SOIL SURVEY OF THE MODESTO-TURLOCK AREA, CALIFORNIA, WITH A BRIEF REPORT ON A RECONNAISSANCE SOIL SURVEY OF THE REGION EAST OF THE AREA.

By A. T. SWEET, J. F. WARNER, and L. C. HOLMES.

DESCRIPTION OF THE AREA.

The Modesto-Turlock area lies approximately in the center of the State of California from east to west and slightly north of the center from north to south. It is about 100 miles east of San Francisco, 300 miles north of Los Angeles, and near the center of the great valley which extends from northwest to southeast between the Sierra Nevada Mountains on the east and the Coast Range on the west. The upper part of this valley is drained to the south by the Sacramento River and the southern part is drained to the north by the San Joaquin River, the two uniting and emptying into Suisun Bay. Rising in the Sierra Nevada Mountains along the east side of this valley, flowing to the west and emptying into the San Joaquin, are three rivers of considerable importance, the Merced, the Tuolumne, and the Stanislaus. The Modesto-Turlock area lies on the east side of the San Joaquin and is drained

FIG. 34.—Sketch map showing location of the Modesto-Turlock area, California.

and watered by these rivers, the Merced forming the southern boundary and the other two passing through it, the Tuolumne in the center and the Stanislaus in the northern part.

The area lies between the parallels of 37° 20′ and 38° north, thus having about the same latitude as southern Kansas, central Kentucky, and Richmond, Va. It covers a portion of three counties, San Joaquin County on the north, Stanislaus County in the center, and Merced County on the south. The area extends, from north to south, a distance of almost 40 miles and from the San Joaquin River east into the lower foothills, an average distance of almost 25 miles, the area actually surveyed being about 808 square miles.

For this work no satisfactory base maps were available, hence maps were constructed in the field for the entire area, except that portion occupied by the overflow lands along the San Joaquin River, a part of which, on account of high water, numerous sloughs, and cut-offs, was inaccessible at the time the survey was made. For this part of the area and the location of the San Joaquin River the county maps based on the Government surveys have been accepted.

Topographically the larger part of the area is a broad, almost level valley floor of slight but uniform slope from the low hills, into which the northeastern part merges, to the flat overflow lands along the San Joaquin River, but this plain is tilted very slightly to the west and northwest, so that the lowest part has an elevation of only about 20 feet above sea level, while the higher parts reach an elevation of almost 200 feet. Although young geologically this valley floor has been considerably modified by erosion. The higher parts along the eastern side have been dissected by many small streams and their tributaries, which carry the water of the rainy season, and have weathered into numerous hills so well rounded that all portions of them may be cultivated, while lower portions of the area along the San Joaquin River have been filled to some extent by deposits from this stream and its tributaries. In addition to these topographic features there are along the Tuolumne and Stanislaus rivers and also along Dry Creek abrupt bluffs and terraces which separate the present valley floor of these streams from the upland or old valley floor. These vary in height from 20 feet to 80 feet or more and are usually quite abrupt, showing outcrops of the underlying formations. In some places two and even three well-defined terraces mark former positions of the streams. These are especially noticeable along the valley of the Stanislaus southwest of Oakdale.

Another feature, not very conspicuous but of interest in connection with a study of the soils, is to be found in old overflow stream courses of the Stanislaus River, which are noticeable as broad, rather shallow depressions. One of these leaves the river at a point almost due

north of Modesto and extends in a south and then westerly direction until after dividing into several parts it is lost in the lowlands along the San Joaquin, while on the opposite side of the Stanislaus a similar stream course leaves the river and extends due west to the San Joaquin. These old channels seem to indicate that at some time in its early history the main channel of the Stanislaus became choked at the point where the channels leave the river, causing its waters to spread out over the country on both sides. Still another of these old channels leaves the river on the north side near Oakdale and can be traced in a westerly direction beyond Escalon.

On the upland immediately south of the Stanislaus and Tuolumne rivers dunelike ridges of wind-blown sand occur. Extensive areas of this sand also occur south of Manteca and in the extreme southeastern part of the area.

The area is drained by the San Joaquin River and the tributaries above mentioned, each having small tributaries of its own, the largest of these minor streams being Dry Creek, a tributary of the Tuolumne, which drains a considerable area east of Modesto. A small portion of the northern part of the area is also drained by Little John Creek, which empties directly into the San Joaquin, but at a point outside of the area. A peculiar feature of the drainage is that it is well defined in the eastern part of the area among the foothills, numerous small streams having their sources there, but as these reach the more gentle slope of the valley floor proper they become less clearly defined, until they are almost or entirely lost, the water which they carry during the rainy season being absorbed by the soils of the lower part of the valley.

A rapid and marked change in the character of the population is taking place at present in parts of the Modesto-Turlock area. It is a change from a scattered population of grain growers to a dense population of dairymen, vineyardists, orchardists, truck and melon growers, and others who farm intensively; from a 1,000-acre[a] farm unit to one of 20 acres. This change is confined principally to those sections which have been brought under irrigation, but even those parts not yet irrigated have begun to feel the stimulus of the new order of things.

With the breaking up and marketing of the large grain ranches, on account of decreasing profits in grain farming and the introduction of irrigation, settlers have come in from all parts of the United States. In addition large numbers of foreigners are settling in the area. Of the foreign element, Swedes, Portuguese, and Italians predominate, the Italians being engaged almost exclusively in gardening, while

[a] The average size of the farms in Stanislaus County, as given by the United States Census for 1900, is 873.5 acres.

the Portuguese have gained considerable reputation as successful growers of sweet potatoes.

Much of the contract labor, such as planting and caring for vineyards and picking fruit and berries, is done by Japanese.

Modesto, the county seat of Stanislaus County, situated near the center of the Modesto irrigation district and on the main line of the Southern Pacific Railroad, is a progressive town of about 3,500 inhabitants with all modern city improvements. A company has recently been formed and sufficient funds subscribed for the erection of a large canning factory. This will be of value to Modesto and the surrounding country. Oakdale, located in the northeastern part of the area, on the Stanislaus River, contains about 1,600 inhabitants and has good shipping facilities. Turlock, a town of about 800 population, is situated on the main line of the Southern Pacific system, near the center of the Turlock irrigation district. Ceres, Ripon, Manteca, and Escalon are small towns situated in the northern part of the area. Many other important towns and shipping points are scattered throughout the region.

Good shipping facilities are afforded a large part of the area by two lines of the Southern Pacific system and one of the Santa Fe, which pass through the central part of the area from northwest to southeast, thus connecting this section with both San Francisco and Los Angeles by direct line and furnishing shipping facilities to the East in either direction. The Sierra Railway affords means of shipping the products of a part of the area to the mines. The San Joaquin River has been used to some extent for shipping products grown along that river to San Francisco, Crows Landing being the principal shipping point.

One of the main hindrances to intensive farming has been the lack of suitable markets for perishable products, but with better railroad facilities, and with the building of canneries, packing houses, and wineries, much of this trouble will be overcome and products from the area will be put into such a form that they may be sent to the mines, to the East, or to foreign countries.

CLIMATE.

The climate of this section, like that of a large part of the interior valley, consists of two principal seasons—the winter, or rainy season, and the summer, or dry season. The former consists of rainy and foggy weather interspersed with clear, warm days, while the latter is noted for its cloudless skies and fresh, dry air. During the winter the weather is often damp and chilly, necessitating warm clothing and fires in the houses, but is rarely cold enough to interfere with out-

door work. In fact, much of the plowing for grain and of ditching and leveling for irrigation is done during the winter months.

The fogs, which are at times so disagreeable, are of considerable value in furnishing moisture and in protecting olives, citrus fruits, and winter garden truck from frosts.

During the winter season on clear nights heavy frosts and even thin ice is not uncommon, but unless coming late in the spring little damage is done, except to unpicked fruit and to winter-grown vegetables.

No record of the occurrence of killing frosts within the area is obtainable, but damage to fruits, nuts, and vegetables from their occurrence between the first of February and the middle of April is not uncommon, the greatest damage usually being done in the lower valleys, which are more subject to frosts than the uplands. The lower portions of the uplands near the trough of the valley are also more subject to frosts than the higher portions.

The following tables of monthly and annual mean temperature and precipitation and the maximum and minimum temperature for the years 1904, 1905, 1906, and 1907 are compiled from the report of the United States Weather Bureau.

Normal monthly and annual temperature and precipitation.

Month.	Modesto.		Oakdale.	
	Temperature.	Precipitation.	Temperature.	Precipitation.
	°F.	In.	°F.	In.
January	46.6	1.84	45.7	3.17
February	50.1	1.20	48.7	1.82
March	55.9	1.37	52.7	2.37
April	62.2	.92	59.3	1.34
May	69.4	.47	64.9	.86
June	76.6	.10	73.9	.34
July	81.5	.01	79.7	.00
August	79.7	.00	76.3	.02
September	74.7	.19	71.4	.14
October	65.3	.56	62.5	1.14
November	55.8	1.43	52.9	2.00
December	48.1	1.85	44.9	2.23
Year	63.8	9.94	61.1	15.43

Maximum and minimum temperatures for the years 1904 to 1907, inclusive.

	Modesto.								Oakdale.							
	Maximum.				Minimum.				Maximum.				Minimum.			
	1904.	1905.	1906.	1907.	1904.	1905.	1906.	1907.	1904.	1905.	1906.	1907.	1904.	1905.	1906.	1907.
January	71	70	81	79	32	38	34	30	71	65	63	62	26	29	26	26
February	75	84	85	79	34	35	40	43	67	72	71	66	28	25	38	32
March	75	86	84	79	40	44	45	40	74	77	72	73	32	31	34	30
April	87	92	89	90	41	49	53	55	87	81	83	82	40	42	33	45
May	103	100	86	94	50	49	52	60	101	93	88	95	46	44	45	48
June	104	99	102	98	55	60	53	69	103	98	101	99	58	50	53	43
July	106	110	109	98	63	60	70	82	105	114	110	101	57	57	60	60
August	108	105	106	101	60	60	60	80	103	107	107	103	57	55	56	55
September	108	104	102	104	56	59	60	80	107	100	97	95	52	48	52	48
October	98	102	106	90	41	45	47	50	89	94	92	88	40	38	34	48
November	89	90	89	70	44	39	34	38	77	75	73	76	32	30	24	31
December	78	84	84	60	36	30	33	38	62	58	62	68	27	21	20	29

During the winter months grass and alfalfa remain green and furnish much pasture, while vegetables are grown successfully in warm, sheltered places during the entire winter. In the summer the air is usually clear, dry, and invigorating, although at times quite hot, a temperature of 110° F. in the shade being not uncommon. Owing to the dryness of the air and the rapidity of evaporation, the heat is not oppressive like that of a humid region. The evenings are usually cool and pleasant. These long, dry summers furnish ideal conditions for the maturing and harvesting of fruits and other crops.

Records of rainfall have been kept by the station agents of the Southern Pacific Railroad, by grain dealers, and by others. Two of these—one from the Grange Company, giving the rainfall at Modesto for a period of twenty years, and the other from the Oakdale Milling Company, giving the record at Oakdale for a period of twenty-three years—are inserted. The rainfall in these tables is given by seasons rather than by years, since the crop for any year is dependent upon the seasonal rather than upon the annual rainfall.

Rainfall at Modesto, 1888–1908—Record of the Grange Company.

Season.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	Total.
1888–89	.....	.....	.....	.....	3.26	1.42	0.28	0.38	2.22	0.22	1.39	.....	9.17
1889–90	.....	.....	.....	2.49	2.54	6.66	3.74	1.36	.23	1.48	.59	.....	19.09
1890–91	.....	.....	1.29	.....	.....	2.34	.27	2.66	1.03	1.10	.....	.....	8.69
1891–92	.....	.....	.38	.....	.12	4.06	2.63	1.77	2.21	.57	1.09	0.04	12.87
1892–93	.....	.....	.01	.89	3.70	2.20	1.68	1.83	3.18	.54	.21	.....	14.24
1893–94	.....	.....	.10	.....	.97	1.34	3.61	3.40	.09	.23	1.76	.57	12.07
1894–95	.....	.....	.....	1.73	.32	6.25	3.80	1.41	1.68	1.07	.35	.....	16.61
1895–96	.....	.....	.17	.07	.93	1.02	5.16	.07	.78	2.08	.29	.....	10.57
1896–97	0.30	0.02	.25	1.32	2.45	1.23	3.16	2.77	1.86	.14	.09	.02	13.61
1897–98	.....	.....	.....	.97	.18	1.17	.51	.69	.31	.12	.67	.....	4.62
1898–99	.....	.....	.28	.48	.33	.89	2.36	.12	3.39	.02	.94	.....	8.81
1899–1900	.....	.....	.....	1.89	2.88	1.29	1.31	.15	.88	1.73	1.47	.....	11.60
1900–1901	.....	.....	.14	.71	4.62	1.03	1.28	3.90	.35	.84	1.24	.....	14.11
1901–2	.....	.....	.05	.66	1.58	.65	.73	4.46	.65	1.06	.....	.....	9.84
1902–3	.....	.....	.....	.41	1.54	.59	2.19	.89	6.08	.32	.....	.....	12.02
1903–4	.....	.....	.....	.....	2.39	.17	.52	1.84	2.43	1.39	.09	.....	8.83
1904–5	.....	.13	2.57	.95	1.01	1.31	1.34	2.10	2.12	2.72	.....	.....	16.25
1905–6	.....	.....	.....	.....	.73	.93	2.56	2.50	6.17	1.50	1.14	.74	16.27
1906–7	.....	.....	.05	.....	.85	7.20	3.62	3.06	4.90	.11	.22	.54	20.55
1907–8	.03	.....	.....	.79	.04	2.14	3.70	1.13	.82	(a)	(a)	(a)	8.65
Average	.01	.007	.26	.66	1.52	2.19	2.32	1.82	2.06	.86	.57	.08	12.42

[a] No record after April 15.

Rainfall at Oakdale, 1885–1908—Record of the Oakdale Milling Company.

Season.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	Total.
1885–86	.....	.....	1.13	6.54	1.26	3.61	.....	2.86	3.51	.....	.....	18.91
1886–87	.....	.....	.19	.95	.79	.48	3.14	.17	2.04	.....	.....	7.76
1887–88	.....	0.27	.....	.11	1.97	2.56	.47	2.21	.27	0.45	0.08	8.39
1888–89	.....	.73	.....	3.87	1.48	.37	.37	2.89	.27	1.58	.....	11.56
1889–90	.....	.....	2.48	3.20	6.65	3.51	1.47	1.06	1.74	1.67	.....	21.78
1890–91	0.10	1.12	.....	.....	2.56	.27	2.23	2.48	1.39	.06	.....	10.21
1891–92	.....	.14	.22	.28	4.54	.32	1.73	3.43	.73	1.26	.....	12.65
1892–93	.....	.18	.74	3.73	3.68	1.95	2.16	5.25	.66	.....	.....	18.35
1893–94	.....	.20	.....	1.42	1.63	5.34	4.94	.38	.90	2.46	.97	18.24
1894–95	.....	.35	1.15	.66	7.65	5.94	2.05	2.07	1.58	.50	.....	21.95
1895–96	.....	.22	.30	.99	1.34	5.46	.....	1.53	3.79	.65	.....	14.28
1896–97	.....	.....	1.70	3.04	1.86	2.76	3.73	2.83	.90	.08	.12	17.02
1897–98	.....	.23	1.56	.67	1.36	.78	1.33	.71	.16	1.47	.....	8.27
1898–99	.....	.44	.97	.44	1.67	2.61	.10	4.99	.16	.56	1.00	12.94
1899–1900	.05	.....	2.90	3.20	1.99	1.46	.51	2.17	2.93	1.50	.....	16.67
1900–1901	.....	.....	.94	5.79	1.15	1.83	5.45	.38	1.30	.76	.....	17.60
1901–2	.....	.62	1.09	2.74	1.13½	.88½	4.69	1.33	.91	.67	.07	14.14
1902–3	.....	.....	1.33	2.60	.82	3.61	1.02	6.66	.53	.....	.....	16.57
1903–4	.....	.....	.....	3.36	.49	.83	5.38	3.91	1.75	.13	.....	15.85
1904–5	.06	1.71	1.44	1.16	1.83	3.64	1.44	2.83	1.04	2.63	.....	17.78
1905–6	.....	.....	.....	1.10	.96	5.26	4.06	8.13	2.21	2.15	.09	23.96
1906–7	.....	.07	.....	.75	9.09	4.51	2.83	7.18	.18	.10	.65	25.36
1907–8	.....	.....	.46	.01	2.70	3.59	1.50	.77	(a)	(a)	(a)	9.03
Average	.01	.27	.81	2.03	2.55	2.67	2.20	2.88	1.30	.81	.13	15.62

[a] No record after April 15.

From these records it will be noted that the average annual rainfall at Modesto for twenty years is 12.42 inches, although the records obtained by the Weather Bureau are something less, and at Oakdale for twenty-three years it is 15.62 inches; that the principal rainfall occurs during the months from November to March, inclusive; that a very much smaller amount occurs during April and May; and that during the months from June to September, inclusive, the precipitation is very slight.

In the parts of the area which have not yet been brought under irrigation the crops are dependent not only upon the amount of rainfall but very largely upon its distribution. A rainfall of from 7 to 10 inches, if well distributed, is sufficient to insure a crop of grain, but if coming at unfavorable seasons or not well distributed even a larger rainfall does not insure a crop. It is usually desirable to have sufficient precipitation in the fall to moisten the soil deep enough for plowing and to start the grain well; then with occasional rains during the winter and spring until the ground is well shaded fair grain crops are assured. Even in the irrigated sections these winter and spring rains are of great value in keeping the soil in proper condition.

AGRICULTURE.

The early settlers in this section were engaged principally in stock raising, as had been the Mexicans who preceded them, but as far back as the early fifties some of them had begun farming in a small way. Stock raising, however, continued to be the principal business until several years later. About 1867 grain farming on a large scale began and rapidly increased until 1872, when Stanislaus County became the banner grain-producing county of the State, the yield for that year being approximately 5,000,000 bushels, and the county has ranked high in the production of grain ever since. This change from a stock-raising to a grain-producing country was due to the productive nature of the soil, combined with the methods adopted, which made the sowing of a large acreage comparatively easy and gave large returns on the money invested.

Although the irrigated sections of the Modesto-Turlock area are attracting much attention and the consideration of their problems occupies a correspondingly large part of this report, the fact must not be overlooked that at present much more than half of the area is devoted to grain growing and that a very large part of it will probably be so used for many years to come.

In this grain-growing section the methods employed are those that have been in use for many years. The ground is plowed to a depth of from 3 to 6 inches with a gang plow drawn by 8 to 12 mules, plowing from 6 to 8 acres a day.

Two methods of sowing are used. One plan is to summer fallow; that is, the ground is plowed during the winter and spring and allowed to lie exposed to sun and wind until the next fall, when it is again cultivated either by replowing or by harrowing and then sown. When impracticable to summer fallow, the ground is plowed after the fall rains have begun, and immediately sown, an attachment for seeding being used on the plows, so that the ground is plowed, seeded, and cultivated at the same time. Grain sown in this way is said to be winter sown. Although a crop is harvested only every alternate year when the land is summer fallowed, the yields are ordinarily almost twice as large as on the land which has been winter sown, except in the case of the bottom lands, where under favorable conditions good crops are sometimes secured every year.

For many years headers and thrashing machines were used, but at present the harvesting is done almost exclusively by combined harvesters, which cut, thrash, and sack the grain at the same time, thus harvesting from 30 to 40 acres a day. These harvesters are usually drawn by teams of from 24 to 32 mules, although traction engines both for harvesting and for plowing are used to some extent. Self-binders also have been used to a small extent during the last few years.

In the earlier days of grain farming wheat was grown almost exclusively, but for several years past the acreage of barley has greatly increased, and at present oats are being sown to a greater extent than ever before. While no records are obtainable covering the exact area included in this report, the relative importance of these crops is well shown in the statistics for Stanislaus County for the year 1906–7, compiled by order of the board of supervisors. This gives the area of these grains as follows: Wheat, 179,956 acres; barley, 87,663 acres; and oats, 24,115 acres. The variations of soil, of seasons, and of methods of farming are so great that it is impossible to give the yields of grain except within very wide limits, but on the better soil a yield of from 8 to 14 sacks of wheat or 10 to 16 sacks of barley or oats to the acre is considered a good yield on summer fallow, while winter-sown grain yields a little more than half these quantities. On poorer soil or under unfavorable climatic conditions the yields vary from this minimum to a crop which will not pay for harvesting.

For many years no more prosperous people could be found than the men who were engaged in raising grain in this part of the San Joaquin Valley, but for several years past the grain men of this section, like those of almost the entire State, have made much smaller profits than they once did, and, in fact, the case of men who have lost heavily on grain crops is not uncommon. This decline in a business once so profitable is due to a number of causes, among which the most important are decreased yields, lower prices, and increased cost of labor and work animals.

The decreased yields are due to the improper conditions of the surface soil from continued cropping, to the formation of a plowsole at the average depth of cultivation, and to lack of thorough cultivation of the summer fallow. It has also been shown that the wheat crops in California could be considerably increased by using more care in the selection of seed.[a]

Hundreds of examinations in the grain fields during the dry season the past year showed almost invariably at a depth of from 4 to 6 inches a hard, compact layer, varying in thickness from 2 to 4 or 5 inches, entirely different from hardpan and almost impenetrable to the soil auger. This has been caused by successive plowings for years to about the same depth, thus allowing the rain water to penetrate to this depth readily, but checking its progress farther, and at the same time cutting off the soil from capillary supplies from below. In the warm, dry weather the moisture in this surface soil above the plowsole is soon exhausted, and the plants suffer. The most important thing, then, for the farmer who would improve his yield is an occasional deep plowing and under some conditions a thorough subsoiling.

Some farmers have obtained excellent results from subsoiling, the beneficial effects being noticeable in increased crop yields for the following two or three years. Other grain farmers have found subsoiling on shallow soils harmful, the yield being reduced not only for that season, but for the following seasons, so that this, like so many other problems on the farm, must be worked out by each farmer for himself. One of the most successful grain farmers in this area avoids the formation of a plowsole by varying the depth to which he plows, making each plowing an inch shallower or deeper than the preceding plowing.

One of the principal purposes of summer fallowing is to conserve the moisture and to enrich the soil through nitrification, which takes place best in a loose, porous soil under such heat and moisture conditions as are obtained in well-cultivated fallowed land.

Another purpose is to prepare a seed bed in which the soil shall be in the best possible physical condition. It should be loose and granular and contain sufficient moisture to sustain growing plants. This can best be obtained by plowing the ground when in good moisture condition and following the plows closely by some leveling and pulverizing implement, such as a harrow, until the surface is smooth and loose. This surface mulch retains the moisture in the ground for future use. It is not uncommon to see grain land plowed when not in good condition and left quite rough. When in this condition

[a] Shaw, California Experiment Station Bulletin No. 181.

the soil bakes very hard, the moisture is soon almost entirely removed, nitrification can not take place, and little is gained under such conditions by the summer fallow. Should the surface become compacted by rains after it has been leveled, it should again be cultivated to restore the mulch. At intervals during the summer surface cultivation to break up the crust which forms and to prevent the escape of moisture from below should be given, but unless necessary to prevent the growth of weeds and grass a second plowing until seeding time in the fall will not be necessary. If, however, a second or even a third plowing in the spring is necessary, it should be very shallow and should be followed, as should also the fall plowing, by thorough surface cultivation. By these means moisture enough to start the grain well will be retained from the previous season's rainfall.

In the early spring much damage is done to grain crops by the formation of a surface crust, which pinches the tender plants and retards their growth until a rain comes to soften the crust. This crust also permits of the escape of moisture from below. Cultivation of grain crops early in the spring with a light sharp-toothed harrow is often found very beneficial, especially when dry weather follows. This injures the grain to some extent, it is true, but the benefits derived from a breaking of the crust and the formation of a loose surface mulch overbalance the injury done to the grain.

In the dry-farming sections of Utah much better results are obtained by thin than by thick seeding,[a] good crops often being secured when only 35 to 45 pounds of wheat per acre are sown, but under the same field conditions only half a crop when 75 pounds are sown. Experiments to determine the effect of thin seeding in the San Joaquin Valley would be of interest and might easily be carried on by any grain rancher.

Although only a very limited rotation with the crops at present grown can be arranged, better results may be obtained by following each crop with one of a different kind than by the continued use of one crop.

It is believed, then, that by a breaking up of the plowsole, by conserving the moisture with a surface soil mulch, by rotation of crops, by using the most favorable amount of seed, and by sowing seed of good quality, the yield of dry-farmed grain can be considerably increased. The difficulty of practicing such thorough methods where grain ranches are as large as they are in this section is not underestimated, but if the grain farmers are to become as prosperous as their neighbors of the irrigated sections they must improve upon the prevailing methods of farming.

[a] Scofield, Bulletin No. 130, Bureau of Plant Industry.

Since the beginning of irrigation in this area the price of land has increased very materially. At its beginning in 1901 the better grain land, if for sale at all, could be bought at prices ranging from $30 to $45 an acre, while the poorer grain land, including the large body of sandy soils in the southwest part of the area, could be bought for $10 or less an acre. At the present time the prevailing price for first-class land in small tracts is $100 an acre, although some excellent tracts are on the market at prices ranging from $60 to $90 an acre. For poorer land the price varies from $40 an acre up. In tracts of several hundred acres the price is usually considerably less than is asked for the small subdivisions.

The bottom lands along the Tuolumne and Stanislaus rivers and also along Little John Creek, although not irrigated, are held at prices ranging from $75 to $100 or more an acre, while the nonirrigated grain lands are held at $15 to $25 or more. Improved irrigated lands are selling at prices ranging from $75 to $200 an acre, the price depending upon the kind of soil and character of the improvements.

If a man wishes to engage in alfalfa growing and the dairy business in a small way, 30 or 40 acres of good land is sufficient, and even then the employment of help will be necessary. If he wishes to grow fruit, berries, or vegetables a good living for a family of moderate size can be made on a farm of 20 acres or less.

Labor is often inefficient and hard to secure. The price paid for men on the grain ranches is $30 to $40 a month and board, and during grain harvest $2.50 to $4 a day, the price depending upon the kind of work done. The price paid for day labor is $1.50 to $2.50 a day without board. Much of the work in vineyards, as picking fruit and other like work, is done by contract, largely by Japanese.

SOILS.

The soils of the Modesto-Turlock area are very complex in character and distribution. Not only is there a great range in kinds extending from sand to the heaviest adobe, but the occurrence of small bodies of one soil within or partly surrounded by those of entirely different character is quite usual. In fact the occurrence of several distinct and widely differing soils within a 10-acre tract or even within a single acre is not uncommon.

On a scale of 1 inch to the mile, which is used in the soil survey, it is impracticable to show a soil body of much less than 10 acres, so that it has often been necessary to include a small soil body of one type within that of an entirely different one which surrounds it. In other places, where there is a multiplicity of small soil bodies of different character, it has been necessary to map the whole with the soil which it most nearly resembles.

At some former time the only part of the area covered by this survey which existed as land, was the hills in the northeastern part. West and south of these a great body of water extended entirely across the valley to the Coast Range. These hills themselves were also formed under water, but at an earlier date, and were part of a gently sloping, smooth ocean or lake bed like that which now exists in the valley west of them. This is shown by the horizontal position of the beds of rock which compose them, the same beds being found at about the same elevation in different hills. While the remainder of the valley was protected from erosion by the water which covered it, this portion was raised and exposed, and by erosion carved into its present form. These hills are made up of various kinds of rock, which in the northern part of the area consist largely of a coarse, horizontally bedded sandstone, which often outcrops near the tops of the hills, as may be seen east and north of Oakdale. These are really an andesitic tufa which weathers into a heavy purplish-brown adobe. Farther south the prevailing beds are older and are those of a buff-colored stratified silt or clay which weathers into a bluish-black adobe. These two types of adobe, however, are so closely related and so blended that in the soil map they have not been separated. Still farther south the predominating outcropping beds are those of sharp sand very largely granitic in origin which weather into a rough, sharp sandy loam. In some places beds of a fine chocolate-brown sand occur and weather into a fine sandy loam of like nature. Through many parts of the area a mixture of these various soils has resulted in a loam which has some of the characteristics of each. These soils have no hardpan in the true sense of the word, but are underlain at various depths by the formations from which they are derived. They have been called the Arnold soils. The Oakdale line of the Southern Pacific Railroad approximately separates these types from the soils of the lower part of the valley.

The topography of this section is markedly different from that of the remainder of the area and consists of well-rounded hills, the highest of which reach an elevation of 200 feet or more above sea level. These stretch away in all directions like immense billows of almost uniform slope, only a narrow valley here and there serving to break the monotony. Although the slopes of these hills are steep they are usually smooth and the entire surface is cultivated, except where an outcrop of the underlying formation occurs. The Arnold soils are characterized by brown color, and the frequent occurrence of the subsoil near the surface.

West and southwest of the Arnold soils there was formed along the margin of the old lake which covered the valley floor, from the action of its waters upon the material washed into it from the adjacent hills,

a series of peculiar red soils, usually light and sandy at the surface but underlain by a heavier subsoil, which is in turn underlain by an indurated ferruginous hardpan. These are easily recognized by their brick-red or yellowish-red color and by the dense, red hardpan. These are called the San Joaquin soils.

During the existence of the Pleistocene lake, though probably while it was receding, the Stanislaus, Tuolumne, and Merced rivers brought down from the mountains sands worn from granite, quartz, porphyry, and the numerous other rocks of which the mountains are composed, and emptied them into its waters. These sands were carried by the currents until they were distributed along its shores and over its bed, and now form the basis of the great body of gray sandy soils, underlain by white hardpan, which stretch from the red soils on the east almost to the San Joaquin River. Soils of this description belong to the widespread Fresno series.

After the old Pleistocene lake had been emptied into Suisun Bay, probably by means of a fissure caused by an earthquake, the Stanislaus River would at times overflow the bluffs, which were then its banks, and flow across country, leaving strips of sand and gravel to mark its course. Even the Tuolumne and Merced rivers and Dry Creek laid down similar deposits, but not to so great an extent. As these streams continued to cut deeper channels they sometimes wandered to one side or the other, leaving the benches or terraces now to be seen along their courses. As the channels grew deeper their overflow was confined to the bottom lands which lie but a few feet above their beds. These more recent soils, consisting of the old overflow channels and of the soils which are now year by year being formed along these streams and along the San Joaquin River, make up the fourth group and have been designated by different local names.

There are in the area four broad classes of soils—the sandy and adobe soils of the higher foothills, the red soils underlain by indurated red hardpan, the ashy-gray sandy soils underlain by white hardpan, and the more recent coarse sandy soils of the old stream courses and bench lands, with the silty soils of the stream bottoms. Each has been greatly modified by numerous agencies since it was first laid down. Rains have worn down the hills, carrying the coarser material but a short distance, while the finer clay and silt have been carried well out into the valley to mix with its sands. Poorly drained areas have been filled with water, and by its action their soils have been greatly modified, that which was once loose and coarse becoming sticky and heavy. Winds have scooped out the looser sands in places and piled them up in others. Plant life has added organic matter where it could flourish, but left the soil destitute where it could not. So through differences which originally existed and through the action of modifying agencies each of these broad divi-

sions may be separated into other groups, or series, and these series into soil types.

The following table shows the number of acres of each soil type in the Modesto-Turlock area:

Areas of different soils.

Soils.	Acres.	Per cent.	Soils.	Acres.	Per cent.
Fresno sand	117,504	22.7	Modesto loam	8,896	1.7
Fresno sandy loam	111,616	21.6	Stockton clay loam	8,512	1.6
San Joaquin sandy loam	75,328	14.6	Fresno fine sand	5,440	1.1
Fresno fine sandy loam	26,496	5.1	Stockton clay adobe	3,456	.7
Oakdale coarse sandy loam	26,304	5.1	Sacramento sandy loam	2,432	.5
Arnold clay adobe	23,296	4.5	Oakdale sandy loam	2,432	.5
Hanford silt loam	21,696	4.2	Arnold fine sandy loam	2,240	.4
Arnold loam	21,504	4.2	Oakdale sand	2,048	.4
Sacramento silt loam	16,960	3.3	Riverwash	576	.1
Fresno loam	15,552	3.0	Stockton loam	512	.1
San Joaquin loam	14,976	2.8			
Arnold sandy loam	9,344	1.8	Total	517,120	

From this table it will be noted that more than half of the area surveyed is occupied by soils belonging to the Fresno series, of which the Fresno sand covers the largest area, though the area covered is only slightly in excess of that covered by the Fresno sandy loam. The San Joaquin soils occupy approximately one-sixth of the area, the Arnold one-ninth, the Oakdale one-sixteenth, and the Sacramento and Hanford somewhat less than this last amount.

FRESNO SANDY LOAM.

The Fresno sandy loam and fine sandy loam, owing to a peculiar ashy-gray color at the immediate surface, when dry are known in many parts of the San Joaquin Valley as "white-ash land." The former is made up of rather sharp, medium to fine sand, largely granitic in origin, but also contains enough silt and clay to make it quite sticky when wet, puddling easily and forming a crust at the surface when it becomes dry. The soil proper is light brown or grayish brown to occasionally chocolate brown in color. Below the surface foot it usually becomes a lighter color and somewhat heavier in texture, and at a depth of from 30 inches to 5 feet or more is underlain by a silty layer quite similar to the white silty material found in the hills of the eastern part of the area. This silty layer may in turn be underlain by a sticky sandy loam, or it may continue to the depth of 6 feet or more. At the surface of this material, or occasionally below the surface, it is cemented by carbonate of lime into a white hardpan varying in hardness from a slightly cemented mass, which easily disintegrates, to material so firmly indurated that it is practically impenetrable to plant roots and impervious to water.

The Fresno sandy loam is subject to considerable variation in color, texture, and crop value. In the vicinity of Modesto it has been modified by the same agencies which helped to form the Modesto loam, in places being a decided brown and heavy, while in others it contains a very large quantity of coarse, sharp sand and fine gravel. These local areas of coarse material, together with others in which the soil is almost a fine sandy loam, occur throughout this section. The surface of the best of this soil is usually smooth and level, or at most only gently sloping, so that it requires little work to prepare it for irrigation. The level portions are also usually of better depth than where the surface is hummocky or marked by numerous depressions or "hog wallows," the latter being almost certain indications of shallow soil and indurated hardpan.

Extensive areas of the best phase of Fresno sandy loam are found west and southwest of Ripon, surrounding Salida, north of Modesto, on the McHenry road, extending from Ceres to Hickman, south of Keyes, west of Waterford, and in smaller bodies throughout a large part of the survey. South of the Tuolumne River a considerable area has been mapped as a sandy loam which contains a very large percentage of sand, but also enough finer material to come just within the limits of a sandy loam. In the entire western part of the area this soil has a more uneven surface, is shallower, and also contains alkali. This is especially noticeable in certain areas between the Tuolumne and Merced rivers, where on account of its uneven surface, shallow soil, indurated hardpan, and alkali content it is of little value except for grazing purposes.

Under the old system of dry farming the Fresno sandy loam was one of the most productive grain soils, and when so farmed still produces good crops. Where it is of good depth and well drained it is a productive, easily cultivated soil, well suited to irrigation. It is one of the best alfalfa soils in the area, and taken as a whole is the most valuable soil for general agricultural and horticultural purposes. Figs, peaches, olives, berries, vines, melons, vegetables, and in fact any plant suited to this climate and requiring a warm, light soil can be grown on it successfully.

The following table gives the average results of mechanical analyses of samples of this soil.

Mechanical analyses of Fresno sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
17023, 18034.....	Soil.....	1.7	11.9	11.0	26.8	10.7	32.7	5.3
17024.....	Subsoil.....	1.0	7.6	6.8	23.4	6.7	46.3	7.3

FRESNO FINE SANDY LOAM.

The Fresno fine sandy loam somewhat resembles the Fresno sandy loam in color at the surface, having the same ashy-gray color though usually having a lighter gray appearance when dry. When moist, the soil becomes light brown in color and sometimes has a slightly greenish tinge. It is composed of fine sand and very fine sand mixed with a considerable quantity of silt and clay. When rubbed between the fingers it has a smooth, velvety feel. At a depth of 15 inches to 5 feet or more it is underlain by the same silty subsoil found under the sandy loam, but the hardpan seems to be more firmly cemented and the surface more generally uneven than that of the sandy loam, often being marked by the "hog-wallow" depressions. It also more frequently carries alkali than does the sandy loam. The same condition of shallow soil and alkali noted in the sandy loam in the vicinity of the San Joaquin River is also found on this soil.

Usually the Fresno fine sandy loam occurs in comparatively small bodies. Many of these, too small to be shown in the map, are included in the areas of sandy loam. Between Waterford and Modesto a rather large area of this soil is found, the eastern portion of which has a smoother surface and greater depth than is found elsewhere in the survey.

The Fresno fine sandy loam when dry-farmed has probably been the most productive upland grain soil and is still quite productive. Where of good depth, free from alkali, and well drained, it is well suited to alfalfa, vines, figs, peaches, and other orchard crops, and is especially suited to berries, sweet potatoes, melons, and crops requiring constant and thorough cultivation.

The following table gives the results of mechanical analyses of this soil:

Mechanical analyses of Fresno fine sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
18894	Soil	0.2	5.1	3.5	25.4	18.5	39.6	7.1
18895	Subsoil	.5	5.0	4.3	27.9	20.1	33.8	8.1

FRESNO SAND.

The Fresno sand, as found in this area, is a medium to fine, loose, incoherent, micaceous sand, often containing considerable coarse, sharp, granitic material. In other places the soil is almost a fine sand in texture, these areas of fine material usually being due to a sorting of the fine material by the wind. In color it is light brown or yellowish brown, usually somewhat lighter below the surface foot, though typically it differs but slightly in color or texture to a depth

of 6 feet or more. It is very loose at the surface and does not compact in the roads after rains, but even in this soil a plow sole is sometimes formed. When cultivated, the surface is readily drifted by the winds, causing considerable damage to young crops and recently planted vines.

In many parts of the area the sand has collected in dunelike ridges or in billowy areas and is so deep and loose that the rooting of trees and vines is very difficult, but if a foothold can once be secured it proves quite productive. This sand contains a higher percentage of fine sand than does the undrifted soil, but otherwise does not differ from it. The largest of these drifted areas occur southeast of Manteca and in the vicinity of Delhi and have been indicated on the soil map by the proper symbol, but many smaller areas of drifted sand occur throughout the survey and others may be formed wherever sand areas are cultivated and left exposed to the action of the wind.

Although typically 6 feet deep, there are certain sections, especially in the vicinity of the San Joaquin River and in the southwestern part of the area, where the Fresno sand is underlain by hardpan at depths varying from 1 to 4 feet. These shallower areas usually contain some alkali.

When farmed to grain, the Fresno sand in favorable seasons at first produces fair yields, but it rapidly declines in production, and for several years a large part of it has been practically abandoned for grain farming. Since the beginning of irrigation extensive areas have been used, especially in the vicinity of Turlock, for the growing of sweet potatoes, cantaloupes, berries, and garden truck, and very large and satisfactory yields have been obtained. It is also being used extensively for peaches and vines, a large acreage of the latter being planted on it in the vicinity of Manteca.

When used for alfalfa the results obtained have not been very satisfactory, probably owing to a considerable extent to overirrigation and too heavy pasturing. For this crop the soil could be improved by the use of manure. Where well drained and of good depth, the Fresno sand shows special adaptation to certain varieties of peaches, grapes, almonds, olives, and to sweet potatoes and melons, but when the two last-named crops are grown, their rotation with other crops will be necessary. Several concrete examples of crops grown on this soil are given under the head of crop adaptation.

The following table gives the average results of mechanical analyses of this soil:

Mechanical analyses of Fresno sand.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
18883, 18887.....	Soil.....	1.0	12.7	19.9	41.1	15.9	7.4	1.7
18884.....	Subsoil.....	2.1	21.6	15.4	36.0	16.2	6.6	1.9

FRESNO FINE SAND.

The soil of the Fresno fine sand is grayish brown or greenish brown, and in the western part of the area very dark brown in color, is smooth and micaceous, and made up almost entirely of fine sand and very fine sand. At a depth of from 3 to 5 feet the silty subsoil of the Fresno series is usually encountered, but in numerous places the surface foot of soil grades into material similar to that composing the Fresno sand or Fresno sandy loam, which in turn is underlain by the Fresno hardpan. The surface is smooth and level and the soil is easily cultivated. Owing to its high capillary power, alkali, if present in the subsoil even in very small quantities, comes to the surface readily under favorable conditions, its presence being indicated by moist spots.

This soil is usually of good depth and well suited to irrigated crops. Alfalfa, trees, and vines do well. Like the better parts of the fine sandy loam it is especially well adapted to those crops which require constant cultivation.

It occurs in numerous rather small bodies scattered throughout a large part of the area, the largest of these being west of Ripon and in the vicinity of Escalon.

The following table gives the results of mechanical analyses of this soil:

Mechanical analyses of Fresno fine sand.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
18888	Soil	2.2	10.(	8.0	40.0	15.7	17.5	5.5
18889	Subsoil	1.3	9.3	9.0	41.6	16.1	16.9	6.2

FRESNO LOAM.

The Fresno loam, as mapped in this area, is an ashy-gray or brown silty loam soil, containing sufficient sharp medium sand to give it a rough, gritty feel. When in good moisture conditions it is quite friable, especially near the surface, but when wet is very sticky, having a plastic, puttylike appearance and puddling readily. The subsoil is usually slightly heavier than the surface soil, and where exposed to the weather shows an adobe structure. It is underlain by calcareous hardpan at a depth of 1½ to 5 feet.

This soil occurs principally in the vicinity of the San Joaquin River, although a few small areas occur north of Modesto, and has been formed by the wash from adjacent areas and the action of the water on the soils where poorly drained. It is characterized by a hummocky, uneven surface, although some of the areas are comparatively level, and by the frequent occurrence of barren white spots on the

surface. These usually contain a rather high percentage of alkali, a part of which is the injurious carbonate or black alkali, but the soil quite close to these spots may be comparatively free from alkali.

This soil has been dry-farmed to grain to some extent, but on account of its uneven surface, puddling tendencies, and the comparatively high percentage of alkali which it contains, it is not of much value except for grazing purposes. It is unsuited for irrigation and irrigated crops.

The following table gives the average results of mechanical analyses of this soil:

Mechanical analyses of Fresno loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
17025, 18311, 18313.	Soil.....	0.5	4.2	3.0	12.3	15.0	46.3	18.8
17026, 18312, 18314.	Subsoil.....	.7	4.7	3.5	12.5	17.0	39.8	21.3

The following sample contained more than one-half of 1 per cent of calcium carbonate ($CaCO_3$): No. 18312, 0.95 per cent.

SAN JOAQUIN SANDY LOAM.

The San Joaquin sandy loam consists of a fine-textured bright brick-red sandy loam. The sand grains are sharp, making the soil rough and harsh. At a depth of from 15 to 60 inches the surface material is underlain by a ferruginous hardpan, the upper part of which is impenetrable to plant roots, and below this is a soft yellow incoherent sandstone. Between the surface soil and the hardpan a layer of heavy red loam or clay loam often occurs. This varies from 1 or 2 to several inches in thickness, and in some parts of the area is entirely wanting, the sandy soil resting directly upon the hardpan.

Under proper moisture conditions this soil is loose and friable, but when wet it becomes very sticky and upon drying excessively hard. During the rainy season or when irrigated, on account of the hardpan, the water is held near the surface, which then becomes quite soft and miry.

This soil is subject to considerable variation in color, often having a gray or brown appearance at the surface, although the subsoil retains the red color. In depth it sometimes extends 5 feet or even more, although over the larger part of the area the hardpan occurs at a depth of not more than 30 inches and in many places may be found at a depth of less than 15 inches. In texture the soil varies from a sandy loam, or in some cases from a fine sandy loam, to a loam, the gray color, slightly finer texture, and greater depth often occurring together.

Small bodies of the San Joaquin sandy loam of more than usual depth occur between Oakdale and Thalheim west of the railroad, east

of Escalon, south of Hickman, east of Oakdale, and in a few other places, while shallow areas occur in the vicinity of Claus, northwest of Thalheim, and in numerous other places.

Over a large part of the area the surface is that of a comparatively level valley floor, except where pitted by small hog wallows or slightly larger shallow depressions. Where it extends into the foothills, however, it frequently occurs as well rounded hills of low elevation or partly dissected bench lands.

Along its western margin a few low hills of this soil also protrude through the surrounding Fresno soils. It extends in a broad, though not continuous, belt parallel with the general trend of the valley, the larger part of which is included between the Atchison, Topeka and Sante Fe Railway and the Oakdale line of the Southern Pacific.

The soil is usually free from gravel, although in the northern part of the area a few small bodies have a considerable quantity of small, well rounded pebbles and gravel scattered over the surface and through the soil.

The San Joaquin sandy loam has been used extensively for dry-farming, and in the early days under favorable conditions gave good yields of grain, but by constant cropping and through poor methods of handling the yields have greatly decreased. Although not well adapted to irrigation, except where of more than average depth, preparations are being made to irrigate considerable bodies of this soil. Where it is of sufficient depth and proper care is used this may be done successfully, but where the soil is shallow and drainage poor it will be a very difficult problem. A large part of this soil is suited only to grain, beans, and other shallow-rooting crops which can be grown by dry-farming methods. Where the drainage is good and the soil has a depth of 30 inches or more it can be used for vines, figs, olives, citrus fruits, and other crops suited to this climate.

The following table gives the average results of mechanical analyses of the San Joaquin sandy loam:

Mechanical analyses of San Joaquin sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
17790, 17792, 18919.	Soil.....	3.7	17.2	8.0	22.9	12.4	27.8	8.2
17791, 17793, 18920.	Subsoil.....	3.2	14.3	7.7	30.5	13.0	28.4	12.4

SAN JOAQUIN LOAM.

The San Joaquin loam, like the sandy loam, is red in color and underlain by the ferruginous hardpan, but is subject to greater color and textural variation than the lighter soil. Typically it is a heavy

sticky loam containing considerable sharp sand. Under proper moisture conditions it is loose and friable, but when wet it puddles easily and upon drying bakes very hard, the heavier portions cracking and showing an adobe structure. At a depth of 3 or 4 to 12 inches it grades into a clay loam, heavy and adobelike, and is underlain by hardpan at a depth of from 15 to 30 inches. In some of the poorly drained areas this soil has a mottled gray and brown appearance. Many small spots, which on account of their size can not be shown on the map, although of an adobe structure, are included with the loam. This soil, especially the heavier portions, is difficult to cultivate, and especially so when irrigated. In places there are surface indications of alkali, but several examinations of the most pronounced spots failed to show the presence of enough alkali to be injurious to plant growth.

In the lower portions of the foothills in the northeastern part of the survey a few small areas of a red gravelly loam have been correlated with this soil, although closely related to the older soils of the hills and also closely resembling the soils of the Redding series which occur in the northern part of the Sacramento Valley. The soil varies in color from a brick red to brown, usually contains waterworn gravel, and in places is underlain by a red conglomerate instead of by the red hardpan of the lower soils. The top soil is frequently a very light loam, but at a depth of from 6 to 20 inches grades into a very heavy red loam or clay loam, which is in turn underlain by the red conglomerate at a depth of from 15 to 30 inches. This phase of the San Joaquin loam is used principally for grain and pasture. Under a thorough system of cultivation the deeper portions might be used for vines and trees.

The following table gives the average results of mechanical analyses of the soil and subsoil of the San Joaquin loam:

Mechanical analyses of San Joaquin loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
17797, 18917, 18921.	Soil.....	2.2	9.5	6.1	15.0	12.1	40.1	14.7
17798, 18918, 18922.	Subsoil.....	1.6	8.1	5.1	12.5	9.9	30.5	32.8

ARNOLD SANDY LOAM.

The Arnold sandy loam is a gray or brown sandy loam containing a large percentage of coarse, sharp sand, largely of granite and quartz particles, and considerable fine material. Small waterworn gravel and pebbles often occur on the surface and scattered through the soil mass. A few inches of the surface soil may be in some cases

very light, but at the depth of a few inches it grades into a heavier soil composed very largely of coarser sand, silt, and clay, the clay giving it a very sticky, plastic texture. This sticky subsoil, which is yellowish red in color, usually persists to a depth of 6 feet or more. This subsoil holds moisture to a remarkable degree, numerous examinations during the dry season showing the soil at a depth of only a few inches, in summer fallow, to be in good moisture condition, and that at the depth of 2 feet or more almost saturated.

The Arnold sandy loam comes from the weathering of the sandy beds found in the foothills and may occur in any position in these hills, covering the entire surface, or only the crest, side, or base. The largest areas of it lie northeast of Waterford, but many small areas are found throughout the section covered by the Arnold soils. In the valley of Dry Creek, on the eastern margin of the area, a small body of level sandy loam, although not typical, has been correlated with this soil. The Arnold sandy loam has been used almost exclusively for dry farming to grain and under favorable conditions produces fairly good crops, though not so good as those produced on the heavier soils of the series.

If properly managed, it is believed that grapes, olives, almonds, and figs could be grown on many areas without irrigation. The discussion of this will receive further attention under the head of irrigation and dry farming.

The following table gives the results of mechanical analyses of the soil and subsoil of the Arnold sandy loam:

Mechanical analyses of Arnold sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
17811	Soil	10.2	29.4	10.3	12.4	3.5	24.6	9.6
17812	Subsoil	5.0	29.0	13.1	11.2	1.8	18.8	20.7

ARNOLD FINE SANDY LOAM.

The Arnold fine sandy loam is a chocolate-brown, smooth, micaceous fine sandy loam, occasionally containing waterworn gravel. It is friable and easily cultivated and holds moisture well. The subsoil differs but little in color or texture from the surface soil. At a depth of 3 to 5 feet it is underlain by more resistant beds of formation similar in texture.

This type of soil occupies the crests of a few of the hills 4 miles north of Waterford and a few small areas along the south side of the Stanislaus River above the terraces. This soil, like the sandy loam, has been used almost exclusively for grain. If irrigated, it

would be well adapted to fruit, vegetables, and grapes, and on the deeper phases of it these might even be grown without irrigation.

The following table gives the average results of mechanical analyses of this soil:

Mechanical analyses of Arnold fine sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
17813, 17815.....	Soil.....	0.5	5.7	6.5	30.6	13.5	36.4	6.3
17814, 17816.....	Subsoil.....	.4	5.2	5.7	28.8	16.4	33.4	10.1

ARNOLD LOAM.

The Arnold loam is typically a grayish-brown soil slightly tinged with the purplish hue of the andesite rocks, but in many places it approaches the red of the San Joaquin soils, while in others it is a chocolate-brown color, sometimes almost black, the colors blending into each other and occurring without reference to position, so that the hills often have a mottled appearance. In texture it varies from a coarse sandy loam, in which the sand is sharp, to a heavy dark-colored loam. Usually the surface is light in texture, often resembling the Arnold sandy loam, but the soil immediately below the surface is so heavy that the type is classed as a loam. At a depth of 10 to 15 inches the soil grades into a heavy, sticky, light-brown loam or clay loam containing coarse sand, which in many places is underlain at 30 to 45 inches by a yellowish-brown silty sandstone.

The topography of the loam, like that of the sandy loam, is of the undulating hill type and the areas occur in any position on the hills or entirely covering them. Irregular bodies of this soil are found throughout the area covered by the Arnold soils, the larger part of the type lying, however, along the border between the Arnold and San Joaquin soils. It has been used almost exclusively for dry farming to grain, and under favorable conditions is the most productive soil of the series. While not usually so deep or so retentive of moisture as the sandy loam, it is believed that by thorough cultivation much could be done on the deeper portions of it to conserve the moisture and grow crops by dry-farming methods.

The following table gives the average results of mechanical analyses of this soil:

Mechanical analyses of Arnold loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
17799, 17803, 17806.	Soil.....	2.9	12.1	6.7	16.9	7.3	44.2	10.4
17800, 17804, 17807.	Subsoil.....	1.3	7.8	4.4	15.9	7.3	45.1	18.1

ARNOLD CLAY ADOBE.

There are two phases of the Arnold clay adobe—a heavy purplish-brown adobe and a black, dark-gray or brown adobe, somewhat lighter in texture than the former. The two, however, are so closely related and grade so readily into each other that no attempt has been made to separate them. The heavier soil comes from the weathering in place of tufaceous andesitic beds, is very heavy, and cracks readily, but it also contains considerable coarse, sharp sand. It is in places very shallow, the underlying rock frequently showing at the surface, but it may have a depth of 2 or 3 feet or more. It is very difficult to cultivate and only fairly productive, and is used for dry farming or for pasture. The other phase is more easily cultivated and more productive. It consists of a smooth clay adobe containing little sand, and at a depth of 15 to 24 inches or more rests upon the light-colored beds of stratified silt. When wet it is very sticky and upon drying cracks badly, the cracks in many cases extending almost to the underlying rock formation.

In many places scattered through the soil and over the surface of the Arnold clay adobe are numerous well-rounded gravels and cobbles. The smaller gravel is smooth and well rounded, probably coming from the breaking down of the conglomerate beds already referred to, but much of the larger material is angular and only slightly rounded, having probably been carried to its present position by an old lava flow.

The surface of much of the Arnold clay adobe is comparatively level, but other portions extend along the hillsides or over their crests. Among the San Joaquin soils a few small and unimportant areas of adobe have been mapped and classed with the Arnold clay adobe, although probably more closely related to the former.

The following table gives the average results of mechanical analyses of fine-earth samples of the soil and subsoil of the Arnold clay adobe:

Mechanical analyses of Arnold clay adobe.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
17801, 17944	Soil	0.1	2.1	2.3	10.5	4.9	37.4	42.5
17802, 17945	Subsoil	1.8	12.5	5.3	12.1	9.5	46.3	11.9

SACRAMENTO SILT LOAM.

The Sacramento silt loam as found in this area is a chocolate-brown, reddish-brown, or yellowish-brown, very smooth micaceous silt loam. Typically it is uniform in texture to a depth of 6 to 20 feet or more, there being little difference between the surface soil and the subsoil.

It is friable and easily cultivated, holds moisture well, does not puddle nor bake badly upon drying, and is especially adapted to irrigation. It has been formed by annual or occasional overflows of the streams along which it occurs, and is composed of the material worn from rocks of various kinds and from the washings of old mines. It also contains considerable organic matter from the soils which have been worked over and from the decay of plant growth. The higher, better drained, and more productive portions of this soil are now overflowed only at intervals of several years and are quite uniform, but the lower lying portions, which are overflowed almost every year, are much less uniform, the surface being uneven and the soil varying from almost a clay loam to a light, fine micaceous sandy loam, and in places being underlain at a depth of one to several feet by a sandy or gravelly loam. These more recent deposits are usually lighter in color, sometimes having a gray appearance. The sandier portions occur as elongated strips, while the heavier areas are lower and poorly drained, often having a heavy sticky subsoil.

This soil has been correlated with the Sacramento silt loam, although differing slightly from that soil as mapped in the Sacramento Valley. It has a somewhat higher silt content, the surface is more nearly level, and smoother, and the soil usually occupies the entire flood plain instead of only a portion of it near the river channel, as in the Sacramento Valley. As a whole, it also has a somewhat higher agricultural value.

The largest bodies of this soil in the area occur in the valley of the Stanislaus west of Oakdale and in the valley of the Tuolumne southwest of Modesto. Almost continuous, though in most places narrow, strips of it extend entirely across the area and for several miles east of it along the Stanislaus, Tuolumne, and Merced rivers, the soil in these three valleys being remarkably similar. In many places the area occupied by the Sacramento silt loam is bordered on one side by a semicircular bluff or terrace. That part adjacent to this terrace is often heavier in texture, poorly drained, and sometimes carries an appreciable quantity of alkali, this being of sufficient concentration in many small areas to be injurious to plant growth. In places this contains some sodium carbonate, or black alkali, but the principal part of it consists of sulphate, bicarbonate, and chlorides, or white alkali. These areas are too small to be shown on the alkali map.

The level, well-drained portions of the Sacramento silt loam are the most productive and easiest cultivated soils in the area. They have been farmed to grain extensively and have almost invariably given good yields. Even when cropped from year to year without summer fallowing fair yields are obtained. The yields on summer fallowed land in favorable seasons are not far from 20 sacks of wheat and 24 to 26 sacks of barley or oats to the acre.

Considerable areas of this soil are used for alfalfa, this crop being grown without irrigation, and three or four cuttings of a ton or more each are obtained. The greatest difficulty encountered is the injury done by the gophers, which have an opportunity to work in the unirrigated soil. Sometimes the rank growth of weeds, especially upon the land that has been overflowed, is also a hindrance.

Practically all of the older orchards of the valley were planted on this soil. Although the greater number of them have died, this has been principally through neglect, and the soil is well adapted to fruit trees. The larger area devoted to orchards lies west of Oakdale, where a few hundred acres are planted in peaches, prunes, apricots, pears, grapes, and various other fruits. Most of these are grown without irrigation, sufficient moisture for the trees being retained in the soil by frequent cultivation. A few irrigating plants have been installed, but have usually been found unprofitable for orchard purposes.

Aside from the orchard interests, that of truck gardening is the most important. The gardeners are mainly Italians. Pumping plants are installed and crops of radishes, lettuce, turnips, onions, cabbage, cauliflower, carrots, beets, peas, peppers, corn, tomatoes, potatoes, melons, celery, and many other products follow each other in quick succession, one crop being removed and another immediately planted in its place throughout the year. The produce of these gardens is disposed of in the local markets through the grocery stores, distributed from wagons that have regular routes through the country, or is shipped to the cities and to the mines. Owing to the small areas devoted to each crop, the quick succession of crops on the same soil, and the difficulty of securing information from the men engaged in the business, it is impossible to give any figures as to the yields and profits made by these gardeners, but it is known that the profits are large. In addition to the crops now grown it is believed that hops, sugar beets, asparagus, and berries could be grown with good results and that within a few years the larger part of this soil will be used for such specialized crops.

The following table gives the average results of mechanical analyses of the Sacramento silt loam:

Mechanical analyses of Sacramento silt loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
17028, 17817.....	Soil.....	0.1	0.2	0.3	11.3	6.6	74.2	7.1
17029, 17818.....	Subsoil.....	.1	.5	.6	7.9	6.3	75.4	9.4

The following sample contained more than one-half of 1 per cent of calcium carbonate ($CaCO_3$): No. 17029, 1.14 per cent.

SACRAMENTO SANDY LOAM.

Typically, the Sacramento sandy loam is a brown, micaceous, smooth, medium to fine sandy loam with a depth of 6 feet or more, but it is subject to considerable variation in color, texture, and depth. The coarser areas are gray in color, while the finer and heavier portions have the chocolate-brown color of the silt loam. In texture it varies from a very fine silty sandy loam to almost a medium fine sand, but it contains very little clay. While it usually has a depth of 6 feet or more, it may be underlain by coarse sand or gravel at any depth between 30 inches and 6 feet.

This soil has been deposited during recent overflows, and is made up of the sand and silt carried by the streams along which it occurs. The larger areas are comparatively level and usually higher than the small areas, which are frequently uneven and have ridges of sand extending across them. Numerous small areas of this type of soil occur in the lower and more recently overflowed portions of the Sacramento silt loam, and on account of their small size and the difficulty of accurately outlining them they have been mapped with the silt loam.

The principal bodies of this soil are found along the Tuolumne River west of Modesto, near the Paradise Gardens, but smaller areas occur in other places along the Tuolumne, Stanislaus, and Merced rivers. Owing to its limited extent, it is a comparatively unimportant type, used in part for orchards and for gardening. If well drained and protected from overflow, it would be well adapted to truck gardening, berries, and melons.

A mechanical analysis of a sample of this soil gives the following results:

Mechanical analysis of Sacramento sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
18925	Soil	0.7	14.2	10.1	40.4	11.5	14.6	8.4

HANFORD SILT LOAM.

The Hanford silt loam is a brown, dark-brown, or nearly black, heavy, micaceous silt loam, containing considerable organic matter. When wet it is very sticky and puddles easily, and when dry the surface cracks and checks. There is considerable variation in the subsoil, the surface soil in places grading into a very heavy dark-colored silt or clay loam. At a depth of about 20 inches this grades into a whitish-brown silty loam, which often contains calcareous nodules and weathers into an adobe where exposed. At a depth of

about 4 feet this is underlain by a very sticky, micaceous, gray or light-brown fine sandy loam, which becomes lighter in texture with increasing depth. In other places the surface soil grades into lighter colored, very micaceous silt loam at a depth of 6 or 8 inches, and this at a depth of about 12 inches into a smooth, micaceous fine sandy loam containing much silt. This may extend to a depth of 6 feet or more, or may be underlain at a depth of 4 or 5 feet by the heavy silt or clay loam above noted. While the surface soil has much the same appearance regardless of the subsoil, that which has the heavier subsoil usually occurs as the lower lying areas around lakes, lagoons, and old stream courses, while that having the lighter subsoil is higher and more nearly level.

This soil has been formed very largely from the deposition of material by the overflows from the San Joaquin River and its tributaries, a large part of it being flooded almost every year. It is made up of sand, silt, and clay, carried down and worked over by these streams, to which has been added considerable organic matter from a rank growth of native plants.

The heavier parts of this soil, especially those flat, low-lying areas somewhat away from the sloughs and lagoons, often contain a small quantity of alkali, both black and white alkali being present, but in a soil of this character a given quantity of alkali is less harmful and easier controlled than in a lighter soil.

The topography of this soil as a whole is that of a flat, smooth flood plain, though it has been much dissected by many deep sloughs and dry channels, left by swift flood waters. A few of these are located on the map, but many others, on account of their being almost inaccessible, are not shown. The lower lying areas have in many places ridges of sand and gravel on the surface, the result of recent deposition. The entire area is separated from the adjacent soils by a low bluff or terrace which in most places is quite distinct. Along the edge of the lowland just below this terrace a string of lakes connected by sloughs extend throughout the greater part of the area.

This soil occurs along the San Joaquin River in a long, narrow strip, varying in width from less than half a mile to 1½ miles. Much of it, especially that adjacent to the river, is covered by a growth of willows and underbrush, while on some of the higher parts is a growth of valley oak. Many of the broader, more level stretches have been cleared and used for grain. A few have been diked, pumping plants installed, and the soil sown to alfalfa, but owing to unusual high water during the past few years these dikes have been partly destroyed and the reclaimed portions abandoned. For the same reason little of this land is now used for grain, this entire body of rich alluvial bottom

land being abandoned almost entirely to grazing. Although many parts of this soil, on account of uneven surface, areas of sand, and numerous sloughs and lakes, could not be prepared for cultivation without great expense, there are some comparatively level bodies of rich, productive soil, hundreds of acres in extent, that would well repay the cost of such reclamation as has been carried on in the vicinity of Stockton. If reclaimed by means of dikes and the installation of pumping plants for the removal of seepage water and for irrigation where needed, this soil would be found well adapted to alfalfa and garden truck of all kinds.

The average results of mechanical analyses of the soil and subsoil of Hanford silt loam are given in the following table:

Mechanical analyses of Hanford silt loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
18911, 18914.....	Soil.....	0.1	0.7	0.3	2.2	4.4	62.1	30.8
18912, 18915.....	Subsoil.....	.0	.5	1.0	24.6	14.3	37.8	21.6

STOCKTON CLAY LOAM.

The Stockton clay loam is a smooth, silty, heavy loam or clay loam, of yellowish color. When wet it is slick and sticky and puddles readily, and when dry it cracks and becomes rather hard, but under favorable moisture conditions it is friable and easily cultivated. At a depth of 18 to 24 inches the surface soil grades into one of heavier texture, which shows an adobe structure upon weathering, but retains the light-yellow color of the surface soil. At a depth of 4 to 5 feet this is underlain by a light-yellow silty fine sandy loam. This soil is free from alkali and in that portion of the area near Farmington no hardpan is encountered within 6 feet of the surface. Farther east it is underlain in places by a rather heavy hardpan at a depth of 3 to 6 feet. As a whole, this is a comparatively uniform soil, though subject to some variation in color and texture, a few small areas being heavier and usually slightly darker in color, often brown or reddish brown.

The Stockton clay loam is sedimentary in origin, and has been carried down from the foothills by Little John Creek. Except for a few low-lying areas along the creek, it is not at present subject to overflow. It is a smooth, flat, or gently sloping flood plain, well adapted to cultivation. It occupies the small valley in which Farmington is located, in the extreme northern part of the area. It has been used principally for grain farming, giving yields of 8 to 10 sacks of wheat or 12 to 16 sacks of barley on summer fallow. A few

small low-lying areas have been used for alfalfa, yielding two or three cuttings without irrigation. Some vineyards have been put out on this soil and give promise of making good growth and large yields, the Tokay grapes already grown being especially well colored. These vineyards have been grown without irrigation, sufficient moisture being conserved by cultivation. The soil is naturally adapted to the growing of grapes, peaches, prunes, figs, and, if irrigated, to alfalfa, berries, and garden truck.

The following table gives the average results of mechanical analyses of the soil and subsoil of the Stockton clay loam:

Mechanical analyses of Stockton clay loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
18878, 18881.....	Soil.....	0.1	1.4	1.3	12.1	14.5	48.3	21.8
18879, 18882.....	Subsoil.....	.0	.6	1.3	13.8	11.9	46.0	26.2
18880.....	Lower subsoil.	.0	.4	3.4	30.6	15.9	32.0	18.1

STOCKTON CLAY ADOBE.

The soil of the Stockton clay adobe is a yellowish-brown or dark-brown clay or clay loam of smooth uniform texture. It is sticky and puddles easily when wet and cracks when dry, the cracks extending to considerable depth. At a depth of about 20 inches it grades into a yellow clay or clay loam, which may extend to a depth of 2 feet or may in the lower part of the section grade into a yellow silty sandy loam.

In origin this soil does not differ essentially from the Stockton clay loam, but it differs in texture, being heavier, and in structure, being an adobe. It is also more difficult to cultivate. It occupies the valley of Rock Creek, northeast of Farmington, the poorer drained areas along the edge of the valley occupied by the Stockton clay loam, and also a small area on Dry Creek.

The results of mechanical analyses of the soil and subsoil are given in the following table:

Mechanical analyses of Stockton clay adobe.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
18929.....	Soil.....	0.0	1.3	0.7	3.3	3.7	48.6	42.6
18930.....	Subsoil.....	.0	.8	.5	1.9	4.8	65.1	25.9

OAKDALE COARSE SANDY LOAM.

The Oakdale coarse sandy loam is dark chocolate brown, reddish or yellowish brown, or occasionally almost black in color, and is made up of coarse, sharp sand and fine, sharp gravel, largely of granite and quartz rock. Adhering to this coarse material and in the spaces between the grains there is a considerable amount of smooth, fine, micaceous sand and silt. The soil varies considerably in texture, some of it being quite heavy and breaking up into large clods when cultivated. The larger part of it, however, is loose and incoherent when dry, and sticky when wet. Where used for roads or streets it compacts readily, making a firm, solid surface. In some areas a considerable quantity of waterworn gravel and pebbles occurs. Where these are sufficient to affect the crop value of the soil or its power to hold moisture, they have been indicated on the soil map by the proper symbol. At a depth of about 12 inches the soil is often lighter in color, showing a yellow or gray tinge, this probably being due to the absence of the small amount of organic matter found in the surface soil, but the texture often remains the same to a depth of 6 feet or more, although in many places, and especially where the soil has been irrigated for some time, the subsoil is much heavier.

This soil is free from hardpan and alkali and is well drained, except in the lower parts of some of the old channels, north and northwest of Modesto.

The Oakdale coarse sandy loam is sedimentary in origin and has come from the weathering and working over of the sand and gravel beds of the hills, which in places form the basis of the lighter members of the Arnold soils. An interesting outcrop of these beds may be seen at the north end of the wagon bridge across the Stanislaus River at Oakdale.

This soil is uniformly level, or almost so, and is well situated for irrigation and easy cultivation. The principal bodies are found along the Stanislaus River west from Oakdale, considerable bodies being located on both sides of the river. There are other small areas, some of the smaller ones on account of their size being mapped with the Fresno soils.

Southwest of Escalon, near Weston, and in other parts of the survey considerable bodies are so light that the soil is a coarse sand; but on account of the very slight difference in texture and crop value between this soil and the lighter portions of the Oakdale coarse sandy loam, these areas have been included with the latter soil.

Areas where the soil is loose and incoherent are of little value for grain, but some of the heavier portions produce fair crops. It is said that alfalfa gives poor yields and dies out badly, but this is

probably due in part at least to careless methods of overirrigation, too heavy pasturing, and failure to supply needed humus. The soil seems especially adapted to the growing of strawberries, bramble berries, and almonds, for which it is used extensively in the vicinity of Oakdale. The berries are irrigated, but almonds are grown without irrigation. Olives, citrus fruits, vegetables, melons, and many other crops are produced with considerable success. Few vineyards in bearing are found on it, but where strips of it extend into recently planted vineyards a good growth of vines has invariably been made. This is especially noticeable in some of the larger vineyards in the vicinity of Weston, where the soil boundaries can be easily traced by the larger growth of vines on the coarse sandy loam, but this is probably due to better moisture conditions, rather than to differences in the soil.

Average results of mechanical analyses of samples of the Oakdale coarse sandy loam are given in the table following:

Mechanical analyses of Oakdale coarse sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
17016, 17042, 17809, 18909, 18923.	Soil.....	13.2	38.8	11.1	14.0	2.7	14.4	5.2
17017, 17043, 17810, 18910, 18924.	Subsoil.....	12.8	34.7	11.5	16.0	3.4	15.8	6.7

OAKDALE SANDY LOAM.

The Oakdale sandy loam is a chocolate-brown, medium to fine, rather micaceous sandy loam, containing a considerable proportion of coarse, sharp sand. It has been formed by a mingling of the materials giving rise to the Fresno and Oakdale soils, and has the fine material of the former and the coarse, sharp material and brown color of the latter. It is of comparatively uniform texture to a depth of 5 or 6 feet, where it may be underlain by the white hardpan of the Fresno soils, although in many places no hardpan is reached at that depth.

The surface is comparatively smooth and level. The largest body of this soil is found about 5 miles north and slightly east of Modesto. A few small areas occur in other places. In crop value it is quite similar to the better portions of the Fresno sandy loam.

Mechanical analyses of the soil and subsoil give the following results:

Mechanical analyses of Oakdale sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
18907	Soil	5.2	22.1	10.1	21.8	9.1	24.6	7.6
18908	Subsoil	5.3	22.5	9.7	19.3	13.5	22.1	7.6

OAKDALE SAND.

The Oakdale sand is a smooth, micaceous, light-brown sand or fine sand, carrying noticeable quantities of silt and clay. It is uniform in color and texture to a depth of 6 feet or more and is well drained and free from alkali and hardpan. This soil has resulted from the working over of the Oakdale coarse sandy loam by the wind, the finer material being thus collected along the lower side of the terraces on the south side of the valley and in a few other places. The surface is smooth and level or gently sloping.

The Oakdale sand is confined to a few small areas along the Stanislaus River, the largest of which lies south and east of Oakdale. It is used principally for almonds, but if irrigated would be adapted to many other crops.

A mechanical analysis of this soil gives the following results:

Mechanical analysis of Oakdale sand.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
17789	Soil	Trace.	11.3	25.8	45.5	5.3	8.9	2.2

STOCKTON LOAM.

The Stockton loam is a light chocolate-brown loam containing much silt and fine micaceous sand. When wet it is quite sticky and puddles easily, and upon drying it bakes hard. Under proper moisture conditions it is friable and fairly easy to cultivate. The subsoil is subject to considerable variation in texture, the soil grading in places at a depth of 12 or 15 inches into a very light loam or almost fine sandy loam which may continue to a depth of 6 feet or more. In other places the surface soil grades into a very heavy silty loam, which at about 3 feet is underlain by a lighter colored fine sandy loam or loam. The soil is free from hardpan and alkali, and in most places is well drained, though at times subject to overflow. In places a considerable quantity of waterworn gravel and pebbles is scattered over the surface and throughout the soil.

This soil is a recent deposit along the flood plain of Dry Creek, which is an intermittent stream carrying considerable water at times during the rainy season. The soil is composed of material eroded principally from the hills which lie east of the area, and occurs as a series of narrow flats varying in width from a few rods to one-half mile or more, these being separated from the upland soils by steep terraces or bluffs rising to heights of 30 to almost 100 feet. A small area in the extreme northwest part of the survey has also been correlated with this soil.

Only a small part of the Stockton loam has been irrigated, and that by means of small pumping plants near Modesto. Under irrigation it is well suited to alfalfa, peaches, prunes, walnuts, grapes, and garden truck. The small vineyards located on it are planted principally to wine grapes, which give fairly good yields. It is believed, however, that the Tokay and other varieties of table grapes might be grown profitably and with only a little irrigation, or possibly without irrigation.

Mechanical analyses of this soil give the following results:

Mechanical analyses of Stockton loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
18927	Soil	0.2	8.4	4.7	25.3	12.6	30.9	17.9
18928	Subsoil	.4	6.9	5.6	26.8	14.4	26.9	19.1

MODESTO LOAM.

The Modesto loam is a dark chocolate-brown or grayish soil containing a relatively large proportion of coarse, sharp quartz and granite sand and a very large percentage of silt. It is subject to considerable variation in texture, much of it being quite sandy at the surface, while other portions are much heavier. At a depth of about 12 inches the surface soil grades into a heavy loam or clay loam of adobe structure, also containing some coarse, sharp sand. This is underlain at a depth of 3 to 5 feet by the silty material forming the subsoil of the Fresno series, often cemented into a calcareous hardpan.

The lighter parts of this soil are free from alkali. Smaller patches of the heavier soil have an appreciable though small percentage of the injurious salts, both the black and white alkali being present. Usually the quantities are not large enough to be directly injurious to plants, but through its effects on the structure of the soil, causing it to run together and bake, it is harmful in a few limited areas.

The origin of this soil is rather difficult to determine. It seems to be the result of deposition from an old overflow course of Dry Creek, probably caused by a damming or choking of this stream

near its mouth and by deposition from a small unnamed stream which crosses the area about 1½ miles north of Modesto. It has also resulted from fine sediments carried into this part of the valley along the old overflow channel of the Stanislaus River. This material, as is the case of the materials forming the Fresno soils, with which it was deposited, has been further modified by the action of water, the result of deficient drainage.

The surface of the Modesto loam as a whole is uneven, consisting of comparatively level stretches, marked by slight, almost circular or elongated mounds. Other parts have hog-wallow depressions, with intervening mounds, giving the entire surface a hummocky appearance. The level and higher lands are usually lighter in texture and of better depth than the lower lying and hummocky portions.

One body of the Modesto loam extends in a strip three-fourths of a mile wide from Dry Creek directly west through the city of Modesto. Another strip extends east and west a mile north of Modesto, while a third and larger body is located about 5 miles west of that city.

The lighter parts of this soil under favorable conditions are friable and easily cultivated; the heavier portions are cultivated with considerable difficulty, especially under irrigation. When wet it puddles badly, and upon drying becomes very hard.

When the crops will permit the furrow system of irrigation should be used, and each irrigation should be followed as soon as possible by surface cultivation, to prevent the escape of moisture and the formation of a crust. The soil holds moisture well, and its conservation by thorough and frequent cultivation will be found much more beneficial than frequent irrigations. This is a strong, durable soil, the heavier portions of which may be improved by the methods already recommended for other heavy soils.

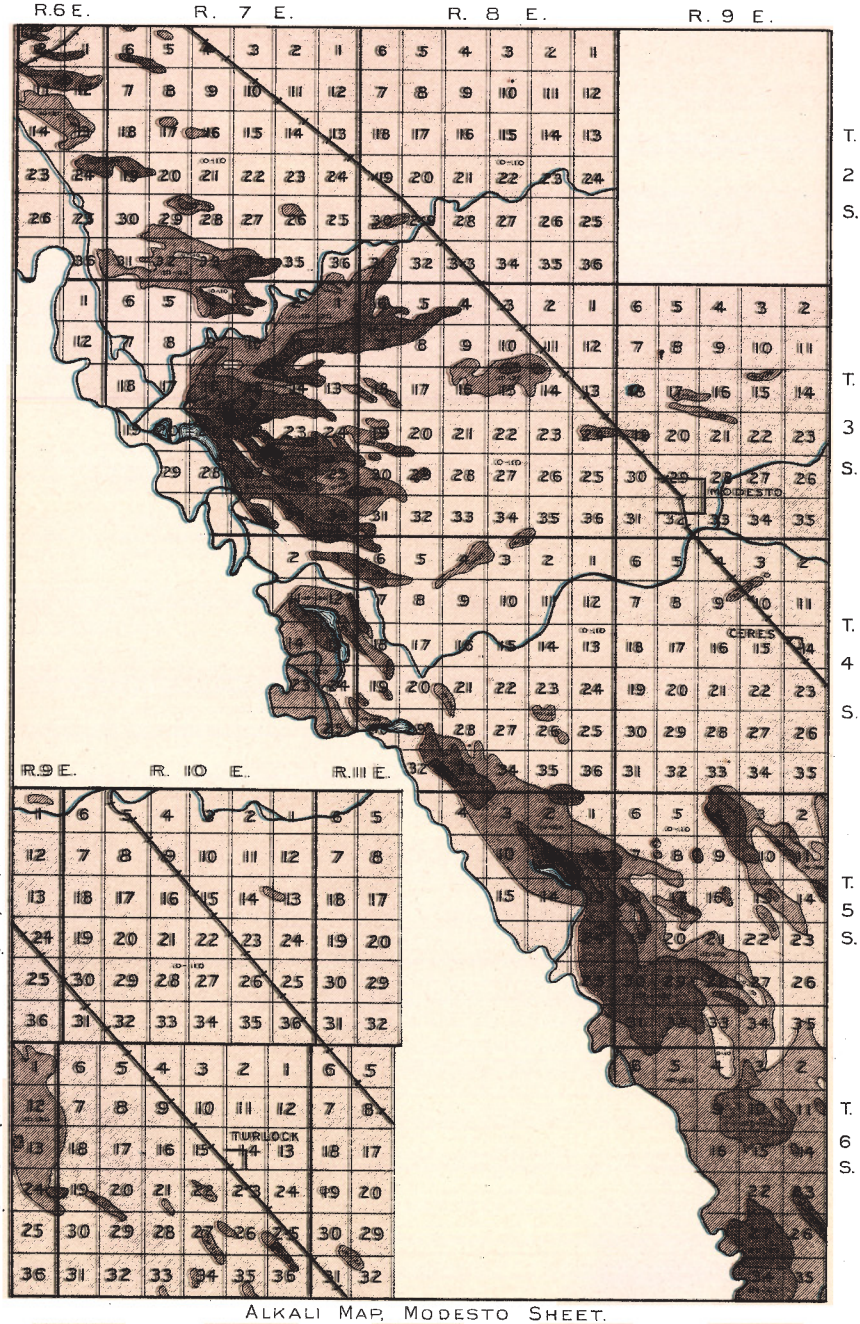
Lands of the lighter and deeper phases are well adapted to alfalfa, grapes, and peaches, and may be successfully used for vegetables, berries, and, in fact, for any crop suited to the climate.

The average results of mechanical analyses of the soil and subsoil of the Modesto loam are given in the following table:

Mechanical analyses of Modesto loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
17018, 17021, 18902, 18904.	Soil.....	1.9	8.8	6.5	18.4	9.9	37.9	16.1
17019, 17022, 18903, 18905.	Subsoil.....	1.3	7.7	5.8	9.1	8.4	40.2	16.7
17020, 18906.....	Second subsoil.	1.9	12.2	7.6	18.2	7.0	39.8	8.7

The following sample contained more than one-half of 1 per cent of calcium carbonate ($CaCO_3$): No. 17020, 3.72 per cent.



ALKALI MAP, MODESTO SHEET.

0 – .10	.10 – .20	.20 – .40	.40 – .60	.60 – 1.
Less than .10 per cent.	From .10 per cent to .20 per cent.	From .20 per cent to .40 per cent.	From .40 per cent to .60 per cent.	From .60 per cent to 1. per cent.

RIVERWASH.

Riverwash as occurring in this area consists of sand and small water-worn gravel. In depth it varies from a few inches to 6 feet or more. It occurs in small irregular bodies usually lying close to the river channels, but occasionally extends in narrow strips across portions of the flood plains. This material has been carried from the stream beds to its present position by swift currents during periods of high water. Occasionally deposits of this kind are carried into low-lying orchard or alfalfa fields, and in this way valuable land is in a single season made almost worthless. The surface of the Riverwash when first deposited is quite barren, but in time weeds and willows gain a foothold on it; but where the sand and gravel are of any considerable depth it is of little agricultural value. Some areas in which the sand and gravel are underlain at a depth of a few inches by heavier soil might be utilized for the growing of eucalyptus.

But little of this type occurs in this area, there being small bodies of it in the valleys of the Stanislaus and Tuolumne rivers, the most of which are too small to be indicated in the soil map.

ALKALI.

In parts of the Modesto-Turlock area considerable apprehension is felt in regard to the rise of alkali and its attendant evils. During the progress of the soil survey numerous examinations and tests were made throughout the entire area, and while these have indicated the presence of small quantities of alkali in many places, they have also shown that the area which is seriously affected or likely to become so is comparatively limited. In most cases the total alkali is much less than the surface appearance would lead one to believe. This is due to the fact that much of the soil has a high capillary power, which permits of the free movement of the soil moisture and the concentration of alkali at the surface. It is believed that if the causes that lead to the concentration of alkali are clearly understood and available means taken to prevent its accumulation near the surface the damage done may be confined to small areas.

The term "alkali" is commonly applied to any soluble salt in the soil which leaves an incrustation at the surface when moist soil is exposed to the air and allowed to become dry. If this salt is white, the term white alkali is applied to it, but if it becomes black or brown, as it often does around the edges of small water holes, it is called black alkali. The most common alkali salts are sodium and magnesium sulphate, sodium, calcium, and magnesium chlorides, and calcium, sodium, and magnesium carbonates and bicarbonates. Of these, the chlorides, bicarbonates, and carbonates are the prevailing salts of this area, although in places small amounts of sulphates occur.

Sodium carbonate is a true alkali, and by its corrosive action on organic matter produces the black or brown appearance known as black alkali. It is the most injurious form, and although not occurring in all parts of the area is usually found wherever a heavy concentration occurs. The sulphates and bicarbonates are the least injurious form, but the latter may[a] by the loss of carbon-dioxide be converted into the more injurious carbonates.

It was found in this area, as was demonstrated at Fresno, that small pools of water standing on alkali soil usually contain relatively large quantities of carbonates,[a] even when tests failed to show more than a trace in the adjacent soils, the carbonates having been formed from the bicarbonates by loss of carbon-dioxide through evaporation.

Alkali comes from the breaking down of the rocks and from the further disintegration which takes place when a coarse, sandy soil breaks down into a heavier one. On the east side of the San Joaquin Valley much of these salts is believed to have come directly from the breaking down of complex silicates,[b] pyrites, and other minerals which make up these rocks, but silt and clay of volcanic origin and of the andesitic tufa which occurs along the eastern edge of the area also contain an appreciable amount of alkali, principally bicarbonates, as do also the silty material and hardpan under the Fresno soils. The salts vary in quantity from a mere trace in many places to a considerable concentration in others.

In humid regions these soluble materials have been leached out and carried away by the rain, but in semiarid regions they are dissolved a little at a time and carried into the valleys. If drainage is good, they remain in solution and are carried into the rivers and no harm is done; but if drainage is restricted, a continual evaporation results in their accumulation in injurious amounts. The filling of a subsoil and the rise of ground water to within a short distance of the surface presents ideal conditions for the accumulation of alkali. This water from its movement through the soil and from a slight softening of the hardpan usually contains small amounts of alkali. When the water comes near enough to reach the surface by capillarity, evaporation takes place very rapidly and the alkali remains at the surface.

In the area surveyed the presence of alkali is indicated at the surface by moist spots where the soil has been packed, as along the road; by bare, smooth spots on which grass will not grow and which run together and bake badly when the soil is cultivated; by the black appearance of surface water and incrustations around water holes; and by the growths of alkali weeds and salt grass.

The principal alkali lands consist of a broad, irregular strip parallel with the San Joaquin River, and of many scattered local areas,

[a] Bulletin No. 42, Bureau of Soils, U. S. Dept. Agr., p. 16.
[b] Bulletin No. 18, Bureau of Soils, U. S. Dept. Agr., p. 14.

principally west of the Southern Pacific Railroad. In most cases these concentrations occur in low-lying areas and otherwise accompany the soil with hummocky surface and shallow hardpan. In this area the accumulations of alkali are very erratic, not extending over broad stretches, but often occurring as small spots of high alkali content, surrounded by comparatively free soils.

The areas of different concentrations are approximately outlined in Plate I. In those areas in which a concentration of 0.10 to 0.40 per cent is indicated alkali occurs in quantities not prohibitive to the growth of the more resistant crops. When more than 0.40 per cent occurs, owing to the high percentage of carbonates present, it is doubtful if any field crop can be grown.

In the alkali map considerable areas containing from 0.10 to 0.20 per cent of alkali have been outlined. Except in a few small spots these areas do not at present contain sufficient alkali to be injurious, but with insufficient drainage and other conditions favoring accumulation of alkali, such land may readily become affected to a degree that will interfere with cropping.

The effects of alkali are usually noticeable in grain and alfalfa fields by a poor, uneven stand, bare spots, weak, stunted plants, and slow growth, although such an appearance does not necessarily indicate its presence. Vines and trees when affected show signs of distress by wilted leaves, dead branches, and falling, poorly developed fruit.

The amount of alkali which any crop will stand depends very largely upon the character of the soil and the position of the alkali in the soil, a definite concentration in a rich soil or a heavy soil proving much less harmful than in an exhausted soil or in a light, sandy soil. This is probably due, in the first place, to the fact that a rich soil so abundantly supplies the plant with food that it is able to overcome the retarding effect of the alkali, and, in the second place, to the fact that a heavy soil has a higher moisture-holding capacity than a sandy one, and so the concentration of the soluble salt is really less. Alkali at the surface is more injurious than when occurring below the surface, for in this position it forms a crust which, in many instances, prevents tender plants from coming up, or, after they are up, prevents their growth by contracting the soil around the stems.

The crops most resistant to alkali are sorghum, barley, and alfalfa, when once started, and sugar beets, but these are injured by excessive amounts, depending upon the conditions stated above. Eucalyptus trees are able to make good growth on soil containing considerable alkali. Fruit trees suffer from excess of alkali. Pomegranates, figs, olives, and pears are said to be the most resistant. Grapevines[a] and citrus fruits are very sensitive to alkali.

[a] Bulletin No. 42, Bureau of Soils, U. S. Dept. Agr., p. 19.

The control and removal of alkali depends very largely upon the control of the ground water. This is especially true where the soils are light and have high capillary power, a condition present in a large part of the affected region of this area. So long as the ground water, even though it carries only a very small percentage of alkali, remains within 3 to 5 feet of the surface during a large part of the year, danger from a surface accumulation is imminent. Until the ground water can be lowered by drainage, or where it can not be controlled, such a concentration can be very materially delayed by using every possible means to retard evaporation. This can best be done by keeping the surface protected by a growing crop or by cultivation where not so protected.

When small local spots occur and the ground water is not near the surface, they should be well cultivated and quantities of well-rotted manure, which will improve the texture, should be worked into the soil. When irrigated these spots should be flooded thoroughly to drive the alkali down and the surface cultivated as soon after as possible to prevent its return. By this means a stand of barley or alfalfa can usually be secured on such places and these crops may be followed later by other crops.

DRAINAGE AND HARDPAN.

The most serious problem of the irrigated portion of the Modesto-Turlock area is lack of drainage.

When irrigation began in 1901 and 1903 the soils of the valley took up great quantities of water. After a few years of irrigation, however, it was noticed that the water in the surface wells of the lower portions of the irrigation districts was rising. Wells in which the water was reached at a depth of 30 or 40 feet when irrigation began were now filled to within 10 feet or less of the surface. In wind-blown depressions small lakes began to appear. During the irrigating season some portions of the fields became so soft that they could not be crossed with teams and machinery. In this way the process of filling the subsoil with water has gone on year after year. At the present time only a comparatively small percentage of the land has been seriously injured by the ground water, but the affected area has increased from year to year. In these sections injury to alfalfa, trees, and vines results not only from shallow rooting, which should be deep, but also from a fluctuating water table, which permits roots to develop during one season at a certain depth, and then by a rise or fall of the ground water either drowns them or leaves them inadequately supplied during another.

What the final outcome of this process of pouring water into the soil in the higher areas and having it come to the surface in the

lower will be, it is impossible to determine. Some believe that since the subirrigated area as a whole is not a basin but a plain sloping to the San Joaquin and intersected by the Tuolumne and Stanislaus rivers, the subdrainage will gradually adjust itself. Others who have made a careful study of the matter believe that a complete system of drainage ditches will be necessary, and at the present time both the Turlock and Modesto districts are working with dredges on large ditches which in time may become the centers of such drainage systems.

In the meantime large crops are being grown on much of the subirrigated lands, some of the best yields of cantaloupes and sweet potatoes near Turlock and of other crops northwest of Modesto being produced without the application of water to the surface. While these yields in themselves are very gratifying, it should be kept in mind that in much of this subirrigated soil the ground water has already reached the danger point, and that its further rise in many cases means the abandonment of the land.

It would seem that a conservative use of water and a complete system of drainage are just as necessary for the highest and most profitable use of the soils of a large part of this region as is the construction of irrigation works.

Another subject very closely related to drainage, and one of interest to almost the entire area, is that of hardpan. Hardpan in the true sense of the term is not bed rock nor a material formed under water as sedimentary rocks are formed, but is a secondary product. All water which percolates through the soil soon dissolves from it soluble material of different kinds. If by any means, whether it be a change of temperature, a checking of the movement of the water, or a rapid loss of the contained gases, the water is unable to carry all the dissolved material, a part of it is deposited. Any abrupt change of soil texture might produce one or more of these causes, and as a result a part of the material carried by the water would remain near the zone of change in soil texture. Again, if soil under comparatively uniform conditions, for instance, when pastured or allowed to remain unused for years, as the soils of the San Joaquin Valley must have been, receives about the same quantity of rainfall each year the moisture will sink to about the same depth. This moisture will carry down to this depth soluble materials and leave a portion along the zone of maximum penetration and in this way a hardpan might be formed.

By one or both of these processes there has been formed under a considerable portion of the soils of the Fresno series and the Modesto loam an ashy-gray or white hardpan. Under the San Joaquin soils there is a red hardpan or sandstone. The remainder of the soils of the area either have no hardpan within a depth of 6 feet from the

surface or are underlain by a bed rock, from which the soils have been formed. The white hardpan varies in thickness from a few to several inches; in hardness from a slightly cemented material to an indurated mass so dense that it can scarcely be broken with a hammer, and occurs at the surface of the silty subsoil which underlies the entire valley at depths ranging from near the surface to 4 feet or more.

This hardpan consists of the upper part of the silty subsoil of the Fresno soils and in some cases of the lower part of the sandy soil cemented with carbonate of lime, and usually carries alkali in varying quantities. Where it occurs at a depth of from 3½ to 5 feet or more it is very thin, easily disintegrated, of relatively low alkali content, and easily penetrated by plant roots. Here it is not harmful, and may even be beneficial in holding the moisture within reach of the plants. Where it occurs near the surface or where it is very hard it is harmful in several ways. It prevents the deep penetration necessary for the best development of trees, vines, and alfalfa. It restricts drainage even where the water table is of a good depth, often holding shallow basins of saturated soil fatal to the plants which send their roots into them. In some cases the excess of lime occurring in the hardpan is injurious. This is especially so in the case of citrus fruits where such injury is indicated by yellowing of the leaves. Irrigation and seepage waters appear to soften the hardpan in some places, but it is doubtful if much improvement will ever result from this process.

Unlike deficient drainage, the serious result of hardpan to a very great extent can not be overcome, and the surest remedy lies in avoiding shallow soil for deep-rooted crops. It is true that with irrigation under certain conditions, where thorough underdrainage is assured, vineyards may be set on soil 30 inches or even less in depth, but in the irrigated districts where the surface is comparatively level and there is danger of restricted drainage the advisability of using soil of less depth than 3 or 4 feet for orchards or vineyards is questionable, and no orchard or vineyard on soils underlain at less than 5 or 6 feet by impenetrable hardpan or ground water can be relied upon to continue for a number of years in the highest state of fruitage. Indications of shallow hardpan are usually to be seen in a hummocky, uneven surface and small, shallow depressions, these being the result of deficient drainage, but no orchardist, vineyardist, or prospective buyer should select his land without first carefully examining it with a soil auger (see footnote, p. 65). If hardpan is reached with the auger its character should be examined, which may be done along the irrigating ditches or by digging a hole for that purpose. Owing to the erratic character of the hardpan in occurring at greatly

varying depths in a comparatively small area, it has been found impossible to outline areas of shallow hardpan without including other areas in which it occurs at greater depths.

In general the more shallow hardpan of the Fresno soils occurs under the heavier members of the series, in the western part of the area. In the south and southwest parts of the area, however, is found a large section of Fresno sand underlain by hardpan at a depth of from 1 to 4 feet. Here much of the hardpan assumes the character of a sandstone, and is several inches in thickness. In townships 5 and 6 south, range 9 east, the hardpan under certain areas is shallow and hard and in places outcrops at the surface. The selling of such shallow, alkali-impregnated soils as occur in many places in this strip to inexperienced settlers for farming purposes can not be too strongly condemned.

Underlying the red soils of the San Joaquin series there occurs a very thick, indurated, red, yellowish-red, or reddish-brown coarse-grained hardpan cemented with iron salts. This is in fact a red sandstone, probably formed under the water along the edge of the old Pleistocene lake and not a secondary product, or true hardpan. This is found at depths varying from 12 inches to 5 feet or more, but the average depth for the entire area is probably not more than 2½ feet. The nature of this material precludes the possibility of its being penetrated by plant roots to any considerable degree, or of drainage being provided except along its surface without considerable expense. The boggy nature of the red soils during the rainy season is due to the fact that the hardpan prevents underdrainage. When irrigated by the check system the same cause produces like results. When the red soils can be irrigated the border method, described under "Irrigation," which will permit of a quick but not excessive moistening of the soils, will be found beneficial for alfalfa and grain. The furrow system, with quick irrigation followed by cultivation, should be used for all other crops.

The red soils underlain by shallow red hardpan are used in some other parts of the State for citrus fruits, peaches, and vines, the hardpan being shattered by blasting; but the thickness of the hardpan, as shown in exposures along Dry Creek, the Tuolumne River, and along railroad cuts in many places in the area, makes such a method of doubtful success here; for if, instead of an outlet for drainage entirely through the harpdan, only a basin is made, this will fill with water and be much more dangerous than the unbroken hardpan. There may, however, be portions of the area in which the hardpan is much thinner than is indicated in the outcrops, and where blasting could be carried on successfully. Experiments to determine this would undoubtedly give valuable information.

The shallow nature of much of the soil overlying this hardpan would seem to preclude its use for the growing of orchards and vines, still in some cases rather surprising results have been obtained where the hardpan is very near the surface.

On the Hickman ranch, 3 miles south of Hickman, oranges, olives, figs, eucalyptus, and other trees, as well as grapes, are planted on this soil, a part of it being of somewhat less than average depth, and these have not only made a good growth, but have given fairly good yields. In this case the oranges were irrigated, but the remainder of the orchard and vineyard received cultivation only, and not a great deal of that.

RELATION OF SOILS TO CROPS.

The soils of the Modesto-Turlock area as a whole have to a certain extent suffered from continuous cropping. When wet they become sticky and run together, and when dry they bake and form a crust at the surface. In other words, they are lacking in organic matter and are not in the best physical condition. Nevertheless, under irrigation and with thorough and careful cultivation they respond to a remarkable degree, and the growth of various crops under favorable conditions is almost phenomenal. The present need of the entire area is a system of farming which will build up rather than deteriorate the soil. The incorporation of well-rotted manure and the plowing under of green crops of alfalfa, clover, and field peas will do this. The judicious rotation of crops, where rotation is possible, must also be practiced if the best results are to be obtained.

ALFALFA AND DAIRYING.

The most important industry of the irrigated districts of this area is the growing of alfalfa in connection with dairying.

Other industries give promise of larger returns under the most favorable conditions, but none offers such good returns with the same degree of certainty. Alfalfa sown on suitable, well-prepared land yields one or two small cuttings the first season, and by the second season is ready to support the dairy herd.

Alfalfa is used, both as hay and as pasturage, almost exclusively for feed by the dairymen. It is cut greener than in many other sections of the West, being cut from 4 to 6 times a season, the best fields yielding from one-half to 1½ tons per acre at each cutting, the average for the season probably being about 5 tons. Ensilage is used to only a very slight extent, a straight alfalfa ration being considered cheaper, but corn for this purpose can be easily grown, and with the development of the industry will probably come into greater favor.

Alfalfa can be grown on almost any kind of soil, but it reaches its best development on a deep, well-drained loam, sandy loam, or silt loam. The deeper portions of the Modesto loam, the Fresno sandy

loam, the Fresno fine sandy loam, and the Sacramento silt loam are well adapted to alfalfa. By drawing a line from a point about 5 miles west of Modesto to a point the same distance west of Turlock, thence to Denair, Waterford, Empire, Escalon, Ripon, and then to the starting point the best alfalfa section will be roughly outlined. On shallow soil or on that in which the water table comes nearer than 4 feet of the surface it may do well for a few seasons and then decline, but even under these conditions alfalfa is often found to be the most profitable crop which can be grown on land unsuited for trees or vines. Considerable difficulty is experienced in parts of the area in securing good yields on the sandier soils. This is due in part to the fact that these soils are not so well suited to alfalfa, but is also due to overirrigation and to too heavy pasturing. On the heavier soils which bake very readily spots often occur in which the alfalfa makes only a scant growth, while the surrounding plants grow vigorously. These spots are often supposed to be due to alkali, but are due very largely to a peculiar structure of the soil which causes it to compact and pinch the plants. The remedy consists in thorough cultivation by means of a spading disk or some similar implement and the incorporation of a liberal supply of stable manure or other coarse litter. The use of stable manure on alfalfa, in both the heavier and the sandier soils, will be found very beneficial. The use of gypsum on alfalfa seems to be quite general throughout this area, and is said to give good results. Its continued use from year to year is of doubtful advisability.

At present the best alfalfa land in the irrigation districts without improvements but including water can be bought at prices varying from $60 to $100 an acre. The cost of leveling, checking, and seeding by the methods used in this part of California varies from $15 to $30 an acre, depending upon the amount of work necessary.

The following interesting information has been furnished by Mr. W. P. Stephenson, 1 mile northeast of Ceres, who had 30 acres in use for alfalfa. He has 30 head of dairy cows. For the year ending November 1, 1907, the gross returns from cream, and from skimmed milk, which was fed to hogs, was $2,902.84, the difference between the cost and selling price of hogs being taken as value of the milk. Alfalfa alone was used for feed, being cut and hauled to cows which were confined to a small lot. No feed except that grown on the 30 acres was used. During the month of July alfalfa fed to cows brought $20 per ton. Calves raised were not included as a part of the above returns. The alfalfa is 5 years old, and has never declined in yield. The manure has been applied on a part of the field each year, while the remainder of the field was given a light dressing of gypsum. The alfalfa is cultivated, but is not pastured. Last year it yielded six cuttings, making 6 tons per acre.

GRAPES.

The following table from the books of the assessor of Stanislaus County for the years 1906 and 1907 shows the interest which is being taken in the grape industry in a part of the Modesto-Turlock area. A like table for the entire area would indicate even a greater activity in vineyard planting, since a large part of the region in which the acreage is being most rapidly increased lies in San Joaquin and Merced counties.

Acreage of grape vines in Stanislaus County for 1906 and 1907.

Kind.	1906.			1907.		
	Bearing.	Non-bearing.	Total.	Bearing.	Non-bearing.	Total.
	Acres.	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*
For table	78	95	173	80	110	190
For raisins	205	219	424	250	250	500
For wine	267	925	1,192	300	2,820	3,120
Total	.....	.....	1,789	.....	.....	3,810

This table shows that in 1906 over 69 per cent of the total acreage was nonbearing, that in 1907 over 83 per cent was nonbearing, and that the total increase was over 2,000 acres. Within the area, but in San Joaquin County, in one colony south of Manteca, 3,000 acres of wine grapes in adjacent vineyards have been planted during the past two years, and another single vineyard contains 500 acres. It is the opinion of conservative vineyardists, however, that the acreage of wine grapes is being too rapidly increased, and that the extension of the industry will result in an oversupply and a corresponding reduction in prices.

The grape is adapted to great variation in soils. It may be grown with success upon heavy adobe, medium loam, or light sandy soils. It thrives best, however, on deep, well-drained soil of good moisture-holding capacity, and responds to thorough and careful cultivation.

On shallow soils grapes are often grown with considerable success; but under such conditions the question of drainage is a most important one. In level areas of shallow soil basins often occur on the surface of the underlying hardpan, which in case of excessive irrigation or heavy rainfall collect the surplus water and injure the vines which send their roots into the water-logged soil. Such injury is usually confined to small areas, and, while not entirely under control, can be relieved by providing good surface drainage and by conserving the moisture by cultivation to as great an extent as possible, thus avoiding the necessity of frequent and heavy irrigations. This precaution is especially necessary on the shallower red soils, where

the basins seem most likely to occur. Where drainage is adequate and sufficient moisture for good growth either by means of irrigation or by conservation of the rainfall is assured, grapes may be grown on soil having a depth of 30 inches or even less.

The grape is very sensitive to alkali even in small quantities, and alkali-impregnated soils, or those which are likely to become so, should be carefully avoided in selecting locations for vineyards.

While the largest acreage of vines is on the Fresno sand and sandy loam, almost every soil in the area is used to a greater or less extent for grapes. On some of the lighter soils and on those that are heavier irrigation is used for the first year or two, after which the vines thrive without irrigation. In other vineyards irrigation is used every year, while on others, especially on the silt and clay loams, no irrigation whatever is used.

In addition to soil conditions, the three most important elements necessary for the perfect production of the grape are dry air, clear, unfiltered sunshine, and high temperature. In the San Joaquin Valley nature has provided all of these most abundantly. Under these conditions almost all varieties thrive and give large yields of fruit of good quality, yet the adaptation of varieties to soils and to localities varying slightly in climatic conditions is important. This can only be worked out as the industry develops.

The total cost for planting a vineyard on fairly level light soil, with unrooted cuttings and caring for it for the first two years, is about $30 an acre. The cost is, however, subject to wide range, depending upon the character of the land, cost of cuttings, number of cuttings to the acre, and amount of cultivation given. With varieties such as the Tokay or Thompson Seedless, which require stakes, the cost is considerably increased. The third year most varieties should produce fruit enough to pay all expenses.

The average yield for the entire State last season was about 3 tons per acre, and for the Modesto-Turlock area it should be considerably above this figure. The price of wine grapes ranged from $10 to $13 or more per ton, while of table grapes it was much higher, probably averaging $25 per ton. Very choice Tokays and Emperors bring even $60 per ton.

The net profits on grapes in San Joaquin County last year was estimated at $63 per acre.

On the Fresno sand and sandy loams, of the table and raisin grapes, the Thompson Seedless, Sultana, Muscat, Malaga, Golden Queen, and Almeria will be found well suited to local conditions. The Thompson Seedless is best suited to a deep sandy soil without hardpan, and on account of its early ripening qualities is a good variety for this part of the valley. It has the very great advantage of being marketable either as a green or dried product. The Muscat requires a rather

heavy sandy loam and produces a fair quality of grape, but on account of lateness in ripening it is not so well suited to this section as some other varieties. Of the colored table varieties, the Black Prince and Black Cornichon are well suited to the sandy soils of the lower part of the valley. On the red soils and on the hill soils the Emperor, Flame Tokay, Black Morocco, and Purple Damascus are among the most desirable table varieties.

On the sands and sandy loam of the lower part of the valley the wine grapes Burger, Palomino Blanco, Feher Zagos, and Zinfandel are good varieties, the last named being a good bearer, though, on account of a tendency to injury by early fall rains and liability to black rot, it is not always satisfactory. On the red and hill soils the Grenache, the Alicante Bouschet, Zinfandel, and Val de Peñas will be found among the most satisfactory.

The silt loams of the river bottoms have been used to some extent for grapes and fair results with Mission, Zinfandel, and some other varieties of wine grapes obtained, but the advisability of extensive planting of grapes upon these soils is questionable.

CANTALOUPES.

During the season of 1907 there were grown in Stanislaus County 764 acres of cantaloupes, and the acreage for the present season will be greatly increased. The larger quantity is grown on the Fresno sand and the light phase of the Fresno sandy loam in the vicinity of Turlock. The largest yields and best melons are obtained from the light soils with the ground water within about 4 feet of the surface, but the growing of cantaloupes is not confined to subirrigated sections, and they may be readily grown on almost any of the lighter soils of the area.

The favorite varieties of cantaloupe in the Turlock section are the Rockyford, Klechley Sweet, Chilon, and Angelano. The first melons are ready for the market about the middle of July, following those of Imperial, Cal., and preceding those of Rockyford, Colo.

Mr. John A. Green is one of the largest cantaloupe growers at Turlock. Last year his gross returns for a large acreage was from $50 to $100 an acre, the profits depending on the crop and time of marketing. The entire cost of raising this crop, including $5 an acre rent, was about $15 an acre.

Mr. H. Fowler, 1 mile west of Irwin City, last year planted 35 acres to cantaloupes, a part of the land being too wet to produce a good crop. He began planting in April and marketed the first melons July 22. His soil is Fresno sand with ground water at about 5 feet. From the 35 acres he marketed nearly 3,000 crates of melons worth $1 a crate delivered at Turlock.

WATERMELONS.

Watermelons are grown to a considerable extent in the vicinity of Turlock, in the section lying between Escalon and Manteca, and in other parts of the area. The soil requirements are much the same as for the cantaloupe. This crop is used extensively in the young vineyards, the melons being planted between the rows of vines. The yields in many cases have been very large and the quality of the melons excellent, but owing to lack of shipping facilities the crop the past season was an unsatisfactory one.

SWEET POTATOES.

Sweet potatoes require a loose, warm, light sandy soil for their best development. Extensive areas especially suited to their production are to be found on the lighter members of the Fresno series throughout the area, the wind-blown sand where it can be irrigated being perhaps the best suited to this crop. At present the largest acreage is in the vicinity of Turlock, but other large, though undeveloped, areas equally well suited for this crop occur in the vicinity of Manteca, west, south, and southeast of Ceres, and in the region around Delhi. Many smaller areas are to be found throughout the sections covered by the lighter Fresno soils. In the vicinity of Oakdale the Oakdale coarse sandy loam is also used for this crop and has proved fairly satisfactory. A medium-sized, cream-colored potato is grown almost exclusively.

Manuel Garcia, an experienced sweet-potato grower, who lives about 1 mile northwest of Turlock, last year received $4,000 as the gross returns from 15 acres of sweet potatoes. He received 3½ cents per pound when he began marketing his potatoes early in August and 1 cent per pound at the close of the season, the average for the entire crop being about 2 cents. Mr. Garcia says that under the most favorable conditions he raises from 160 to 200 sacks of 115 pounds each per acre.

The production of sweet potatoes in Stanislaus County for the year 1907 was estimated at 8,987,613 pounds, valued at $134,813.

IRISH POTATOES.

The raising of Irish potatoes has until recently been confined very largely to the silt soils in the river bottoms, but the lighter sandy soils are gradually being used for this purpose. Although the yields are occasionally satisfactory the crop is not a very certain one.

On 5 acres of the Sacramento silt loam, about 4 miles west of Oakdale, Mr. Walker last year raised 1,000 sacks of 120 pounds each of potatoes of excellent quality.

OLIVES.

The growing of olives is an undeveloped industry in the Modesto-Turlock area, but one in which it is believed there are great possibilities. Olive oil and pickled ripe olives, on account of their recognized value, are rapidly becoming food staples with a large and increasing number of people, and the likelihood of overproduction is slight.

Although olive trees are to be found in almost all parts of the area, usually planted as ornamental or shade trees, the fruit of which drops to the ground or is eaten by birds, in only a very few places have small orchards been planted, and these for the most part suffer from lack of attention.

It is a popular belief that any soil is good enough for the olive, and while it is true that the tree will live under very adverse circumstances it is also true that it reaches its best development in a deep, well drained, well cultivated soil, and does especially well upon soils of granitic origin, such as are found in this area. It may be grown either with or without irrigation, but where too freely irrigated the fruit has a lower percentage of oil than where water is sparingly used. Olive trees live but do not bear well on low-lying or poorly drained soils. The lighter members of the Fresno, Oakdale, and Arnold series are especially adapted to olive culture.

Mr. A. V. Stewart, 1½ miles northwest of Ripon, has an olive orchard of 170 acres, 11 acres of which are bearing. The trees which have come into bearing are 8 and 9 years old, and last year produced 60 tons of olives, a large part of the fruit being of very high grade.

The soil is a light Fresno sandy loam or sand, with ground water at a depth of about 9 feet. No irrigation is used, but the ground is thoroughly plowed once, or, if necessary, twice each year, and then given frequent surface cultivations to conserve the moisture.

The cost of picking and delivering at the factory was about $15 per ton, and the price received ranged from $30 to $40 per ton for Mission, Oblonga, and Rubra for oil, and from $65 to $75 per ton for high-grade fruit of the Manzanillo, Savilano, and Ascolano varieties for pickling, the very choicest being worth even $100 per ton. In his younger orchard Mr. Stewart has planted his trees 30 feet apart, thus giving 48 trees to the acre, and hopes thereby to secure more satisfactory fruit both as regards quality and quantity.

The varieties most commonly raised in this part of the State are the Mission, well suited for oil or for pickling; the Manzanillo, an excellent variety ripening early and uniformly; the Savilano or Queen olive; the Ascolano, Oblonga, Rubra, and the Navadillo Blanco. On account of its late maturity the first-named variety should be grown only on light sandy soils.

FIGS.

Scattered throughout the area, almost regardless of soils and of other conditions, may be found fig trees in various stages of growth and bearing. They seem to thrive equally well in light and heavy soils, and are often found in those that are shallow and not well supplied with moisture. While they appear to do well with these adverse circumstances, they also respond to the more favorable conditions of deep, well-drained soil and cultivation. The mere production of fruit, however, is not so important as the quality of the fruit and the conditions favorable to its proper curing.

There are in California three distinct varieties of figs, the Mission or black fig, the Adriatic or white fig, and the Smyrna fig. Of these the Mission fig is most widely distributed, immense trees of this variety being found on many of the older ranches and at Knights Ferry, La Grange, and Snelling, east of the area. Very little attention has been given to this fig and little use made of the fruit until recently, but within the last few years its excellence as a fruit, its prolific bearing, and wide adaptation to soil and climatic conditions is bringing it into favor and a few orchards of this variety are being planted.

The Adriatic fig is a smaller white variety and until the introduction of the Smyrna fig was used principally for orchard planting, the large orchard on the Bald Eagle ranch north of Modesto being of this variety. This fig is hardy and prolific, but its value is reduced to a considerable extent by a tendency of the fruit to sour on the tree, and in this respect at least it is inferior to the black fig.

Many orchards of the Smyrna fig of commerce, locally known as the Calimyrna fig, have been planted in the vicinity of Ceres and Modesto. The soil used is principally the Fresno sandy loam and fine sandy loam. Few of these orchards are old enough to bear, except in small quantities, but the growth of trees and quality of fruit produced so far are very encouraging.

It is believed that figs may be profitably grown in all parts of the irrigated portion of the area where the soil is well drained, and that they may be grown, even without irrigation, where conditions are favorable for the collecting and conservation of soil moisture.

ORANGES.

The growing of oranges here has never been considered very seriously, although a few oranges, some of them of fair quality, are produced in various parts of the area, the principal small orchards being at Modesto, at Oakdale, and in the Orange Blossom Colony, between Oakdale and Knights Ferry. In all cases a light sandy loam is used, although oranges may be grown on much heavier soil. In most cases

the orange orchards do not receive proper care and are not well protected.

Mr. George C. Stoddard has near Modesto 5 acres of light Fresno sandy loam planted to oranges, of which 194 trees are 12 years old, 130 are 5 years old, 120 are 4 years old, and 306 are 3 years old, the larger number being Washington navel.

The past year the older trees yielded about 4 boxes per tree, and the 4-year old trees about 1½ boxes per tree. The quality was good, skin fairly thin and well colored, the fruit juicy and sweet. Picking began November 10, and the first shipment to San Francisco was made December 10, although fruit was highly colored Thanksgiving Day. The price received was $2 per box in San Francisco for sizes under 200.

ALMONDS.

The acreage of almonds has greatly increased during the last two years in the vicinity of Oakdale. The soils of the Oakdale series have been used almost exclusively for this crop, although some of the more recent plantings have been placed on the Arnold loam. Almonds do not thrive on a poorly drained soil, and the best results are obtained without irrigation. They are rather sensitive to cold, and the crop is sometimes injured by late frosts. They may be grown on any of the well-drained soils of the area, but do better in higher positions, where there is less likelihood of frost. They seem especially adapted to the deeper and sandier portions of the hill soils, and it is believed that the industry is capable of much greater extension. By the planting of more resistant and later blooming varieties, and by protecting the orchards by means of wind breaks, the profits of this crop may be very materially increased. The Texas Prolific is recommended by successful almond growers of other parts of the State as being an excellent nut, a prolific bearer, and, on account of its late-blooming habit, very resistant to frosts. The planting of this variety in alternate rows with Drakes seedlings or the Nonpareil should give desirable results. Much protection from cold winds might be secured by planting one or two rows of olives or a double row of closely planted Eucalyptus along the north and west sides of the orchards. The use of smudges and other forms of artificial protection against frost, such as are used in the citrus sections, might also be of profit.

PEACHES.

The peach requires a deep, rich, well-drained, silty or sandy soil containing much fine material for its best development. If planted on shallow or poorly drained soils it may thrive for a while, but will eventually prove unprofitable. In the Modesto-Turlock area there are a few peach orchards planted on soils less than 20 inches deep and some others in portions of which the ground water during the

irrigating season rises to within 3 feet or less of the surface. The planting of orchards under such conditions is unwise and is almost sure to be followed by uneven, poorly developed, unprofitable trees. Signs of distress are usually indicated by slender twigs and branches and small fruit in the earlier stages, followed by "die back," rosette, sour sap from rotten roots, and finally yellowing and death.

The Sacramento silt loam along the river bottoms, the Modesto loam, and the heavier phases of the Fresno sandy loam of the upland are well suited to the production of canning peaches, the favorite varieties of which are Phillips cling, Tuscan cling, and Persian cling. For drying varieties the lighter phases of the Fresno sandy soils are deemed better. Here the Muir, the Lovell, and the late Crawford are desirable varieties. For shipping purposes the Elberta is a favorite.

OTHER TREE FRUITS.

Other valuable fruits especially suited to the heavier soils of the river bottoms are prunes and plums, but when grafted on stock suitable for the soil selected may be grown on a wide range of soils. Apricots are also a valuable crop adapted to the river bottoms and heavier sandy soils, although frequently injured by frost. Favorite varieties are the Royal and Blenheim.

The English walnut offers another valuable crop best suited to the rather loamy deep soil of the river bottoms, but by grafting on the California black walnut stock trees adapted to considerable soil variations are produced. On account of its late blooming habit, the Franquette is perhaps the best variety for this section.

The following table from the statistics of Stanislaus County for the year 1906–7 shows the leading orchard crops, as indicated by the number of bearing and nonbearing trees:

Number of bearing and nonbearing trees in Stanislaus County for 1906–7.

Fruit.	Bearing.	Nonbearing.	Fruit.	Bearing.	Nonbearing.
Apricot	32,120	39,380	Orange	18,320	12,050
Fig	55,160	130,520	Peach	64,330	266,040
Olive	27,440	14,650	Almond	28,965	52,060

SMALL FRUITS.

The production of berries is rapidly becoming an important industry of the area, the largest acreage at present being in the vicinity of Modesto, west of Oakdale, and near Turlock. Of these products, strawberries are the most important, but blackberries, logan berries, raspberries, and dewberries are also receiving attention. A loose, friable, easily cultivated, well-drained soil is best adapted to berry culture.

ASPARAGUS AND OTHER VEGETABLES.

The growing of asparagus has received little attention in this area, but has good possibilities, the silt loams along the rivers being well suited to its production, while the growing of tomatoes, pumpkins, squashes, corn, peas, and beans for canning purposes on both the bottom and upland soils can be made a very profitable industry.

FORESTRY.

The planting of Eucalyptus is very deservedly receiving much attention in the Modesto area, where protection from the strong winds of the valley is absolutely necessary for the best development of the orchard industry, and where scarcity and high price of fuel and timber of all kinds make its use for those purposes most desirable.

At present the principal plantings are confined to wind-breaks and small groves for private use. On account of its rapid growth and towering height, the Eucalyptus excels all other trees in value for wind-breaks, and the horticultural interests of many parts of the State have been greatly enhanced by its use. Not only does it in a few years furnish a high, close protection along the windward side of orchards, but it also furnishes one which by its elastic nature directs the air currents high above the protected trees instead of breaking them into eddies and countercurrents, as a solid wall would do. It is true that some loss occurs from shading of the adjacent trees in the orchards and by the appropriation of needed moisture by the Eucalyptus, but if they are planted only on the north and west sides of the orchards and are made to root deeply the injury will be greatly lessened. For wind-breaks the blue gum or red gum, on account of its resistance to frost in the lower portions of the valley where moisture is abundant, and the sugar gum, which is more drought resistant on the higher and drier portions of the area, will be found desirable, although gray and Manna gums are also leading varieties. For wind-breaks they should be planted in double rows about 4 feet each way, the trees in one row being opposite the spaces in the other.

The planting of Eucalyptus groves on a commercial basis has been undertaken to a considerable extent in the southern part of the State and has proved very profitable. State Forester G. B. Lull says:[a] "The cost of planting large areas should not exceed $15 or $20 per acre," and "the returns on investments in Eucalyptus plantations have been generous, in many cases exceeding those received from equal areas under cultivation in orchards or agricultural crops. Groves set out in the fertile Los Angeles Valley have yielded 50 to 80 cords per acre at every cutting. Yields of 75 cords per acre every seven or eight years have been frequent."

[a] Circular No. 2, California State Board of Forestry.

In the Modesto-Turlock area scattering trees and small groves around ranch houses are to be found thriving under almost all conditions of soil and moisture, many of these presenting striking evidence of the rapid growth of this tree even under adverse conditions.

By careful summer fallowing and using a small amount of straw mulch around the trees as soon as planted, followed later by cultivation the first season, Eucalyptus groves may be started in many parts of the area without water. In other parts occasional watering the first season may be necessary, but the Eucalyptus may be profitably grown in any part of the area. Many areas of considerable extent in the river bottoms which, on account of sandy and gravelly soils or uneven surface, are not suited for other crops but are well supplied with moisture would, if planted to red or blue gum, require little attention beyond the setting and in a very few years yield very large returns on the investment.

IRRIGATION.

Before water was obtainable from the present canal systems irrigation on a small scale had been undertaken at a few places along the Stanislaus and Tuolumne rivers, the water being brought to the land by pumping. On these places alfalfa had been the principal crop, and when irrigation on a larger scale was made possible it received first attention, and has continued to be the most extensively irrigated crop in the entire area, although other and more specialized crops are rapidly growing in importance.

Of the area covered in this survey approximately one-half is included in the Modesto and Turlock irrigation districts, 81,143 acres being in the Modesto district and 176,210 acres in the Turlock district. Four thousand acres were last year irrigated with water furnished by the Stanislaus Power and Water Company of Oakdale, while a few bodies of land north of the Stanislaus River are irrigated by private pumping plants, the water being raised from wells or from the Stanislaus River.

The Modesto and Turlock districts are irrigated with water from the Tuolumne River. This river being much lower than the country to be irrigated, the water had to be diverted at a higher point farther up its course and brought down in canals. At a point 1½ miles above La Grange, in the foothills, 22 miles east of the area to be irrigated, the Tuolumne flows through a narrow gorge between massive walls of the most resistant quartzite. At this point a dam of solid rubble masonry and concrete 127 feet high and 325 feet long was constructed, over which the river flows when its waters are not needed for irrigation. At the south end of this dam water is diverted through a long tunnel into the Turlock Canal and at the north end through massive concrete headgates into the Modesto Canal. These canals,

one on each side of the Tuolumne River, pass through 5 miles of rough hill country, requiring heavy and expensive construction, before reaching the more level valley plain.

This system with dam, headgates, spillways, canals, and laterals, costing over $2,500,000, was built for and is owned by the landowners of the two districts.

The Modesto and Turlock districts[a] were organized under the Wright law in 1887. This law was later repealed and followed by the irrigation act of 1897. At the time the districts were organized the greater part of the land was owned by men who were engaged in extensive grain farming. The farms were large. The farmers had been very prosperous and were still fairly so, and although the yields were somewhat reduced, they wished to make no change in methods or crops. There was thus considerable opposition to the introduction of irrigation, but this was finally overcome. The main canal of the Turlock system was not completed until 1901, during which season it carried a small amount of water for irrigation. The Modesto Canal was completed in 1903 and carried the first water in the fall of the same year. Since that time there has been a steady increase in the acreage which has been brought under irrigation each year, as is shown by the following tables furnished through the courtesy of the offices of the Modesto and Turlock irrigation districts:

Number of acres under irrigation.

Year.	Modesto district.	Turlock district.	Year.	Modesto district.	Turlock district.
1901	.....	3,757	1905	10,500	(b)
1902	.....	a 7,000	1906	12,685	32,587
1903	.....	a 12,000	1907	14,020	47,802
1904	6,895	a 20,000	1908	20,000	a 57,802

a Estimated. b Records wanting.

The cost of water is based on the assessed valuation of the land, which varies from $25 to $50 an acre. The rate for 1907 is $3 per hundred on the valuation, thus making the total cost of water from 75 cents to $1.50 per acre, except in the case of small tracts with good improvement where the tax may be as high as $4 or $5 per acre.

In the Turlock district 20,000 acres were irrigated in 1904, and in the Modesto district nearly 7,000 acres were irrigated the same year. This amount has increased from year to year, but at the present time

a A very complete account of the development of these districts has been prepared by Frank Adams and is published in No. 3 of the Annual Report of Irrigation and Drainage Investigations of the United States Department of Agriculture.

only about one-fourth of the entire area of both districts has been brought under irrigation.

The water used in the Modesto and Turlock districts is exceptionally pure, coming almost directly, especially during the principal irrigation season, from the melting snows of the Sierra Nevada Mountains above Hetch Hetchy Valley, and it is believed by those in a position to know that the supply is in excess of any demands likely to be made upon it for irrigation purposes for years to come.

In the Modesto-Turlock area, and in fact throughout a large part of California, the check method of applying the water is the principal one used for alfalfa, and this is used even for other crops. By this method the ground is divided into checks of convenient size, depending upon the slope of the land. These may be rectangular, or if the land is contoured, irregular. When the land is contoured lines of the same elevation are laid out at convenient intervals, and along these the soil is ridged up by means of Fresno scrapers, cross levees being located at convenient points. The soil for these is taken from the higher portions of the checks between the levees, after which the remaining irregularities are removed by filling the lower portions with earth removed from the higher. By the rectangular method all levees are constructed along straight lines, which are crossed at right angles by other levees, thus dividing the fields into rectangular checks.

The rectangular checks have the advantage of conforming to land lines, being more conveniently handled when cultivated, and of presenting a neater and more symmetrical appearance. A closely related method, known as the border system, is coming into use to some extent, and by many is found preferable to the check system. Either contour or straight borders may be used, but the evident advantage of the straight borders in most cases is so great that this method only is described. By the border method the field is laid off in long, narrow checks from 50 to 100 feet wide, depending upon the cross slope of the land. Along the edge of these checks low borders or levees not more than 12 inches high and 6 to 10 feet wide through the base are thrown up, the soil for these being removed by Fresno scrapers from the higher side of the checks, after which the surface of each check is made smooth, but with a uniform slope, the checks extending from the high to the low side of the field. A levee is constructed across the lower end of the checks, or they may be left open and the water admitted at the upper end. In many places these straight checks can be used on grades of as much as 10 feet to the mile. By the use of a large head of water irrigation can be done very rapidly and effectually, and this method seems especially suited to the loose, sandy soils of this part of the San Joaquin Valley which takes up the water rapidly and may be easily injured by overirrigation. For this reason, and because of less expense in leveling and the

greater ease with which the low, broad levees can be cultivated and crossed with farm machinery, it would seem that this method should come into greater use.

Where the soil is not too light the system of flooding from small laterals used almost exclusively for alfalfa and grain in some other parts of the West, but almost unknown in this part of California, might be profitably introduced. By this method the surface of the land is smoothed but not leveled. Laterals from 100 to 300 feet apart, depending upon the slope of the land, are run along contours, the first one being located along the highest portion of the field. The water is then turned into one of the laterals, and near its entrance to the field thrown out by a canvas dam and allowed to pour over the side of the ditch until it has spread across the field to the upper side of the next lateral, when the dam is moved to a lower point and the operation repeated until the entire field has been watered. By this method, if the land is fairly smooth, the cost of preparing the land is very small, since only sufficient transfer of soil to secure a smooth, sloping surface and not a level one is necessary, but the labor of applying the water is somewhat greater than with the check system. The laterals are easily and rapidly constructed by a "crowder" or "go-devil." This "wild flooding," as it is termed, without retaining levees is not permitted, however, in the irrigation districts.

The cost of leveling and checking land depends so largely upon the character of the land that no very satisfactory estimate can be given, but for fairly level land not difficult to handle the entire cost, including building of levees, leveling of checks, and putting in boxes, will probably fall between $15 and $25 an acre where the check method is used. Much land in this area has, however, been checked at a cost greatly in excess of the larger amount, and on account of levees of unnecessary height and frequency has been injured for cropping. Under most conditions a field can be prepared for irrigation by the border method at a considerably less cost, while the method of irrigating from small laterals will be found still less expensive.

For trees, vegetables, vines, and berries the ditch method is used almost exclusively.

Many of the people of the irrigated portion of this area, like those of most newly irrigated sections, have made the mistake of over-irrigating. Seeing the almost magical results obtained by applying water to soil, they at once conclude that the application of water alone may be made to produce a crop, and that the more water that is applied the larger the results will be. In 1904[a] enough water entered the Modesto district near Waterford to cover the land irrigated that year to a depth of 11 feet. This amount was not all applied to the land, it is true, but that an excess of water has been and is

[a] Report on Irrigation and Drainage Investigations, U. S. Dept. Agr., 1904, p. 112.

being used can not be questioned. The past year water was allowed to stand in many checks in alfalfa fields until the alfalfa was killed entirely or in part. If the irrigation water is free from silt, a sandy soil like that of a large part of the irrigation districts will become sufficiently moist in two or three hours and further irrigation is detrimental. While the soil is saturated the air is excluded from it and plant growth to a large extent is suspended. In addition to this, every particle of water which forces its way through a soil and down into the subsoil carries with it material needed for the nutrition of the plant.

Where the furrow method of irrigation is used, if the character of the crop will permit it, each irrigation should be followed as quickly as possible by surface cultivation to conserve the moisture and to prevent the soil from baking and cracking. Frequent cultivation following necessary irrigations will invariably prove more beneficial than too frequent or excessive irrigations.

DRY-FARMING.

For nearly half a century grain has been grown in California by dry-farming methods, and to many the term "dry-farming" means this and nothing more. In recent years, however, there has developed along the eastern slope of the Rocky Mountains, in western Kansas and Nebraska and in eastern Colorado, Wyoming, and Montana, and other semiarid regions of the West, a newer and more intensive system of dry-farming by which not only grain but also intertilled crops, such as corn, sorghum, sugar beets, and many other crops are raised, and it is to this newer method that the term is now applied.

The underlying principles of this method are the same as those upon which the summer fallow of grain land depends, and consist of three things: (1) The preparation of the ground so that all moisture which falls upon it will be absorbed by the soil; (2) the conservation of this moisture by surface cultivation, thus retaining it for the use of growing crops instead of allowing it to escape unused into the air; (3) the use of crops able to withstand drought, such as durum wheat, kafir corn, etc.

The average annual rainfall at Modesto is approximately 12 inches, at Oakdale 15 inches, and in the foothills along the northeastern part of the area probably a little more. That a large part of this is wasted in the run-off during and following a hard rain is apparent to the most casual observer. The roadside ditches filled with rapidly running muddy water, the sharp gullies washed across the grain fields, and the fan-shaped piles of sand at the base of the steep hillsides, all bear evidence of moisture lost to the farmer.

When the ground is plowed in the spring, the freshly turned surface is well filled with moisture, but so dry are the winds that within a few

hours almost every particle of moisture has been taken from the exposed soil.

A method of farming which would catch all the moisture falling upon the soil and then hold it until needed by growing crops would greatly increase the yield, in many cases reduce the need of irrigation, and under favorable conditions make the growing of some other than grain crops possible without the use of irrigation at all. The skillful use of methods for this purpose is dry farming.

When rain falls upon soil the surface of which has been compacted as in a pasture, or in a field which has not been cultivated for some time, or even on a recently cultivated field where a dashing compacting rain has followed cultivation, much of the water runs off and is lost. This loss may be avoided to a great extent by keeping the surface loose or covered with a growing crop. During the winter season each rain should be followed as soon as possible by surface cultivation with disk or harrow, which will prepare the surface to receive the next rainfall. On steep slopes all cultivations should be across instead of in the direction of the slope.

The conservation of this moisture is based upon the principle that moisture escapes from the soil by capillarity—the same process by which oil reaches the top of a wick in a lamp—and from an uneven surface more readily than from an even one. When a soil is plowed up rough and uneven a much greater surface is exposed to the drying influences of the wind than if the surface is almost smooth. To avoid this some smoothing implement, such as a harrow, should follow the plows closely. Even then much moisture is lost by the movement of air through the spaces left along the bottoms of the furrows and to prevent which an implement known as a subsoil packer has been used successfully. This resembles somewhat an ordinary disk harrow in which small wheels with V-shaped rims take the place of the disks. These compact the soil at the bottom of the furrows but leave the surface loose. Capillarity is greatest in a compacted soil when exposed at the surface and least in a loose, dry soil, but even a loose soil, if allowed to remain undisturbed for some time, will run together and allow the moisture to escape. The crust which forms after a rain, the compacting of the surface by tramping or by rolling, and the plowsole which forms underneath the surface, all provide a means for the rapid escape of moisture. The first step in conservation, then, consists in breaking up the plowsole and in providing a smooth, loose surface-soil mulch, which if frequently cultivated will hold the moisture for the use of the plants.

Heavy silt and clay soils have much greater capacity for taking up moisture than have light, sandy soils, but when exposed they bake and crack, thus permitting of its rapid escape. On the other hand,

light, sandy soils can not hold so much moisture, and when of considerable depth allow much of the rainfall to sink out of reach of plant roots and escape in that way. The most suitable soil for dry farming, then, consists of one of good depth, having a heavy subsoil to hold the moisture and a lighter surface soil which can be thoroughly and easily cultivated.

In that portion of the Modesto-Turlock area outside of the irrigation districts there are considerable areas to which it is believed the principles of intensive dry farming might be successfully applied. The subdividing of these lands into small holdings and their colonization as is done in the irrigated sections, however, is not recommended, or without some means of irrigation believed to be possible, and the immediate planting of trees or vines on a large scale without careful preliminary field experiments is not advised.

Many portions of the Arnold sandy loam, some portions of the Arnold loam, and a few limited areas of the San Joaquin sandy loam present very favorable conditions for growing crops by dry-farming methods. These areas can not be outlined in the soil map, for they depend much more upon the subsoil than upon the surface soil, and although during the progress of the field work hundreds of borings were made, many more would be necessary to establish the exact boundaries. The location and extent of such areas can, however, easily be determined by persons intending to use them.[a]

On selected areas of these soils it is likely that by dry-farming methods profitable crops of grapes, figs, olives, and almonds can be produced, and while the yields would probably not be large the quality would be good and the profits satisfactory. Beans, Egyptian corn, sorghum, and field peas can also be grown.

Even in those portions of the area which are abundantly supplied with water it will be found that irrigation will not take the place of thorough cultivation, and that moisture conserved in the soil is much better than moisture added to soil from which it has been allowed to escape.

REGION EAST OF MODESTO-TURLOCK AREA.

Lying east of the Modesto-Turlock area and between it and the more rugged foothill country, there is an extensive region, varying

[a] For examination of the subsoil a common 1½-inch auger may be used. It should have the central bit cut out and be welded to a one-half inch rod 3 feet long, on the upper end of which a thread should be cut. This may be attached to 3-foot sections of gas pipe five-eighths inch in diameter and a gas-pipe handle attached to the upper end. By boring into the soil a few inches, withdrawing the auger and removing the soil, a section to any desired depth may be secured. The use of a soil auger by prospective buyers, orchardists, vineyardists, and others in determining depth of soil, impenetrability of hardpan, and distance to ground water is strongly recommended.

in width from 5 or 6 miles in the northern part to more than 20 miles at the south. Of this region a large part, on account of shallow, refractory soil and rough surface, will probably always remain a grazing country. There are, however, other portions used largely for growing grain, some of which it is believed may in time be used more profitably for specialized crops.

The topography is similar to parts of the area surveyed and consists of undulating hill lands, and farther north and east there is a considerable extent of mesa land. The mesa lands are quite pronounced west of Warnersville, where heavy beds of andesitic tufa form the resistant layers which weather into broad, flat-topped hills. The upper slopes of these hills are quite steep, but upon reaching the less resistant underlying beds they become more gradual. Though comparatively smooth the hilltops have an even, uniform slope to the west, the same beds forming the capstone of successive hills, so that at a distance they have the appearance of being a continuous elevated plain.

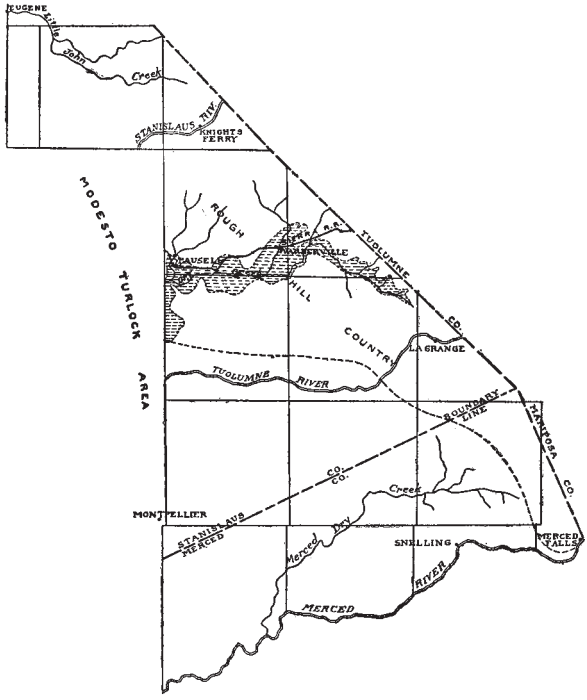


FIG. 35.—Region east of the Modesto-Turlock area.

Extending entirely across this region and into the mountains beyond are the deep, narrow valleys of the Stanislaus, Tuolumne, and Merced rivers. The region also contains the valleys of three smaller streams. The valley of Little John Creek begins near Knights Ferry on the north side of the Stanislaus River and extends northwest, entering the surveyed area at Eugene; that of Dry Creek, which heads within 2 or 3 miles of La Grange on the north side of the Tuolumne River, extends west and enters the surveyed area 5 miles northeast of Waterford; and the valley of a tributary of the Merced River, also called Dry Creek, which begins a few miles northeast of Snelling and extending west and southwest, joins the Merced Valley outside of the surveyed area.

SOILS.

Beyond the area surveyed there is only a small amount of tillable land along the Stanislaus Valley, this consisting of a few flats of fine sandy loam and silt loam. In the valley of the Tuolumne a strip of Sacramento silt loam varying in width from less than one-fourth to more than three-fourths mile, much of it level and of excellent quality, extends to a point about 7 miles east of the surveyed area. Beyond this point the valley is considerably narrower, but still contains numerous small flats of sandy and silty soil here and there all the way to La Grange, 7 miles farther east. Along the Merced River the silt loam and sandy loam areas, varying from less than half a mile to almost 2 miles in width, extend to Merced Falls, a distance of 22 miles east of the extreme southeastern portion of the area surveyed. The soil along these three valleys is remarkably similar to the Sacramento silt loam, and, like that soil, is well suited for the growing of alfalfa, peaches, prunes, apricots, and garden truck, though injury from frost along the rivers is not uncommon.

The upland of the northern part of this region consists principally of shallow adobe soils, the underlying hardpan formation being often seen at the surface and outcropping along the hillsides. Scattered through the soil and over its surface are numerous cobbles and bowlders, the traces of an old lava flow, probably from Table Mountain. In a few places soils of a better depth and lighter texture occur, but only a very small part of this portion of the upland region can ever have any agricultural value except for grazing. Along an irregular line indicated on the sketch map, and varying from 1 to 2 miles north of the Tuolumne, the adobe hills gradually merge into hills of more uniform slope, the latter being covered with a sandy loam or loam quite similar to the lighter soils of the Arnold series already described. These hills of lighter soil extend east, north of the Tuolumne, to within 4 or 5 miles of La Grange, and then swinging south and east approach the Merced Valley between Snelling and Merced Falls. The eastern boundary, like the northern, is indefinite, the hills of more uniform slope, and soils deeper, gradually changing to those of more uneven surface and outcropping rock beds.

East of Montpellier a considerable body of the red San Joaquin sandy loam extends east and southeast to the valley of the Merced River, while in the extreme southwestern portion of this region a small area of Fresno soil occurs.

At present the larger proportion of these hill soils is used exclusively for grain, of which they produce fair yields, but it is believed that by thorough cultivation, even without irrigation, certain areas might be more profitably devoted to orchard crops.

The soil in the valley of Little John Creek is quite similar to the Stockton clay loam as found at Eugene or Farmington, there being

about 2,000 acres in the valley east of Eugene. In the valley of Dry Creek north of the Tuolumne there are about 7,000 acres of comparatively level land, which is indicated by the shaded area on the accompanying sketch map. Of this land about 4,000 acres, principally in the upper part of the valley, resembles the Stockton clay loam type, though lighter, and is well suited to irrigated crops and to the growing of other crops without irrigation, while the remainder is a heavy dark-brown adobe also suited to such crops but very difficult to handle when irrigated.

North of Snelling in the valley of Merced Dry Creek the soil is a yellowish loam quite similar to the Stockton clay loam, though lighter. As seen along the road between La Grange and Snelling the soil is underlain by hardpan at a depth of from 2½ to 4 feet. In the lower portion of this valley between Snelling and Montpellier is a considerable area of level sandy loam, which occurs as upland valley or bench land and resembles the Fresno sandy loam.

POSSIBILITIES OF A FOOTHILL FRUIT BELT.

For many years oranges in small quantities have been grown at Knights Ferry, La Grange, and Snelling, the fruit ripening early and being of fair quality. The most encouraging results so far obtained are at La Grange, where a little citrus garden of navel oranges, lemons, and limes is growing. The trees are thrifty and free from disease, produce fruit of excellent quality, and bear prolifically. These small orchards and the success attained in growing fruit in the foothill country in other parts of the San Joaquin Valley have led to frequent inquiry as to the possibilities of the foothills along this part of the valley as a fruit region, and especially as a citrus belt. There may be climatic conditions favorable or unfavorable to the development of such a belt which can only be ascertained by experiments; but, aside from this, the extent of available lands of suitable quality and the possibility of irrigation are factors to be considered.

The limited area of available tillable land in the vicinity of Knights Ferry or La Grange precludes the development of the fruit industry to any considerable extent at either of these places, while at Snelling there is a rather large body of rich silt loam, which is better suited to the growing of prunes, apricots, and peaches than to citrus fruits. There remains, then, a few small valleys of the minor streams, and the better portions of the foothills farther west where the growing of citrus fruits might prove a success.

The lands along Little John Creek can be irrigated from the canal of the Stanislaus Power and Water Company, and a ditch down this valley is at present contemplated. Along the main canal of this

company there are several small, well-protected valleys which could be irrigated by water from the canal at a moderate cost. The lower portions of Dry Creek Valley, including a considerable body of level sandy loam of excellent quality and good depth within the surveyed area, numerous small sandy flats and valleys on both sides of the canal east of the area, and a considerable portion of the lower sandy foothills north of the Tuolumne could be reached by laterals and by pumping from the Modesto Canal. The upper portion of Dry Creek Valley could also be reached by a lateral from the Modesto Canal, but probably at much greater cost. The lands along the Merced Dry Creek could probably be irrigated by the storage of water near the source of that stream. A part of the valley lands along the Merced River is now supplied with water from that river. In all of these minor valleys there is a possibility of reaching underground water in sufficient quantities and at depths which would justify the cost of pumping for orchard use.

At present, water for irrigation can be obtained from the Modesto irrigation district by persons who have lands outside of the district, which can be reached by laterals from that system. For such service a flat rate of $2.50 per acre a year is charged, but the company agrees to supply water only when it is not needed in the district and makes no promises for future delivery.

The climatic conditions depend largely upon elevation, protection from cold winds, and direction of slope. The elevation of Pausell is 167 feet, of Warnerville 219 feet, and of the tillable portion of this entire region probably between 150 and 300 feet.

The average annual rainfall at Oakdale, as recorded by the Oakdale Milling Company for twenty-three years, is 15.62 inches, and at Snelling, as recorded by Mr. E. N. Neighbor for twenty-five years, is 16.04 inches.

The valleys and hill slopes are well protected, the principal slopes being to the south and southwest, so that climatic conditions seem favorable.

The orange is adapted to a great variety of soils, being grown successfully upon types ranging from a light sandy loam to a clay adobe. The success of the crop depends rather upon the conditions of heat, air, sunshine, protection from frost, and drainage than upon any particular type of soil.

From the favorable conditions found to exist it is believed that, whenever water for irrigation can be supplied, these minor valleys and the better portions of the foothills may become an important region for the growing of citrus fruits.

SUMMARY.

The Modesto-Turlock soil survey covers an important area on the east side of the San Joaquin Valley, extending from the valley well into the foothills.

This entire area was used for many years for the production of grain, but recently water for the irrigation of a large part of it has been made available, the large ranches are being subdivided, settlers are rapidly coming in, and specialized crops are being introduced.

In the unirrigated portions of the area grain production remains the principal industry, but oats and barley are to a considerable extent taking the place of wheat. The profits are much smaller than they formerly were. Further changes will undoubtedly result either in the use of the grain ranches for grazing purposes, or in the adoption of better methods of farming, whereby the yield of grain crops can be increased and other crops introduced and grown by dry-farming methods.

In the irrigated portion of the area a great variety of crops is being introduced, and in many cases very encouraging results obtained. The dairy business is at present the most important, but will probably soon be superseded by the vineyard, orchard, melon, and truck-growing industries, which are developing very rapidly.

The soils as a whole are light, the largest part of the area consisting of sandy loams and sands. These have suffered from continuous cropping to grain. In portions of the area the soils are too shallow for the planting of deep-rooted crops, and in places they have been injured by alkali and the rise of ground water; but, on the other hand, a very large part of the area consists of deep, well-drained, easily cultivated soils, responsive to irrigation and cultivation, especially suited to vineyards and orchards, and under favorable conditions producing almost phenomenal yields of all crops suited to the climate.

Since the introduction of irrigation, the price of land has advanced sharply, but the best land is still obtainable at a low price, and considering the quality of soil, low cost of water, great diversity of crops, and advantages of close markets, probably no other area of equal size in the entire West offers greater attractions to the prospective settler than does this.

NRCS Accessibility Statement

This document is not accessible by screen-reader software. The Natural Resources Conservation Service (NRCS) is committed to making its information accessible to all of its customers and employees. If you are experiencing accessibility issues and need assistance, please contact our Helpdesk by phone at 1-800-457-3642 or by e-mail at ServiceDesk-FTC@ftc.usda.gov. For assistance with publications that include maps, graphs, or similar forms of information, you may also wish to contact our State or local office. You can locate the correct office and phone number at http://offices.sc.egov.usda.gov/locator/app.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or a part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250-9410 or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.