Oregon Agricultural College
Experiment Station

BIENNIAL REPORT

Oregon Soil Investigations

1918-1920

JANUARY, 1920

CORVALLIS, OREGON

STATION STAFF IN SOILS

	Time allotted Station work 1920 basis
Jardine, J. T., Director of the Experiment Station.	
Powers, W. L., Chief in Soils	25%
Ruzek, C. V., Associate in Soil Fertility	20%
Torgerson, E. F., Assistant in Soil Survey	18%
Johnston, W. W., Assistant in Irrigation	30%
Cretcher, Ward, Assistant in Drainage	10%
Ritchie, Douglas, Assistant in Soils and Field Agent, Burns	50%
Tuck, John, Field Agent, Redmond	4 mo.
Alicante, M. M., Field Agent, Moro—half time	4½ mo.
Assistant in Soil Survey	1 mo.

CONTENTS

December 29, 1920

To the President of the College,

Sir:

I hereby submit for publication the Report of the Department of Soils of the Experiment Station for the biennium ended December 31, 1920.

This report discusses briefly the investigations conducted, the results secured, and services rendered with funds made available through a special State appropriation of $7500 per annum for the biennium (Chapter 350, Session Laws, 1919).

Attention is directed also to investigations under way which should be continued and to other investigations which should be undertaken if the important problems of soil improvement and maintenance are to be effectively investigated for the different important sections of the State. In these matters as well as in the discussion of investigations undertaken the report has my most hearty endorsement.

JAMES T. JARDINE,
Director, Experiment Station.

BIENNIAL REPORT

Oregon Soil Investigations

INTRODUCTION

To the President and Board of Regents of Oregon Agricultural College, and the Director of the State Agricultural Experiment Station,

Gentlemen:

Herein are reported the soil investigations conducted during the biennium now closing, pursuant to the provisions of chapter 350, Session Laws of 1919, including studies completed, those under way, and others needed to maintain efficiently the soil improvement work.

Soil investigations like other developmental work were seriously affected by the war; field men withdrew to enter the military service, and costs increased. Yet good progress has been made. Several studies have been concluded and reported in bulletin form. Seventeen specific experimental projects are under way, dealing with different phases of soil survey, irrigation, drainage, and soil fertility.

Soil is the greatest basic resource of the State, and its reclamation, improvement, and preservation are vitally related to the welfare and permanent prosperity of the commonwealth. Next to the soil itself the water, which gives value to arid land and furnishes our perpetual supply of "white coal," constitutes our greatest public resource. Oregon soil investigations deal with feeding and watering of plants. The purpose of these investigations is to discover and establish practical methods of increasing and permanently maintaining the productive capacity of Oregon soils. Important subjects covered include soil surveying, physical composition and properties, soil moisture control, irrigation, drainage, dry farm tilling, soil fertility, soil acidity, alkali control, crop rotation, and soil management.

COOPERATION

Cooperation of the United States Department of Agriculture, and of the branch experiment stations has helped in carrying on soil studies. Many farmers have generously cooperated in the work and three of the larger experimental fields are under contract. The United States Bureau of Soils cooperates with the State Experiment Station to the extent of maintaining two field men on the detailed soil survey work during the growing season, and in publication of reports. The United States Office of Irrigation Investigations and the Bureau of Plant Industry temporarily discontinued cooperation, due to reductions in their appropriations.

SUMMARY OF SOILS PUBLICATIONS DURING BIENNIUM

BULLETINS

157. **The Improvement of Marsh Lands in Western Oregon.** Powers, W. L. This bulletin reports data which show that tile can be successfully used in tide lands. It reports successful methods employed in tiling at the Astoria branch experiment station on overflow and tide lands, of which there are one hundred fifty thousand acres on the Oregon coast and on the lower Columbia and other streams. Feasibility surveys and tiling experiments have proved that to both classes

of this land, drainage is an improvement, and that it is feasible and desirable from an agricultural, engineering, and economic standpoint.

Drainage-district procedure under the State Drainage Law is outlined, and the design and construction of dikes, tide boxes, outlet ditches, and pumping plants are briefly described. The design, installation, and early operation of the tile system in the diked tide land of the branch station at Astoria are recorded.

Preliminary results from experimental sections of this tile system indicate that tile placed four feet deep with lines five rods apart will sufficiently control the excess water and water table, and provide suitable drainage for staple field crops on tide lands. Where outlets limit the depth of laterals to three feet the lines should be put four rods apart.

Fig. 1. TALENT IRRIGATION DISTRICT DITCH BRINGING WATER TO DRY LAND

Upper Rogue River Valley. The wealth of Oregon rests in her soils, their development, utilization, and preservation; and next to the soil itself the water that gives value to arid lands and affords our perpetual supply of "white coal," constitutes our greatest public resource.

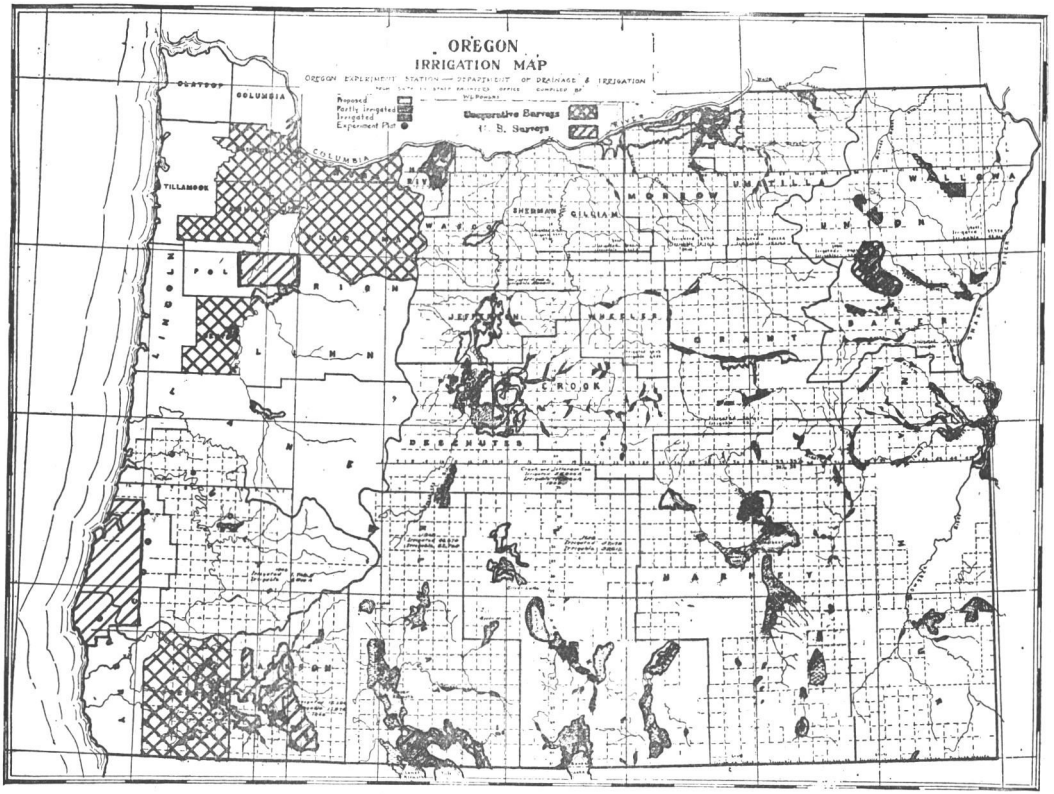
For truck crops, or valuable onion land, like the beaver-dam soils, spacing three rods apart is desirable, yet a depth of four feet should be maintained at this closer spacing on account of soil shrinkage. Silt loam having some variation in topography, like the overflow and "bank land," may require only a natural system of interior tiles to take care of the interior water in question.

Experiments indicate that near the north Oregon coast tide boxes should have a capacity of one square foot to each twelve acres. On the lower Columbia suplementary pumping plants which have a capacity to handle one-quarter to one-half inch an acre of rainfall in twenty-four hours are satisfactory. Measurements of outflow indicate

"We must remain a self-supporting country and raise food enough within our borders to feed our people."

Fig. 2. MAP SHOWING PROGRESS OF SOIL SURVEYS

Detailed soil surveys have been made of cross-hatched areas, constituting only one-fifth of the tillable area of the State. General or feasibility surveys have covered most of the shaded areas, thus increasing the total area covered to one-third of the tillable area of the State. At the present rate two or three summers will be required to complete the soil survey of the Willamette Valley.



that near the north coast of Oregon tile may need a capacity to handle one inch an acre in twenty-four hours, near the south coast seventy-five hundredths of an inch, and in the Willamette Valley one-third to one-half inch an acre. The tile drainage system described has disposed of excess water and reduced the water table, frequently running full for several days at a time in heavy weather.

The cost of the tile system as designed, averaged about $40.00 an acre as installed. The first crop, five tons of field-pea hay to the acre, is double the yield on the portion not yet tiled. This crop was worth $20.00 a ton at the time, so that the cost of tiling was repaid by the first crop. Tiling will double the productive value on the greater part of the marsh lands in Western Oregon.

The reclamation of these lands consists of three operations. (1) Protection work. (2) Field of Farm Drainage. (3) Subjugation of wild Growth and Establishment of Improved Crops. These latter operations are described.

Fig. 3. TANK USED FOR WATER REQUIREMENTS STUDIES

Water requirement, wilting point, and irrigation requirement are there determined. The wild meadow grasses have been found to require 1000 pounds and upwards of water to the pound of dry matter, while alsike and timothy require about 600 pounds under average conditions. The wilting point for clover has been determined to be substantially lower than for potatoes, and this affects the time for most profitable irrigation. (See Station Bulletin 167.)

160. **The Small Irrigation Pumping Plant.** Powers, W. L., and Gilmore, W. J. This bulletin describes the selection of pumping machinery and the installation and operation of the same. The cost, value, and profit from irrigation by pumping at the home Station at Corvallis for the twelve-year period are reported, as well as the pumping operations at the Harney Valley Branch Experiment Station.

161. **Duty of Water in Irrigation,** Powers, W. L. Irrigation requirement is defined as that portion of the total water needed by crops

which should be supplied artificially, as by irrigation. "Water requirement" is described as the total water, including rain, soil, and irrigation water, needed per ton or bushel produced. The results of twelve years' irrigation experiments are sumarized to show: (1) the maximum returns per unit of water, (2) the maximum returns per unit of land, and (3) the maximum net profit an acre.

The highest probable duty of water, where rainfall and soil water are negligible, based on the average water requirement of the plants that have each year given the maximum net profit an acre, gives a water requirement for crops as follows: 5.25 inches per ton for alfalfa; 3.84 inches per ton for clover; 4.27 inches per ton for clover and timothy; .50 inch per ton for mangels; and 3.00 inches per hundred bushels for potatoes. On this basis the duty of water is not likely to be less than 21.00 inches for a four-ton yield of alfalfa, or 31.50 inches for a six-ton yield.

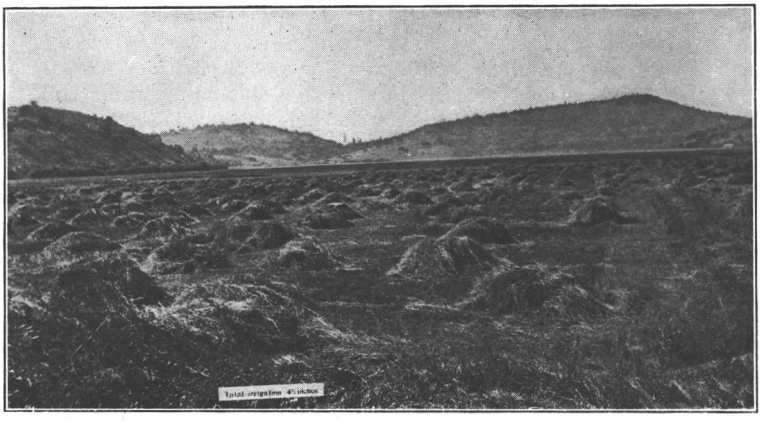
The factors affecting duty of water are summarized. The value of rotation, manure, and irrigation in reducing the irrigation requirements is reported from long-time experiments.

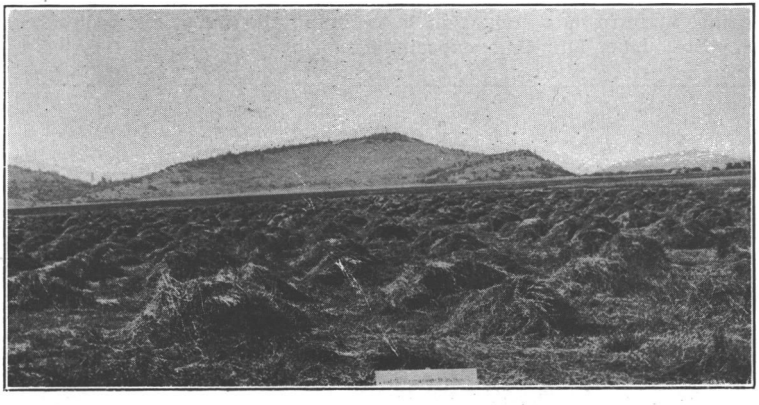
Fig. 4. WEIR USED IN IRRIGATION AND DUTY OF WATER STUDIES

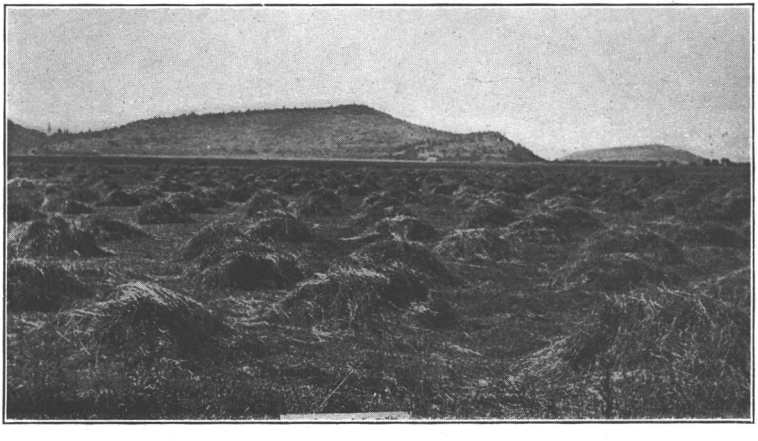
(From Station Bulletin 140)

163. **Sulfur As a Fertilizer for Alfalfa in Southern Oregon.** Reimer, F. C., and Tartar, H. V. This bulletin reports experiments by the Southern Oregon Branch Experiment Station in cooperation with the Station chemist, showing that sulfur is the most profitable fertilizer for alfalfa in that section.

"The most important material problem of the United States is to maintain the fertility of the soil."—Cyril G. Hopkins.







Figs. 5, 6, 7. VIEW OF DUTY OF WATER PLOTS, KLAMATH, 1919
Above, total irrigation, 4½ inches; middle, total irrigation, 6 inches; below, total irrigation, 9 inches. (From Station Bulletin 167)

164. **The Soils of Jackson County,** Tartar, H. V., and Reimer, F. C. Studies reported were conducted largely by the Southern Oregon Branch Experiment Station and in cooperation with the Station chemist. Soil analyses, results of fertilizer trials, and methods of management of Southern Oregon soils are given.

167. **The Improvement and Irrigation Requirement of Wild Meadow and Tule Land,** Powers, W. L., and Johnston, W. W. This study was begun to determine a reasonable duty of water for wild meadow land at a time when the duty of these lands was very low, and when the water requirement of wild grass was unknown. Investigations covered a period of five years, or five seasons' experiments with tanks and diked

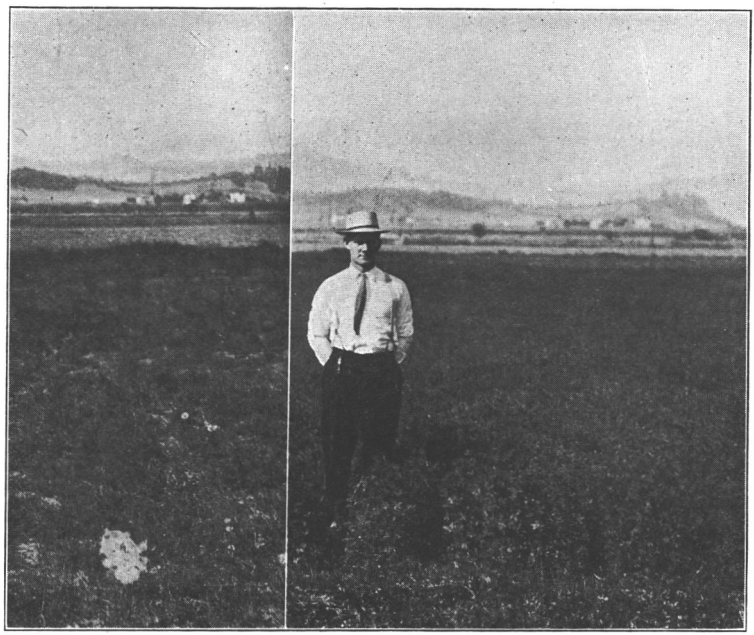


Fig. 8. IRRIGATION VERSUS NO IRRIGATION, CORVALLIS

The plot at the left has been in unirrigated alfalfa for twelve years, and the average yield has been 3.25 tons an acre. The plot at the right has received irrigation averaging six inches depth a season, and the average yield in the twelve years has been 5.32 tons.

fields, controlled by drainage and irrigation pumping plants and located in Harney, Chewaucan, and Klamath basins. In Oregon there are over a half million acres of these lands and in the West several million acres.

The results of the past five years show that an average depth of eighteen inches of water on the field could produce the maximum yield now

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"The rule is almost universal that old land is less productive than new land. If the art of agriculture has ruined land, the science of agriculture must restore it."

obtained. An average of twelve inches has been given the largest yield per acre inch. The water requirement of wild grasses ranged from one thousand pounds per pound of dry matter and upward, while for alsike and timothy or field peas and oats when substituted on these lands, it was about six hundred pounds. By control of water and some storage, systematic irrigation and drainage, and the use of the strip-border system, the greater part of this area could be made to produce three to four tons of field peas and oats, or of alsike and timothy, or especially in Harney Valley three to five tons of alfalfa. In other words more than twice the feed value can be produced and with less than half the water formerly used. An increase of one ton an acre on these lands represents half a million tons possible increase in the Eastern Oregon hay crop.

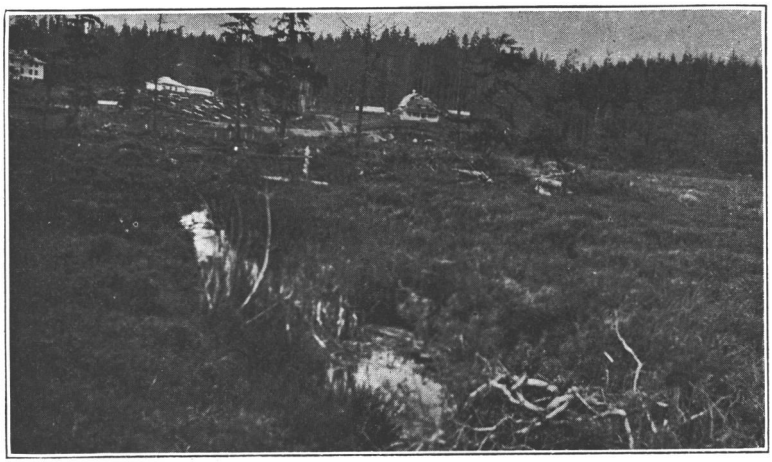
Fig. 9. IRRIGATED GRASS MIXTURE ON HEAVY SOIL AT CORVALLIS

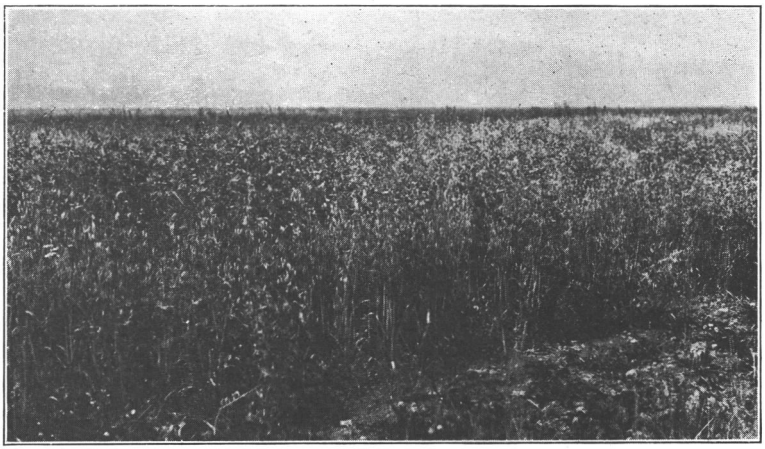
A grass and clover mixture has stood on this land for five years, yielding from five to six tons a year, besides affording late pasture. More grass mixtures are needed for pasture on irrigated lands.

173. Irrigation of Potatoes, Powers, W. L., and Johnston, W. W. This new bulletin summarizes the results of twelve years' experiments in the irrigation of potatoes, under conditions where the rainfall for the growing season, April 20 to October 1, is five and one-half inches and the average evaporation is about twenty-four inches for the period. The main experiments were conducted on the Willamette silty clay loam, which has a usable moisture capacity of nearly two acre inches to the acre foot.

Irrigation gave a higher seasonal moisture content and this was associated with higher yield. Two irrigations proved better than the same amount applied in one heavy irrigation for potatoes. The most economical returns were secured with light, frequent irrigation, which provided a uniform moisture content. Irrigations of one inch every ten days have given very economical returns and constitute good practice for gardens.

The best time to irrigate potatoes in this soil is when the soil moisture content of the first foot drops to the twenty-percent point, dry weight. Two light irrigations have given good returns, and three light irrigations have given economical returns for this crop in dry season.





TIDE LAND BEFORE AND AFTER DRAINAGE

Fig. 10. Tide land at Astoria branch station before drainage.
Fig. 11. Four-ton yield of field peas and oats at Astoria station after tiling. The first crop paid for tiling the reclaimed area. There are 150,000 acres of similar lands in Oregon, most of which it is feasible to reclaim. (Station Bulletin 157)

The most economical return obtained with potatoes has been secured when the depth applied per season was two or three inches in wet seasons and six inches in dry seasons; the maximum yields of potatoes have been

produced with three or four inches in wet seasons and six inches in dry seasons. Application of nine inches depth decreased the yield below that obtained with six inches of irrigation. Ten to eighteen rods have been proved a suitable length of run for irrigation furrows on the type of soil employed. It was found disastrous to neglect cultivation after irrigation.

The water requirement under field conditions has been greatly reduced by the use of a moderate amount of irrigation. Water requirement varies about the same as do the most economical returns per acre inch. Above the most economical yields per acre inch the water requirement is increased. Growing potatoes on irrigated legume sod reduced the water requirement about twenty-five percent below the water requirement of potatoes on dry-farmed legume sod. Water requirement can be greatly reduced in irrigation by practicing a good rotation, including legume crops, by using good varieties, maintaining a good state of fertility and tilth, irrigating at just the right time and in proper amounts, and practicing good general farm methods.

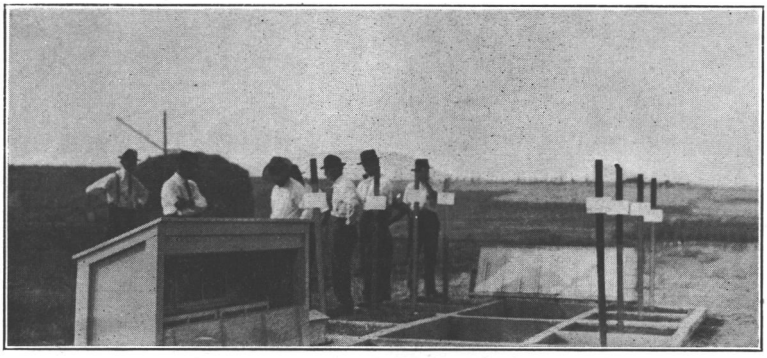


Fig. 12. DRAINAGE GAUGES OR LYSIMETER TANKS

These tanks, used for studies at Hermiston and Corvallis, are the only lysimeters in the West. Water capacity of soils, factors affecting percolation, and plant foods lost in drainage are thus studied.

Proper irrigation did not injure the palatability or marketability of potatoes. Twelve years irrigation had little appreciable effect on soil acidity, or on content of available plant food. Soil temperature was lowered by irrigation of potato plots as much as 3°F. at two inches below the surface. Heavy irrigation increased the moisture content of potatoes, caused a higher proportion of vines to tubers, and slight change in chemical composition of the product Proper irrigation decreased the percentage of culls.

In Central Oregon experiments, sulfate of potash increased the yield per acre inch from twenty-four and one-half bushels on untreated to thirty-nine bushels on treated land. In the Eastern Oregon experiments, irrigation of five to nine inches depth an acre has given the best results; and in several of the potato-producing sections, the best yields have frequently been obtained with six to eight inches total depth, applied in two or three doses.

"The city is the first to feel the country's poverty."

Soil Survey of Yamhill County, Oregon. Cocher, A. E., and Carpenter, E. S. (of the U. S. Bureau of Soils) and Ruzek, C. V., and Cooter, J. E. (of the Oregon Agricultural College Experiment Station). This report and colored soil map is of Yamhill county, which has an area of 445,440 acres. The climate and agriculture of the area are described, and the occurrence and character of each soil type are given, together with suggestions as to its management.

Fig. 13. OUTLET DITCH, TRASK DRAINAGE DISTRICT, TILLAMOOK COUNTY

The first drainage district organized under the 1915 Drainage Law was in Tillamook county, where there are now ten drainage districts. There are over fifty drainage districts now organized, and the Soils department has made feasibility surveys and assisted in organization of practically all of them.

Rational Use of Lime. This circular contains an acidity and rainfall map of the State and recommends application of lime where legumes are to be grown on soils that are known to be acid and of medium fertility. Forms of agricultural lime and rate and method of application are explained.

SCIENTIFIC PAPERS AND PRESS ARTICLES

The Soils department has issued on an average a press article a week during the past biennium. About half of the bulletins given above have been in such demand that they are now out or nearly out of print. A list of bulletins and mimeograph circulars issued on soils, is appended. There has been heavy call for the circulars and mimeographs.

"Thorough work renders sufficient the smallest quantity of ground to each man; and this conforms to what must occur in a world less inclined to wars."—Abraham Lincoln.

PROGRESS REPORT OF SOIL PROJECTS UNDER WAY

A. COOPERATIVE SOIL AND FEASIBILITY SURVEYS—CLASSIFICATION AND IMPROVEMENT

Soil Survey

The field work for the soil survey of Josephine and Multnomah counties was completed during the season of 1919. Some work was done in Benton county also. Work was completed in Benton county in 1920, and field work was conducted also in Clackamas county. Two field parties, each composed of one man from the department, and one man from the United States Bureau of Soils, equipped with an "auto," work during the summer. The areas of these counties are mapped in detail, except the land included in National forest. The published Soil Report and Soil Map of Yamhill county has been received from the press, and the Washington county report is in press. Up to the present time, reconnaissance soil surveys have been made of about one-third of the agricultural land in the State,

Fig. 14. RYE ON RECLAIMED TULE LAND WEST OF UPPER KLAMATH LAKE

This crop, grown in 1920, yielded 56 bushels an acre.

and detailed soil surveys have been made of only one-fifth of the agricultural area of Oregon. These soil surveys locate the important soil areas, and form a basis for sampling in making a chemical invoice of the land and for locating field fertilizer trials on the main types, and pot tests of minor types, calculated to develop a permanent system of soil management.

Feasibility Surveys

Preliminary feasibility soil and agricultural surveys including twelve irrigation projects and 23 drainage projects have been made during the past biennium, the area included in the former being 447,800 acres, and the area included in the drainage districts being 108,400 acres. The pro-

"Let us never forget that the cultivation of the earth is the most important labor of man. Unstable is the future of a country which has lost its taste for agriculture. If there is one lesson of history that is unmistakable, it is that national strength lies very near the soil."—Daniel Webster.

jects are estimated to cost collectively about $60,000,000. Farm drainage systems were designed or surveyed on thirty-eight farms, with an area of 3000 wet acres; and irrigation pumping plants for distribution systems were laid out on sixty farms with an area of 5320 acres. These surveys established the merits of reclamation for about 500,000 acres of land, which will be doubled in productiveness thereby. The majority of these projects have been organized as reclamation districts. The projects inspected are listed in Table I.

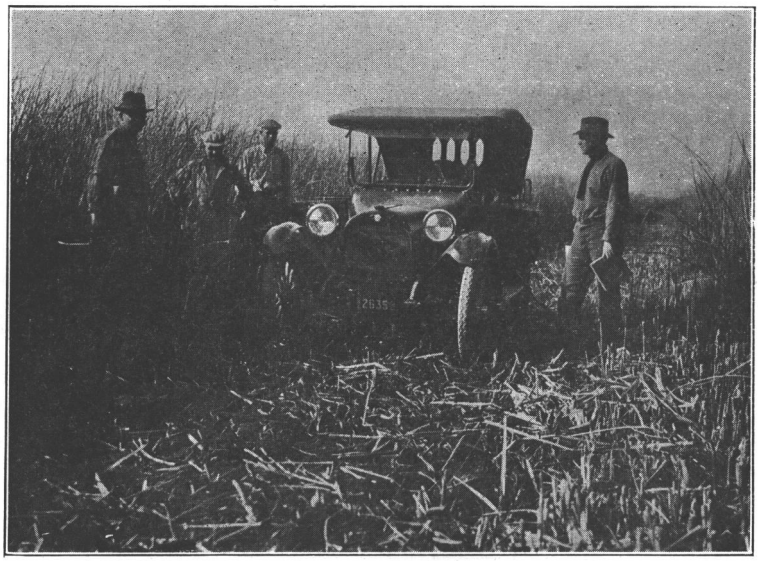
TABLE I. RECLAMATION PROJECTS AIDED, BIENNIUM 1918-1920

	County	Approximate area
Irrigation Projects		Acres
Silver Creek	Harney	20,000
Sparta Irrigation District	Baker	8,000
Goose Lake Valley	Lake	40,000
Jordan Valley Project	Malheur	30,000
Summer Lake Irrigation District	Lake	5,000
Silver Lake Irrigation District	Lake	8,000
Medford Irrigation District	Jackson	10,000
Central Oregon Irrigation District	Deschutes	40,000
Lone Pine Irrigation District	Klamath	1,800
Langell Valley Irrigation District	Klamath	30,000
Grants Pass Irrigation District	Josephine	5,000
John Day Irrigation District	Morrow	250,000
	Total	447,000
Drainage Projects		
Aimsville Ditch	Marion	300
Crowley Project	Polk	1,000
Haines Project	Baker	2,500
Multnomah Drainage District No. 1	Multnomah	1,400
Penninsula Dev. Co. District No. 2	Multnomah	1,400
Umatilla Drainage District	Umatilla	1,500
Depot Slough Drainage District	Lincoln	1,000
Beaver Slough Drainage District	Lincoln	800
Ontario Drainage District	Malheur	5,000
Wocus and Caledonia Marshes	Klamath	10,000
Scappoose Drainage District	Columbia	5,500
Prescott	Columbia	500
Tualatin Project	Polk-Washington	10,000
Catching Inlet	Coos	3,000
Lakeside	Coos	2,000
N. Van Brimmer Drainage District	Klamath	3,000
Lookingglass Drainage District	Douglas	1,000
West Umatilla		1,000
Fairview Drainage District	Tillamook	1,200
Wheeler Project	Tillamook	800
N. E. Unit Drainage District	Malheur	2,400
Sauvie Island Project		22,000
Lower Klamath Drainage District	Klamath	27,500
	Total	108,400

Cooperative Tillage and Soil-Moisture Studies

These studies have been extended and provision has been made so that half the time of the field agent in season is devoted to this work at the branch experiment station at Moro, and a good part of the time of

Soil investigations should ultimately make it possible for every farmer to learn what type or types of soil cover his farm, their average physical and chemical composition, properties, and reaction, and what treatments will be most permanently profitable.



Figs. 15 and 16. DIKED LAND, CHEWAUCAN SWAMP

Above, bulrushes on Chewaucan Swamp. Below, Chewaucan Swamp, where 3⅓ tons of alsike and timothy was secured on this diked swamp land. A half million acres of wild meadow and tule lands can be doubled in productiveness and irrigated with about half the water formerly used. (See Station Bulletin 167.)

a field agent during the growing season is devoted to soil-moisture studies on the branch experiment station at Burns. Important soil-moisture studies are also carried on at the Umatilla Branch Experiment Station. Important moisture points for the main soil types irrigated are being determined and soil-moisture studies are being conducted. A new moisture equivalent centrifuge is being installed with which to extend these tests.

Records of soil-moisture conditions throughout the growing season are kept on the irrigation plots and on the tillage and rotation plots at Burns.

Mr. Ritchie, who made the moisture studies at Burns, reports: "Records were kept of moisture determinations in the soil at the time of seeding and of harvest from the dry-land tillage plots which were cropped to wheat but which had been in fallow the preceding year. The plots which were fall plowed and spring disked gave evidence of the greatest moisture content at time of harvest. Late spring plowing indicated more moisture retention than did July plowing."

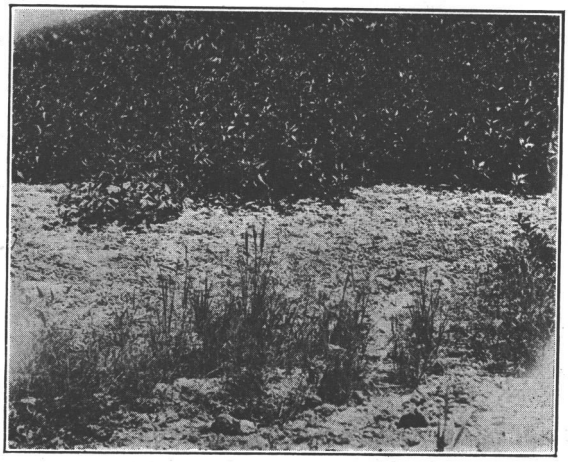


Fig. 17. SWEET CLOVER TRIAL ON ALKALI SOIL

Sweet clover has been used with some success in restoring the structure of alkali land. In preliminary trials at Klamath, Burns, and Ontario, gypsum has been found to stimulate the growth of this deep-rooted green-manure crop.

Soil Moisture and Nitrate Studies at Moro, the nitrate work being outlined and supervised by the Station chemist, J. S. Jones, are described as follows by Superintendent D. E. Stephens of the Moro branch station.

Soil-Moisture and Nitrate Investigations. Soil-moisture studies were begun at the Sherman County branch station in 1919 and these were continued and supplemented by nitrate studies during the season of 1920. These investigations are being carried on for the purpose of ascertaining what effect different soil cultivation and cropping methods have on the moisture and nitrate content of the soil.

"In New York land by the tens of thousands of acres has been deserted and is advertised by the state."—Franklin K. Lane.

"Considerable information has already been obtained at this branch station on the effect on the yield and quality of crops of different methods of cultivating the soil, but it is not yet known just what role the soil moisture and nitrate play in this connection. Any information bearing on the subject would be of much value in finally determining the correct tillage methods for getting the maximum production out of our dry lands without unnecessarily depleting them of their fertility.

"The soil-moisture investigations thus far made, indicate that keeping the ground free from vegetation is the chief function of cultivation of the summer fallow. The moisture in the soil in the spring available for a crop, after different fallow treatments, does not vary widely, though at the end of the fallow season, or before the autumn rains set in, there is a significant difference in the moisture content of the soil of fallow plots given different tillage treatments. The poorly cultivated or neglected fallow usually absorbs autumn and winter precipitation more read-

Fig. 18. FIELD PEAS AND OATS VERSUS TULES, LOWER KLAMATH BASIN, 1920

This trial, located on diked tule land near Keno, shows tules at the left, while on the right is a 4-ton crop of field peas and oats (in cocks) raised on the same kind of land.

ily than the frequently cultivated fallow, apparently compensating for the greater loss of moisture from the poor fallow during the summer. The deficiency of moisture in the poor fallow during July, August, and September, however, appears to prevent the formation of nitrates in the soil. This deficiency in nitrates is always indicated by the difference in the growing habits of the plants. By actual determinations made in September, 1920, the nitrate content of the soil properly cultivated was nearly twice that of the soil where the fallow had been neglected. The investigations thus far have also shown that for the plants grown on the poor or neglected fallow more moisture is required per unit of dry matter.

Soil investigations increase the producing power of the state.

"Investigations are also in progress to determine the water requirements of plants when grown in large pots, under controlled moisture conditions, and when grown in the field after different soil cultivation methods and in various crop rotations. The quantity of moisture removed from the soil by various crops, such as wheat, peas, and corn is also being determined.

"If sufficient funds can be made available, it is planned also to carry on at the Sherman County branch station a series of permanent fertility experiments to ascertain how the fertility of these dry-farm soils can be permanently maintained. These experiments will include trials with commercial fertilizers, green manure crops, crop residues, and barnyard manure. While these soils may, at the present time, contain enough plant food for maximum grain yields, it is very probable that under the present one-crop system of farming the fertility problem will become a serious one and a difficult one to solve. It is considered important that reliable data be now secured on the different methods of economically maintaining a permanent agriculture on our dry farms."

Fig. 19. LAND FITTED FOR STRIP-BORDER METHOD OF IRRIGATION

Harney branch experiment station. This method often saves time, water and money, and should be more generally used. (Station Bulletin 167.)

Critical Soil-Moisture Points

The object of this study is to determine the critical soil-moisture points for the leading soils and crops of the State. The special problem undertaken is to determine and measure any difference in the wilting point and time of irrigation for different crops, and factors affecting the same. Work by other stations has led to the belief that the wilting point varies mainly with the different soils, and little with different crops. Oregon experiments in the field show that the best soil-moisture point to irrigate potatoes in brown silt loam is about the twenty-percent point, while for

"A quick, practical, economical aid in maintaining soil fertility is the conversion of farm crops into livestock products and manure, and the intelligent preservation and application of this manure."

clover it is about the fifteen-percent point. Recent tank experiments tend to substantiate this, and indicate that the organic matter and amount of available plant food may affect the wilting point. Studies are being made with two dozen large soil tanks and four crops. The moisture equivalent certifuge will help in checking up this work and applying it to soils of the State. It is believed that this investigation will throw light upon the proper time to irrigate and the quantity of usable soil moisture that can be applied and retained under field conditions.

Soil Correction Trials

Soil correction trials with the white land and the black sticky lands are being continued. Applications of lime, manure, green manure, and combinations of these have been given to the drainage experiment field west of the grand-stand at the home Station, and lysimeter tanks have been provided to check field work. Quicklime and manure have given some returns in the improvement of black sticky soils. This plot was in sunflowers and will be seeded down to a grass mixture so that it will require little attention thereafter. Experiments on the white land

Fig. 20. WELL-PREPARED SEED BED ON ADOBE SOIL, JACKSON COUNTY

This soils experiment field has been leased to protect old sulfur trials. Irrigation experiments have been added, and the land shown was successfully seeded to alfalfa and irrigated by the corrugations as shown in the photograph.

indicate that the use of manure, legumes, deep plowing, and probably lime will improve the physical condition of the land and facilitate the entrance of water, so that the drainage of these lands may be successful and profitable. Management of sandy land is studied mainly at Umatilla Branch Experiment Station, where subject-matter is largely supervised by this department. A bulletin on the management of sandy soils is being prepared by Superintendent Dean of the Umatilla branch station.

Stock feeding conserves fertility; it increases demand for, and maintains the high value of, important farm products.

Maintenance of Organic Matter

The object of these studies is to determine the most practical means of maintaining and increasing the organic content of Oregon soils, which in most cases would benefit. Many of the soils of the State have a good total plant-food content, but its availability seems to be intimately related to the maintenance of a good supply of active organic matter. The problem over considerable areas of the State is closely related to that of soil moisture. On the College farm with irrigation, crop rotation, and use of maure, increases in the organic-matter content in these plots are being made. The manuring experiment in connection with the irrigation fields affords additional opportunity for study of this problem. A new experiment to be initiated at the branch experiment station at Moro will afford opportunity to study this problem under dry-farming conditions, where straw, stubble, green manure, and barnyard manure, will be utilized in different ways. Routine tests in the laboratory are giving us something of an invoice to the organic content of the various soils of the State. Study of this organic-matter problem has been assigned to Assistant Professor E. F. Torgerson for development as a special project.

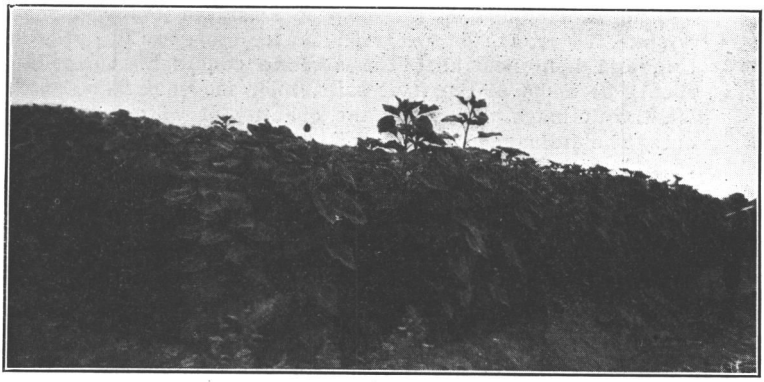


Fig. 21. IRRIGATED SUNFLOWERS, BURNS BRANCH STATION, 1920

Sunflowers in these trials yielded 27 to 54 tons an acre and received 19 inches total depth of irrigation by pumping.

B. DRAINAGE INVESTIGATIONS

Drainage and Improvement of Wet Soils

Study of water table and outflow are being continued on the white land in the Corvallis experiment field in the Willamette Valley; and the effect of clover, lime, and manure to facilitate percolation, used alone and in combination, is being observed.

The State appropriation of one thousand dollars a year for two years has made it possible to install a considerable part of the under-drainage system on the branch experiment station at Astoria. Preliminary data

It is cheaper to make good lands better than to restore the fertility of exhausted soils.

are being secured as to water table and outflow conditions on tiled lands there. Yields on the well-drained portion have been five tons an acre, and on the untiled ground, two and one-half tons, the crop being field peas and oats. This fall the drainage field there will be in good shape for a thorough study of the effect of these drains on water table and outflow.

Improvement of Alkali Land

Drainage for so-called "greasewood land" for removing the alkali, and subsequent management to restore the structure of these lands so as to facilitate percolation and complete reclamation, constitutes one of the serious soil problems of the State. The State guaranteed interest on a million and a quarter of reclamation bonds for the Warm Springs irrigation district of thirty-five thousand acres in Malheur county. About half of this project is in need of drainage. Preliminary studies are being made on some under-drained areas there. Preliminary trials have been arranged in both Malheur and Klamath basins, where tiled land can be checked up and given copious irrigation, and then planted to green manure crops, such as rye, followed by sweet clover, and alfalfa. Sweet clover on drained alkali land has been treated with sulfur in Klamath and Malheur sections and has shown a difference of growth over the untreated. It is hoped that the sulfur or land-plaster will help to keep the alkali in soluble form, stimulate the growth of the green-manure crop, lessen "puddling" of the soil, and help neutralize the alkaline condition. Quantitative studies should be made of the total salts, their movement and rate of removal in the drainage water, and the quantity of water applied and drained out. The drainage of these lands is rather expensive and tedious, and successful methods of after-treatment need to be developed. Malheur Valley affords the most attractive field for these studies, and a field agent should be placed there the coming season. Similar extensive, serious drainage problems occur in Harney and Klamath and other districts.

Evaporation and Weather Studies in Relation to Soil Production

Evaporation records are being secured by field agents at both the home and branch stations. The evaporation and rainfall data over the State are compiled and studied in connection with the general weather conditions and crop yield in the soil and irrigation experiments. A comparison of different evaporation tanks has been made at the Corvallis Station, to aid in correlating different records.

Improvement of Water Laws

This department is cooperating with the State Irrigation Congress, the State Drainage Association, and State Engineer's Office, in securing needed improvemens in the water laws of the State. Cooperation was given in drafting a modern drainage district law, enacted in 1915, under which fifty drainage districts have been organized. Some minor amendments to water laws enacted at the special session will have to be reenacted as most of them were vetoed as not qualifying for emergency action.

Alfalfa, the child of the sun—our greatest forage crop.

At present it is accepted that the water laws of Oregon are among the very best. During the past three years, some fifteen millions of reclamation bonds have been issued and about half of these marketed under our district laws. Further reclamation legislation, however, can be expected.

It has very recently developed that delays are caused in ditch construction because there is no clause in our water law providing that drainage and irrigation districts can put up bonds for crop injury and proceed to use the right of way before it has actually been settled for. An amendment is needed similar to the one in our road laws.

Fig. 22. IRRIGATED ALFALFA, HARNEY BRANCH EXPERIMENT STATION, 1920

This alfalfa received 16 inches total depth of surface irrigation by pumping and yielded 8.5 tons total from three cuttings. This crop was grown on sage-brush land worth only a few dollars an acre when the experiment was started.

The head of the Soils department attended the Western States Reclamation Conference at Salt Lake City last November and also the Seattle Conference this fall, and worked for a national policy of reclamation such as that proposed in the Smith-Fletcher Bill. It is believed that a national policy of reclamation will provide a revolving or capital fund which will aid any feasible approved project in irrigation or drainage.

C. IRRIGATION INVESTIGATIONS

Duty of Water Investigations

Duty of water and related investigations have been continued on the experiment fields at Corvallis, Hermiston and Burns, and on the cooperative field in the Deschutes and Klamath basins.

Representative fields are divided into three or four parts. The owner applies the customary irrigation to one portion and it is measured by a field agent. Then a second portion is given about 30 percent more and another portion 30 percent less to see if a different amount would give better returns. Frequently a fourth portion is fertilized or irrigated by a

"For an easy and economical method of maintaining the fertility of the soil there is nothing equal to the practice of dairying."

different method to test possibility of improvement. Water, plots, and yields are measured, giving data as to quantity needed. One field agent can look after three or four such trials on meadows and two trials each with grain and with row crops, or a total of about eight trials. Several seasons' work is desirable in a given valley, so that the average yield and percentage of different crops may be determined. Results so far have shown wide variation in needs of different soils and crops and different valleys, suggesting need for further study. Extravagance in use of water on the one hand and undue economy on the other are both bad for the irrigation farmer.

Arangements were made to secure irrigation on most of the soils experiment field, near Medford, and duty of water and irrigation trials have been added. A preliminary trial last year showed a five-hundred-percent increase with the use of irrigation on this heavy adobe soil, where farmers had questioned the feasibility of trying to irrigate. Five years results as to reasonable duty of water for wild meadows have been secured and a bulletin issued. Water variation trials on wild meadow lands have been concluded. The work must be transferred to other valleys that are calling for help. Based on the twelve-year average water cost and conditions at the home Station, three inches of water is required to produce one hundred bushels of potatoes, and five to six inches to produce a ton of hay. The duty of water is thus not likely to be less than fifteen or eighteen inches for a three-ton hay country, and thirty to thirty-six where the yield is six tons an acre.

This is the fifth year in which duty of water trials have been conducted in the Harney Basin, the third season in Klamath and Deschutes basins, the second at Medford. The latter two have had some previous study. There are several years data for the Hermiston station, and twelve years for the Corvallis Station, on which to base a reasonable duty of water according to the need of the soils and crops in these sections.

Effect of manure, crop rotation, and fertilizers on irrigation requirement. The effect of irrigation on bacterial activity, on accumulation of organic matter, and on quality and ratio of plant parts, is included in these studies. The wilting point of different crops and the moisture point at which irrigation should be applied are being studied by plots supplemented by tank tests. These studies have pretty definitely established the fact that for our brown silt loam, meadow crops should be irrigated when the moisture content drops to the fifteen-percent point by weight; while cultivated crops, like potatoes, should be irrigated at the twenty-percent point, there being a difference in the wilting point of these crops with this soil.

Superintendent Shattuck of the Harney Valley Branch Experiment Station reports: "The addition of manure to the average irrigation increased yield of peas one ton per acre over that obtained by addition of three inches more water."

"The farm feeds the cow, the cow feeds the farm, and they both feed the people."

Experiments in Distribution of Water and Improvement of Irrigation Practice

This project was segregated to accommodate work which Doctor Fortier, Chief of the United States Office of Irrigation Investigations, wished to carry on cooperatively. Financial cooperation of his office has not been continued on account of the reduced appropriation. The field agents, however, are giving attention to the amount of water required where different methods of distribution are used. The strip-border method of irrigation has been tried out, and in several localities has proved economical as compared with the corrugation method of irrigation. Experiments have been conducted to determine the proper length of run. Trials on different types of soil show the strip border to be a superior method to that now generally used. Work during the past biennium developed the fact that corrugations need to be employed within the strip borders in establishing new seeding on some soil types. This is true on the medium loamy sand, in the upper Deschutes Valley, and on the heavier adobe at Medford. These indicate that the system of delivery of water must be changed on some of our projects, to provide for larger irrigation heads.

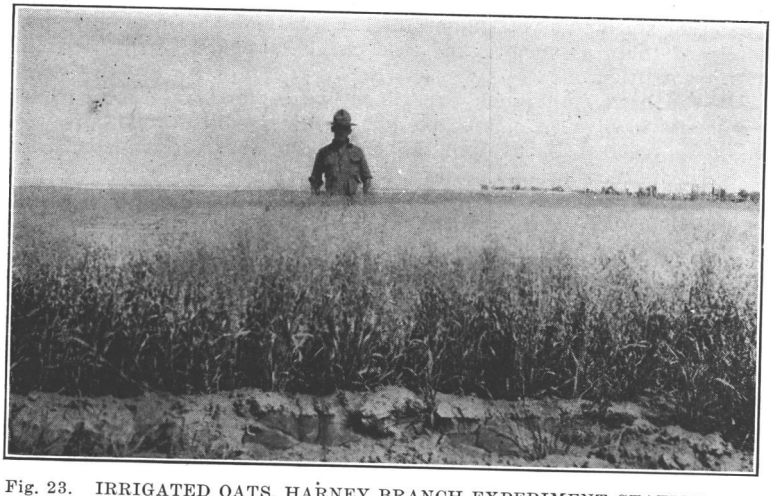


Fig. 23. IRRIGATED OATS, HARNEY BRANCH EXPERIMENT STATION, 1920

This plot yielded at the rate of 127 bushels an acre and was irrigated by pumping. Irrigated wheat plots in this field yielded 87 bushels an acre.

D. SOIL FERTILITY

Fertility Rotations

Rotation experiments over which the Station has control in the Willamette Valley are confined to the home Experiment Station, and the new cooperative trial on a soils experiment field on the red hill soil near

As the period of agricultural expansion in public lands draws to a close we must increase the use of land in farms.

Corbett, Multnomah county. The oldest plots on the College farm showing the accumulative effects of rotation, are the irrigation plots on the home Station, where the oldest rotation is now of twelve years duration. In this rotation clover has appeared each four years in rotation with grain, potatoes, and beets, each fifth year a block of alfalfa being put into the rotation. With irrigation there has been more root growth as well as top growth, and the accumulation of organic matter is found to be one half to one percent. A secondary experiment, including a three-year rotation of grain, alsike clover, and beets, has gone through two three-year courses; the value of the crop increase due to rotation over continued cropping where beans are grown continuously in comparison with those in rotation after clover sod, being, at five cents a pound, approximately $31.00 an acre under rainfall-farming conditions, and $38.00 an acre under irrigated conditions. The value of the increased yield an acre, if figured at ten cents a pound, would be twice this amount. Extensive rotation experiments started north of the railroad on the home Station in 1915, as yet show but little differences due to the different rotation treatments. The crops removed have, in some cases, been light due to late spring seeding.

The rotations in connection with the fertilizer trials at the branch experiment station on the Coast at Astoria are the only rotations under way at that station as yet. Some further rotation experiments should be established there as soon as the land can be subdued and reduced to a uniform condition.

On the dry-farm branch experiment fields, elaborate crop rotation experiments have been carried on for several years. Twenty-nine rotations were tried at Burns, and the only thing that offered competition to the wheat-fallow system so far was a rotation of fallow, grain, spring rye, the latter disked in the stubble. Rotations which have proved good at Moro include (1) winter wheat, summer fallow; (2) spring wheat, summer fallow; (3) winter wheat, peas; (4) spring wheat, peas; (5) spring wheat, corn, barley; (6) spring wheat, barley, potatoes; (7) winter wheat, corn, winter wheat, fallow; (8) winter wheat, peas, winter wheat, fallow. Some information regarding crop rotation has been obtained at the Union branch experiment station, where rotation of about six years alfalfa, followed by a crop of barley and oats, then a crop of wheat, using wheat as the nurse crop, and seeding down again to alfalfa, is regarded best.

On the irrigated experiment fields, rotation experiments are under way at Hermiston, Burns, and Medford. Alfalfa has been a better legume than clover, both at Hermiston and Burns. Corn at Hermiston has been the best cultivated crop included in the rotation, and the stock beet at Burns has been the most successful cultivated crop thus far found. At Hermiston alfalfa starts quickly and can be used for three or four years in rotation with barley, field peas, and corn. The experiment at Medford was started last spring. These experiments will need to run through a long period of years.

Fertilizer Experiments

Fairly complete and permanent fertilizer experiments are now in progress on sixteen different soil types in the State. Several of these are

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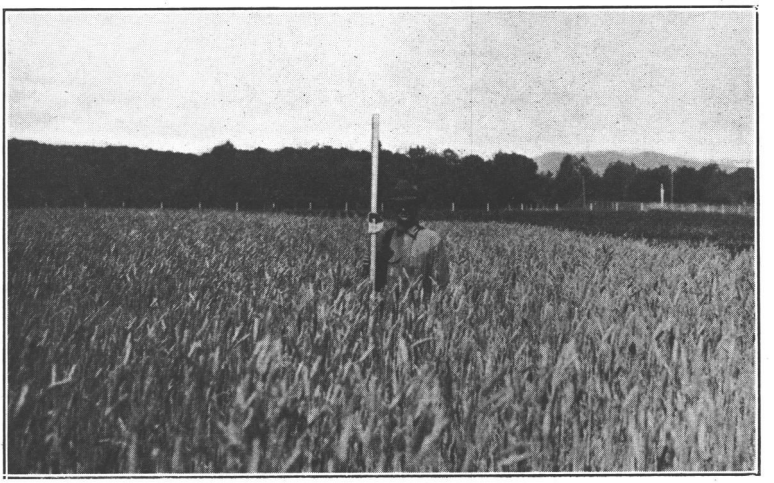
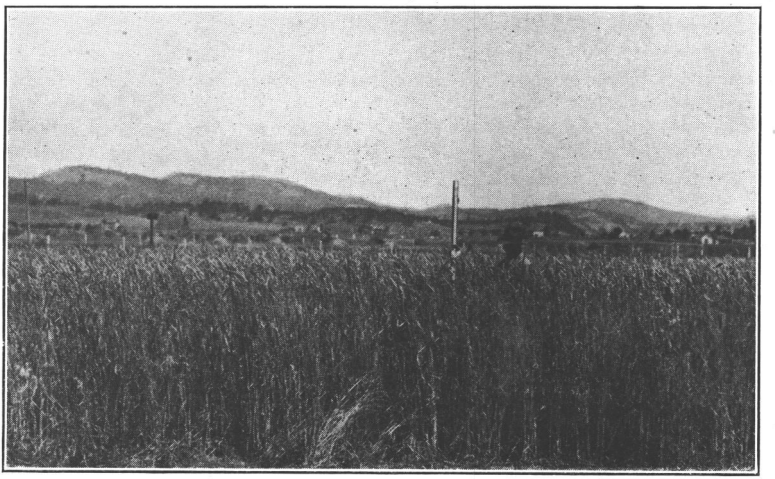
That it is possible to reduce the plant food supply of many Oregon soils below the limit of profitable crop production is certain.

on the home Station or on the branch stations, and include crop rotation so that more than one crop is represented each season. Certain applications have proved very profitable and their use is being continued in demonstration experiments, in cooperation with the county agricultural agents. These trials and their locations are shown in Table II.





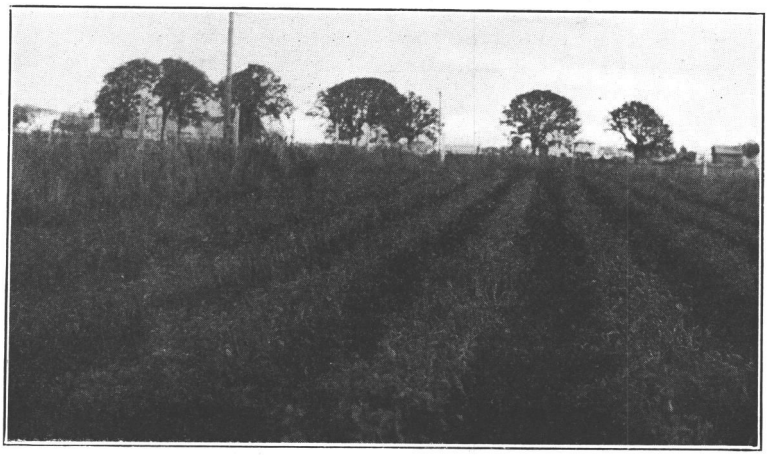
Figs. 24 and 25. INCREASE FROM USE OF MANURE

Above, wheat, no manure, irrigation field near Corvallis, 1920; yield 46.16 bushels to the acre. Below, wheat on manured plot, irrigation field, Corvallis, 1920; yield, 55.66 bushels to the acre. Manure used in this experiment has given increases in yields of wheat, clover, and beans, returning from $2.50 to $10.00 per ton of manure.

TABLE II. GENERAL FERTILITY TRIALS UNDER WAY BY OREGON AGRICULTURAL COLLEGE EXPERIMENT STATION, DEPARTMENT OF SOILS, JUNE, 1920

No.	Soil type and owner	Location and address	When started	Number of plots	Size of plots	Crops per yr.	Cooperation
1	Willamette silt loam Oregon Agricultural College	West of Farm Lane Corvallis	1914	25	1/24 A.	1	.....
2	"White Land," Dayton Si. C. L.	S. of R. R.	1920		1	.....	.....
3	Newberg sandy loam Aver.ll, W. 4	1 mile east of Corvallis	old—1914	50	1/20	1	.....
3	Newberg sandy loam Averill, W. 4	1 mile east of Corvallis	new—1920	13	1/10	1	.....
4	Salem gravelly loam Ables, I. C.	1 mile east of Springfield	1920	12	1/10	1	Ables
5	"Red Hill" Olympic silt loam, Salzman, A. G.	1 mile S. Crown Point Corbett	1920	10	1/2	1	Hall, S. B.
6	"Red Hill" Melbourne Si. Br. Sta., Astoria	S. of Sta. House, Astoria	1918	22	1/10	2	Engbretson A. E.
7	Peaty silt loam Br. Sta. Astoria	S. W. Corner Sta., Astoria	1920	12	1/10	1	Engbretson A. E.
		N. of Bldg's Field A 4	1910	15	1/10	1	Dean, H. K.
8	Umatilla medium sand Br. Sta., Hermiston	Hermiston					
9	Deschutes medium loamy sand 3 trials	1 mi. N. Redmond; 1 mi. N. Tumalo and at Cloverdale	1918	8 each	1/10	1	Stevens Becker; Jamieson
10	E. Ore. dark silt loam Br. Sta. Union	.....	1920	11	1/10	.....	Withycombe, R.
11	E. Ore. very fine silt loam Br. Sta. Moro	.....	1920	40	1/10	2	Stephens D. E.
12	Dark very fine silt loam Br. Sta. Burns	Irrigation Field, 6 miles E. Burns	1919	60	1/10	6	Shattuck O.
13	Coker clay adobe Medford Exp. Field	7 mi. North Medford	1914	See rep't	1/10	Alf. series also other crops	
14	Medium peat, McCormack, F.	5 mi. N. W of Klamath	1918	7	1/10	1	McCormack
15	Yakima sandy loam 2 trials	5 S. E.	1919	14	1/10	2 Alf. Pota.	Snow, C. N. Hazelton, A.
16	"Pumice" medium sand Sisemore	.....	1919	11	1/10	1 crop	Sisemore, L. C.

Simple cooperative demonstration experiments this season are under way in Lincoln, Clatsop, Multnomah, Polk, Benton, Lane, Deschutes, Morrow, Umatilla, Union, Baker, and Malheur counties.



Figs. 26 and 27. INCREASES FROM CROP ROTATION

Above, beans in rotation, Corvallis, 1920; yield, 5-year average, 14.73 bushels per acre, grown on alsike-clover sod in a three-year rotation of grain, clover, beans, at the end of the sixth year, the closing year of the second course. Below, beans continuous 6th year, 5-year average yield 8 bushels per acre. Gain from crop rotation is obtained at very little expense.

"The total agricultural product of the United States increased 1900-1910, nearly 20 percent, while the population increased 21 percent. At the present rate of increase we shall in 50 years double the population. It is necessary, then, that our acreage and also our product per acre must increase proportionately so that our people may be fed."—Wm. H. Taft.

Numerous simple trials including from two to six plots each are being conducted in various counties in cooperation with county agriculturists. These are mostly temporary in character, and they are regarded as demonstration experiments.

The successful use of fertilizers, of course, depends upon their cost and value of increase in crops secured from them. Trials over the State by the Experiment Station on the leading Oregon soils and crops have reached a definite stage in several particulars, and a more extended use of certain constituents on certain soils should be profitable.

Phosphorus has been regarded the master key to permanent agriculture in humid climates and while the supply of this element is comparatively good, on most of the basaltic soils in the Pacific Northwest and in Oregon, yet it is frequently unavailable in quantities sufficient for crop needs. The phosphorus supply is materially reduced by 50 to 70 years cropping, at least in humid climates, and must be physically put back on the soil to maintain fertility. At the Astoria branch experiment station it is found profitable to use super-phosphate for the red hill soil of that section, and Professors Ruzek and Cooter found it beneficial to the red soils in other parts of Western Oregon. Super-phosphate is now being used commercially on the red hill soil in Clackamas, Multnomah, Douglas, and Jackson counties, and by potato and onion growers on sandy and peat soils in the Willamette Valley. Our acid marsh soil gives an indication of benefit from applications of available phosphate. Raw rock phosphate has been secured for use in connection with super-phosphate, and a new project has been outlined to study the availability and utilization of phosphate in the red hill soil. Our soils, such as the granitic and some others in Southern Oregon and sedimentaries in the lake region are below average in this element, as determined by our feasibility surveys of reclamation projects in those regions.

Idaho raw rock phosphate is now shipped to Japan and should be made available on the Oregon market. The manufacture of acid phosphate at Portland would reduce its cost in Western Oregon to a point where its use would be much more generally profitable. Lower classification of this and other fertilizer as to freight rate is worthy of careful consideration as being related to the agricultural prosperity of the territory served.

Sulfur has been found by Superintendent Reimer of the Southern Oregon Branch Experiment Station, to be a limiting element in legume production for certain soils of the Rogue River Valley, and it was simultaneously found to be profitable in alfalfa production in the Deschutes Basin by Professor Powers. It was found that acid phosphate, calcium, and potassium sulfate caused crop increases which could be produced by elemental sulfur. In Southern Oregon, experiments with fertilizers other than those carrying sulfur have given little increase in alfalfa, and certain rich loam soils there have not responded to applications of sulfur for alfalfa. Analyses show certain of these soils in the Deschutes Valley, the Umatilla Basin, and Southern Oregon to contain sulfur sufficient for only ten to eighteen average crops. Eighty pounds of sulfur has been sufficient to meet crop requirements for a period of four or five years. The trials strongly indicate that in our arid and semi-arid soils sulfur is not present in sufficient amounts to maintain or increase yields. During a period of

five years, sulfur has doubled the yield of alfalfa when applied in experiments in Goose Lake Valley. In experimental trials in Deschutes Valley, extending back to 1912, sulfur has given from one to two tons increase an acre a year. An average increase of nearly two tons an acre has been secured in Klamath Basin during the past three seasons. Definite increases in yields have been obtained in Grande Ronde, Wallowa, Baker, Umatilla, and Malheur valleys. Acid soils in Willamette Valley have shown little or no response to sulfur treatment, though calcium sulfate is commonly used and seems beneficial to legumes. It can be safely said that our experiments out over the State have proved that sulfur will increase the yield of alfalfa by at least one ton an acre on at least 200,000 acres of alfalfa land. This increased crop value at $10.00 a ton would be worth two million dollars per year.

Fig. 28. FIELD DAY: FARMERS VIEWING A RANGE OF FERTILITY PLOTS

Complete fertility trials are started on sixteen soil types, but these should be extended to include other important soils of the State and to develop permanent systems of management for each important soil type.

Sulfur and gypsum even with manure have not proved beneficial on the coarse soil at the Hermiston station. Inoculation is being tried there to aid such applications. It may be that the water carried sufficient sulfur to meet the need there. Experiments this season are showing positive benefits from sulfur applied to field peas in the Klamath Basin, and to corn and beans in Southern Oregon. Reports of definite increases on vegetables and protection from crop pests are coming from Columbia Basin, where sulfur has been used. One of its main benefits on legumes is believed to be a beneficial effect on the activity of nitrifying bacteria, or nitrification. On the non-legumes it may aid, due to liberation of phosphorus.

Deposits of sulfur occur west of Crater Lake, but it has not been determined whether they can be economically developed at present. It is

"During 110 years, 1800-1910, the population of the world increased from 840 million to 1,600 million, or an increase of 152 percent."—Director F. S. Harris, Utah Experiment Station.

estimated that about one-tenth of the land which, according to our experiments, will respond to sulfur, has received commercial applications.

Potash. This element, so far as tried, has given little indication of increase in yield on marsh soils. Most of our marsh lands contain a considerable amount of potash, received with the silt inwash from the surrounding uplands. On upper Klamath marshes some increase was obtained from potash the past year. Residual soils in the Deschutes Basin are somewhat below average in this element, and experiments in 1912 have given profitable increases from its application on potatoes. During the present year different commercial forms of potash fertilizer are being applied to potatoes at different rates on four farms in Deschutes county, to determine the most economical treatment. Under normal conditions it is believed that sulfate of potash will be the ideal fertilizer in the Deschutes section, because the sulfur benefits legumes there.

Nitrogen has proved helpful on many non-legumes and is used in the semi-arid sections devoted to commercial orcharding. The use of legumes will, usually, be a more constructive and profitable treatment than applications of commercial nitrate, and it is believed that the use of this element should be discouraged, except as a starter, wherever rainfall or irrigation will make it possible to secure this element from the inexhaustible supply in the air by means of nitrifying bacteria and legumes. Our experiments show that in establishing legumes under new conditions, especially alsike clover with timothy on marsh lands, inoculation has helped. Inoculations have helped to establish alfalfa under severe conditions, as in the upper Deschutes Valley.

Ground Limestone has been furnished by the State Lime Plant to the amount of about three thousand tons. It is needed to correct soil acidity in the more humid sections. Definite results from its application are more certain in the most humid sections than in the hill lands, in the lower Willamette Valley, and in the north Coast Region. These lands are more highly acid and perhaps more thoroughly leached with a heavy precipitation. The marsh lands in that region, where drained, are removed of their excess acid, or its further accumulation prevented; and they are often wonderful forage producers, even with legume crops. Lime may be expected to benefit soils known to be acid or to possess medium fertility with legumes such as clover. At the home Station nine-tenths of the increase was secured from limestone where vetch was grown. Where necessary to successsful production of legumes, lime becomes of vital importance in permanent agriculture.

Organic Manures. Rather poor use is made of barnyard manure in this State, and there is great need for extended use of green manure. Nearly all of the land in this State is benefited by increase in the organic-matter content. Where moisture is received by precipitation or supplied by proper irrigation, with a good system of crop rotation, with clover or alfalfa, the use of stable manure once in the rotation will make it possible to maintain a good supply of active organic matter. This improves the tilth and usable water capacity of the soil; in the semi-humid

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Soil investigations aim to discover things which will be a direct benefit to the people over the State.

section it tends to increase the nitrogen supply. Land in the humid section should not be left without crop over winter but should be supplied with a cover crop, such as vetch. On dry or alkali lands, rye and sweet clover are valued for the green manure produced. Field-pea green manure has been beneficial at Moro. Manure used on the experiment field at Hermiston, and on the irrigation experiment field near Corvallis has returned a profit of from $2.50 to $10 per ton. Superintendent Shattuck's report shows that manure, this past season, gave a greater increase than any simple fertilizer at Harney Valley Branch Experiment Station, and results indicate some increase from reinforcing it with super-phosphate.

A humus-building experiment has been outlined for the Moro branch experiment station. The twelve tenth-acre plots on the south side of the main irrigation distribution line at the Corvallis Station are available for manure experiments which should be initiated this winter.

Practically all of the complete fertilizer experiments listed should be protected and continued, for they are helping to develop permanent systems of soil management for different regions of the State.

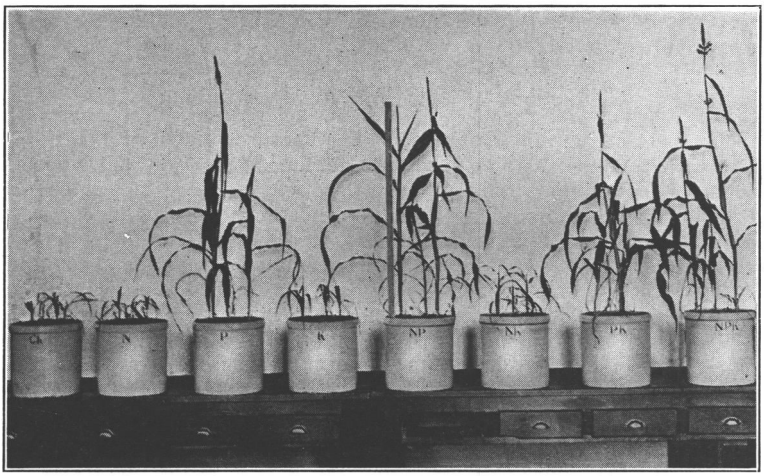

Fig. 29. EFFECT OF SOLUBLE PHOSPHATE ON "RED HILL" SOILS

One of the earliest fertilizer trials showing value of superphosphate on upland soils. P, superphosphate added; N, nitrogen added; K, potassium; Ch, check untreated.

Soil Acidity Tests and Lime Trials

The main fertilizer plots in humid sections of the State or frequently the lower half of the entire plot series has received an application of ground limestone. Soil-acidity tests by the Truog method are made of a large number of samples submitted by landowners. These develop something of a soil-acidity survey of the State. Outside of this routine work no special investigation of the subject has been made the past biennium. Arrangement has been made to inspect and secure reports on fields furnished lime by the State Lime Plant.

Availability and Utilization of Phosphorus Compounds for Crop Use

This project is outlined and described by Professor Ruzek as follows: "The object of this study is to determine the factors affecting availability of different phosphates in the soil and treatments necessary so crops can utilize these compounds. Red hill soils of Oregon occupy a large area in the State. Chemical analyses of these soils usually show a high percentage of phosphorus. Plant-food tests, both in the greenhouse and in the field, show that these soils respond to soluble phosphates. An investigation has been outlined to determine the best means of utilizing phosphorus in these soils, or of best meeting crop needs for it. It is planned to determine (1) what forms of phosphorus fertilizer will give best results, (2) what practices will make insoluble phosphate fertilizer available to crop use, (3) what practices will make phosphate compounds of the soil more available, and (4) what differences there may be in feeding power of crops for rather insoluble phosphates. Plots on 'red hill' near Crown Point and at the Astoria branch station on Melbourne silt loam and Olympic silt loam are being used and checked by the laboratory pot tests and perhaps analytic tests. Pot tests and field trials the past season (1920) indicate that lime and sulfur increase availability. Manure seemed to have a depressing effect."

Functions of Sulfur in Relation to Soil

The head of the Soils department has been connected with the sulfur investigations since their beginning in 1912. These trials have been extended to most of the alfalfa-producing sections of the State, and require further extension and study. With the acquirement of the supervision of the Soil experiment field near Medford, it seems advisable to outline a special sulfur project, and determine if possible the functions of sulfur in relation to soil productiveness. Plots on the Medford experiment field afford perhaps the best opportunity for this, while Central Oregon plots are also valuable for this work. The plan is as follows: (1) Determinations will be made of sulfur and important plant-food contents of plots that have received heavy applications of sulfur during the past six years, as well as some check plots on other soils of the State where sulfur is used. (2) The bacterial content of these soils may need to be studied. (3) Various crops that respond to sulfur in different arid sections will need to be determined. (4) The value of sulfur in connection with restoring the reclaimed alkali land will be determined. (5) Sulfur content of rainfall and drainage water will be determined. There may be some liberation of plant food from the use of sulfur, and the color and vigor of the plots and the size of the nodules indicate the effect of sulfur in stimulating nitrogen-fixing bacteria. The oldest,heaviest-treated plot continues to show increase in yield after six years' time. Several crops other than legumes have shown some increase from the application of sulfur. So little is known regarding the subject and surprises are coming so fast that it is difficult to say what will be developed. Except on certain red hill soils as at the branch station at Astoria, sulfur has not been beneficial when applied to soils of humid sections. Under humid conditions it may be aiding liberation of phosphorus.

Care, Use, and Value of Manure

Many questions come up regarding the handling of manure and the time, method of applying, and working in of manure, to which there is not a definite answer. Some studies have been made of the value of manure. At the Hermiston branch station $2.50 per ton from manure applied and at the home Station from $2.50 to $10.00 a ton has been realized. Very definite visible results can be seen at the present time in the crop rotation series south of the railroad on the home Station, showing the cumulative effect and the lasting value of manure. It is planned, however, to extend these studies somewhat and to add a new experiment on twelve tenth-acre plots situated in the irrigation plots, using manure at different rates and disking in and plowing under the applications. The

Fig. 30. SEASONAL YIELD WITH SULFUR EIGHT TONS, UNTREATED FIVE TONS

Two hundred thousand acres of alfalfa can be made to yield one ton increase an acre with sulfur. Value of increase at $10 a ton, $2,000,000.

economy of supplementing light manure dressing with light applications of phosphate fertilizer will also be tried. At the Astoria branch station ten tons of manure and one hundred pounds of super-phosphate have done as well as forty tons of manure. One-quarter of each plot in the duty-of-water trials at Burns is being manured to test the value of manure in reducing the water requirement. At that station in 1920 manure gave one ton more yield than did increasing the amount of irrigation three-fourths or from 12″ to 15″. It has been deemed desirable to make something of a study of this subject and carry it in a special project.

MISCELLANEOUS

During the past biennium several thousand letters have been answered and many thousands of bulletins and circulars distributed giving specific information on soil problems. These could not have been answered by any means as well, had not the information been accumulated by soils experiments. Perhaps a thousand soil samples have been identified as tested in the Soils laboratory and advice given as to their management. The soils plots furnished subject-matter for several field days and contributed to the demonstration or extension work.

PRACTICAL RESULTS FROM SOILS INVESTIGATIONS

Preliminary feasibility soil and agricultural surveys have been made during the past two years of five hundred thousand acres of wet land and two million acres of irrigable land. These surveys have helped to establish the merits of feasible projects and have led to the organization of a million acres into feasible reclamation projects. Over fifteen million dollars in bonds have been voted and six to seven million dollars of Oregon reclamation district bonds sold. About two hundred thousand acres have already been reclaimed, and have more than doubled in productive value. The projects examined and reported upon during the past biennium will take several years to reclaim and will require an investment of fifty to sixty million dollars.

In recent years numerous farm irrigation systems have been designed and, during the past ten years, tile systems have been laid out on two hundred twenty-five farms, including four hundred miles of tiling which has been largely constructed and serves eighteen thousand acres. The estimated increase in crop value due to drainage in this area is $10.00 an acre or one hundred eighty thousand dollars annually.

Fertilizer trials conducted the past several years have been extended to most of the important soil types of the State. We have developed the practice of using sulfur on alfalfa in arid and semi-arid sections. Nitrogen is used to good profit in orchard sections, and soils have shown that potash can be profitably used on potatoes in Central Oregon. While phosphorus has been found to pay on the red hill soils and worn grain lands of the more humid sections, surveys indicate that soils in this latter section are acid, and legumes were benefited by the use of ground limestone applied thereon. From $2.50 to $10.00 has been realized from the use of barnyard manure. At the home Station crop rotation has caused increases in crop value of $31.00 an acre for three-year rotation over and above the crop value where grown continuously.

As a result of these trials, sulfur was used the last year on sixteen thousand acres, and made increase of at least a ton an acre. This sixteen thousand tons at $10.00 a ton represents an increase in crop value of $160,000 a year. Extensive trials prove that this treatment applied to at least two hundred thousand acres of alfalfa land in Oregon, will safely give a ton an acre increase, worth two million dollars at the conservative price of $10 a ton. An increase in the yield of one ton an acre should add to the productive value of the land affected at least $33.00 an acre.

It is estimated that at least three thousand tons of lime which has been applied to acid soils will increase the yield of legumes by 25 to 50 percent on twenty-five hundred acres.

Two thousand tons of phosphate were applied during the past year to about twenty thousand acres in the humid sections of Oregon, with a crop increase estimated at 25 percent.

These few examples show how Oregon soil investigations pay.

PRESENT NEEDS AND ESTIMATES

From the practical results obtained, it is evident that soil investigations are a good investment for the State, and it is held to be the duty of the workers in this field to present the soil problems that need solution

Fig. 31. AT RIGHT, SUPERPHOSPHATE ON CORN, DOUGLAS, 1920

Trials are proving that use of superphosphate will pay on considerable areas. As a result of experiments 4200 acres were fertilized in this past year and gave increases ranging up to one hundred percent and averaging perhaps twenty-five percent.

if the State is to pursue a wise policy of improvement. The carrying forward of Oregon soil investigations to meet Oregon demands for the coming two years should involve the following things:

(1) **Funds should be provided for continuation of soils survey work.** This work is regarded as fundamentally important in connection with the utilization of the soil resources of the State. It serves as an invoice to the agricultural resources of the commonwealth; permits consistent, scientific soil investigations; and gives a basis for recommendation for soil improvement. The work aids the new settler in selecting a location, guides the county agent in advising the settler as to the management of his land, and permits the introduction of new farm crops and improved farm practices. It is a valuable guide in determination of the irrigation requirements for different arid soils, or feasibility of drainage for wet areas. The soil map and report give the farmer information as to the methods

for permanent soil building. The United States Bureau of Soils cooperates in this work and bears over half the expense. This work should be pushed on so that needed information as to occurrence, comparison, and management of different soils can be secured for farmers as early as possible. Funds are needed (a) for matching the Bureau of Soils with a field man, (b) for analyses of official samples, and (c) for publication of reports. The car which has been used three seasons should be replaced with a new one.

(2) **Studies in irrigation practice should be provided for.** Irrigation ultimately will reclaim about two and one-half million acres in Oregon. Feasibility soil and agricultural surveys of each proposed project, aided by selection of the most desirable land for irrigation, make possible establishing the merits of worthy projects and providing a proper duty of water or drainage capacity. Heavy expenditures for engineering surveys should not be incurred without careful soil and agricultural classification of the lands involved, especially as the State may be called on to certify a guarantee interest on project bonds.

Economical use of water is necessary if the highest productive land values are to be realized and retained under irrigation. Frequently if we could save fifty percent of the water now diverted for irrigation it would be possible almost to double the irrigable area; the amount of water rather than the amount of land is usually the limiting factor.

Irrigation projects are successful only as irrigation farmers are successful; hence, studies in improvement in irrigation practice are fundamantal to ultimate financial success.

(3) **Drainage investigational work should be continued.** Proper drainage will reclaim or double in productiveness about three million acres of Oregon land. Feasibility surveys are necessary in shaping up projects in the most economical way. Methods of tiling and management of tide and overflow and alkali lands require investigations to secure best returns on the seventy-five million dollars or more that will be required for drainage reclamation in Oregon. This is an area equal to about one-half the improved farm land in Oregon, and with the irrigable area represents collectively an area equal to that in improved farms at the time of the last census, and capable of producing above the average in terms of an acre. The drainage work contemplated plans to continue experiments under way and undertake study of drainage of irrigated or alkali lands, also taking care of emergency feasibility surveys. It would pay the State to extend the drainage investigations.

(4) **Studies in soil fertility problems should be provided for.** Soil fertility problems are as varied in Oregon as in any state. Soil surveys need to be followed up by chemical analyses of each soil type, which often indicates the presence of any injurious substance or the fertilizer most likely needed. Field fertilizer trials are more conclusive and should be extended so as to be carried on with each important soil, using staple crops in their rotation. Minor types should be tested in the greenhouse, but it is impossible to carry forward these analyses and tests with the current amount of funds. Fertilizer and crop-rotation experiments should be pressed so the State can continue to be self supporting and feed our increasing population, developing permanently profitable systems of

soil management before our lands are worn to the point of unprofitable production. There are already in the South and East many thousands of acres of "abandoned farms" or lands that have become so poor in fertility by constant cropping as to be totally unprofitable to operate and consequently large areas have gone back to brush.

Fig. 32. EFFECT OF LIME ON VETCH AND OATS, LINCOLN COUNTY

Above, unlimed plot where vetch failed. Below, increased hay yield of one ton an acre on limed plot. On this land lime is essential to production of legumes and maintenance of soil nitrogen and humus.

Use of fertilizers in Oregon is increasing and needs careful direction About $300,000 was expended for fertilizers in the State the first year and if, as the United States Department of Agriculture estimates, one-

third the amount invested annually in fertilizers is wasted through improper, careless use, then a need for improvement of practice in this line is indicated.

(5) **Publications giving results of investigational work should be provided for.** Bulletins published have been mostly of preliminary nature and in limited editions. Information is on hand for several needed bulletins, and these should be of more thorough character. Funds will be needed for some colored soil maps. When the survey of the Willamette Valley is completed a general report dealing with management of Willamette Valley soils and a map containing data on analyses and fertilizer trials should be published. Drainage bulletins are out of print. A bulletin is needed on improvement of irrigation practice. A new bulletin on sulfur in relation to soils will be needed. Data are at hand for bulletins on irrigation of alfalfa and on management of Deschutes Valley soils.

Needs of Various Stations and Sections

Soil investigation funds are used in that part of the State where emergency soil problems arise; the work has thus been distributed. Present needs of some sections of Oregon are noted.

Deschutes Valley has serious duty-of-water and fertilizer problems to contend with. The work there has paid well in results, and should be continued without interruption. Arrangements for an experiment field of forty acres would allow cumulative effect of crop rotation, manure, and fertilizers, to be obtained there. This could be arranged by an option lease, as is now done with the soil experiment field at Medford. Centering the work on one control tract should save nearly enough traveling expense to pay the rental of such a field.

At Medford one of the original sulfur-alfalfa experiment fields is leased to protect it and at the same time to determine more definitely the effects of sulfur. The plots have been extended under a four-year lease, and irrigation and rotation and manuring trials added. The work there must go on.

A field agent is needed in Malheur Valley during the growing season, to investigate the most practical methods of management of drained alkali land for restoring the soil structure and facilitating reclamation. The State is guaranteeing interest on a million and a third of reclamation bonds in that section, and serious irrigation and alkali problems are developing that require prompt attention.

There is need for fertilizer, drainage, and alkali studies in the Klamath Basin, and it would be a good investment for the State to continue the work there, which has now run for four years without interruption.

The irrigation plots at the home Station have gone through three four-year rotations and are the oldest experimental plots in the State, showing cumulative effects of irrigation, manure, and crop rotation. Results are striking and of great value to students from irrigated sections and to agriculture in general. These plots must be cared for and made permanent.

A good block of ground should be secured for permanent soil-fertility and rotation experiments at the home Experiment Station, with provis-

ion for operation. Additional greenhouse facilities are anticipated, and will be a great aid in control work. The Experiment Station soils labratory room should be equipped so that investigational work can be closed off and separated from student work. A research assistant is needed for work in laboratory, greenhouse, and field.

A State Policy of Soils Investigations and Improvement

The State, as a matter of public policy, should pursue a fairly comprehensive program of soil investigation. To conduct major lines of investigation, including the experiments above described, it is estimated that the soil survey work, irrigation investigations, drainage investigations, and soil-fertility program will require at least $20,000.00 a year for the next biennium. This will provide little more than an effective one-man unit for each of the four divisions of the work. It would be highly desirable to have this appropriation increased by $2,500.00 each biennium until it becomes a fund of $25,000.00

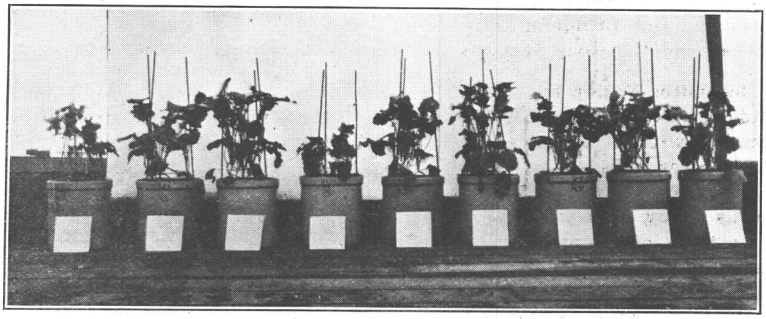

Fig. 33. POTS USED TO STUDY UTILIZATION OF PHOSPHORUS

"Red hill" soils. Lime and sulfur have increased growth, while manure has had a depressing effect in preliminary trials. Field fertilizer trials in Multnomah and Clatsop counties have given profitable increases from use of soluble phosphates on these upland soils, which analyses show to be well supplied with phosphorus but in a rather unavailable form.

a year for the next ten years. This would permit planning and carrying out a comprehensive program of work. Illinois with remarkably uniform agricultural and soil conditions provides $100,000.00 annually for soil investigations, or more than Oregon appropriates to all of the agricultural experiment stations in the State for all investigational work. California provides more annually for irrigation investigations than the above estimate of carrying our entire soil program. It is fundamentally important that permanent systems of soil management be developed before the virgin fertility of our soil is reduced to the point where profits are uncertain. Such systems should provide for the maintenance of fertility and secure maximum profit per unit of land and of water utilized. Our highest productive values will never be realized unless we fully develop, utilize, and conserve the soil and water resources of this State.

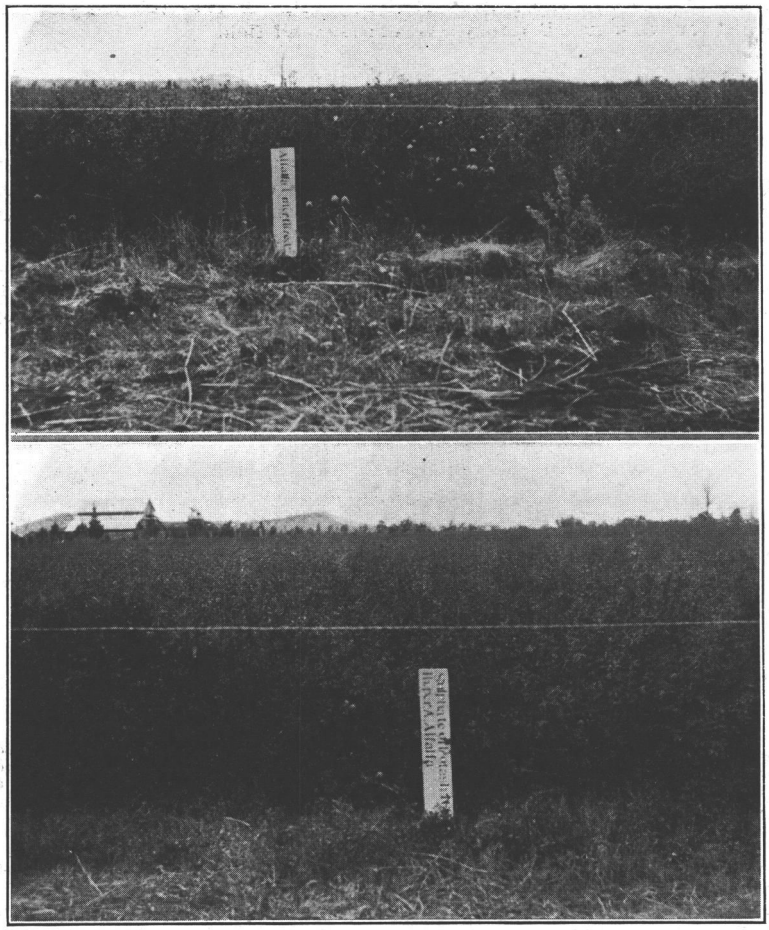

Fig. 34. ORIGINAL SULFATE PLOTS, DESCHUTES VALLEY, 1912

Upper plot untreated yielded three tons of alfalfa. Lower plot treated yielded four tons. On adjoining plots calcium sulfate caused a yield of 3.4 tons and potassium chloride a yield of 3.27 tons. This trial indicated need of sulfur and led to its successful use in Deschutes Valley, where the average increase from later trials has been 1.8 tons an acre.

DEPARTMENT OF SOILS, OREGON EXPERIMENT STATION

Bulletins

Irrigation and Soil Moisture Investigations in Western Oregon
Oregon Experiment Station Bulletin 122 (out of print)

Drainage of White Lands and Other Wet Lands in Western
Oregon, Oregon Experiment Station Bulletin 137 (out of print)

Economic Use of Irrigation Water, Oregon Experiment Station
Bulletin 140

Dry Farming Investigations, Harney Branch Experiment
Station, Oregon Experiment Station Bulletin 150 (out of print)

Improvement of Marsh Lands in Western Oregon,
Oregon Experiment Station Bulletin 157 (limited supply)

The Small Irrigation Pumping Plant, Oregon Experiment
Station Bulletin 160

Duty of Water in Irrigation, Oregon Experiment Station
Bulletin 161 (out of print)

Sulfur as a Fertilizer for Alfalfa in Southern Oregon,
Oregon Experiment Station Bulletin 163 (out of print)

Soils of Jackson County, Oregon Experiment Station Bulletin 164

Improvement of Wild Meadow and Tule Lands,
Oregon Experiment Station Bulletin 167 (limited supply)

The Irrigation of Potatoes, Oregon Experiment Station Bulletin 173

Rational Use of Lime, Oregon Agricultural College Extension Bulletin 305

The Work of the Umatilla Reclamation Project Experiment
Farm in 1918 and 1919, United States Department of Agriculture,
Circular 110

Mimeographs

Fundamental Principles of Irrigation Practice
Measurement of Irrigation Water
Preparation of Land and Methods of Applying Irrigation Water
Time, Amount, and Frequency of Irrigation
Irrigation of Meadow Crops
Materials and Structures for Irrigation Distributaries
Maintenance of Irrigation Systems
Delivery of Water to Irrigators
Construction of Farm Drainage Systems
Drainage of Irrigated Lands
Origin and Formation of Soils
Classification of Soils
Physical Properties of Soils and Their Improvement
Organic Matter of Soils
Use of Land-plaster
Crop Rotation and Permanent Irrigation Agriculture
Use of Fertilizers in Oregon
Sulfur in Relation to Soil
Use of Phosphorus in Oregon Soils

SOILS INVESTIGATIONS

Statement showing appropriations for years 1919 and 1920. Expenditures to December 1, 1920, and balance of said date.

1919 Appropriation		$7500.00	1920 appropriation		$7500.00
Expenditures:			Expenditures:		
Salary	$3151.01		Salary	$2273.77	
Labor	785.30		Labor	923.40	
Publications	77.88		Publications	488.76	
Telephone and Telegraph	5.70		Telephone and Telegraph	9.34	
Heat, etc.	5.00		Freight and Express	98.25	
Supplies	942.17		Supplies	1777.90	
Tools, Etc	151.84		Travel	1457.38	
Scientific Apparatus	387.74		Rent	382.50	
Travel	1315.70				
Contingent	350.00				
		$7200.46			$7411.30
Cash Bal., 12/1/20		$299.54	Cash Bal., 12-1-20		$88.70

Respectfully submitted,
E. M. DUFFY,
Business Manager.