SOME INTERESTING SOIL PROBLEMS.

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INTRODUCTION.

The vast scope and importance of agriculture in the United States at once lends interest to any investigation which promises to aid in increasing the productiveness of our soils. Owing to the great variety of conditions, however, which may be presented, the solution of any particular problem is usually of somewhat local application; but to the vast number of Eastern agriculturists, dependent on the vagaries of summer rains, there is no problem so important as the maintenance of a proper supply of water in the soil. Unfortunately, the extreme complexity and lack of homogeneity of Eastern soils, together with our peculiar climatic conditions, surround the solution of this problem with great difficulties.

As a rule, soil problems in the extreme West are simpler and easier to study than anywhere else in the country. In the first place, the soils themselves are more uniform in their texture, and the climatic conditions are more stable. Hilgard has called attention to the fact that, under the conditions prevailing where the rainfall is scanty, rocks have disintegrated with comparatively little decomposition, so that the soil grains are still composed of the several minerals of which the original rock was made up. This disintegration in most cases has reached to a considerable depth and results in soils having similar physical properties to great depths. There is seldom a difference between the soil and subsoil, as there is under the more humid climate of the East. The soils generally are silty in character and contain relatively little very fine material having the properties of clay.

The relation of some of these soils to water and to crops is very remarkable. They absorb moisture so readily, lose it through evaporation so slowly, and yet supply the needs of plants so regularly and abundantly, that they can stand long periods of drought, during which the crops continue to grow without any signs of suffering for lack of water. These properties are so marked, that if properly understood they will undoubtedly throw an important light upon the general principles of the relation of soils to moisture. For this reason they are of unusual interest to students of agriculture, and it is hoped that a simple presentation of the subject will arouse an interest in those who have ready access to the soils in question, and encourage a thorough and detailed study of the reasons for the extraordinary properties the soils possess.

The facts are not new. The farmer in these favored sections is as familiar with the fact that certain soils will withstand droughts of six months' duration as our Eastern farmer is that his crops require rain at intervals of a week or ten days. Hilgard has in numerous publications called the attention of the scientific world to the facts. They are so unusual, however, and so unlike the conditions in the Eastern portion of our own country or of Europe, that too much attention can not be drawn to them nor too much thought and study be given to the explanation of the conditions.

The accompanying tables give a summary of the rainfall and relative humidity at a number of places in the West toward which attention should be directed. The records were furnished by the Chief of the Weather Bureau, who states that the summary is made up from data which is very incomplete and in many ways unsatisfactory, so that too much reliance can not be placed upon the records, nor can the conditions at different places be compared with any degree of exactness. They are sufficiently exact, however, to serve the present purpose.

Mean annual and seasonal rainfall.

Locality.	Rainfall.			Remarks.
	Annual.	May to September.	July and August.	
	Ins.	*Inches.*	*Inches.*	
Tulare, Cal	7.0	0.6	Trace.	Conditions in the San Joaquin Valley, Cal., where crops are only grown under irrigation.
Fresno, Cal	9.3	0.7	Trace.	
Mohave, Cal	5.0	0.3	0.1	Conditions on the desert in southern California, where crops are not grown at present.
Chino, Cal	15.7	0.3	0.1	Conditions in southern California, where crops are grown on certain soils without irrigation.
San Bernardino, Cal	16.6	0.9	0.2	
Claremont, Cal	18.0	1.2	0.2	
Pomona, Cal	19.4	0.6	Trace.	
Merced, Cal	10.3	1.0	Trace.	Conditions in California, Washington, and Montana, where wheat is grown on certain soils without irrigation.
Stockton, Cal	13.2	0.9	Trace.	
Wallawalla, Wash	15.4	4.5	0.8	
Bozeman, Mont	18.2	12.2	2.3	
Pullman, Wash	22.8	5.3	1.1	
Miles City, Mont	12.8	6.7	1.3	Conditions in Yellowstone Valley, Montana, where crops are grown under irrigation.
Bismarck, N. Dak	18.5	11.5	4.3	Conditions in North Dakota, where wheat is grown without irrigation.
Fargo, N. Dak	19.5	13.9	5.6	
Jamestown, N. Dak	20.3	11.8	4.2	
Wadsworth, Nev	4.1	1.0	0.3	Conditions in Nevada, where crops are only grown under irrigation.
Tecoma, Nev	5.0	1.7	0.4	
Reno, Nev	5.3	0.4	0.0	
Humboldt House, Nev	5.6	1.2	0.0	
Golconda, Nev	5.9	2.0	0.2	
Elko, Nev	6.3	1.6	0.3	

IRRIGATED LANDS OF THE SAN JOAQUIN VALLEY, CALIFORNIA.

The conditions at Tulare and Fresno, Cal., are typical of a large area under irrigation in the San Joaquin Valley. Around Fresno some of the soils possess in a remarkable degree the property of transporting water for the use of crops. The soil of the locality has become so filled with water through overirrigation that the older and well-established vineyards no longer need irrigation. Vineyards and fruit trees grow most luxuriantly without irrigation and with no rain whatever during the growing season. As a matter of fact, however, while water is not applied directly to the surface of the ground, the canals are allowed to run, in order to supply the new vineyards which are being set out. These canals, as a rule, are somewhat higher than the surrounding fields on account of the sediment which they have brought down, and which has been partially thrown out on the banks. It is generally believed that the maintenance of the water supply in the soil is dependent really on the water running through these canals. The seepage from the canals is undoubtedly very great. It is stated that if the flow should at any time be obstructed in a canal and the water held there, that it would be absorbed by the soil and completely disappear in the course of two or three days, provided the supply also was cut off. It is the impression there that if canals are running on two sides of a section, that is, a mile apart, the soil between them will be sufficiently watered. This has not been exactly determined, but is stated in order to give a general idea of the magnitude of this subject of subirrigation, as it is called. It seems perfectly incredible that the lateral movement of water could be so great in these soils as to supply the need of plants for half a mile on either side of an irrigation ditch. If these soils were packed into cylinders and water applied in the ordinary manner of a drainage experiment, it is certain that the movement would not be so extremely rapid as this would indicate. There is nothing special in the texture of the soil to indicate such an unusual property as it would have to possess in order to secure the magnitude of the lateral movement which the facts indicate. The standing water is not so very near the surface of these lands. One would have to go probably from 12 to 25 feet in digging a well to get a sufficient supply of water. It may be that the seepage from the canals merely maintains this underground supply, and that the soil has the power of drawing water up from that distance to supply the needs of crops. However improbable the facts may appear, nevertheless they exist, and a careful study of the conditions can not fail to throw light upon important properties of soils, of which, at any rate, we do not appreciate the full value.

SOILS REQUIRING NO IRRIGATION NOR RAINFALL DURING THE GROWING SEASON.

At the four stations selected from southern California, namely, Chino, San Bernardino, Claremont, and Pomona, there are certain soils upon which crops are grown without irrigation. There are on an average between 17 and 18 inches annual rainfall at these places, the most of which falls during the winter months. Less than an inch of rain falls on the average during the five months of the growing season, from May to September, inclusive. The Weather Bureau records for the present season show that there has been no rain in Pomona since April. Tobacco set out since the rains stopped and with no irrigation matured a crop aggregating a considerable yield per acre, and then matured a sucker crop, which was cut toward the last of September. These two crops of tobacco were grown with no rainfall during their period of growth, with but little attention to cultivation, and yet were luxuriant and healthy. The soil was still moist just below the surface. No apparent reason for this is revealed by examination of the soil itself, which consists of a light loam inclining to rather a coarse, sandy structure. It is in an artesian district, but the surface wells are 30 or 40 feet deep, showing that there is no standing water near the surface of the ground. At Chino sugar beets are grown without irrigation under the average conditions here reported. At Pomona orchards and vineyards flourish for months without any rainfall whatever, and with no standing water within 20 or 30 feet of the surface of the ground.

WHEAT LANDS.

In the great wheat areas in the northern part of the San Joaquin Valley of California, in the Palouse district around Pullman, Wash., and on the foothills at Wallawalla, Wash., and at Bozeman, Mont., the soils produce fine crops of wheat without irrigation. In Montana and Washington the crop is harvested during September or the very last of August. It is therefore strictly a summer crop, and is produced during the months for which the records are here given. The soils all have, undoubtedly, the power of retaining the winter rains and of giving the moisture up to the crops as it is needed. The rainfall amounts to from 13 to 18 inches, and most of it falls during the winter months. With so little rainfall it is doubtful, and by many it is thought to be wholly improbable, that any of the water leaches downward through the soil and runs off in the country drainage. By far the largest portion at any rate, and probably in most cases all, of the rainfall evaporates from the surface of the ground or is transpired by the growing crop.

In the humid regions of the Eastern States, with 40 inches of annual rainfall, half of this leaches down and runs off in the drainage. This leaves but 18 or 20 inches of rainfall there for the use of crops. This is a familiar fact, and under the conditions it is perfectly possible to make a crop if the rainfall is well distributed. The soils have no such power, however, as they have in the extreme West of retaining moisture, a drought of a few weeks' duration in the East doing more harm to the crop than a drought of the same number of months would do in these Western soils. The soils at Pullman are typical of these fine wheat lands, in that they are very deep and there is no difference between the soil and the subsoil, to a great depth at least. The soil is a fine loam, derived from the disintegration of basaltic rocks. The wells are from 30 to 40 feet deep, occasionally 200 feet. The surface soil dries out during the summer to a considerable depth and dry dust is left on the surface. This dry surface, however, seems to protect the soil from excessive loss of moisture through evaporation and to conserve the moisture for the use of the crop.

The foothills soil of Bozeman, Mont., produces without irrigation a very sure crop of hard wheat. In the valley between the mountains, with but little difference in the elevation and within 1 or 2 miles, the valley soil has to be irrigated several times during the season, and the wheat produced is a soft wheat. Surely there are no more interesting conditions affecting the relation of soils to water and to crops than those present in these two soils at Bozeman, and their investigation should throw much light on this interesting subject.

It is interesting to compare the conditions prevailing over the noted wheat areas of the Red River and Jamestown valleys of North Dakota. At Fargo and Jamestown there is an average of about 20 inches annual rainfall and about 2 inches per month during the crop season, so that the rainfall is very well distributed throughout the year. At Bismarck, with the same rainfall and apparently the same distribution, the conditions are altogether different, and there are soils upon which the crop is always uncertain. There is thus shown to be a great difference in the relation of these wheat soils to water. There are only certain kinds of soils which have that extraordinary power of conserving the moisture for the use of crops possessed by the soils at Pullman, the foothills soil at Bozeman and Wallawalla, and the soils of the northern part of the San Joaquin Valley.

DESERTS.

The Weather Bureau records show that on the Mohave desert the average annual rainfall is about 5 inches. Only three-tenths of an inch falls during the season from May to September. The Weather Bureau records show that no rain fell at Mohave during the present season from the first of May to the middle of September. The soils were examined about the middle of September at least 20 miles from the mountains in the midst of a level plain. It was expected that it would be necessary to go to a considerable depth in order to find moist soil.

The surface of the desert is covered with a rather coarse sand, somewhat compact below the surface of the ground. This compact sand is frequently exposed as the loose surface sand is blown off. Contrary to expectation the soil at a depth of from 12 to 18 inches below the surface was still quite moist, in spite of the fact that no rain had fallen for at least five and a half months. The surface wells vary in depth from 6 to 30 feet, occasionally being 200 feet deep. On certain parts of the desert it is the common practice to dig holes 6 or 10 feet deep and allow them to fill up with water for the use of the stock. The distance to water varies according to the nature of the soil, just as it does in the humid portions of the country. The soils in which the water is close to the surface are, as a rule, impregnated with alkali. There is an artesian belt under a portion of the desert. The amount of moisture found in this land was probably not sufficient to support a crop of any of our commercial plants, and what moisture there was, was alkaline, but the fact of there being any moisture at all, with no rain for such a long time, is a matter of the greatest surprise, and is a subject worthy of very careful investigation.

Investigation showed the same conditions to exist on the Nevada and Utah deserts between Reno and Ogden. The annual rainfall is between 5 and 6 inches, the seasonal rainfall about 1 or 2 inches on the average. During the present season there has been no rainfall since the first of May at Tecoma, where a careful examination was made, except a single shower two or three days before the examination. This was not sufficient to have penetrated to any great extent. The soil here is quite alkaline, and is covered with an alkali crust in many places. The alkali consists mainly of common salt, although there are in places considerable quantities of sodium carbonate (black alkali) and some sodium sulphate. In a cellar 5 feet deep the soil on the sides and bottom was quite moist, and the owner of the place stated that it was never dry. Borings made to a depth of several feet in this soil showed that the moist soil extended down to a considerable depth, probably down to water level. There was a well at this place about 30 feet deep. It is stated that water can be found on these deserts about 30 feet below the surface, although the water may be so strongly impregnated with salts that it is unfit for use. The average depth of farm wells throughout the whole of the United States would probably be not far from 30 feet. How is it that these desert soils, 500 miles away from any considerable rainfall area, approach the normal conditions in this respect? In the second place, how is it that with standing water at about the same depth below the surface, and with hardly a tenth of the annual rainfall, these soils are still moist within a comparatively few inches of the surface after five or six months of dry weather?

If the amount of water in these desert lands was supplemented by an amount which would make the quantity equal to that contained in the wheat-producing soils already referred to, and if this water was added at one time during the winter season, could crops be profitably grown upon the soils without subsequent irrigation? These and various similar questions force themselves upon the mind in contemplating the conditions which prevail in these districts. There are here opportunities to study the relation of soils to moisture and crop production which are not offered in any other section of the United States. An investigation of these conditions will undoubtedly throw light upon many problems upon which the development of agricultural methods will depend, and these problems can be studied best under the peculiar conditions of soil and climate prevailing in the West.

THE LOW RELATIVE HUMIDITY.

A fact which makes more remarkable this extraordinary power of the soils to absorb and retain a sufficient quantity of water for the needs of crops for five or six months after the rain ceases is the very low relative humidity of the atmosphere. Records of the relative humidity have been taken from only a few of the places under consideration, and these are given in the following table:

Mean annual and seasonal relative humidity.

Locality.	Annual.	May to September.	July and August.
	Per cent.	*Per cent.*	*Per cent.*
Tulare, Cal	58	42	35
Wallawalla, Wash	62	47	39
Miles City, Mont	65	52	46
Bismarck, N. Dak	72	67	65
Humboldt, Nev	48	36	31

The mean relative humidity of New England for July and August, 1897, determined from the reports of seven Weather Bureau stations, was 85 per cent. At Wallawalla the mean relative humidity from May to September was only 47 per cent, and for July and August 39 per cent. It is hardly conceivable that under these extremely dry conditions the foothills soil could maintain sufficient water from the winter rains to supply the loss due to evaporation from the surface of the soil and to transpiration by the plant for months after the rain had ceased to fall. At Tulare the mean relative humidity during the growing season is 42 per cent, and 35 per cent during the months of July and August—conditions which practically prevail at Fresno. Nevertheless, at Fresno, with nearly the same rainfall and where crops must transpire great quantities of moisture into the dry atmosphere, the soil maintains an adequate supply of moisture for the plants, provided the water continues to run in the canals, although these may be as much as a mile apart.

At Visalia the mountain streams run out and disappear. They are absorbed in the light, loamy soil. The area upon which these conditions exist is said to be about 24 miles square. Vineyards and orchards grow on this soil in the most satisfactory way without irrigation, although there is no rainfall during the growing season. It is a natural oasis in the midst of the dry plains, and is characterized by a fine growth of native trees.

At Humboldt, on the Nevada desert, the relative humidity from May to September is about 36 per cent, and in July and August 31 per cent. The conditions over the Mohave desert are probably not dissimilar from those at Humboldt and Tulare. How is it possible, under the conditions of extremely low rainfall and this low relative humidity, for the soil to retain moisture within 12 or 18 inches of the surface for months after the rains are over?

LINES OF INVESTIGATION.

It must be possible to determine the cause of the great power these soils have of retaining moisture and of supplying it rapidly and regularly to the crops as it is needed. If such power can be imparted to other soils of a droughty character, especially to our soils in the East, it will be of immense value to the farmer. It is clearly apparent from a careful consideration of the conditions presented here, that we know very little of the possibility of the water-holding power of soils and the control of soil moisture. An investigation of these conditions in the section under consideration will throw light upon the problem which can not so readily be secured under any other conditions. There are many young men in the West developing the work of the experiment stations who are already interested in the general subject of soil investigations and earnestly desirous of seeing certain lines of work and of investigation determined for them to follow out. To them, therefore, the study and investigation of the above problem is earnestly commended. Others can investigate the effect of the methods of cultivation, the effect of fertilizers, and the effect of the rotation of crops, but no one has such a good opportunity to study the relation of soils to water and the conservation and movement of water in the soil as those located in the arid regions of the West.

The first question to solve is the distribution of the rainfall. It is important to determine the depth to standing water, that is, the average depth of wells. Then it is very important to know whether any portion of the rainfall passes down into this stratum and runs off into the drainage. The electrical method of moisture determination is admirably adapted to the study of this problem. Electrodes should be buried in the soil at intervals to a depth of from 15 to 20 feet, the interval between the electrodes varying from a few inches immediately below the surface to 4 or 5 feet at the greater depths. The resistance at the deeper electrodes should be determined about once a week. The movement of water, if it takes place at all, will probably be very slow at that depth, but any change will certainly be revealed by corresponding changes in the electrical resistance of the soil. If the electrodes are well placed in the soil at intervals of a few inches in the upper layers and of a few feet in the lower strata, the distribution of the rainfall in the soil may be very carefully studied throughout the year. It would be well worth while to install a very complete system of electrodes; for with the periodic rains there is no doubt a great wave of water going down into the soil, reaching its maximum and minimum at certain depths at different times of the year. The form and the magnitude of this wave is very important.

If the annual rainfall does not descend low enough to form any connection with the underground water drainage, is it possible that 12 to 18 inches of rainfall, occurring during the winter months, is sufficient to maintain crops for five or six months of dry weather with a low relative humidity and often high temperature of the atmosphere, without any additional water supply from any source? In other words, does the crop live on the rainfall which is stored and maintained for its use, or is it dependent partly upon seepage waters which move in from the surrounding country?

Is it possible that in the arid conditions existing over the desert areas there is a slow and continuous movement of water upward from artesian or other sources below the influence of the local climate? The accumulation of alkali on the surface of many of these desert lands seems to point to the gradual but infinitely slow movement of water upward from the lower depths of the earth. Does such a movement really exist, and is it of sufficient magnitude to be taken account of in the practical cultivation of the lands?

The problem presented by these soils as at present understood may perhaps be illustrated by a hypothetical experiment: If a large galvanized iron tank 15 feet deep and 15 feet square were filled with the soil of the Palouse region in its natural condition in the field, and an amount of water equal to 18 inches of rainfall were added to this soil after a crop had been removed or during the winter months, would crops suitable to that climate, including small grain and fruit trees planted after the watering had been done, grow to maturity during the summer months in spite of prevailing high temperature and low relative humidity, without any additional water being added throughout their growing season? Would 18 inches of rainfall be sufficient for this? or 16? or 14? or 12? or 10? In fact, we come finally to this question: What is the minimum requirement of these soils to enable them to support a field crop?

The conditions are so uniform that it would be easy to figure quite closely on this. It is already recognized in practice that some soils, especially those in the more southern districts, retain enough of the winter rains for a crop like wheat, which matures early in the summer, but do not maintain quite enough to mature a crop of corn, which extends on into the late summer and fall in an active growing condition. It was even stated this summer that the crop suffered in certain localities in southern California in August and September, owing to a shortage of half an inch in the April rainfall.

It is not all soils by any means, even in the same district, that show this remarkable power of conserving moisture, and the different soils possess it in different degrees. It does not seem to be a matter of texture, as there is no marked difference between the foothills soil, which will retain the moisture, and the valley soil, which needs irrigation.

It is not sufficient that a soil should be very retentive of moisture and hold a large portion of the rainfall. It must conserve this moisture, there must be little evaporation from the surface, but at the same time it must move readily and rapidly up to the roots of plants to supply their needs. These requirements must be great under the almost tropical arid conditions of the summer climate of those localities. It is, therefore, not only the water capacity of the soil, but also the ability of the soil to supply this water to the crop as needed, which determine its agricultural value.

The following table gives the annual and seasonal rainfall at a large number of stations of the Weather Bureau adjacent to the localities which have been discussed. These are arranged in order of the rainfall during the season from May to September. It is interesting to study this material, together with the practice of agriculture at the different places.

Mean annual and seasonal rainfall.

Locality.	Annual.	May to September.	July and August.
	Inches.	*Inches.*	*Inches.*
Mohave, Cal	5.0	0.3	0.1
Chino, Cal	15.7	0.3	0.1
Reno, Nev	5.3	0.4	0.0
Yuma, Ariz	2.8	0.5	0.4
Tulare, Cal	7.0	0.6	Trace.
Pomona, Cal	19.4	0.6	Trace.
Fresno, Cal	9.3	0.7	Trace.
Los Angeles, Cal	17.2	0.7	0.1
Stockton, Cal	13.2	0.9	Trace.
San Bernardino, Cal	16.6	0.9	0.2
Wadsworth, Nev	4.1	1.0	0.3
Merced, Cal	10.3	1.0	Trace.
Humboldt, Nev	5.6	1.2	0.0
Claremont, Cal	18.0	1.2	0.2
Elko, Nev	6.3	1.6	0.3
Tecoma, Nev	5.0	1.7	0.4
Carson City, Nev	12.1	1.7	0.4
Golconda, Nev	5.9	2.0	0.2
Winnemucca, Nev	8.5	2.0	0.2
Ellensburg, Wash	9.0	2.0	0.3
Phœnix, Ariz	7.1	2.8	2.0
Ogden, Utah	14.0	3.4	0.6
Spokane, Wash	18.6	3.7	0.7

Mean annual and seasonal rainfall—Continued.

Locality.	Annual.	May to September.	July and August.
	Inches.	*Inches.*	*Inches.*
Grand Junction, Colo	9.0	4.0	2.3
Wallawalla, Wash	15.4	4.5	0.8
Colfax, Wash	23.0	5.1	0.9
Fort Lapwai, Idaho	17.2	5.1	1.0
Fort Spokane, Wash	11.8	5.2	1.1
Pullman, Wash	22.8	5.3	1.1
El Paso, Tex	8.9	5.9	3.5
Salt Lake City, Utah	18.7	6.3	2.2
Boulder, Mont	9.6	6.6	1.7
Miles City, Mont	12.8	6.7	1.3
Fort Missoula, Mont	16.1	6.7	1.7
Helena, Mont	13.2	6.8	1.7
Greeley, Colo	11.4	6.9	2.9
Medora, N. Dak	11.9	7.0	1.8
Fort Custer, Mont	13.2	7.8	2.0
Fort Keogh, Mont	12.6	8.0	2.1
Denver, Colo	14.3	8.0	3.1
Pueblo, Colo	12.0	8.5	4.3
Fort Collins, Colo	14.0	8.6	3.1
Santa Fe, N. Mex	14.6	9.0	5.4
Glendive, Mont	15.8	9.5	2.1
Bozeman, Mont	18.2	11.2	3.3
Bismarck, N. Dak	18.5	11.5	4.3
Jamestown, N. Dak	20.3	11.8	4.2
Fargo, N. Dak	19.5	13.9	5.6

THE TEXTURE OF THE SOILS.

A large number of soil samples were collected from North Dakota, Montana, Washington, California, and Nevada during the season of 1897. A description of some of the most interesting of them is given, as follows:

3279. Two miles west of Mapleton, Cass County, N. Dak. Typical Red River Valley wheat land. Sample collected between depths of 15 and 36 inches.

3264. Four miles north of Jamestown, Stutsman County, N. Dak. Prairie. Wheat land of Jamestown Valley. Depth, 9 to 24 inches.

3291. Bismarck, Burleigh County, N. Dak. Sandy prairie. Depth, 15 to 40 inches. Wheat fails on this soil three out of five years.

3285. Steele, Kidder County, N. Dak. Prairie. Depth, 20 to 30 inches. Wheat fails three out of five years.

3322. Eleven miles west of Billings, Yellowstone County, Mont. From prairie above the ditch. Depth, 12 to 24 inches. Wheat can not be produced on this soil without irrigation.

3331. Two miles east of Pullman, Whitman County, Wash. Typical Palouse country wheat land. Depth, 0 to 36 inches. Produces large and very sure crops.

3348. Wallawalla, Wallawalla County, Wash. Valley land. Depth, 0 to 12 inches. This soil is extensively irrigated and cultivated in truck and fruit. Wheat is very uncertain on this soil without irrigation.

3352. Seven miles east of Wallawalla, Wallawalla County, Wash. Typical foothills soil, upon which large and sure crops of wheat are produced without irrigation. Depth, 0 to 12 inches.

3394. Six miles north of Fresno, Fresno County, Cal. Sandy loam. Depth, 0 to 36 inches. This soil requires no irrigation except that the water runs through the ditches throughout the season to supply lands lying beyond.

3416. Visalia, Tulare County, Cal. Depth, 0 to 12 inches. Very fine fruit land, and requires no irrigation.

3378. Tulare, Tulare County, Cal. Alkali land. Depth, 1 to 24 inches. This land requires irrigation for all crops.

3432. Three miles southeast of Pomona, Los Angeles County, Cal. Sandy land. Depth, 2 to 36 inches. Second crop of tobacco being harvested from this land since last rain; soil still moist below the surface, and tobacco is quite vigorous. Crops need no irrigation.

3388. Lancaster, Los Angeles County, Cal. Barren land of the Mohave desert. Depth, 3 to 36 inches. No crops grown without irrigation.

3419. Tecoma, Elko County, Nev. Black alkali land. Depth, 12 to 24 inches. From the Nevada desert. No crops grown without irrigation.

The following table shows the results of the mechanical analyses of the above samples:

Mechanical analyses of soils.

No.	Locality.	Description.	Moisture in air-dry sample.	Organic matter.	Gravel (2-1 mm.).	Coarse sand (1-.5 mm.).	Medium sand (.5-.25 mm.).	Fine sand (.25-.1 mm.).	Very fine sand (.1-.05 mm.).	Silt (.05-.01 mm.).	Fine silt (.01-.005 mm.).	Clay (.005-.0001 mm.).
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
3279	Mapleton, N. Dak.	Red River Valley.	7.84	7.72	0.03	0.07	0.18	0.94	11.51	25.94	6.06	38.00
3264	Jamestown, N. Dak.	Prairie	4.48	4.33	0.86	2.10	6.37	16.69	21.70	14.57	2.75	25.55
3291	Bismarck, N. Dak.	Sandy prairie	2.54	6.02	1.74	6.61	10.67	4.23	28.91	21.17	1.79	16.48
3285	Steele, N. Dak.	Prairie	4.46	5.18	0.00	0.09	0.42	1.87	41.18	22.97	3.58	19.57
3322	Billings, Mont.	do	2.98	4.40	0.00	0.00	0.16	7.96	28.79	34.45	4.67	17.25
3331	Pullman, Wash.	Palouse district—basalt.	5.51	5.08	0.03	0.16	0.16	0.85	27.94	35.80	5.77	18.57
3348	Wallawalla, Wash.	Valley land	4.12	3.08	0.00	0.15	0.41	3.22	35.24	37.73	3.54	12.63
3352	Wallawalla, Wash.	Foothills soil	3.95	5.66	0.00	0.06	0.08	1.05	25.12	42.12	4.24	17.50
3394	Fresno, Cal	Sandy loam	1.61	2.52	0.43	3.40	16.14	30.95	15.90	12.72	1.58	14.60
3416	Visalia, Cal	Loam	2.85	5.85	0.03	0.18	0.61	5.41	34.28	34.28	3.50	14.20
3378	Tulare, Cal	Alkali land	2.72	4.44	0.64	2.57	6.22	12.46	22.79	21.36	6.51	21.05
3432	Pomona, Cal.	Sandy land	1.00	1.94	6.03	10.11	17.26	21.92	20.98	13.13	1.93	5.33
3388	Lancaster, Cal.	Mohave desert	1.77	3.81	0.34	0.89	1.67	7.86	35.12	28.43	3.45	18.63
3419	Tecoma, Nev.	Nevada desert.	3.17	6.43	0.07	0.13	0.37	5.24	44.96	17.94	5.00	17.93
	Average.		3.50	4.75	0.73	1.89	4.33	8.62	28.17	25.90	3.88	18.37