate of evaporation are high. It is a locality in which 2.5 acre-feet of water per acre could be profitably applied in growing alfalfa, deciduous fruits, vegetables, and other crops, but owing to the extreme scarcity of water, experience has demonstrated that since 2 acres of orchards require no more water than 1 acre of alfalfa, greater profits can be made by using the limited water supply to raise crops which have a medium to low water requirement.

Accordingly, the average irrigation requirement of this locality has been placed at 1.9 acre-feet per acre on the assumption that the greater part of the acreage irrigated would be devoted to apples, apricots, peaches, pears, and other deciduous fruits.

DIVISION 16

The highly developed fruit-producing area in Los Angeles and Orange Counties, the western portion of Riverside County, and the southwestern portion of San Bernardino County has been separated into two divisions, mainly because of the influence of the coastal climate on irrigation requirements. Division 16 includes the irrigable lands of Los Angeles and Orange Counties, in which citrus fruits and walnuts are the chief soil products. The normal annual rainfall is slightly below 15 inches, with a wide range between the minimum of dry years and the maximum of wet years.

Due to the underground source of water supply of much of this area and the attendant charges for pumping for irrigation, water is used sparingly and without waste. Irrigation records kept by a number of orchardists through a period of years indicate that walnuts are given slightly more water than citrus and that 1.7 acre-feet per acre is a near approach to the average irrigation requirement of the division.

DIVISION 17

The irrigable lands in the western portion of Riverside and the southwestern portion of San Bernardino Counties are included in division 17. The irrigated area is devoted chiefly to citrus fru grapes, and alfalfa production.

The normal rainfall is about equal to that of Orange and L Angeles Counties, but being farther inland summer temperatures a higher, humidity lower, fogs rare, and evaporation and transpirati higher. The low water requirement of grapes would offset to son extent the high water requirement of alfalfa. For all irrigated cro the average irrigation requirement is estimated to be 1.8 acre-fe per acre.

DIVISION 18

Division 18 comprises the irrigable lands of San Diego Count Here the rainfall and water supply for irrigation are so scanty as cause a limitation in alfalfa acreage and an increase in orchard fruit grapes, and beans. It is one of those localities in which nearly doub the quantity of water usually allotted could be profitably applied we it available, but, owing to its scarcity, landowners aim to raise tho crops which can be produced with the least quantity of water, pr vided the profits are satisfactory.

The climate and soil are well adapted to beans and their low wat requirement tends to lower the average. Conditions are likewi favorable for the production of citrus fruits of high quality on profitable scale, provided the fertility of the soil is maintained by tl growing of cover crops between the tree rows.

To produce a fruit crop and at the same time provide water for cover crop would require at least 1.5 acre-feet per acre. On tl assumption that the leading irrigated crops will be orchard fruit beans, and grapes, the average irrigation requirement is estimated t be 1.4 acre-feet per acre.

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APPENDIX

IRRIGATION WATER APPLIED, RAINFALL, AND CROP YIELDS IN OREGON AND CALIFORNIA

TABLE 6.—*Irrigation water applied, rainfall and crop yields in the Rogue Ri Valley, Oreg.*[1]

CORN

Year	Soil	Irrigations	Monthly application of water: Mar.	Apr.	May	June	July	Aug.	Quantity of water received by crop: Irrigation	Rainfall [2]	Total	Yield per acre
		Number	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Bush.*
1916	Fine sandy loam								0.48	0.63	1.11	55.5
1916	do								.28	.59	.87	43.2
1916	do								.16	.62	.78	43.6

SUGAR BEETS

Year	Soil	Irrigations	Mar.	Apr.	May	June	July	Aug.	Irrigation	Rainfall	Total	Yield per acre
												Tons
1916	Silty clay loam								1.21	0.33	1.54	36.2
1916	do								.85	.33	1.18	37.3
1916	do								.17	.33	.50	28.4
1916	Fine sandy loam								2.21	.33	2.54	12.4
1916	do								.88	.37	1.25	12.0
1916	do								.50	.51	1.01	11.2

[1] Plot experiments with corn and sugar beets in this table were conducted under a cooperative agreem between the Oregon Agricultural College Experiment Station and the office of Public Roads and Ri Engineering, U.S. Department of Agriculture. Plot experiments with alfalfa were conducted by the (gon Agricultural College Experiment Station without cooperation. Plot experiments with pears v made under a cooperative agreement between the Bureau of Agricultural Engineering, U.S. Departmer Agriculture and the Oregon Agricultural College Experiment Station.
[2] Rainfall during growing season.

Table 6.—*Irrigation water applied, rainfall, and crop yields in the Rogue River Valley, Oreg.*—Continued

ALFALFA

Year	Soil	Irrigations	Monthly application of water: Mar.	Apr.	May	June	July	Aug.	Quantity of water received by crop: Irrigation	Rainfall [2]	Total	Yield per acre	Literature cited
		Number	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Tons*	*Reference no.*
1920	Clay adobe								0.00	0.48	0.48	3.18	27
1920	do								.42	.48	.90	4.53	27
1920	do								1.00	.48	1.48	5.09	27
1920	do								1.12	.48	1.60	4.35	27
1920	do								1.00	.48	1.48	[3] 3.39	27
1921	do								.00	.21	.21	1.36	27
1921	do								.42	.21	.63	1.91	27
1921	do								.83	.21	1.04	2.22	27
1921	do								1.25	.21	1.46	1.92	27
1921	do								.83	.21	1.04	[3] 2.13	27

PEARS [4] [5]

Year	Soil	Irrigations	Mar.	Apr.	May	June	July	Aug.	Irrigation	Rainfall	Total	Yield per acre	Literature cited
												Pounds	
1930	Silty clay loam	4			0.26	0.28	0.58		1.12	0.34	1.46	29,316	
1930	do	3			.29	.30	.33		.92	.34	1.26	20,104	
1930	do	1					.79		.79	.34	1.13	23,758	
1930	do	1					.51		.51	.34	.85	22,078	
1930	Clay adobe	4			.20	.31	.33	.34	1.18	.34	1.52	20,708	
1930	do	2				.28	.36		.64	.34	.98	17,348	
1930	do	1					.48		.48	.34	.82	12,133	
1930	do	1				.39			.39	.34	.73	13,743	
1931	Silty clay loam	5	0.22	0.15	.23	.40			1.00	.59	1.59	14,952	
1931	do	2		.62		.27			.89	.59	1.48	13,804	
1931	do	2			.36	.27			.63	.59	1.22	9,170	
1931	do	2				.48			.48	.59	1.07	14,224	
1931	Clay adobe	6		.46	.41	.38	.36		1.61	.59	2.20	13,965	
1931	do	3		.26		.34	.22		.82	.59	1.41	10,780	
1931	do	2		.31		.26			.57	.59	1.16	8,575	
1931	do	1				.35			.35	.59	.94	5,180	
1932	Silty clay loam	5		.11	.12	.18	.55		.96	.68	1.64	23,300	
1932	do	2					.79		.79	.68	1.47	16,280	
1932	do	1					.60		.60	.68	1.28	21,500	
1932	do	1					.45		.45	.68	1.13	15,850	
1932	Clay adobe	7							2.02	.68	2.70	19,860	
1932	do	3							1.09	.68	1.77	17,800	
1932	do	3							.90	.68	1.58	12,880	
1932	do	1							.32	.68	1.00	13,600	
1932	do	7		.13	.13	.27	.53	.54	1.60	.68	2.28	24,250	
1932	do	3					.54	.49	1.03	.68	1.71	21,400	
1932	do	4		.14	.11	.17	.31		.73	.68	1.41	18,560	
1932	do	1						.54	.54	.68	1.22	14,520	

[3] This crop fertilized with 10 tons of manure per acre.
[4] Computed on a basis of 70 trees per acre. Trees 16 to 27 years old.
[5] Information furnished by M. R. Lewis, agricultural engineer, Oregon Agricultural Experiment Station.

TABLE 7.—*Irrigation water applied, rainfall, and crop yields in the Klamath Ba Oreg.*[1]

Year	Soil	Quantity of water received by crop			Yield per acre	Lite tu cit
		Irrigation	Rainfall and soil moisture	Total		
	ALFALFA					
		Feet	*Feet*	*Feet*	*Tons*	*Refer nu*
1917	Sandy loam	1.25	0.10	1.35	4.32	
1917	do	1.02	.10	1.12	3.84	
1917	do	.83	.10	.93	2.70	
1919	Clay loam	1.53	.05	1.58	2.05	
1919	do	1.14	.05	1.19	1.18	
1919	do	.65	.05	.70	.88	
1919	Sandy loam	1.29	.05	1.34	4.98	
1919	do	.88	.05	.93	4.68	
1919	do	.50	.05	.55	4.36	
	ALSIKE AND TIMOTHY					
1917	Deep peat	0.54	0.97	1.51	3.40	
1918	Medium peat	.52	.00	.52	1.07	
1919	do	.80	.36	1.16	3.71	
	SUGAR BEETS					
1917	Deep peat	0.28	0.97	1.25	12.0	
	GRAIN HAY					
1918	Medium peat	0.45	0	0.45	1.07	
1919	do	.92	1.23	2.15	.86	
1919	do	.62	.74	1.36	.94	
1919	do	.45	.40	.85	1.07	

[1] Plot experiments with sugar beets, alsike and timothy, and grain hay were conducted under a coo tive agreement between the U.S. Department of Agriculture and the Oregon Agricultural College Ex ment Station. Plot experiments with alfalfa were carried on by the Oregon Agricultural College Ex ment Station.

TABLE 8.—*Irrigation water applied, rainfall, and crop yields in the Goose L Valley, Oreg.*[1]

Year	Soil	Quantity of water received by crop			Yield per acre	Lite ture
		Irrigation	Rainfall	Total		
	RUTABAGAS					
		Feet	*Foot*	*Feet*	*Tons*	*Refer no*
1915	Clay loam	0.80	0.35	1.15	4.9	
1915	do	.00	.35	.35	1.8	
	BEETS					
1915	Clay loam	0.95	0.35	1.30	6.5	
1915	do	.00	.35	.35	2.3	

[1] These plot experiments were conducted under a cooperative agreement between the Oregon Agricult College Experiment Station and the Office of Public Roads and Rural Engineering, U.S. Departme Agriculture.

TABLE 8.—*Irrigation water applied, rainfall, and crop yields in the Goose Lake Valley, Oreg.*—Continued

POTATOES

Year	Soil	Quantity of water received by crop: Irrigation	Quantity of water received by crop: Rainfall	Quantity of water received by crop: Total	Yield per acre	Literature cited
		Feet	*Foot*	*Feet*	*Bushels*	*Reference no.*
1915	Medium sand	0.62	0.35	0.97	27.3	25
1915	____do	.42	.35	.77	108.6	25
1915	____do	.00	.35	.35	75.0	25

WHEAT

Year	Soil	Irrigation	Rainfall	Total	Yield per acre	Literature cited
1915	Medium sand and gravel	1.33	0.35	1.68	34.4	25
1915	____do	.78	.35	1.13	25.8	25
1915	____do	.46	.35	.81	20.2	25
1915	____do	.00	.35	.35	12.3	25

OATS

Year	Soil	Irrigation	Rainfall	Total	Yield per acre	Literature cited
1915	Medium sand	0.77	0.35	1.12	46.4	25
1915	____do	.62	.35	.97	44.0	25
1915	____do	.00	.35	.35	14.5	25

BARLEY

Year	Soil	Irrigation	Rainfall	Total	Yield per acre	Literature cited
1915	Medium sand	0.57	0.35	0.92	56.6	25
1915	____do	.50	.35	.85	42.1	25
1915	____do	.00	.35	.35	17.2	25

TABLE 9.—*Irrigation water applied, rainfall, and crop yields in the Sacramento Valley, Calif.*[1]

ALFALFA

Year	Soil	Area irrigated	Irrigations	Quantity of water received by crop: Irrigation	Quantity of water received by crop: Rainfall	Quantity of water received by crop: Total	Yield per acre	Literature cited
		Acres	*Number*	*Feet*	*Feet*	*Feet*	*Tons*	*Reference no.*
1906	Gravelly	16.6	10	15.08	1.72	16.80	6.00	20
1906	Gravelly loam	20.1	9	7.90	1.72	9.62	4.38	20
1906	____do	12.2	8	4.78	1.72	6.50	6.07	20
1906	Clay loam	9.5	10	2.64	1.72	4.36	6.43	20
1906	____do	9.5	13	3.34	1.72	5.06	4.03	20
1910	Yolo loam	Plot	0	0	.36	.36	3.85	1
1910	____do	Plot	2	1.00	.36	1.36	4.75	1
1910	____do	Plot	4	2.00	.36	2.36	6.00	1
1910	____do	Plot	4	2.50	.36	2.86	7.53	1
1910	____do	Plot	4	3.00	.36	3.36	7.58	1
1910	____do	Plot	4	4.00	.36	4.36	8.45	1
1911	____do	Plot	0	0	1.76	1.76	6.02	1
1911	____do	Plot	2	1.00	1.76	2.76	7.52	1
1911	____do	Plot	4	2.00	1.76	3.76	8.38	1
1911	____do	Plot	4	2.50	1.76	4.26	9.61	1
1911	____do	Plot	4	3.00	1.76	4.76	9.33	1
1911	____do	Plot	4	4.00	1.76	5.76	9.64	1
1912	____do	Plot	0	0	.76	.76	5.52	1

[1] These experiments were made under various cooperative agreements between the U.S. Department of Agriculture, the State engineer of California, and the University of California Agricultural Experiment Station.

TABLE 9.—*Irrigation water applied, rainfall, and crop yields in the Sacramento Valley, Calif.*—Continued

ALFALFA—Continued

Year	Soil	Area irrigated	Irrigations	Quantity of water received by crop			Yield per acre	Literature cited
				Irrigation	Rainfall	Total		
		Acres	*Number*	*Feet*	*Feet*	*Feet*	*Tons*	*Reference no.*
1912	Yolo loam	Plot	2	1.00	0.76	1.76	6.51	1
1912	do	Plot	3	1.50	.76	2.26	7.02	1
1912	do	Plot	4	2.00	.76	2.76	8.32	1
1912	do	Plot	4	2.50	.76	3.26	9.43	1
1912	do	Plot	4	3.00	.76	3.76	9.38	1
1912	do	Plot	4	4.00	.76	4.76	8.87	1
1912	do	Plot	4	5.00	.76	5.76	10.04	1
1913	do	Plot	0	0	.44	.44	2.75	1
1913	do	Plot	2	1.00	.44	1.44	4.31	1
1913	do	Plot	3	1.50	.44	1.94	5.69	1
1913	do	Plot	4	2.00	.44	2.44	6.37	1
1913	do	Plot	4	2.50	.44	2.94	7.97	1
1913	do	Plot	4	3.00	.44	3.44	8.22	1
1913	do	Plot	4	4.00	.44	4.44	8.97	1
1913	do	Plot	4	5.00	.44	5.44	7.03	1
1913	Silt, clay loam	8.97	4	4.91	.86	5.77	3.02	4
1913	Silt loam	4.31	4	6.06	.86	6.92	7.86	4
1913	do	10.18	4	6.01	.86	6.87	5.38	4
1913	Light gravel clay loam	17.15	5	4.46	.86	5.32	3.78	4
1913	Clay loam	9.21	4	7.41	.86	8.27	7.84	4
1913	Silt loam	24.59	4	3.78	.86	4.64	8.10	4
1913	Clay loam	13.50	4	6.09	.86	6.95	4.46	4
1913	Silt loam	15.00	4	6.38	.86	7.24	5.58	4
1913	do	9.13	4	5.08	.86	5.94	6.29	4
1913	do	18.43	4	2.55	.84	3.39	5.84	4
1913	do	14.93	4	3.42	.84	4.26	7.20	4
1913	do	3.29	4	3.82	.84	4.66	6.83	4
1913	do	26.40	5	4.98	.84	5.82	6.95	4
1913	do	7.42	4	2.64	.84	3.48	9.38	4
1913	Clay loam	27.20	5	2.37	.84	3.21	5.97	4
1913	Silt loam	13.96	5	2.83	.84	3.67	7.28	4
1913	Silt loam, clay loam	67.29	4	2.04	.84	2.88	5.80	4
1913	Silt loam	9.44	5	4.16	.84	5.00	4.19	4
1913	do	17.10	4	3.93	.84	4.77	5.88	4
1913	Sandy loam	7.00	4	2.23	.84	3.07	5.92	4
1913	Silt loam, sandy loam	37.59	6	3.81	.84	4.65	4.84	4
1913	do	16.76	5	3.89	.84	4.73	6.13	4
1913	Clay loam	17.41	6	3.70	.84	4.54	4.54	4
1913	do	10.36	6	2.82	.44	3.26	5.22	4
1913	do	10.01	5	2.27	.44	2.71	6.92	4
1913	do	36.20	8	3.06	.44	3.50	5.61	4
1913	do	12.10	8	3.15	.44	3.59	9.97	4
1913	do	36.74	12	2.79	.44	3.23	[2] 1.72	4
1913	Silt loam	26.64	15	2.93	.44	3.37	7.12	4
1913	Clay loam	74.12	15	3.43	.44	3.87	5.72	4
1913	Silt loam	19.54	3	4.40	.49	4.89	9.12	4
1913	do	15.94	3	4.22	.49	4.71	5.52	4
1913	do	25.63	4	2.38	.49	2.87	5.91	4
1913	Silty clay loam	23.20	4	2.81	.49	3.30	4.77	4
1913	do	37.71	3	1.30	.49	1.79	3.46	4
1913	Silt loam	23.88	3	3.12	.49	3.61	6.69	4
1913	Fine sandy loam	16.65	4	3.07	.49	3.56	7.49	4
1913	Silt loam	48.80	3	3.26	.49	3.75	[2] 2.55	4
1913	Silty clay loam	28.21	4	2.14	.49	2.63	4.42	4
1913	Clay loam	10.26	6	3.39	.49	3.88	7.68	4
1913	do	9.49	6	3.08	.49	3.57	8.51	4
1913	Silty clay	35.76	2	2.11	.49	2.60	4.17	4
1913	Gravelly clay loam	76.45	7	4.73	.58	5.31	3.98	4
1913	Coarse gravel with silt and wash loam	32.45	9	2.83	.58	3.41	4.44	4
1913	Coarse gravel with loam	18.61	9	4.29	.58	4.87	5.29	4
1913	Silt loam	34.20	5	3.16	.58	3.74	6.40	4
1913	Coarse gravel with silt and wash loam	8.06	10	3.91	.58	4.49	4.35	4
1914	Gravelly clay loam	76.45	7	5.04	1.19	6.23	5.49	4
1914	Clay loam	7.75	18	4.03	1.19	5.22	6.13	4
1914	Coarse gravel with silt and wash loam	14.79	8	2.59	1.19	3.78	5.87	4
1914	Coarse gravel with loam	18.61	13	9.59	1.19	10.78	5.84	4
1914	Coarse gravel with silt and wash loam	16.66	9	3.25	1.19	4.44	5.26	4
1914	Coarse gravel with loam	37.00	13	7.56	1.19	8.75	6.26	4
1914	Silt loam	34.20	3	1.04	1.19	2.23	7.17	4
1914	Silty clay loam	19.95	0	.00	1.21	1.21	4.05	4

[2] Young alfalfa.

TABLE 9.—*Irrigation water applied, rainfall, and crop yields in the Sacramento Valley, Calif.*—Continued

ALFALFA—Continued

Year	Soil	Area irrigated	Irrigations	Quantity of water received by crop: Irrigation	Quantity of water received by crop: Rainfall	Quantity of water received by crop: Total	Yield per acre	Literature cited
		Acres	*Number*	*Feet*	*Feet*	*Feet*	*Tons*	*Reference no.*
1914	Silt loam	19.54	2	2.91	1.21	4.12	6.96	4
1914	do	10.23	0	.00	1.21	1.21	3.61	4
1914	Yolo loam	23.20	2	1.59	1.21	2.80	7.28	4
1914	Silty clay loam	16.21	0	.00	1.21	1.21	3.33	4
1914	do	21.50	3	2.03	1.21	3.24	4.92	4
1914	Fine sandy loam	5.48	1	1.41	1.21	2.62	6.12	4
1914	do	11.17	1	1.00	1.21	2.21	5.56	4
1914	Silt loam	24.40	2	1.96	1.21	3.17	7.81	4
1914	do	24.40	2	1.96	1.21	3.17	7.40	4
1914	Clay loam	28.21	2	1.14	1.21	2.35	4.28	4
1914	do	10.26	3	2.14	1.21	3.35	8.07	4
1914	do	9.49	3	1.88	1.21	3.09	9.11	4
1914	Silty clay loam	15.65	9	1.68	1.19	2.87	1.71	4
1914	do	13.00	10	1.83	1.19	3.02	5.32	4
1914	do	35.06	4	1.28	1.19	2.47	3.93	4
1914	do	35.95	6	1.79	1.19	2.98	1.63	4
1914	Silty clay	11.37	4	1.69	1.19	2.88	3.75	4
1914	Clay adobe	3.34	7	1.97	1.19	3.16	5.39	4
1914	Silt, clay loam	8.97	4	2.34	1.54	3.88	5.78	4
1914	Silt loam	4.31	4	4.10	1.54	5.64	8.40	4
1914	Gravelly clay loam	3.08	6	1.42	1.54	2.96	4.44	4
1914	Light gravelly clay loam	23.35	6	3.46	1.54	5.00	4.85	4
1914	Clay loam	9.21	4	6.56	1.54	8.10	6.06	4
1914	Silt loam	13.27	4	8.46	1.54	10.00	5.75	4
1914	do	11.32	4	5.55	1.54	7.09		
1914	Clay loam	13.50	4	5.47	1.54	7.01	5.68	4
1914	Silt loam	6.70	4	6.08	1.54	7.62	6.68	4
1914	Silt, clay loam	9.08	4	3.95	1.54	5.49	8.31	4
1914	Yolo loam	Plot	0	.00	1.38	1.38	3.94	1
1914	do	Plot	2	1.00	1.38	2.38	6.40	1
1914	do	Plot	3	1.50	1.38	2.88	8.42	1
1914	do	Plot	4	2.00	1.38	3.38	9.96	1
1914	do	Plot	4	2.50	1.38	3.88	11.06	1
1914	do	Plot	4	3.00	1.38	4.38	12.48	1
1914	do	Plot	4	4.00	1.38	5.38	11.20	1
1914	do	Plot	4	5.00	1.38	6.38	10.51	1
1918	Fine sandy loam	[3] .61	2	2.50	1.04	3.54	7.84	7
1918	do	[3] .61	3	2.50	1.04	3.54	7.12	7
1918	do	[3] .61	4	2.50	1.04	3.54	7.28	7
1918	do	[3] .61	6	2.50	1.04	3.54	8.00	7
1918	do	[3] .59	8	2.50	1.04	3.54	8.90	7
1918	do	[3] .54	12	2.50	1.04	3.54	10.21	7
1919	do	[3] .61	2	2.50	.98	3.48	9.66	7
1919	do	[3] .61	3	2.50	.98	3.48	10.60	7
1919	do	[3] .61	4	2.50	.98	3.48	10.09	7
1919	do	[3] .61	6	2.50	.98	3.48	10.85	7
1919	do	[3] .59	8	2.50	.98	3.48	11.16	7
1919	do	[3] .54	12	2.50	.98	3.48	11.06	7
1920	do	[3] .61	2	2.50	.44	2.94	8.35	7
1920	do	[3] .61	3	2.50	.44	2.94	8.30	7
1920	do	[3] .61	4	2.50	.44	2.94	6.88	7
1920	do	[3] .61	6	2.50	.44	2.94	7.48	7
1920	do	[3] .59	8	2.50	.44	2.94	8.07	7
1920	do	[3] .54	12	2.50	.44	2.94	9.09	7
1921	do	[3] .61	2	2.50	.53	3.03	6.64	7
1921	do	[3] .61	3	2.50	.53	3.03	8.22	7
1921	do	[3] .61	4	2.50	.53	3.03	7.13	7
1921	do	[3] .61	6	2.50	.53	3.03	9.07	7
1921	do	[3] .59	8	2.50	.53	3.03	8.60	7
1921	do	[3] .54	12	2.50	.53	3.03	8.42	7
1921	do	[3] .68	2	2.50	.53	3.03	8.25	7
1921	do	[3] .68	3	2.50	.53	3.03	7.70	7
1921	do	[3] .68	4	2.50	.53	3.03	6.99	7
1921	do	[3] .82	6	2.50	.53	3.03	8.16	7
1921	do	[3] .77	8	2.50	.53	3.03	8.43	7
1921	do	[3] .71	12	2.50	.53	3.03	9.15	7
1922	do	[3] .68	2	2.50	.80	3.30	8.03	7
1922	do	[3] .68	3	2.50	.80	3.30	8.61	7
1922	do	[3] .68	4	2.50	.80	3.30	7.22	7
1922	do	[3] .82	6	2.50	.80	3.30	7.92	7

[3] Total area of several plots receiving the same treatment.

TABLE 9.—*Irrigation water applied, rainfall, and crop yields in the Sacramento Valley, Calif.*—Continued

ALFALFA—Continued

Year	Soil	Area irrigated	Irrigations	Quantity of water received by crop			Yield per acre	Literature cited
				Irrigation	Rainfall	Total		
		Acres	*Number*	*Feet*	*Feet*	*Feet*	*Tons*	*Reference no.*
1922	Fine sandy loam	[3] 0.77	8	2.50	0.80	3.30	8.42	7
1922	....do	[3] .71	12	2.50	.80	3.30	9.75	7
1923	....do	[3] .68	2	2.50	.46	2.96	7.80	7
1923	....do	[3] .68	3	2.50	.46	2.96	8.50	7
1923	....do	[3] .68	4	2.50	.46	2.96	7.15	7
1923	....do	[3] .82	6	2.50	.46	2.96	8.16	7
1923	....do	[3] .77	8	2.50	.46	2.96	8.42	7
1923	....do	[3] .71	12	2.50	.46	2.96	8.75	7
1924	....do	[3] .68	2	2.50	.53	3.03	8.19	7
1924	....do	[3] .68	3	2.50	.53	3.03	8.24	7
1924	....do	[3] .68	4	2.50	.53	3.03	7.36	7
1924	....do	[3] .82	6	2.50	.53	3.03	9.15	7
1924	....do	[3] .77	8	2.50	.53	3.03	7.58	7
1924	....do	[3] .71	12	2.50	.53	3.03	8.55	7
1925	....do	[3] .68	2	2.50	1.02	3.52	9.36	7
1925	....do	[3] .68	3	2.50	1.02	3.52	8.42	7
1925	....do	[3] .68	4	2.50	1.02	3.52	8.07	7
1925	....do	[3] .82	6	2.50	1.02	3.52	9.65	7
1925	....do	[3] .77	8	2.50	1.02	3.52	9.49	7
1925	....do	[3] .71	12	2.50	1.02	3.52	9.80	7

SUGAR BEETS

1912	Yolo loam	Plot	0	0	0.76	0.76	10.85	5
1912	....do	Plot	1	.88	.76	1.64	13.80	5
1912	....do	Plot	2	1.14	.76	1.90	17.50	5
1912	....do	Plot	0	0	.76	.76	4.85	5
1912	....do	Plot	1	.51	.76	1.27	6.70	5
1912	....do	Plot	2	.96	.76	1.72	14.75	5
1912	....do	Plot	3	1.40	.76	2.16	18.60	5

OATS

							Bush.	
1912	Yolo fine sandy loam	Plot	0	0	0.76	0.76	13.6	7
1912	....do	Plot	1	1.10	.76	1.86	45.9	7
1912	....do	Plot	2	1.82	.76	2.58	64.2	7
1913	....do	Plot	0	0	.44	.44	0	7
1913	....do	Plot	1	.68	.44	1.12	31.7	7
1913	....do	Plot	2	1.32	.44	1.76	47.1	7

GRAIN [4]

							Sacks	
1913		100		1.94	0.49	2.43	20	1
1913		18		.33	.49	.82	24	1
1913		80		1.54	.49	2.03	25	1
1913		80		1.25	.49	1.74	15	1
1913		12		[5] .98	.49	1.47	32	1
1913		30		.83	.49	1.32	20	1
1913		12		.88	.49	1.37	23	1
1913		60		1.67	.49	2.16	25	1
1913		29		1.24	.49	1.73	27	1
1913		7		.67	.49	1.16	23	1
1913		45		.61	.49	1.10	10	1
1913		30		1.56	.49	2.05	21	1
1913		38		.65	.49	1.14	33	1
1913		38		1.40	.49	1.89	28	1

[3] Total area of several plots receiving the same treatment.
[4] The acreage of this grain was mostly barley but it also included several hundred acres of oats and some wheat.
[5] Water estimated.

TABLE 9.—*Irrigation water applied, rainfall, and crop yields in the Sacramento Valley, Calif.*—Continued

GRAIN—Continued

Year	Soil	Area irrigated	Irrigations	Quantity of water received by crop: Irrigation	Quantity of water received by crop: Rainfall	Quantity of water received by crop: Total	Yield per acre	Literature cited
		Acres	*Number*	*Feet*	*Feet*	*Feet*	*Sacks*	*Reference no.*
1913		10		0.87	0.49	1.36	19	1
1913		3		1.11	.49	1.60	18	1
1913		40		1.47	.49	1.96	25	1
1913		30		2.85	.49	3.34	37	1
1913		140		.69	.49	1.18	28	1
1913		250		.71	.49	1.20	33	1
1913		100		.69	.49	1.18	15	1
1913		15		1.64	.49	2.13	32	1
1913		38		.24	.49	.73	21	1
1913		100		1.09	.49	1.58	17	1
1913		145		.99	.49	1.48	21	1
1913		16		.71	.49	1.20	21	

HAY

Year	Soil	Area irrigated	Irrigations	Irrigation	Rainfall	Total	Yield per acre	Literature cited
							Tons	
1913		300		1.90	0.49	2.39	2.5	1
1913		200		1.19	.49	1.68	1.5	1
1913		35		1.03	.49	1.52	1.3	1
1913		8		.31	.49	.80	2.5	1

DWARF MILO MAIZE

Year	Soil	Area irrigated	Irrigations	Irrigation	Rainfall	Total	Yield per acre	Literature cited
							Lbs.	
1910	Yolo fine sandy loam	0.30	0	0	0.36	0.36	1,340	7
1910	do	.30	1	.32	.36	.68	2,680	7
1910	do	.30	2	.46	.36	.82	2,710	7
1911	do	.54	0	0	1.76	1.76	1,018	7
1911	do	.54	1	.15	1.76	1.91	1,565	7
1911	do	.54	2	.38	1.76	2.14	2,453	7
1911	do	.54	3	.47	1.76	2.23	2,530	7
1913	do	.26	0	0	.44	.44	0	7
1913	do	.26	1	.25	.44	.69	230	7
1913	do	.26	2	.50	.44	.94	614	7
1913	do	.26	3	.75	.44	1.19	998	7
1913	do	.26	4	1.00	.44	1.44	1,074	7
1913	do	.26	5	1.25	.44	1.69	1,343	7
1913	do	.26	6	1.50	.44	1.94	1,842	7
1922	do	.25	0	0	.80	.80	3,835	7
1922	do	.36	1	.28	.80	1.08	4,295	7
1922	do	.37	2	.59	.80	1.39	5,187	7
1922	do	.37	3	.92	.80	1.72	5,152	7
1922	do	.37	4	1.13	.80	1.93	5,747	7

WHEAT

Year	Soil	Area irrigated	Irrigations	Irrigation	Rainfall	Total	Yield per acre	Literature cited
							Bush.	
1912	Yola fine sandy loam	Plot	0	0	0.76	0.76	9.4	7
1912	do	Plot	1	.83	.76	1.59	20.2	7
1912	do	Plot	2	1.47	.76	2.23	32.2	7
1913	do	Plot	0	0	.44	.44	2.1	7
1913	do	Plot	1	.17	.44	.61	9.4	7
1913	do	Plot	1	.33	.44	.77	21.9	7
1913	do	Plot	2	.50	.44	.94	26.7	7
1913	do	Plot	2	.67	.44	1.11	27.2	7
1913	do	Plot	2	.83	.44	1.27	29.9	7
1913	do	Plot	2	1.00	.44	1.44	26.8	7
1913	do	Plot	2	1.25	.44	1.69	20.7	7
1913	do	Plot	0	0	.44	.44	22.6	7
1913	do	Plot	1	.57	.44	1.01	28.8	7
1913	do	Plot	2	1.08	.44	1.52	31.2	7
1914	do	Plot	0	0	1.38	1.38	20.4	7
1914	do	Plot	1	.33	1.38	1.71	15.8	7
1914	do	Plot	1	.67	1.38	2.05	15.2	7
1914	do	Plot	2	1.00	1.38	2.38	14.2	7
1914	do	Plot	2	1.33	1.38	2.71	13.6	7
1914	do	Plot	2	1.67	1.38	3.05	12.9	7

TABLE 9.—*Irrigation water applied, rainfall, and crop yields in the Sacramento Valley, Calif.*—Continued

SILAGE CORN

Year	Soil	Area irrigated	Irrigations	Quantity of water received by crop: Irrigation	Rainfall	Total	Yield per acre	Literature cited
		Acres	*Number*	*Feet*	*Feet*	*Feet*	*Tons*	*Reference no.*
1910	Yolo fine sandy loam	0.67	0	0.00	0.36	0.36	6.91	7
1910	do	.32	1	.28	.36	.64	8.84	7
1910	do	.32	2	.44	.36	.80	10.00	7
1910	do	.67	3	.67	.36	1.03	10.50	7
1911	do	.54	0	.00	1.76	1.76	3.67	7
1911	do	.54	1	.19	1.76	1.95	4.86	7
1911	do	.54	2	.39	1.76	2.15	5.22	7
1911	do	.54	3	.59	1.76	2.35	6.88	7
1912	do	.31	0	.00	.76	.76	3.66	7
1912	do	.35	1	.33	.76	1.09	4.57	7
1912	do	.35	2	.72	.76	1.48	5.81	7
1912	do	.35	3	1.22	.76	1.98	6.60	7
1913	do	.26	0	.00	.44	.44	1.54	7
1913	do	.26	1	.25	.44	.69	3.80	7
1913	do	.26	2	.50	.44	.94	3.36	7
1913	do	.26	3	.75	.44	1.19	4.99	7
1913	do	.26	4	1.00	.44	1.44	6.74	7
1913	do	.26	5	1.25	.44	1.69	7.05	7
1914	do	.27	0	.00	1.38	1.38	3.93	7
1914	do	.27	1	.33	1.38	1.71	7.38	7
1914	do	.27	2	.67	1.38	2.05	11.48	7
1914	do	.27	3	1.00	1.38	2.38	12.02	7
1914	do	.27	4	1.33	1.38	2.71	11.65	7
1914	do	.27	4	1.60	1.38	2.98	11.70	7
1914	do	.27	4	1.93	1.38	3.31	11.83	7
1915	do	.63	0	.00	1.37	1.37	4.02	7
1915	do	.56	1	.33	1.37	1.70	9.87	7
1915	do	.59	2	.67	1.37	2.04	12.22	7
1915	do	.54	3	1.00	1.37	2.37	14.15	7
1922	do	.38	0	.00	.80	.80	4.00	7
1922	do	.38	1	.25	.80	1.05	4.96	7
1922	do	.38	2	.48	.80	1.28	6.92	7
1922	do	.38	3	.94	.80	1.74	8.35	7
1922	do	.37	4	1.31	.80	2.11	8.16	7

BARLEY

Year	Soil	Area irrigated	Irrigations	Irrigation	Rainfall	Total	Yield per acre	Literature cited
							Bush.	
1910	Yolo fine sandy loam	1.25	0	0.00	0.36	0.36	24.2	7
1910	do	.50	1	.30	.36	.66	31.8	7
1910	do	.50	2	.52	.36	.88	38.3	7
1911	do	.72	0	.00	1.76	1.76	17.7	7
1911	do	.67	1	.47	1.76	2.23	31.6	7
1911	do	.50	1	.36	1.76	2.12	23.0	7
1911	do	.50	1	.50	1.76	2.26	44.8	7
1911	do	.50	2	.58	1.76	2.34	37.7	7
1912	do	1.48	0	.00	.76	.76	7.2	7
1912	do	.49	0	.00	.76	.76	21.7	7
1912	do	.48	1	.62	.76	1.38	26.7	7
1912	do	.49	2	1.41	.76	2.17	40.6	7
1913	do	1.10	0	.00	.44	.44	9.3	7
1913	do	.25	0	.00	.44	.44	6.7	7
1913	do	.25	1	.77	.44	1.21	44.7	7
1913	do	.25	2	1.12	.44	1.56	53.2	7
1914	do	1.20	0	.00	1.38	1.38	37.4	7
1914	do	.57	0	.00	1.38	1.38	43.1	7
1914	do	.19	1	.33	1.38	1.71	40.8	7
1914	do	.19	1	.67	1.38	2.05	52.8	7
1914	do	.19	1	1.00	1.38	2.38	56.2	7
1915	do	.51	0	.00	1.37	1.37	27.6	7
1915	do	.26	0	.00	1.37	1.37	41.1	7
1915	do	.25	1	.25	1.37	1.62	43.5	7
1915	do	.25	1	.38	1.37	1.75	43.5	7
1915	do	.25	1	.50	1.37	1.87	45.2	7
1915	do	.25	1	.62	1.37	1.99	46.1	7
1916	do	3.90	0	.00	1.17	1.17	20.8	7
1916	do	4.00	1	.27	1.17	1.44	30.4	7

TABLE 9.—*Irrigation water applied, rainfall, and crop yields in the Sacramento Valley, Calif.*—Continued

RICE [6]

Year	Soil	Area irrigated	Irrigations	Quantity of water received by crop: Irrigation	Quantity of water received by crop: Rainfall	Quantity of water received by crop: Total	Yield per acre	Literature cited
		Acres	*Number*	*Feet*	*Feet*	*Feet*	*Sacks*	*Reference no.*
1916	Clay loam and clay	135. 60	[7] 9	7. 80	0. 13	7. 93	33	*28*
1916	do	132. 53	[7] 7	8. 45	. 13	8. 58	25	*28*
1916	Clay adobe	75. 50	[7] 4	6. 46	. 13	6. 59	18	*28*
1916	Loam	61. 00	[7] 5	9. 07	. 13	9. 20	47	*28*
1916	Loam-clay	44. 85	[7] 5	6. 68	. 13	6. 81	35	*28*
1916	Clay	866. 00		6. 39	. 13	6. 52	25	*28*
1916	do	70. 15		6. 49	. 13	6. 62	20	*28*
1916	do	1, 106. 00		5. 41	. 13	5. 54	35	*28*
1916	Clay-adobe	39. 50	[7] 6	4. 27	. 13	4. 40	39	*28*
1916	do	229. 50	[7] 6	4. 66	. 13	4. 79	42	*28*
1916	do	187. 23	[7] 7	4. 80	. 13	4. 93	34	*28*
1916	do	41. 00	[7] 6	7. 26	. 13	7. 39	39	*28*
1916	Loams	36. 70	[7] 5	10. 00	. 13	10. 13	10	*28*
1916	do	13. 95	[7] 5	13. 43	. 13	13. 56	14	*28*
1917	Clay	2, 018. 3		4. 99	. 19	5. 18	32	(11)
1917	Clay adobe	75. 5		5. 31	. 19	5. 50	44	(11)
1917	Clay	115. 79		4. 48	. 19	4. 67	42	(11)
1917	Loam	61. 0		[8] 9. 69	. 19	9. 88	39	(11)
1917	Clay adobe	2, 175. 4		4. 21	. 19	4. 40	35	(11)
1917	do	180. 0		4. 26	. 19	4. 45	[9] 30	(11)
1917	Clay	242. 3		3. 91	. 19	4. 10	50	(11)
1917	do	113. 04		4. 01	. 19	4. 20	48	(11)
1917	do	1, 026. 0		5. 43	. 19	5. 62	29. 5	(11)
1917	do	1, 698. 0		5. 73	. 19	5. 92	29. 5	(11)
1917	Clay adobe	302. 4		8. 13	. 19	8. 32	43	(11)
1917	do	269. 2		4. 12	. 19	4. 31	28	(11)
1917	do	259. 1		5. 07	. 19	5. 26	36	(11)
1917	do	229. 5		4. 41	. 19	4. 60	38	(11)
1917	do	39. 5		4. 37	. 19	4. 56	39	(11)
1917	do	70. 8		5. 06	. 19	5. 25	52	(11)
1917	Clay	823. 3		6. 51	. 19	6. 70	[10] 17	(11)
							Lbs.	
1924	do	63. 28		5. 72	. 05	5. 77	2, 978	*16*
1924	do	102. 38		4. 20	. 05	4. 25	2, 780	*16*
1924	Clay adobe	111. 67		5. 03	. 05	5. 08	2, 770	*16*
1924	do	109. 41		4. 67	. 05	4. 72	2, 496	*16*
1924	Loam	200. 85		7. 41	. 05	7. 46	2, 275	*16*
1925		112. 05		4. 77	. 40	5. 17	2, 699	*16*
1925		38. 8		4. 88	. 40	5. 28	3, 200	*16*

[6] Sacks of rice averaged 100 pounds in weight.
[7] Prior to submergence.
[8] Drain 4 feet deep adjacent to rice field on 2 sides.
[9] Yield for 75 acres only, rest of field not harvested.
[10] Crop was foul with water grass and tules.
[11] Unpublished data in official files.

Table 10.—*Irrigation water applied, rainfall, and crop yields in the San Joaquin Valley, Calif.*

ALFALFA [1]

Year	Soil	Area irrigated	Age of trees and vines	Irrigations	Quantity of water received by crop: Irrigation	Quantity of water received by crop: Rainfall	Quantity of water received by crop: Total	Yield per acre	Literature cited
		Acres	*Years*	*Number*	*Feet*	*Foot*	*Feet*	*Tons*	*Reference no.*
1922	Fine sand	[2] 0.88	------	3	1.00	0.76	1.76	7.04	7
1922	do	[2] .48	------	3	1.50	.76	2.26	7.82	7
1922	do	[2] .88	------	4	2.00	.76	2.76	8.60	7
1922	do	[2] 1.04	------	5	2.50	.76	3.26	8.63	7
1922	do	[2] 1.04	------	6	3.00	.76	3.76	9.23	7
1922	do	[2] 1.04	------	6	3.50	.76	4.26	9.65	7
1922	do	[2] 1.04	------	6	4.00	.76	4.76	8.95	7
1922	do	[2] .88	------	6	5.00	.76	5.76	8.68	7
1923	do	[2] .88	------	3	1.00	.50	1.50	4.98	7
1923	do	[2] .48	------	3	1.50	.50	2.00	5.23	7
1923	do	[2] .88	------	4	2.00	.50	2.50	5.51	7
1923	do	[2] 1.04	------	5	2.50	.50	3.00	6.37	7
1923	do	[2] 1.04	------	6	3.00	.50	3.50	7.36	7
1923	do	[2] 1.04	------	6	3.50	.50	4.00	8.07	7
1923	do	[2] 1.04	------	6	4.00	.50	4.50	7.77	7
1923	do	[2] .88	------	6	5.00	.50	5.50	7.46	7
1924	do	[2] .88	------	3	1.00	.31	1.31	3.79	7
1924	do	[2] .48	------	3	1.50	.31	1.81	4.00	7
1924	do	[2] .88	------	4	2.00	.31	2.31	4.63	7
1924	do	[2] 1.04	------	5	2.50	.31	2.81	6.62	7
1924	do	[2] 1.04	------	6	3.00	.31	3.31	8.02	7
1924	do	[2] 1.04	------	6	3.50	.31	3.81	8.42	7
1924	do	[2] 1.04	------	6	4.00	.31	4.31	8.53	7
1924	do	[2] .88	------	6	5.00	.31	5.31	8.57	7
1925	do	[2] 4.8	------	4	2.00	.70	2.70	6.63	7
1925	do	[2] 5.2	------	6	3.00	.70	3.70	7.15	7
1925	do	[2] 4.6	------	8	4.00	.70	4.70	6.45	7

COTTON [3]

Year	Soil	Area irrigated	Age of trees and vines	Irrigations	Irrigation	Rainfall	Total	Yield per acre	Literature cited
								Lbs.	
1927	Sandy loam	------	------	7	[4] 3.22	0.29	3.51	[5] 853	6
1927	do	------	------	4	[4] 2.07	.29	2.36	[5] 693	6
1927	do	------	------	3	[4] 1.88	.29	2.17	[5] 587	6
1927	do	------	------	5	[4] 2.33	.29	2.62	[5] 640	6
1927	do	------	------	5	2.18	.29	2.47	[5] 607	6
1928	do	------	------	7	[4] 3.22	.14	3.36	[5] 1,333	6
1928	do	------	------	4	[4] 2.07	.14	2.21	[5] 1,110	6
1928	do	------	------	3	[4] 1.88	.14	2.02	[5] 867	6
1928	do	------	------	5	[4] 2.33	.14	2.47	[5] 907	6
1928	do	------	------	5	2.18	.14	2.32	[5] 863	6
1929	do	------	------	7	[4] 3.22	.16	3.38	[5] 1,020	6
1929	do	------	------	4	[4] 2.07	.16	2.23	[5] 687	6
1929	do	------	------	3	[4] 1.88	.16	2.04	[5] 480	6
1929	do	------	------	5	[4] 2.33	.16	2.49	[5] 660	6
1929	do	------	------	5	2.18	.16	2.34	[5] 513	6
1930	do	------	------	7	[4] 3.22	.37	3.59	[5] 930	6
1930	do	------	------	4	[4] 2.07	.37	2.44	[5] 573	6
1930	do	------	------	3	[4] 1.88	.37	2.25	[5] 477	6
1930	do	------	------	5	[4] 2.33	.37	2.70	[5] 580	6
1930	do	------	------	5	2.18	.37	2.55	[5] 533	6

SULTANINA (THOMPSON SEEDLESS) GRAPES [6]

Year	Soil	Area irrigated	Age of trees and vines	Irrigations	Irrigation	Rainfall	Total	Yield per acre	Literature cited
								Tons	
1930	------	7.5	13	7	2.42	[7] 0.37	2.79	3.98	------
1930	------	13.0	9	6	3.58	[7] .37	3.95	8.63	------
1930	------	10.0	9	5	4.83	[7] .37	5.20	5.00	------
1930	------	10.0	10	4	2.75	[7] .37	3.12	6.00	------
1930	------	5.5	10	4	1.50	[7] .37	1.87	2.25	------
1930	------	4.5	9	6	2.58	[7] .37	2.95	3.00	------
1930	------	8.0	8	7	3.42	[7] .37	3.79	5.04	------
1930	------	12.0	10	4	3.00	[7] .37	3.37	5.33	------
1930	------	14.5	8	3	3.00	[7] .37	3.37	7.50	------
1930	------	3.0	9	6	4.67	[7] .37	5.04	4.64	------
1930	------	8.0	8	4	3.58	[7] .37	3.95	7.51	------

Footnotes at end of table.

TABLE 10.—*Irrigation water applied, rainfall, and crop yields in the San Joaquin Valley, Calif.*—Continued

WASHINGTON NAVEL ORANGES [8]

Year	Soil	Area irrigated	Age of trees and vines	Irrigations	Quantity of water received by crop: Irrigation	Quantity of water received by crop: Rainfall	Quantity of water received by crop: Total	Yield per acre	Literature cited
								Packed boxes	
1928	Medium	16.11	20	------	3.52	[9] 0.65	4.17	85.8	------
1928	Heavy	20.00	15	------	3.04	[9] .65	3.69	59.8	------
1928	Medium	14.37	14	------	2.70	[9] .65	3.35	42.3	------
1928		17.63		------	2.61	[9] .65	3.26	130.8	------
1928	Heavy	4.50	15	------	2.55	[9] .65	3.20	149.0	------
1928		8.20	------	------	2.45	[9] .65	3.10	87.0	------
1928	Heavy	4.67	10	------	2.43	[9] .65	3.08	63.0	------
1928		5.43	------	------	2.30	[9] .65	2.95	144.9	------
1928		9.67	------	------	2.26	[9] .65	2.91	132.0	------
1928	Medium	9.09	7	------	2.15	[9] .65	2.80	197.0	------
1928	Heavy	8.91	15	------	2.08	[9] .65	2.73	289.0	------
1928	Medium	17.31	23	------	1.77	[9] .65	2.42	57.0	------
1928	do	10.0	16	------	1.68	[9] .65	2.33	131.0	------
1928	Heavy	10.0	16	------	1.68	[9] .65	2.33	90.6	------
1929	Medium	9.40	24	------	2.56	[9] .56	3.12	188	------
1929	Heavy	8.91	16	------	2.32	[9] .56	2.88	162	------
1929	Medium	35.0	21	------	3.6	[9] .56	4.24	130	------
1929	do	9.60	16	------	1.70	[9] .56	2.26	127	------
1929	Heavy	4.93	16	------	2.36	[9] .56	2.92	122	------
1929	Medium	18.80	7	------	2.06	[9] .56	2.62	91	------
1929	do	9.09	21	------	2.69	[9] .56	3.25	91	------
1929	do	10.0	17	------	3.12	[9] .56	3.68	82	------
1929	do	7.51	17	------	3.20	[9] .56	3.76	79	------
1929	do	14.37	15	------	3.25	[9] .56	3.81	74	------
1929	Heavy	10.00	17	------	1.67	[9] .56	2.23	74	------
1929	do	12.67	16	------	2.14	[9] .56	2.70	68	------
1929	do	4.50	16	------	2.48	[9] .56	3.04	60	------
1929	do	4.67	11	------	2.16	[9] .56	2.72	55	------
1929	Medium	17.31	24	------	2.79	[9] .56	3.35	49	------
1929	do	16.11	21	------	3.18	[9] .56	3.74	36	------
1929	do	11.20	23	------	1.91	[9] .56	2.47	35	------
1929	Heavy	20.0	16	------	3.25	[9] .56	3.81	34	------
1930	Sandy loam	5.7	18	------	2.52	[9] .44	2.96	347.4	------
1930	Adobe	8.91	17	------	2.21	[9] .44	2.65	345.0	------
1930	do	10.0	18	------	2.50	[9] .44	2.94	211.2	------
1930	Loam	9.6	17	------	2.20	[9] .44	2.64	220.3	------
1930	do	5.2	15	------	2.58	[9] .44	3.02	195.6	------
1930	Sandy loam	9.33	13	------	4.23	[9] .44	4.67	180.2	------
1930	Fine sandy loam	13.9	14	------	3.73	[9] .44	4.17	197.1	------
1930	Adobe	4.93	17	------	2.02	[9] .44	2.46	243.4	------
1930	Loam	4.0	14	------	2.52	[9] .44	2.96	192.0	------
1930		9.09	22	------	2.44	[9] .44	2.88	133.7	------
1930	Sandy loam	7.51	18	------	2.03	[9] .44	2.47	124.6	------
1930	Adobe	4.5	17	------	2.97	[9] .44	3.41	126.3	------
1930	do	15.0	16	------	2.25	[9] .44	2.69	193.6	------
1930	Sandy loam	7.16	15	------	2.41	[9] .44	2.85	132.5	------
1930	Adobe	10.0	18	------	2.00	[9] .44	2.44	165.8	------
1930	Sandy loam	16.11	22	------	2.11	[9] .44	2.55	97.6	------
1930	Loam	6.67	17	------	2.71	[9] .44	3.15	149.9	------
1930	Adobe	4.67	12	------	1.72	[9] .44	2.16	121.8	------
1930	do	9.3	19	------	2.50	[9] .44	2.94	73.9	------
1930	do	10.88	22	------	2.08	[9] .44	2.52	79.1	------
1930	Sandy loam	19.42	17	------	2.41	[9] .44	2.85	158.5	------
1930	Adobe	12.67	17	------	1.92	[9] .44	2.36	156.9	------
1930	do	20.0	17	------	2.50	[9] .44	2.94	162.9	------
1930	Sandy loam	11.2	24	------	2.32	[9] .44	2.76	83.7	------

[1] Experiments with alfalfa were conducted under cooperative agreements between the Bureau of Public Roads, U.S. Department of Agriculture, the University of California Agricultural Experiment Station and the division of engineering and irrigation, California State Department of Public Works.
[2] Total area of several plots receiving the same treatment.
[3] These plot experiments on cotton were conducted near Shafter, Calif., by the University of California Agricultural Experiment Station.
[4] Includes preseason irrigation of 6 acre-inches per acre.
[5] These are mean yields from a number of plots receiving the same irrigation treatment. The yields are based on amounts of seed cotton produced by 180 plants per plot in 1927 and 1928 and on 100 plants per plot in 1929 and 1930. Total yields are estimated on a basis of 10,000 plants per acre. Yields of lint cotton are taken as one third of that of seed cotton.
[6] These data were obtained from individual growers by the county farm advisor, agricultural extension service, University of California.
[7] Rainfall computed from Jan. 1 to Sept. 30.
[8] These data were obtained from individual growers by the county farm advisor, agricultural extension service, University of California.
[9] Rainfall computed from Apr. 1 to Mar. 30 of each crop season.

TABLE 11.—*Consumptive use of water in Sacramento-San Joaquin deltas* [1]

[Consumption in feet depth or in acre-feet per acre [2]]

Crop or water-using agency	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total use for season	Total use for year
Alfalfa [3]	(0.06)	(0.08)	0.10	0.30	0.40	0.50	0.65	0.55	0.50	0.20	(0.10)	(0.07)	3.20	3.51
Asparagus [4]	.05	.05	.05	.05	.08	.14	.40	.68	.55	.42	.12	.10	2.69	2.69
Beans [4]	(.06)	(.08)	(.08)	(.16)	(.20)	.14	.24	.58	.37	(.09)	(.07)	(.05)	1.33	2.12
Beets [4]	(.06)	(.08)	(.08)	.13	.32	.51	[5] .61	[5] .53	[5] 20	(.13)	(.10)	(.07)	2.30	2.82
Celery [4]	(.04)	(.04)	(.04)	(.08)	(.10)	.10	.10	.20	.25	.30	.20	.05	1.20	1.50
Corn [4]	(.04)	(.04)	(.04)	(.08)	(.10)	.24	.85	[5] .84	[5] .40	.10	(.10)	(.07)	2.43	2.90
Fruit [3]	(.04)	(.04)	(.04)	.18	.32	.50	.57	.40	.23	.07	(.07)	(.05)	2.27	2.51
Grain and hay [4]	(.04)	(.04)	.07	.60	.83	.20	(.14)	(.23)	(.21)	(.14)	(.07)	(.05)	1.70	2.62
Onions [4]	(.04)	(.04)	.08	.13	.27	.49	.43	.20	(.16)	(.13)	(.10)	(.07)	1.60	2.14
Pasture [6]	.08	.10	.20	.25	.25	.25	.25	.25	.20	.15	.10	.08	2.16	2.16
Potatoes [4]	(.06)	(.08)	(.08)	(.16)	.15	.38	.52	.30	.15	(.09)	(.07)	(.05)	1.50	2.09
Seed [6]	(.06)	(.08)	(.08)	.10	.25	.50	.50	.50	35	.10	(.10)	(.07)	2.30	2.69
Truck [6]	(.06)	(.08)	.10	.10	.25	.50	.45	.45	.30	.15	.10	(.07)	2.40	2.61
Tules [7]	.16	.09	.30	.74	1.10	1.28	1.53	1.32	1.18	.98	.59	.36	9.63	9.63
Bare land [4]	.04	.04	.04	.08	.10	.13	.14	.13	.11	.09	.07	.05	1.02	1.02
Average idle land with weeds below elevation 5 feet United States Geodetic Survey datum [6]	.06	.08	.08	.16	.20	.26	.28	.24	.16	.13	.10	.07	1.82	1.82
Open water surface [7]	.08	.13	.23	.34	.60	.76	.84	.78	.60	.33	.14	.08	4.91	4.91
Willows [8]	.05	.03	.09	.22	.33	.38	.46	.40	.35	.29	.18	.10	2.88	2.88

[1] State of California Department of Public Works, Division of Water Resources, Bul. 27, (*12*) table 1.
[2] Figures shown in parentheses ( ) represent estimated consumptive use on cropped areas before planting and after harvest, or during the dormant season.
[3] From experiments in adjacent areas.
[4] From recent cooperative experiments in Sacramento-San Joaquin delta by Division of Water Resources and U.S. Department of Agriculture.
[5] Includes additional use of water by weeds during these months.
[6] Estimated by U.S. Department of Agriculture by comparison with similar crops.
[7] From data of recent cooperative experiments and other agencies, modified by Charles H. Lee.
[8] From data of recent cooperative experiments and other agencies, modified by Charles H. Lee. Use based upon willows in large groves, with an additional 10 percent for isolated trees.

Table 12.—*Irrigation water applied, rainfall, and crop yields of alfalfa [1] in southern California*

Year	Soil	Area irrigated	Irrigations	Quantity of water received by crop: Irrigation	Quantity of water received by crop: Rainfall [2]	Quantity of water received by crop: Total	Yield per acre
		Acres	*Number*	*Feet*	*Foot*	*Feet*	*Tons*
1931	Fine sand	72		5.81	0.71	6.52	6.7
1931	Loamy sand	45		4.40	.71	5.11	5.7
1931	do	45		4.50	.71	5.21	7.9
1931		80		1.19	.71	1.90	6.3
1931	Sand	60		7.78	.71	8.49	5.8
1931	do	25		9.62	.71	10.33	4.8
1931	Fine sandy loam	24		5.47	.71	6.18	7.2
1931		4		2.20	.71	2.91	5.9
1931	Sand	75		5.77	.71	6.48	5.9
1931	do	60		6.78	.71	7.49	6.4
1931	Sand, heavy	33		8.36	.71	9.07	5.9
1931	Loamy sand	38		8.20	.71	8.91	7.1
1931	Fine sandy loam	35		4.60	.71	5.31	7.0
1931	Sand	10		6.03	.71	6.74	4.8
1931	Fine sandy loam	153		5.19	.71	5.90	5.3
1931	Sand	[3] 15		4.27	.71	4.98	8.1
1931	do	[3] 10		8.61	.71	9.32	5.7
1931		[3] 40		9.75	.71	10.46	4.1
1931		[3] 78		4.86	.71	5.57	4.3
1931	Loamy sand	[3] 30		2.94	.71	3.65	2.4
1931	Fine sandy loam	[3] 14		4.22	.71	4.93	4.0
1931		[3] 77		4.35	.71	5.06	4.2
1931	Sand, heavy	[3] 5		2.80	.71	3.51	3.1
1931		[3] 45		4.94	.71	5.65	2.0

[1] These data obtained from individual growers by the county farm advisor, agricultural extension service, University of California.
[2] Rainfall computed from Oct. 1, 1930, to Sept. 30, 1931.
[3] These fields were newly planted in the fall of 1930.

Table 13.—*Irrigation water applied, rainfall, and crop yields in southern California*

VALENCIA ORANGES [1]

Year	Climatic location [2]	Soil	Area irrigated	Age of trees	Irrigations	Quantity of water received by crop: Irrigation	Quantity of water received by crop: Rainfall [3]	Quantity of water received by crop: Total	Yield per acre
			Acres	*Years*	*Number*	*Feet*	*Feet*	*Feet*	*Packed boxes*
1929	Coastal		10.0	10	5	1.25	0.84	2.09	313.2
1929	do		4.5	19	6	1.26	.87	2.13	357.7
1929	do	Medium	9.0	18	6	1.26	.87	2.13	394.2
1929	do	Heavy	13.0	18	8	3.46	.79	4.25	268.7
1929	do	do	10.5	17	5	1.33	.84	2.17	133.8
1929	do		3.0	17	5	1.82	.79	2.61	377.2
1929	do		10.0	11	7	1.52	.84	2.36	309.4
1929	do	Light	6.5	15	6	1.21	.84	2.05	278.9
1929	do	Medium	10.0	14	9	2.74	.80	3.54	405.7
1929	do		20.0	16	7	1.56	.84	2.40	257.0
1929	do		4.0	16	6	1.65	.80	2.45	265.2
1929	do	Medium	3.5	13	7	2.39	.84	3.23	353.9
1929	do	do	7.0	18	5	1.91	.80	2.71	306.7
1929	do	Light	4.5	13	6	2.38	.84	3.22	268.2
1929	do	Medium	4.5	15	7	2.63	.84	3.47	427.9
1929	do	do	10.0	17	7	1.60	.84	2.44	380.7
1929	do	Light	6.0	17	7	1.46	.84	2.30	138.0
1929	do	Medium	4.0	14	6	1.07	.84	1.91	331.8
1929	do	do	8.0	12	6	.87	.84	1.71	301.1

[1] These data obtained from individual growers by the county farm advisor, agricultural extension service, University of California.
[2] Coastal climate is one where strong ocean influence is manifest. Intermediate climate is found back from the coast but not remote from all ocean modifying influences. Interior climate is remote from the coast and all ocean influences.
[3] Rainfall computed from Oct. 1, to Sept. 30 for each crop season.

Table 13.—*Irrigation water applied, rainfall, and crop yields in southern California*—Continued

VALENCIA ORANGES—Continued

Year	Climatic location	Soil	Area irrigated	Age of trees	Irrigations	Quantity of water received by crop			Yield per acre
						Irrigation	Rainfall	Total	
			Acres	*Years*	*Number*	*Feet*	*Feet*	*Feet*	*Packed boxes*
1929	Coastal	Medium	9.0	15	5	2.25	.84	3.09	403.7
1929	do	do	10.0	12	7	1.26	.87	2.13	274.4
1929	do	Light	20.0	15	9	1.46	.84	2.30	319.2
1929	do	Medium	18.0	13	6	1.47	.80	2.27	346.9
1929	do	Heavy	5.0	17	6	1.51	.84	2.35	409.8
1929	do	Medium	10.0	16	8	1.53	.84	2.37	427.4
1929	do	do	10.0	17	6	1.56	.79	2.35	496.8
1929	do	Light	25.0	15	9	3.27	.84	4.11	368.5
1929	do	do	5.0	13	9	2.73	.84	3.57	167.1
1929	do	Heavy	5.0	18	6	2.26	.84	3.10	290.1
1929	do	Medium	15.0	13	8	2.18	.84	3.02	520.7
1929	do	Light	13.0	15	5	.81	.84	1.65	210.5
1929	do	Heavy	17.0	16	7	1.04	.87	1.91	179.8
1929	do	Medium	12.0	13	5	1.08	.84	1.92	262.6
1929	do	Heavy	19.0	17	6	1.12	.84	1.96	235.0
1929	do	Light	7.0	17	6	1.12	.84	1.96	284.0
1929	do	Medium	10.0	24	6	2.39	.79	3.18	760.3
1929	do	do	8.0	37	4	2.02	.80	2.82	528.8
1929	do	Heavy		16		2.00	.80	2.80	411.2
1929	do	do	12.0	13	6	1.80	.79	2.59	60.6
1929	do	Medium	10.0	14	6	1.80	.84	2.64	178.2
1929	do	Light	9.0	16	7	1.96	.84	2.80	182.3
1929	do	do	5.0	17	7	1.63	.84	2.47	208.6
1929	do	Heavy	10.0	26	5	1.49	.79	2.28	211.7
1929	do	do	10.0	34	7	1.84	.79	2.63	212.0
1929	do	Light	20.0	11	5	.86	.84	1.70	177.5
1929	do		15.0	21	7	1.45	.87	2.32	334.2
1929	do		11.0	10	6	1.97	.87	2.84	152.1
1929	do		4.0	16	9	2.00	.80	2.80	411.2
1929	do	Light	14.0	13	7	2.00	.84	2.84	292.4
1929	do	Medium	10.0	12	8	1.76	.80	2.56	203.0
1929	do		10.0	15	6	1.67	.84	2.51	316.6
1929	do	Light	17.0	8–24	7	1.68	.80	2.48	362.9
1929	do	do	20.0	17	7	1.55	.84	2.39	281.8
1929	do	do	20.0	11	9	1.92	.84	2.76	176.7
1929	do	Medium	6.0	16	9	1.79	.84	2.63	280.2
1929	do	Light	9.0	12	9	3.05	.80	3.85	158.3
1929	do	do	9.0	10	8	1.58	.84	2.42	217.3
1929	do	do	17.0	16–33	6	1.87	.79	2.66	321.0
1929	do	do	13.0	15	6	1.84	.84	2.68	278.9
1929	do	Heavy	33.0	11	7	1.11	.80	1.91	254.7
1929	do		9.0	17	7	1.98	.80	2.78	351.8
1929	do		20.0	23	8	1.98	.80	2.78	305.6
1929	do		10.0	18	4	1.11	.80	1.91	260.2
1929	do	Medium	5.11	11	4	.91	.80	1.71	177.7
1929	do	do	19.16	8	7	2.10	.79	2.89	226.5
1929	do	Heavy	8.0	8	7	1.23	.87	2.10	209.0
1929	do	Light	9.0	7	9	1.80	.84	2.64	198.8
1929	do		10.0	7	7	1.31	.84	2.15	145.4
1929	do		4.0	5	6	.53	.87	1.40	51.9
1929	do	Light	10.0	7	7	1.63	.84	2.47	107.7
1929	do		5.0	7	6	1.82	.84	2.66	182.4
1930	do	Sandy loam	14.44	16	7	1.16	1.13	2.29	179.4
1930	do	do	25.0	16	7	1.78	1.13	2.91	108.6
1930	do	Sand, loam, clay	5.0	14	8	1.73	1.13	2.86	130.4
1930	do		15.0	22	6	1.37	.87	2.24	79.4
1930	do		4.5	16	6	2.00	1.13	3.13	298.0
1930	do		10.0	16	4	1.29	1.13	2.42	138.5
1930	do	Loam	17.0	17	7	1.30	1.02	2.32	163.2
1930	do	Sandy loam	20.0	12	9	1.85	1.13	2.98	135.3
1930	do	Light	9.0	11	7	1.73	1.13	2.86	163.6
1930	do	Gravel loam	17.0	25	6	1.97	1.08	3.05	181.2
1930	do		4.76	17	9	1.81	1.02	2.83	134.4
1930	do		3.5	14	5	1.63	1.13	2.76	301.7
1930	do		3.0	18	5	1.31	1.08	2.39	207.0
1930	do		8.0	13	5	.79	1.15	1.94	215.9
1930	do		15.0	14	7	1.95	1.13	3.08	149.0
1930	do	Sandy loam	13.0	16	7	1.81	1.13	2.94	95.0
1930	do	Heavy	30.5	12	5	1.71	1.02	2.73	177.9
1930	do	Medium	19.16	9	5	1.92	1.08	3.00	133.1
1930	do		9.0	18	5	1.71	1.13	2.84	204.9
1930	do	Light	20.0	18	5	1.09	1.13	2.22	61.1

TABLE 13.—*Irrigation water applied, rainfall, and crop yields in southern California*—Continued

VALENCIA ORANGES—Continued

Year	Climatic location	Soil	Area irrigated	Age of trees	Irrigations	Quantity of water received by crop: Irrigation	Rainfall	Total	Yield per acre
			Acres	*Years*	*Number*	*Feet*	*Feet*	*Feet*	*Packed boxes*
1930	Coastal	Heavy	12.0	14	3	1.05	1.08	2.13	44.8
1930	do	Medium	7.0	18	4	1.03	1.13	2.16	199.7
1930	do	do	7.5	36	4	1.02	1.02	2.04	215.8
1930	do	do	5.11	12	4	.99	1.02	2.01	53.7
1930	do	Light	20.0	12	5	.97	1.13	2.10	50.2
1930	do	Medium	19.0	18	5	.94	1.13	2.07	161.6
1930	do	do	4.0	15	6	.82	1.13	1.95	78.5
1930	do	do	8.0	13	5	.79	1.13	1.92	215.9
1930	do	Heavy	17.0	17	4	.62	.87	1.49	48.6
1930	do		10.0	18	4	1.02	1.02	2.04	137.7
1930	do	Heavy	10.5	18	4	1.24	1.13	2.37	100.8
1930	do		10.0	15	5	1.27	1.13	2.40	243.1
1930	do	Sandy clay	4.0	20	7	1.77	1.13	2.90	230.8
1930	do	Sandy loam	20.0	17	6	1.91	1.13	3.04	220.9
1930	do	do	6.0	18	6	1.33	1.13	2.46	71.3
1930	do		11.0	11	7	1.26	1.13	2.39	60.6
1930	do	Sandy loam and silt	14.0	14	4	1.10	1.13	2.23	54.0
1930	do		9.0	17	5	1.63	1.21	2.84	41.2
1930	do	Medium	10.0	19	8	4.78	1.08	5.86	128.6
1930	do	Heavy	12.0	19	6	2.94	1.08	4.02	162.1
1930	do	Medium	11.0	33	6	2.87	1.02	3.89	216.7
1930	do	do	5.0	11	7	2.68	1.02	3.70	154.6
1930	do	Light	9.0	12	9	2.48	1.02	3.50	33.9
1930	do	do	5.0	14	8	2.33	1.13	3.46	214.8
1930	do	Heavy	4.0	17	6	2.14	1.02	3.16	110.0
1930	do	Medium	10.0	17	6	2.04	1.13	3.17	191.3
1930	do	do	10.0	18	9	2.04	1.13	3.17	136.5
1930	do	do	10.0	25	5	2.03	1.08	3.11	186.3
1930	do	Heavy	8.0	9	7	1.58	.87	2.45	158.3
1930	do	Medium	10.0	35	5	1.57	1.08	2.65	206.4
1930	do	do	7.0	19	5	1.50	1.02	2.52	211.0
1930	do	do	20.0	24	6	1.49	1.02	2.51	157.4
1930	do	do	12.0	14	4	1.46	1.13	2.59	151.4
1930	do	do	9.2	18	6	1.45	1.08	2.53	244.6
1930	do	do	10.0	13	5	1.38	1.02	2.40	132.4
1930	do	Heavy	2.25	19	8	1.40	.87	2.27	138.1
1930	do	Medium	9.0	16	4	1.39	1.13	2.52	261.8
1930	do	do	6.0	17	6	1.39	1.13	2.52	193.4
1930	do	Gravelly loam	10.0	27	4	1.13	1.08	2.21	97.4
1930	do		5.0	18	6	1.87	1.13	3.00	156.4
1930	do	Sandy loam	9.0	9	10	1.31	1.13	2.44	100.4
1930	do		6.5	16	5	1.17	1.13	2.30	172.4
1930	do		10.0	11	5	1.18	1.13	2.31	132.3
1931	do	Sandy loam	4.0	21	7	3.68	.99	4.67	432.0
1931	do		11.0	33	5	1.93	.84	2.77	413.8
1931	do	Clay loam	10.0	19	7	1.63	.80	2.43	411.1
1931	do	Sand	15.0	15	6	1.87	.99	2.86	404.5
1931	do	Light to medium silt	10.5	16	5	1.71	.99	2.70	399.0
1931	do		9.0	17	5	1.58	.99	2.57	389.9
1931	do	Heavy	15.0	23	6	1.23	.98	2.21	356.6
1931	do		17.0	26	6	1.62	.80	2.42	355.9
1931	do	Sandy loam	5.5	20	6	2.31	.84	3.15	346.4
1931	do		3.0	19	7	2.02	.80	2.82	338.1
1931	do		19.0	19	5	.89	.99	1.88	167.6
1931	do	Sandy loam	5.0	15	11	2.35	.99	3.34	161.5
1931	do		10.0	16	6	1.14	.99	2.13	152.9
1931	do	Light sand and loam	9.0	13	10	2.94	.84	3.78	144.5
1931	do	Heavy	10.5	19	5	1.22	.99	2.21	131.2
1931	do	Loam	10.0	36	7	1.81	.80	2.61	130.8
1931	do		6.0	19	7	1.13	.99	2.12	129.1
1931	do		17.0	18	5	.75	.98	1.73	102.4
1931	do	Heavy loam	5.11	13	3	.85	.84	1.69	84.6
1931	do	Medium loam	10.0	14	6	1.83	.84	2.67	72.3
1931	do	Sandy loam	20.0	18	7	2.31	.99	3.30	213.6
1931	do	Medium	5.0	9	4	1.03	.99	2.02	149.9
1931	do	Sandy loam	14.44	17	8	1.25	.99	2.24	171.2
1931	do		5.0	19	6	1.64	.99	2.63	336.2
1931	do	Medium heavy	4.76	18	6	1.05	.84	1.89	197.7
1931	do		10.0	20	7	1.26	.98	2.24	337.8
1931	do		11.0	12	8	2.02	.98	3.00	213.5
1931	do	Sandy loam	9.0	10	14	1.18	.99	2.17	212.3
1931	do		10.0	26	6	2.03	.80	2.83	280.9

TABLE 13.—*Irrigation water applied, rainfall, and crop yields in southern California*—Continued

VALENCIA ORANGES—Continued

Year	Climatic location	Soil	Area irrigated	Age of trees	Irrigations	Quantity of water received by crop: Irrigation	Quantity of water received by crop: Rainfall	Quantity of water received by crop: Total	Yield per acre
			Acres	*Years*	*Number*	*Feet*	*Feet*	*Feet*	*Packed boxes*
1931	Coastal	Medium loam	5.0	16	6	0.97	0.99	1.96	196.6
1931	do		7.5	37	5	1.48	.84	2.32	280.7
1931	do		10.6	19	5	1.45	.84	2.29	304.2
1931	do		32.0	13	4	1.25	.84	2.09	247.5
1931	do		17.0	18	7	1.49	.84	2.33	311.6
1931	do	Sandy loam	7.0	12	7	1.67	.84	2.51	272.0
1931	do	Medium to heavy	10.0	23	5	1.63	.98	2.61	278.9
1931	do	Sandy loam	20.45	13	7	1.14	.99	2.13	174.6
1931	do	Medium sandy	25.0	17	6	1.66	.99	2.65	290.1
1931	do	Silt loam	7.0	19	6	1.61	.99	2.60	234.1
1931	do	Medium Yolo	30.0	4	3	.88	.80	1.68	222.2
1931	do		12.0	15	4	.88	.99	1.87	211.1
1931	do	Silt to sand	14.0	15	6	1.75	.99	2.74	257.1
1931	do	Light	9.0	12	7	1.60	.99	2.59	225.5
1931	do	Sandy loam	3.5	15	7	2.00	.99	2.99	252.3
1931	do	do	9.0	17	5	1.25	.99	2.24	389.9
1931	do	do	13.0	17	7	1.53	.99	2.52	247.6
1931	do	Sandy	10.0	9	8	2.30	.99	3.29	92.2
1931	do	Sand and sandy loam	4.5	15	6	2.09	.99	3.08	286.7
1931	do		10.0	19	8	1.99	.99	2.98	319.2
1931	do	Varies, average heavy	19.16	10	5	1.74	.80	2.54	264.3
1931	do		9.0	19	9	2.04	.99	3.03	234.4
1931	do		20.0	25	6	1.64	.84	2.48	254.9
1931	do	Clay loam	12.0	20	7	1.78	.80	2.58	234.7
1931	do	Sandy loam	6.5	17	6	1.57	.99	2.56	200.5
1931	do		10.0	12	6	1.50	.99	2.49	315.0
1931	do	Sandy loam	30.0	20	7	1.75	.98	2.73	321.9
1931	do	do	10.0	20	8	3.88	.80	4.68	328.4
1931	Intermediate		2.11	37		2.64	1.17	3.81	474.0
1931	do		4.19	13		1.05	1.17	2.22	303.0
1931	do		2.38	29		.86	.98	1.84	303.0
1931	do		2.41	21		1.50	.96	2.46	249.0
1931	do		4.0	17		1.86	.96	2.82	239.0
1931	do		9.0	25		1.41	.96	2.37	236.0
1931	do		8.69	13		1.51	.96	2.47	200
1931	do		8.74	28		1.35	1.17	2.52	225
1931	do		4.94	29		2.29	1.17	3.46	305
1931	do		3.0	30	7	1.82	1.32	3.14	185
1931	do		2.51	29		2.18	1.17	3.35	136
1931	do		4.04	9		1.89	1.32	3.21	39
1931	do		3.09	17		1.99	1.17	3.16	167
1931	do		1.61	50		1.60	1.32	2.92	93
1931	do		14.11	16		2.50	.98	3.48	70
1931	do		1.93	37		2.29	.96	3.25	450
1931	do		3.15	15	7	1.47	.96	2.43	150
1931	do		.66	12		2.23	1.17	3.40	95
1931	do		3.39	20		1.82	1.32	3.14	314
1931	Interior		20.0	11		1.54	1.27	2.81	235

WASHINGTON NAVEL ORANGES[1]

Year	Climatic location	Soil	Area irrigated	Age of trees	Irrigations	Irrigation	Rainfall	Total	Yield per acre
									Field boxes
1923	Intermediate		1.78	31	4	1.29	0.90	2.19	170
1923	do		14.3	7	4	1.61	.90	2.51	[illegible]
1924	do		1.78	32	4	1.86	.84	2.70	[illegible]
1924	do		14.3	8	6	2.46	.84	3.30	170
1925	do		1.78	33	5	1.89	.89	2.78	[illegible]
1925	do		14.3	9	5	1.78	.89	2.67	[illegible]
1926	do		1.78	34	6	3.02	[4] 1.72	4.74	[illegible]
1926	do		14.3	10	7	2.44	[4] 1.72	4.16	[illegible]
									Packed boxes
1931	do		6.00	35		1.86	.96	2.82	[illegible]
1931	do		2.22	21		1.42	.96	2.38	[illegible]

[1] These data obtained from individual growers by the county farm advisor, agricultural extension service, University of California.
[4] Of the total rainfall in 1926, 8.49 inches fell during April.

Table 13.—*Irrigation water applied, rainfall, and crop yields in southern California*—Continued

WASHINGTON NAVEL ORANGES—Continued

Year	Climatic location	Soil	Area irrigated	Age of trees	Irrigations	Quantity of water received by crop: Irrigation	Quantity of water received by crop: Rainfall	Quantity of water received by crop: Total	Yield per acre
			Acres	*Years*	*Number*	*Feet*	*Feet*	*Feet*	*Packed boxes*
1931	Intermediate		4.37	25		2.23	0.96	3.19	379
1931	do		2.66	30		2.55	1.17	3.72	453
1931	do		11.63	28		1.53	.96	2.49	437
1931	do		5.28	45		1.31	1.17	2.48	321
1931	do		10.00	28		1.48	1.17	2.65	318
1931	do		8.94	33		1.32	1.17	2.49	247
1931	do		4.28	33		2.23	1.17	3.40	364
1931	do		2.75	23	6	1.50	.96	2.46	369
1931	do		8.89	18		1.60	1.32	2.92	357
1931	do		2.78	27		2.52	.96	3.48	410
1931	do		2.72	29		2.02	1.17	3.19	239
1931	do		9.34	27		2.62	1.32	3.94	344
1931	do		6.50	24		2.33	.96	3.29	242
1931	do		4.40	40		2.29	.96	3.25	280
1931	do		3.67	11		1.38	1.17	2.55	143
1931	do		3.58	12		2.13	1.32	3.45	73
1931	do		2.77	17		1.99	1.17	3.16	192
1931	do		2.87	31		2.44	1.32	3.76	365

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1923	Intermediate		9.86	11	5	0.97	0.90	1.87	140
1923	do		3.07	13–31	4	1.29	.90	2.19	200
1923	do		7.7		4	1.61	.90	2.51	446
1924	do		9.86	12	6	1.50	.84	2.34	256
1924	do		2.07	14–32	4	1.86	.84	2.70	561
1924	do		7.7		6	2.46	.84	3.30	807
1925	do		9.86	13	7	1.58	.89	2.47	209
1925	do		2.07	15–33	5	1.89	.89	2.78	688
1925	do		7.7		5	1.78	.89	2.67	701
1926	do		9.86	14	8	1.49	[4] 1.72	3.21	374
1926	do		3.07	16–34	6	3.02	[4] 1.72	4.74	854
1926	do		7.7		7	2.44	[4] 1.72	4.16	764
									Cwt.
1929	Coastal	Medium	15.0	19	5	.98	.87	1.85	296.0
1929	do	Heavy	5.5	14	4	1.82	.80	2.62	284.4
1929	do	Medium	9.5	15	5	2.15	.80	2.95	220.8
1929	do	do	2.25	18	6	1.26	.80	2.06	189.6
1929	do	do	3.5	14	4	2.22	.84	3.06	144.8
1929	do	do	2.0	17	4	.67	.79	1.46	123.7
1929	do	do	3.5	10	3	.45	.87	1.32	96.1
1929	do	Heavy	5.0	14	4	1.13	.84	1.97	87.2
1929	do	do	10.0	15	7	.77	.87	1.64	77.0
1930	do	Medium	15.0	20	5	.85	.87	1.72	185.9
1930	do	do	2.25	19	8	1.42	.87	2.29	192.4
1930	do	do	9.5	16	5	1.11	1.02	2.13	138.4
1930	do	do	3.5	15	5	1.67	1.13	2.80	123.2
1930	do	Heavy	5.5	15	4	1.72	1.02	2.74	150.1
1930	do	do	2.75	24	5	1.13	1.08	2.21	148.9
1930	do	Sandy loam	5.0	17	6	1.76	1.13	2.89	137.7
1930	do		20.0	20	5	1.57	1.08	2.65	131.9
1930	do	Medium	3.5	11	7	1.13	.87	2.00	75.4
1930	do		3.0	22	3	1.14	1.08	2.22	124.0
1930	do		25.0	20	4	.75	1.08	1.83	88.8
1930	do	Gravel and sandy loam	4.66	24	6	2.72	1.08	3.80	110.4
1930	do	Heavy	13.9	20	5	.83	1.13	1.96	77.4
1930	do		18.0	16	5	1.63	1.02	2.65	73.0
1930	do	Heavy	10.0	16	3	.33	.87	1.20	35.2
1930	do	Medium	2.0	18	4	.78	1.08	1.86	15.9
1931	do	do	15.0	21	6	1.36	.98	2.34	264.4
1931	do	do	9.5	17	6	.99	.84	1.83	203.8
1931	do		11.0	23	4	1.01	.98	1.99	195.9
1931	do	Medium	2.25	20	7	1.26	.98	2.24	221.8
1931	do	Heavy	5.5	16	5	1.82	.84	2.66	192.4
1931	do		9.5	16	5	1.10	.84	1.94	224.1

[1] These data obtained from individual growers by the county farm advisor, agricultural extension service, University of California.

[4] Of the total rainfall in 1926, 3.49 inches fell during April.

TABLE 13.—*Irrigation water applied, rainfall, and crop yields in southern California*—Continued

LEMONS—Continued

Year	Climatic location	Soil	Area irrigated	Age of trees	Irrigations	Quantity of water received by crop			Yield per acre
						Irrigation	Rainfall	Total	
			Acres	*Years*	*Number*	*Feet*	*Feet*	*Feet*	*Cwt.*
1931	Coastal	Black adobe	2.75	25	5	0.56	0.80	1.36	186.4
1931	do		4.66	25	6	3.67	.80	4.47	234.5
1931	do	Sandy loam	5.0	18	7	2.13	.99	3.12	157.2
1931	do	Medium loam	3.0	22	3	.93	.80	1.73	108.7
1931	do		10.0	17	5	.67	.98	1.65	95.8
1931	do	Medium	2.0	19	6	1.52	.80	2.32	135.6
1931	do	do	3.5	12	6	1.14	.98	2.12	115.3
1931	do	Clay-adobe	13.9	21	8	1.06	.99	2.05	71.0
									Packed boxes
1931	Intermediate		9.15	17		1.88	1.02	2.90	502
1931	do		3.0	40		1.81	1.17	2.98	443
1931	do		7.17	17		1.99	1.17	3.16	348
1931	do		.8	22		1.24	.98	2.22	320
1931	do		7.0	22		2.35	1.32	3.67	348
1931	do		4.38	23		2.33	1.32	3.65	434
1931	do		10.19	23		.89	.98	1.87	252
1931	do		2.62	29		.79	.98	1.77	158
1931	do		13.21	34		1.78	1.32	3.10	236
1931	do		1.11	17		1.38	1.17	2.55	232
1931	do		5.1	35		1.84	1.32	3.16	300
1931	do		5.84	11		2.52	1.32	3.84	221
1931	do		2.23	30		2.29	1.17	3.46	398
1931	do		25.0	17		2.42	.98	3.40	283
1931	do		3.5	15		1.38	.96	2.34	219
1931	do		6.0	35		1.85	.96	2.81	200
1931	do		4.84	11		1.36	1.32	2.68	181
1931	do		2.39	17		1.28	1.32	2.60	121
1931	do		4.0	13		1.32	1.17	2.49	158
1931	Interior		10.0	11		2.17	1.27	3.44	388

AVOCADOS[1]

									Pounds
1930	Coastal	Medium	6.3	4	5	1.70	0.87	2.57	1,175
1930	do	Heavy	4.0	4	6	.97	.87	1.84	850
1930	do	Light	1.98	5	4	1.44	.87	2.31	513
1930	do	Medium	8.77	7	8	.22	.87	1.09	1,566
1930	do	do	12.0	7	4	1.46	1.08	2.54	1,046
1930	do	do	4.5	7	7	1.67	.87	2.54	2,164
1930	do	do	6.5	9	7	1.32	1.02	2.34	115
1930	do	do	15.0	9	8	.80	1.08	1.88	533
1930	do	Heavy	4.0	11	7	2.88	1.02	3.90	582
1930	do	do	7.0	3	10	1.67	.87	2.54	104
1931	do	Medium	4.5	8	6	1.55	.98	2.53	10,289
1931	do	do	8.77	8	11	2.25	.98	3.23	6,824
1931	do	Light	1.98	6	6	2.52	.98	3.50	6,374
1931	do	Medium	2.0	5	6	1.12	.98	2.10	7,418
1931	do	do	6.3	5	5	1.77	.98	2.75	5,568
1931	do	do	1.82	5	9	1.10	.98	2.08	2,970
1931	do	Heavy	7.5	6	10	2.86	.98	3.84	5,733
1931	do	Medium	6.75	14	4	1.61	.80	2.41	2,540
1931	do	do	12.0	8	4	1.80	.80	2.60	4,800
1931	do	do	5.5	8	6	.89	.84	1.73	3,425
1931	do	Heavy	4.0	5	4	.73	.98	1.71	2,246
1931	do	Medium	2.86	5	5	1.87	.98	2.85	1,692
1931	do	Heavy	4.0	12	23	2.87	.84	3.71	1,006
1931	do	Medium	20.0	8	12	2.86	.98	3.84	1,152
1931	do	Light	3.5	3	12	.73	.98	1.71	1,089
1931	do	Medium	5.7	3	7	.57	.98	1.55	221
1931	do	do	4.0	3	7	.64	.98	1.62	189
1931	do	Heavy	7.0	4	11	1.78	.98	2.76	512

[1] These data obtained from individual growers by the county farm advisor, agricultural extension service, University of California.

TABLE 14.—*Irrigation water applied, rainfall, and crop yields of walnuts* [1] *in southern California*

Year	Climatic location [2]	Soil	Area irrigated	Age of trees	Irrigations	Monthly application of water: Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Quantity of water received by crop: Irrigation	Rainfall [3]	Total	Yield per acre
			Acres	*Years*	*Number*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Pounds*
1927	Coastal	Heavy	17	24	2							0.62		0.45			1.07	1.36	2.43	3,069
1927	do	do	5	20	4						0.17	.17	0.17	.16			.67	1.36	2.03	2,715
1927	do	do	19	36	3						.66	.67	.67				2.00	1.36	3.36	2,778
1928	do	do	17	25	2					0.76				.50			1.26	1.05	2.31	1,591
1928	do	do	5	21	5					.22	.17	.19	.18	.17			.93	1.05	1.98	870
1928	do	do	19	37	3					.67		.67			0.66		2.00	1.05	3.05	479
1928	do	Medium	20	24	4			0.70		.31	.52			.44			1.97	1.28	3.29	657
1929	do	Heavy	5	30	3		1.03					1.52			.74		3.29	.87	4.16	1,608
1929	do	Medium	17	26	3			.76					.76	.58			2.10	.87	2.97	1,875
1929	do	Heavy	42	25	3				0.52				.52		.41		1.45	.87	2.32	1,076
1929	do	do	5	22	3	0.56					.36		.30				1.22	.87	2.09	2,109
1929	do	do	19	38	3				.92		.72		.64				2.28	.87	3.15	2,001
1930	do	do	5	31	3	.95						.69		.64			2.28	.87	3.15	930
1930	do	do	16	27	3		.72						.68		.72		2.12	.87	2.99	1,155
1930	do	do	19	34	3					.58		.58		.59			1.75	.87	2.62	931
1930	do	do	5	23	3	.81						.36		.36			1.53	.87	2.40	1,081
1930	do	do	42	27	3	.21					.72	.54		.37			1.84	.87	2.71	850
1930	do	Medium	11.0	16	6												2.40	1.13	3.53	1,280
1930	do	do	12.0	39	4												3.19	1.13	4.32	1,434
1930	do	do	14.7	12	4												2.40	1.08	3.48	1,325
1930	do	do	20.0	31	4												1.90	1.02	2.92	1,500
1930	do	Heavy	7.5	35	5												1.25	1.02	2.27	1,463
1930	do	Medium	10.0	25	4												1.73	1.08	2.81	1,179
1930	do	do	30.0	37	2												3.17	1.08	4.25	1,288
1930	do	do	10.0	27	3												3.13	1.13	4.26	1,521
1930	do	do	10.0	30	5												1.77	1.02	2.79	1,063
1930	do	do	8.0	14													1.30	1.13	2.43	827
1930	do	do	7.2	37	6												3.66	1.13	4.79	1,569
1930	do	do	8.3	35	6												1.67	1.13	2.80	979
1930	do	do	5.0	13	4												1.52	1.08	2.60	1,166
1930	do	do	14.2	15	5												1.17	1.13	2.30	706
1930	do	Light	15.0	23	5												1.17	1.13	2.30	1,188
1930	do	do	5.0	9	5												1.80	1.02	2.82	452

[1] These data obtained from individual growers by the county farm advisor, agricultural extension service, University of California.
[2] Coastal climate is one where strong ocean influence is manifest. Intermediate climate is found back from the coast but not remote from all ocean modifying influences. Interior climate is remote from the coast and all ocean influences.
[3] Rainfall computed from Oct. 1 to Sept. 30 for each crop season.

Table 14.—*Irrigation water applied, rainfall, and crop yields of walnuts in southern California*—Continued

Year	Climatic location	Soil	Area irrigated	Age of trees	Irrigations	Monthly application of water: Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Quantity of water received by crop: Irrigation	Rainfall	Total	Yield per acre
			Acres	Years	Number	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Pounds
1930	Coastal	Medium	5.0	22	3												1.49	1.08	2.57	910
1930	do	Light	21.6	22	6												1.69	1.13	2.82	913
1930	do	Medium	22.0	35	4												1.70	1.02	2.72	1,382
1930	do	do	17.0	22	5												2.42	1.13	3.55	907
1930	do	do	20.0	26	3												2.20	1.13	3.33	1,365
1930	do	do	15.0	36	3												1.60	1.02	2.62	771
1930	do	do	20.0	25	4												1.65	1.02	2.67	775
1931	do	do	20.0	36	3												4.79	.80	5.59	1,218
1931	do	do	14.2	16	5												1.20	.99	2.19	806
1931	do	do	11.0	17	7												2.77	.80	3.57	899
1931	do	do	8.0	15	5												1.11	.99	2.10	600
1931	do	do	8.33	36	5												1.65	.99	2.64	1,333
1931	do	do	5.0	14	4												.78	.80	1.58	1,017
1931	do	do	10.0	31	4												1.85	.84	2.69	1,078
1931	do	do	30.0	32	5												2.78	.84	3.62	1,062
1931	do	do	20.0	26	4												1.38	.84	2.22	1,242
1931	do	do	10.0	26	3												1.68	.80	2.48	1,004
1931	do	do	22.0	36	3												1.31	.84	2.15	1,082
1931	do	do	12.0	40	3												2.78	.99	3.77	891
1931	do	Heavy	7.5	36	5												1.43	.84	2.27	1,733
1931	do	Medium	15.0	37	4												1.50	.84	2.34	1,115
1931	do	do	5.0	23	3												1.29	.80	2.09	562
1931	do	do	20.0	27	4												.94	.99	1.93	1,203
1931	do	do	10.0	28	4												1.96	.99	2.95	770
1931	do	do	6.75	38	4												2.17	.99	3.16	700
1931	do		16.0	28	2						0.56			0.73			1.29	.98	2.27	1,623
1931	do		42.0	28	3	0.18					.21			.55			.94	.98	1.92	786
1931	do		5.0	24	4	.86					1.09		0.58	.36			2.89	.98	3.87	744
1931	do		5.0	32	3			0.58				0.72		.63			1.93	.98	2.91	1,180
1927	Intermediate	Light	18.0	27	3							.38	.36	.32			1.06	1.90	2.96	2,017
1927	do	Medium	40.0	22	3						.30	.22		.30			.82	1.84	2.66	2,251
1927	do	Light	23.0	30	3							.43	.40	.30			1.13	1.90	3.03	2,170
1927	do	do	110.0	30	2							.64		.54			1.18	1.90	3.08	2,005
1927	do	Medium	10.0	17	3	0.69						1.21		.75			2.65	1.84	4.49	1,815
1927	do	Light	17.5	19	2							.96		.43			1.39	1.94	3.33	1,664
1927	do	do	19.0	28	2							.39		.41			.80	1.90	2.70	1,605
1927	do	Medium	9.0	19	5						.27	.22	.28	.28	0.25		1.30	1.84	3.14	2,079

1927	do	Light	20.0	15	3						.38		.41	.60			1.39	1.90	3.29	1,449
1927	do	Heavy	35.0	14	0												.00	2.05	2.05	1,130
1927	do	Light	32.0	34	2							.98		.88			1.86	1.90	3.76	1,512
1927	do	do	15.0	21	5						.39	.52	.80	.80	.27		2.78	1.63	4.41	1,035
1927	do	Medium	70.0	19	3	.43					.76			.76			1.95	1.84	3.79	2,375
1927	do	Light	10.0	14	0												.00	1.63	1.63	1,489
1927	do	Heavy	9.0	13	1							.24					.24	2.05	2.29	1,533
1927	do	Light	15.0	14	2							.52		.38			.90	1.90	2.80	1,004
1927	do	do	36.0	24	3						.88		.82		.87		2.57	1.90	4.47	1,809
1928	do	do	18.0	28	3						.51		.59	.92			2.02	1.04	3.06	798
1928	do	Medium	80.0	21	2							.78		1.00			1.78	1.07	2.85	793
1928	do	do	40.0	22	3							.24	.23		.38		.85	1.07	1.92	747
1928	do	Light	23.0	31	3					0.51		.77		.51			1.79	1.04	2.83	731
1928	do	do	110.0	30	2				.53				.98				1.51	1.04	2.55	719
1928	do	Medium	10.0	19	3						.57		.37	.58			1.52	1.07	2.59	699
1928	do	Light	17.5	22	3						.67	.68		.63			1.98	1.13	3.11	688
1928	do	do	19.0	30	2						.39			.48			.87	1.04	1.91	686
1928	do	Medium	9.0	20	5					.28		.25	.33	.17	.33		1.36	1.07	2.43	670
1928	do	Light	20.0	16	4						.46	.57	.41	.47			1.91	1.04	2.95	580
1928	do	Heavy	35.0	15	2					.44			.44				.88	1.14	2.02	474
1928	do	Light	32	35	2						.83			1.05			1.88	1.04	2.92	408
1928	do	do	15	22	2								.28	.33			.61	1.04	1.65	79
1928	do	Medium	14	17	4						.53	.52		.48	.50		2.03	1.01	3.04	797
1928	do	do	70	19	3				.56			.45		.52			1.53	1.07	2.60	705
1928	do	Light	10	25	1								.62				.62	1.04	1.66	616
1928	do	Heavy	9	15	2						.28	.27					.55	1.14	1.69	528
1928	do	Light	17	14	2						.52			.60			1.12	1.04	2.16	495
1928	do	do	36	15	4					.85	.73	.81		.62			3.01	1.04	4.05	621
1929	do	Medium	10	19	5		.38	1.00					.93	.64	1.18		4.13	.70	4.83	1,065
1929	do	do	40	23	4			.56			.39		.38	.54			1.87	.70	2.57	1,609
1929	do	do	80	22	2								1.33		1.54		2.87	.70	3.57	1,082
1929	do	do	25	22	4				.44		.58	.71		1.06			2.79	.70	3.49	1,092
1929	do	do	32	13	3						.58		.70	.53			1.81	.70	2.51	1,143
1929	do	do	10	20	3						.80			.78	.60		2.18	.70	2.88	985
1929	do	do	17.5	23	3						.62		.52	.76			1.90	.70	2.60	1,216
1929	do	do	14	14	4				.55			.44	.48	.41			1.88	.70	2.58	1,118
1929	do	Light	23	32	3							.42	.59		.64		1.65	.70	2.35	1,399
1929	do	Medium	70	20	3				.56			.53		.53			1.62	.70	2.32	1,269
1929	do	Light	18	29	2							.67		.92			1.59	.70	2.29	1,022
1929	do	do	15	36	2							.71		.81			1.52	.70	2.22	919
1929	do	Medium	9	21	4					.39		.39		.40	.32		1.50	.70	2.20	946
1929	do	do	5	15	4				.17		.72		.35		.14		1.38	.70	2.08	1,590
1929	do	Light	15	15	2							.68			.64		1.32	.70	2.02	473
1929	do	Medium	12	36	2						.80			.50			1.30	.70	2.00	749
1929	do	Heavy	20	17	2							.73		.55			1.28	.70	1.98	1,103
1929	do	Light	110	31	3						.48		.39		.36		1.23	.70	1.93	1,193
1929	do	Medium	10	13	3						.38		.35		.29		1.02	.87	1.89	2,293
1929	do	Heavy	9	16	2							.09		.27			.36	.87	1.23	1,295
1929	do	do	35	16	2						.45				.27		.72	.70	1.42	797
1929	do	Medium	20	14	2							.30		.35			.65	.70	1.35	862
1930	do	do	9.8	14	2							.28		.48			.76	.87	1.63	1,269

TABLE 14.—*Irrigation water applied, rainfall, and crop yields of walnuts in southern California*—Continued

Year	Climatic location	Soil	Area irrigated	Age of trees	Irrigations	Monthly application of water: Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Quantity of water received by crop: Irrigation	Rainfall	Total	Yield per acre
			Acres	*Years*	*Number*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Pounds*
1930	Intermediate	Heavy	19.5	17	3	0.39						0.71		0.34			1.44	1.14	2.58	864
1930	do	do	7.7	16	2	.27						.28					.55	.87	1.42	544
1930	do	Medium	19.9	14	3	.32							0.27	.27			.86	1.14	2.00	315
1930	do	do	14.0	12	4		0.37					.60	.60		0.62		2.19	1.14	3.33	532
1930	do	do	17.0	15	2							.29		.29			.58	1.14	1.72	692
1930	do	do	34.0	13	3	.64						.31		.52			1.47	1.14	2.61	476
1930	do	do	8.9	16	3		.55					.42		.34			1.31	1.14	2.45	352
1930	do	Light	13.0	16	2							.75		.90			1.65	1.14	2.79	649
1930	do	Medium	70.0	19	4	.35			0.13			.50		.41			1.39	1.14	2.53	344
1930	do	do	13.0	21	3			0.57				.44		.40			1.41	1.14	2.55	452
1930	do	do	23.4	28	4	.56						.26	.40	.66			1.88	1.14	3.02	734
1930	do	do	9.7	20	2							1.39	.62				2.01	1.14	3.15	560
1930	do	do	38.8	24	5	.39				0.44	0.46		.43	.37			2.09	1.14	3.23	771
1930	do	do	9.0	22	5					.44		.37	.47	.22	.44		1.94	1.14	3.08	918
1930	do	do	80.0	23	2												2.31	1.14	3.45	709
1930	do	Light	16.4	22	3			.70					.98	.95			2.63	1.14	3.77	432
1930	do	Heavy	35.0	15	0												.00	1.14	1.14	561
1930	do	Light	110.0	33	3		.18					.44		.53			1.15	1.14	2.29	646
1931	do		16.4	23	2							.68	.76				1.44	.96	2.40	433
1931	do		39.0	25	3		.34			.60		.40	.53				1.87	.96	2.83	1,172
1931	do		110.0	34	3			.42			.89			.97			2.28	.96	3.24	820
1931	do		9.0	23	4					.23	.17	.31		.27			.98	.96	1.94	654
1931	do		23.4	29	4	.82						.75	.92	.60			3.09	.96	4.05	1,028
1931	do		9.8	15	3	.35				.51		.45		.32			1.63	.98	2.61	2,277
1931	do		7.7	17	2	.24							.33				.57	.98	1.55	1,861
1931	do		20.0	15	3	.29				.22			.22				.73	.96	1.69	1,021
1931	do		40.0	17	3	.48						.55	.70				1.73	.96	2.69	1,506
1931	do		8.9	17	3	.37						.46		.43			1.26	.96	2.22	824
1931	do		19.5	18	3	.42						.23		.64			1.29	.96	2.25	1,391
1931	do		14.0	13	3				.38				.62	.43			1.43	.96	2.39	948
1931	do		70.0	20	4	.40						.37	.49	.43			1.69	.96	2.65	1,270
1931	do		17.0	16	4	.37						.25	.35	.16		0.56	1.69	.96	2.65	1,464
1931	do		34.0	14	4	.30						.58	.34	.48		.36	2.06	.96	3.02	1,057
1927	Interior	Medium	20.0	12	2							.98		1.22			2.20	2.06	4.26	1,800
1927	do	do	20.0	20	3			.96				.80		.66			2.42	2.06	4.48	1,783
1928	do	do	20.0	12	2						.77			.73			1.50	1.19	2.69	1,172

1928	do	do	20.0	20	6					.25	.25	.25	.48	.35	.46		2.04	1.19	3.23	787
1929	do	do	40.0	12	3						.39	.91	.50	.93			2.73	1.09	3.82	1,132
1929	do	Heavy	20.0	6	3						.96		.37		.33		1.66	.92	2.58	507
1929	do	Medium	52.0	8	4		.19			.37		.26		.36			1.18	.92	2.10	739
1929	do	do	20.0	8	5						.15	.17	.18	.26	.22		.98	.92	1.90	916
1929	do	Light	5.0	9	8				.97		.60			.48			2.05	1.09	3.14	594
1930	do	Heavy	10.0	9	3				.42				.26		.39		1.07	1.14	2.21	1,006
1930	do	Medium	48.0	11	4		.34				.53	.56			.49		1.92	1.14	3.06	1,073
1930	do	Heavy	9.5	12	3		.67					.46	.35				1.48	1.14	2.62	789
1930	do	do	5.0	14	4					.27		1.61	1.51		.20		3.59	1.14	4.73	958
1930	do	Medium	40.0	13	3						.42		.65	.44			1.51	1.17	2.68	482
1930	do	do	45.5	9	4	.35						.41		.45	.34		1.55	1.14	2.69	560
1930	do	do	14.0	9	2							.66		.64			1.30	1.14	2.44	911
1930	do	Heavy	20.0	8	3				.42				.55		.41		1.38	1.14	2.52	556
1930	do	Medium	19.5	9	4	.21						.28	.44	.45			1.38	1.14	2.47	404
1930	do	do	16.5	24	5	.47			.18			.87	.50	1.36			3.38	1.17	4.55	750
1930	do	do	3.0	15	4	.36						1.17	1.02		1.02		3.57	1.14	4.71	496
1931	do		40.0	14	3							.91	.93	.59			2.43	1.17	3.60	1,640
1931	do		48.0	12	4	.24						.83	.47	.60			2.14	1.10	3.24	1,130
1931	do		10.0	10	2							.88		.59			1.47	1.10	2.57	919
1931	do		45.5	10	2							.59		.57			1.16	1.10	2.26	475
1931	do		20.0	9	2							.66		.47			1.13	1.10	2.23	519
1931	do		9.5	13	3					.52		.53		.42			1.47	1.10	2.57	712
1931	do		16.5	25	3							.40		.76	.52		1.68	1.17	2.85	1,200
1931	do		3.0	16	3						.15		.44		.58		1.17	1.10	2.27	481

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