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Some Experiments With Subsoiling.

BY B. C. BUFFUM AND W. H. FAIRFIELD.

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Some Experiments With Subsoiling.

BY B. C. BUFFUM AND W. H. FAIRFIELD.

The natural requisites for farming are soil, water, air, heat and sunshine. With one exception these natural blessings are sufficiently abundant in the arid west. That exception is water. The greatest question in our agriculture is how to make the most of our limited supply of this life-giving element. Making use of our water supply would be a comparatively simple matter if all the moisture which might be brought to the soil could be held there until plants could make use of it. But water is never still. In seeking its common level, the sea, it runs off the surface of the land, or seeps through the upper layers, escaping from below and that which is retained for a time by the soil is being continually dissipated into the air as invisible vapor. In our dry climate the evaporation is so great that five or ten times as much water as comes to the earth in a year by rain would be lost by this process alone. Any practical plan then of saving as much moisture as possible for the use of crops is of great importance and value.

Tillage consists of stirring the soil and is as old as agriculture. Its effect is somewhat complex. It breaks up the soil admitting air, without which plants can not grow. It loosens the soil so it becomes suitable for planting the seed, as well as for the development of plant roots and for the absorption of water, brought to it by rain or irrigation. It disintegrates the soil particles continually unlocking and making available to the plant new stores of plant food. It destroys weeds. Breaking up the surface forms a blanket which prevents the rapid loss of water by evaporation. Is it enough that we shall cultivate the surface of the earth, or

shall we find it profitable to extend tillage deeper into the hitherto undisturbed subsoil?

Subsoiling is stirring the earth below the region of the plow. For convenience we speak of the first eight inches of soil which may be turned over in plowing as the surface soil and all below this as the subsoil. Plowing turns the surface soil bottom side up. Subsoiling does not change the position of that part of the soil, but it breaks up and stirs the ground below the ordinary depth of plowing. This may be effected by a spur or prong attached to the plow which breaks up the soil at the bottom of the furrow, or it may be done with a separate implement to be drawn along through the soil beneath the bottom of the furrow after the plow, to stir the ground to greater depths than can be done with a small attachment to the ordinary plow. This implement is called the subsoil plow and usually consists of a mole or a more or less flat piece of iron pointed at one end and attached to the beam by a strong flat vertical blade. When drawn through the soil in the bottom of the furrow left by the plow this implement can be made to break up and stir the subsoil to a depth of from one to two or more feet.

The advantages claimed for subsoiling are that it makes more room for root development, and enables the plant to extract food and moisture from a greater area, and that by loosening up more of the soil its capacity for absorbing and retaining moisture is increased. By the absorption of greater amounts of moisture in winter and spring it is supposed that subsoiling provides against summer drouth. It is reasonable to suppose that this is what would happen and the many favorable reports on subsoiling from humid and semi-arid regions indicate that loosening the lower layers of soil is a valuable way of conserving moisture for those regions. Before discussing the effects of subsoiling in Wyoming the differences between a truly arid region and one

which is only semi-arid should be briefly pointed out. Places where the annual rainfall is less than fifteen inches are generally called arid. The air is dry; the evaporation is great; the rainfall is not sufficient to mature cultivated crops. In the semi-arid region the rainfall is more than fifteen inches and may be enough to mature profitable crops if the moisture can be stored up in the soil and saved until the crop can make use of it. In Wyoming the conditions are truly arid unless it be in the extreme northeastern portion of the state. There is little precipitation during the fall and winter, so very little moisture escapes by running directly off the surface of the land. If, then, subsoiling is not necessary to increase the holding capacity of the soil, and absorb water during time of extra supply, will it save more of the water which may be applied artificially during the growing season and will this and other advantages make it profitable to go to the extra expense of such tillage in our state?

To solve this question we have been experimenting with subsoiling for three years and this bulletin is published to report the results obtained. The experiment was conducted in the same manner on the several experiment farms in the state. Unfortunately the records of the Lander farm were lost in transit, and the publication of this bulletin has been long delayed with the hope they might be found. The soil of the Lander and Sundance farms is almost identical, the altitude of the two places is not far different and while the experiment in subsoiling was only carried out one season at Sundance, a comparison of the results obtained would be highly interesting. The climate of Sundance is semi-arid or sub-humid, crops being raised without irrigation, while that of Lander is arid and no crops are raised without irrigation. A comparison of the results at these places would give more trustworthy evidence of the difference in value of subsoiling under such conditions of climate and farm practice.

The experiment was begun in the spring of 1896 and car-

ried out that year at Laramie, Lander, Sheridan, Sundance and Wheatland. In 1897 the cropping was repeated on the same land at Laramie, Lander and Sheridan, and in 1898, at Laramie only.

PLAN OF THE EXPERIMENT.

Following is an outline of the instructions for subsoiling which, with slight modifications for each locality, were furnished the farm superintendents in the spring of 1896—

This experiment is to be carried on alike on each of the farms. Select a suitable acre plat. Plow the land over the whole plat the same and let all other operations such as harrowing, etc., be the same for all parts of the plat. Subsoil thoroughly one-half of the plat. Mark carefully and permanently the line where the subsoiling stops.

Divide the plat into four equal parts so one-half of each fourth is on the subsoiled portion and one-half on the part merely plowed.

Upon the first fourth acre plant oats.

Upon the second fourth acre plant potatoes.

Upon the third fourth acre plant wheat.

Divide the last fourth into two parts and plant beets on the one and corn on the other.

Treat the crops on the plowed and subsoiled land the same throughout the season. Keep careful notes of any variations on the two parts of each plat.

When you harvest each crop cut out a strip six feet wide along the line on which the subsoiling stops, casting out the crop from a strip three feet wide on each side of this line, which part is to be taken no account of in figuring up the yields on subsoiled land or land not subsoiled. This is important as the effects on the ground treated or untreated will reach across the line some distance.

Measure the area in square feet occupied by each crop to be used in figuring up the yields. In the case of rowed

crops, allow for the number of rows at their distance apart and take the length of row on treated and untreated land.

This experiment will be repeated upon the same ground for a number of years to determine the effect of subsoiling on soil and crops—.

In 1898 some additional land was subsoiled and on one plat of oats covering one-half acre an accurate measurement was made of the irrigation water used. In 1897, the next year after the land was subsoiled for this experiment, the Physicist made a study of the moisture content of different soils which was published in Bulletin No. 35 of this Station, a resume of which is used in this report.

Results of the Experiments.

Plants of different kinds act very differently when grown on subsoiled land. The effect on a crop of loosening the soil to a depth greater than by ordinary plowing is also very different on different soils and under varying climatic conditions. Our experiments were carried out in widely separated parts of Wyoming and with the more important crops raised in each section. Again there are often accidental variations which throw doubt on the value of an experiment and where possible the work has been repeated more

than one season. The conclusions reached have been carefully drawn and we believe the results of these experiments are worthy of consideration by our farmers.

The soil on the station farm at Laramie contains considerable gypsum and lime carbonate, is quite sticky when wet and becomes firmly compacted below the plow. The land selected for this experiment had been cultivated for a number of years. It was plowed about eight inches deep and one-half the plat was subsoiled to a depth of fourteen to sixteen inches in April, 1896. The ground was so hard that four horses were required to pull the subsoil plow and if larger areas were to be treated six horses would be necessary. The land was not again subsoiled but the difference in the yield of crops produced was observed for three seasons. This shows the lasting effects of subsoiling and the return which may be expected from one such treatment, and throws light on the absorption and retension of water through the entire year. The second year there was a slight difference in the depth of the plowing on the two portions of the plat. Where the land had been subsoiled the plow sunk one to three inches deeper than on the plowed portion.

On the other station farms in the state the plowing and subsoiling was done in the same manner as at Laramie. At Sheridan the soil is clay underlaid with true hardpan. It is not known to what extent this hardpan was broken up by the subsoil plow. At Wheatland the soil conditions are much the same as those at Laramie. At Sundance the soil is deep, contains gypsum and much of the subsoil consists of red shale which is not tenaceous but comparatively easy to work.

The average rainfall is nearly ten inches at Laramie; about the same at Wheatland, nearly fourteen inches at Sheridan and twenty inches at Sundance. At Laramie and Wheatland from fifty to sixty percent of the total annual precipitation falls in the growing months of May, June,

July and August. The greater amount of precipitation at Sundance and the fact that the land was not irrigated undoubtedly accounts for some of the difference noted in the effects of subsoiling between the Sundance and other farms.

Subsoiling for Grain Crops.

Table I. gives the effects of subsoiling on the yields of wheat. Though the difference was not great, the yield from the subsoiled land was less than that from the land only plowed, at Laramie, the year the subsoiling was done. The second and third years there was a slight increase in yield from the subsoiled land. The increase in the yield of straw is greater in proportion than that of grain. This condition would be expected as the increased feeding area of the roots and other conditions favoring rank growth would produce more straw and less grain where the growing season is short. The reason for this is indicated in Wyoming Station Bulletin No. 37 on the "Stooling of Grains." It is a general law that under adverse conditions plants strive to mature seed in order to reproduce themselves. Under these conditions then, grain will mature earlier and produce more seed in proportion to the rest of the plant than where everything is favorable to long continued growth.

TABLE I.—*Subsoiling for Wheat.*

Yields in Pounds per Acre.

		LARAMIE.		SHERIDAN.	WHEATLAND.	SUNDANCE.	
		Straw and Grain	Grain	Grain.	Grain.	Straw and Grain.	Grain.
First Year.	Subsoiled	2627	943	3000	1526	3920	1440
	Plowed.	2863	997	2550	1614	3441	1160
	Gain.			450	112	480	280
	Loss.	236	54				
Second Year.	Subsoiled.	2174	901	2700			
	Plowed.	1894	876	1950			
	Gain.	280	25	750			
Third Year.	Subsoiled.	2170	908				
	Plowed.	2127	833				
	Gain.	43	85				

The increase in yield of wheat at Laramie the second and third years on the land which had been subsoiled is but little more than enough to balance the decrease the first season. At Sheridan there was an increase in yield the first year of seven and one-half bushels and the second year of twelve and one-half bushels on subsoiled land. At Wheatland and Sundance the increase on subsoiled land was small but was over twice as much at Sundance as at Wheatland.

The results with oats are given in Table II. The lengthening of the season for oats by subsoiling was more marked than with wheat. At Sundance the oats on the subsoiled portion of the plat seemed to be making better growth during the first part of the season but, when harvested, Superintendent Hoyt reported a smaller yield than was obtained from the land treated in the ordinary way. At Laramie the oats were later in reaching maturity on the subsoiled land. It may be stated that late varieties of nearly all crops, if not interfered with by frost, produce heavier yields than those which require only a short season in which to mature. Lengthening the growing season for the same variety would be expected to increase the yield, but at the high altitude of the land over a large part of Wyoming the time between late and early frosts is comparatively short and earliness in ripening is a most important factor. There was a slight increase in yield of oats the first two years, but the third season the decrease in crop was almost enough to balance the gains of the first two seasons, though whether or not the effect the third season was due to subsoiling may be questioned.

At Sheridan there was a loss of seventy pounds more of oats the first year than was gained the second year by subsoiling. At Wheatland there was a small increase on the subsoiled land, but the variation was small, probably not more than would be obtained on any two plats, though treated exactly alike. To all appearances the yields of oats

were not materially influenced at any place by subsoiling the land.

TABLE II.—*Subsoiling for Oats.*

Yield in Pounds per Acre.

		LARAMIE.		SHERIDAN.	WHEATLAND.	SUNDANCE.	
		Straw.	Grain.	Grain.	Grain.	Straw.	Grain.
First Year.	Subsoiled.	4390	1520	3070	1898	1960	512
	Plowed.	3898	1345	3360	1614	2224	648
	Gain.	492	175		184		
	Loss.			290		356	136
Second Year.	Subsoiled.	3555	1345	2700			
	Plowed.	3378	1194	2480			
	Gain.	177	151	220			
	Loss.						
Third Year.	Subsoiled.	3645	1302				
	Plowed.	4445	1526				
	Gain.						
	Loss.	800	224				

Because of the high altitude with the accompanying short seasons and cold nights, corn is not grown at Laramie, so barley was planted on one portion of the subsoiled plat at this place and corn was grown at Sheridan, Wheatland and Sundance instead of barley. The results with barley and corn are given in Table III. It is doubtful if any effect on the yields of barley one way or another can be traced to the subsoiling. The first year there was less straw and more grain on the subsoiled land. The second year this was reversed, there being more straw and less grain where subsoiled, and the third year there was approximately no difference in the production of straw, but there was quite a decrease in the yield of grain.

Subsoiling for corn did not pay at the sub-stations except at Sundance where a good increase in yield was obtained. At Sheridan there was quite a large decrease in yield of corn the first season, and no difference the second year. Superintendent Lewis reported that the corn did not mature as well on the subsoiled land. The first year the estimated yield on the subsoiled part of the plat was

thirty bushels per acre, and on the land not subsoiled thirty-five bushels per acre. Ten per cent. of the corn on the land merely plowed ripened thoroughly, while all the grain from the subsoiled portion of the plat was soft and immature. The second season fifty bushels of mature and thirty bushels of soft grain per acre were harvested from each portion of the plat. To compare with others in the table, these yields have been reduced to pounds by using the weight of seventy pounds per bushel for corn in the ear.

At Wheatland during the season of 1896, the supply of water for irrigation was somewhat limited, and if the crops suffered for water, as they probably did to some extent, those on the subsoiled land would be expected to have the advantage. Mr. M. R. Johnson, the superintendent, states that all the crops made a better growth on the subsoiled land, that they seemed to withstand drouth better, and that the quality as well as the quantity of the product, indicated beneficial effects from subsoiling. The corn gave an increased yield of 363 pounds per acre on the subsoiled land.

TABLE III.—*Subsoiling for Barley and Corn.*

Yield in Pounds per Acre.

		LARAMIE.		SHERIDAN.	WHEATLAND.	SUNDANCE.
		Barley.		Corn.	Corn.	Corn.
		Straw.	Grain.	Grain.	Grain.	Grain.
First Year.	Subsoiled	2944	1325	2100	3590	3008
	Plowed	2989	1292	2450	2227	2416
	Gain		33	—	363	592
	Loss	45	—	350	—	—
Second Year.	Subsoiled	4602	1479	3500		
	Plowed	4123	1668	3500		
	Gain	479	—	—		
	Loss		189	—		
Third Year.	Subsoiled	2169	527			
	Plowed	2175	752			
	Gain		—			
	Loss	6	225			

Subsoiling for Root Crops.

The fact that deep soils are favorable for the growth of roots is recognized everywhere, and as would be expected subsoiling produced more marked effects on the yields of root crops than it did on grains. In Table IV., reporting the results with root crops, it will be seen that in every trial there was increased yield from the subsoiled land, and in some instances there are important gains. The lasting effect of subsoiling is well brought out in this table. All the tables show that, at Sherman, where the experiment was carried out two years, and at Laramie where results were obtained three seasons, the beneficial effect of subsoiling is greater the second year than it is the season the subsoiling is done. This indicates that it would be advisable to subsoil in the fall rather than in the spring. The third year the soil has probably become compacted again so the effect is much less than it is the first two seasons.

TABLE IV.—*Subsoiling for Root Crops.*

Yield in Pounds per Acre.

		LARAMIE.			SHERIDAN.		WHEAT-LAND.		SUNDANCE.	
		Potatoes.	Beets.	Turnips.	Potatoes.	Beets.	Potatoes.	Beets.	Potatoes.	Beets.
First Year.	Subsoiled			8695	12858	13860	2425	8302	8224	17161
	Plowed			8380	10620	12600	2151	8009	6960	14841
	Gain			315	2238	1260	274	293	1264	2320
Second Year.	Subsoiled	3672	12893			28700				
	Plowed	2620	11643			24795				
	Gain	1052	1250			3905				
Third Year.	Subsoiled	6940	5450							
	Plowed	6865	4522							
	Gain	75	928							

POTATOES—At Laramie the potatoes planted the first year failed to grow because the soil was too dry. The second and third years the stand was poor and small yields were obtained, but there was a good increase of crop on the sub-

soiled land. In Table IV, only the yields of potatoes which were of sufficient size for market are reported. The proportion of large and small tubers on the two kinds of ground and the increase in size on the subsoiled land is of interest. Table V, gives the yields of large and small potatoes, the percent marketable and the weight of the largest twelve tubers from each portion of the plat at Laramie in 1897 and 1898. The difference in yield in 1898 is small and there was practically no difference in the size of the potatoes, indicating that little effect on this crop was produced by the lower soil having been loosened up three years before. The second season after subsoiling, however, there was not only a large increase in the yield, but in the size of the tubers as well.

TABLE V.—*Effect of Subsoiling on Size of Potatoes.*

at Laramie, Wyo.

	1897.				1898.			
	Yield.		Percent Market- able	Weight of largest twelve.	Yield		Percent market- able.	Weight of largest twelve.
	Large.	Small.			Large.	Small.		
Subsoiled	3672	1552	70.3	5.1	6940	2417	74.2	4.6
Plowed	2620	1660	61.2	4.5	6865	2212	75.5	4.6
Gain	1052	892	9.1	0.6	75	205		

At Wheatland the subsoiling produced little effect on potatoes. The increase in yield of marketable potatoes was only 274 pounds. Of the entire crop 62.8 percent were marketable on subsoiled land, and on the land not subsoiled the marketable tubers were 63.6 per cent of the whole crop. At Sheridan and Sundance the small potatoes were not reported, but at Sheridan the largest 12 tubers from subsoiled land weighed six and one-half pounds and from plowed land six pounds.

SUGAR BEETS—Subsoiling gave satisfactory increase in yields of sugar beets at every place except Sheridan. At

Laramie the increase in size of the beets is worthy of special mention. Not only were the largest twelve very different, from the two plats, but the average size of the roots was much larger on the deep soil. In 1897 the largest twelve roots from the subsoiled plat weighed nineteen pounds and from the plat not subsoiled twelve roots weighed eleven pounds. In 1898 the difference was less.

Twelve of the largest beets from the subsoiled plat weighed in the aggregate seven and one-half pounds and from the plowed land six and one-half pounds. Analysis of the beets showed slightly better results from the land not subsoiled. Beets from subsoiled land contained 19.7 percent sugar and had a purity of 88.2, while those from the adjoining plowed land contained 20.3 percent sugar and had a purity of 92.7.* The analyses were made from the crop of 1897, the second year after subsoiling.

SUBSOILING, IRRIGATION AND SOIL MOISTURE.

The subsoil plats were small, and as it was necessary to treat the crops alike on both parts of the plat, it was impossible to measure the amount of water used on each portion. An experiment was carried out with different amounts of water on the potatoes growing on the subsoiled land in 1897. Measurements were made of the total amount of water used on the plat, one half of which was subsoiled and also on another subsoiled plat, and we are able to compare these measurements with the amount of water used on other fields. During the season of 1897 the Physicist made a series of moisture determinations on the different soils and published the results in Bulletin No. 35, a resume of which is shown in the accompanying diagram. These observations enable us to draw some conclusions in relation to the soil moisture and the use of irrigation water on such deeply tilled soils at Laramie.

In 1896 the barley, oats and wheat, were irrigated twice,

*See Wyoming Station Bulletin No. 26, Page 197.

on the acre of land one-half of which was subsoiled. At the first irrigation on July 2, enough water was applied to cover the land 11.4 inches deep and at the second irrigation enough water was applied to cover the land 6.12 inches deep, or a total depth for these crops of 17.52 inches. The precipitation for the year was 10.75 inches of which 4.75 inches fell during the months of May, June, July and August. This gave a total of 22.27 inches for the growing season or 28.22 inches of water for the year. The same year wheat and oats on other fields received enough water by irrigation to cover the land to a depth of 14.88 inches, and barley received 14.52 inches of water, showing that enough more water was applied to the acre, one-half of which was subsoiled, to cover the whole plat three inches deep. If this was due to the effect of subsoiling it means a requirement of six inches more water on the subsoiled land. Unfortunately the record of measurements of water on the subsoiled plat was broken, so it cannot be reported for 1897, but in 1898, trustworthy measurements were secured. The wheat, oats and barley were irrigated twice. On June 24, enough water was applied to cover the land 11.52 inches deep, and July 13 enough water to cover it 9.12 inches deep or a total of 20.64 inches. Including the rainfall, the land received enough water during the growing season to cover it to a depth of 25.22 inches, and in the year 28.26 inches. It is not possible to draw conclusions in regard to the effect of the subsoiling on this plat in 1898, as other crops of the same kind received varying quantities of water, some more and some less than this amount.

On another plat, however, which was subsoiled in the spring of 1898 and planted to oats, the amount of water used in irrigation was very large. The land was irrigated twice. At the first irrigation on June 27, enough water was used to cover the land 30.84 inches deep, and all of it was absorbed by the soil. At the second irrigation, July 11, enough was used to cover the land 13.44 inches deep,

FIVE FEET OF SOIL, LARAMIE FARM.
One Year after Subsiding.

making a total for the season of 44.48 inches, or 3.69 feet. Including the rainfall, this gave a depth of water brought to this land in the year of 51.91 inches or for the growing season of 48.47 inches. The amounts of water used on other plats of grain in 1898, was 1.90 feet on one field of oats, 2.58 feet for oats on sod, 1.55 feet for oats and cultivated grain, 2.70 feet for one plat of barley, 1.74 feet for one plat of wheat and oats, and 3.63 feet for one field of wheat, which was irrigated three times and given an unusual amount of water.

The illustration of five feet of soil on the Experiment Station is made from a photograph taken one year after the subsoiling was done. The upper eight inches of dark soil is the portion turned over each year by the plow. The next six or eight inches of subsoil shows the effect of having been loosened by the subsoil plow, leaving it porous. On the native plains the soil below the first one or two feet may not have been wet for ages, as the natural rainfall is not sufficient to wet more than the first few inches of surface, and there is practically no difference in composition between the surface and subsoil. Breaking up the layer which is compacted by the plow in the bottom of the furrow gives the water a new reservoir below the plowed land and affords a means of escape by seepage, which would account for the large amounts necessary to soak it up when irrigated and perhaps also for easy dissemination and loss of the moisture afterwards.

In 1898 the potatoes on the plat, one-half of which was subsoiled, were divided into two parts. One part was irrigated twice, using only a small amount of water each time and the other part was irrigated three times. Those irrigated twice received enough water to cover the land 2.04 inches deep on July 28, and 1.56 inches deep on August 4. The ones irrigated three times received the first irrigation on July 7, when enough was applied to cover the land 10.20 inches deep. At the other two irrigations they were

given the same amounts as the potatoes which were irrigated but twice. The results are given in Table VI., which shows the amount of water applied and the yields on land subsoiled and not subsoiled.

TABLE VI.—*Potatoes with Two and Three Irrigations on Subsoiled Land.*

Laramie, Wyo., 1898.

	Total amount of water applied. Inches.	Yield on land plowed Pounds.	Yield on subsoiled land. Pounds.	Average yield. Pounds.	Weight of largest twelve plowed. Pounds.	Weight of largest twelve Subsoiled. Pounds.
Irrigated twice	3.6	4972	5290	5131	3.6	3.9
Irrigated three times.	13.8	8759	8591	8675	5.6	5.3
Increase	10.2	3787	3301	3544	2.0	1.4

This shows an increase due to the increased amount of water applied, of over seventy-six percent on plowed land, and sixty-two percent on subsoiled land, the average increase being about sixty-nine per cent. The fact that increased water applied in irrigation did not increase the crop as much on subsoiled land as on the land which was plowed is in favor of the subsoiled land as it indicates that the crop actually needed less water to produce the same yield. This may be true, as the variation is small and may be accidental, and it is possible and probable that more water was actually absorbed by the subsoiled portion when irrigated. It is unfortunate that we are not able to make a like comparison the first and second seasons after subsoiling.

If moisture comes to the soil during any part of the year, the friends of subsoiling claim that it is retained and made more available to the crop. The study of the moisture in the soil of the different plats at Laramie in 1897, which was made by the Department of Physics, does not seem to bear out such statement. The accompanying chart illustrates the difference in moisture content of the soils on sod land, on land which was plowed in the usual way and on the subsoiled land. The determinations of moisture were made

daily and these have been averaged for each month. The samples were taken to the depth of one foot by driving tubes about one inch in diameter into the soil. On the loose ground some of the soil might be driven down in front of the tube instead of entering it, but the samples were carefully taken and no effect of the kind was noted. The vertical black lines in the chart represent the average percent of moisture in the soil which is also expressed in figures at the top of each column. The last three columns at the right represent the average percent of moisture for the summer. The lowest moisture content observed was 2.52 percent in sod land, September 24. The highest percent observed was 22.25 on the land plowed but not subsoiled and immediately after irrigating it. The amount dropped to 19.7 percent the second day, and to 15.76 percent the third day. On the subsoiled part of the plat after irrigating the percent was 21.15 the first day, 21.76 the second day, decreasing to 16.23 the third day after applying the water. There is little difference in the average moisture of the surface soil on the plowed land and that subsoiled, but what difference there is shows less moisture on the subsoiled land throughout the summer. These facts indicate that more water was needed at Laramie to irrigate subsoiled land and less of it was retained by the surface soil for the use of the plants growing thereon. It is possible there was more water in the soil below the depth of these samples on the subsoiled plat, but the difference was not great enough to produce marked effects on the crops. At Sheridan the Superintendent states that more water was required at the first irrigation and less at the second on the subsoiled land. At Wheatland the crops seemed to be less affected by drouth where subsoiled. This may have been due to an excess of water absorbed by the subsoiled land when it was irrigated.

Soil Moisture, 1897.

DOES SUBSOILING PAY ?

The test of the advisability of any operation on the farm lies in the final result measured in dollars and cents. Subsoiling is an expensive operation which more than doubles the ordinary cost of preparing the land for the crop by plowing. The cost of subsoiling will vary with the condition of the soil and the price of labor. The cheapest it could be done on large areas, and thoroughly done as in these experiments, would be at a cost of not less than three dollars per acre. Where we broke up the subsoil to a depth of fourteen to sixteen inches, on small plats the expense was five or six dollars per acre. Unless it increases the yield, improves the quality and therefore the value of the crop, or reduces the expense of producing it, or requires less water so the same supply will irrigate more land, the practice of subsoiling cannot be recommended as one to be adopted on the farm.

Referring to Table I. in which the yields of wheat on subsoiled land and on land prepared in the ordinary way are compared, it is evident that the accumulated increase for three seasons at Laramie would not pay the expense of one subsoiling. At Sheridan the increase of 450 pounds of wheat per acre the first year and 750 pounds the second due to subsoiling would give a total value of twelve dollars per acre more from the subsoiled land. If the subsoiling cost four dollars per acre more than the ordinary expense of plowing, the margin of profit is large enough. Even though we allow for a considerable increase in yields the second year at Wheatland and Sundance, subsoiling would not pay for wheat in these localities.

The results with oats as given in Table II. do not show any marked or uniform improvement in the crop. So far as our experiments may be relied upon as showing the true effects of subsoiling in this state, the indications are that it will not pay to so prepare the soil for oats. The same

statement may be made for barley and corn unless it be at Sundance, where the increase the first year and the probability that there would also be a like increase in the crop the second year, indicate that subsoiling for corn might pay in that region.

Subsoiling for root crops did not give a return the first year at Wheatland, large enough to pay the cost, though the quality of the crop was improved and the increase the second season might leave a profit. At Laramie the increase in the potato crop the second year (see Table IV, page 11), would be worth \$10.50 to \$13.00 at the local market price. On the Sheridan farm the increased yield of potatoes the first year was worth from \$11 to \$20, and at Sundance from \$6 to \$12, depending on the market price. The value of sugar beets for stock food would make the increased yields from subsoiled land at Laramie, Sheridan and Sundance profitable. As a rule we believe that subsoiling for root crops will bring a profitable return.

Whether or not subsoiling will pay depends largely on local conditions and the kind of crop. Before adopting so expensive a system of tillage the farmer should satisfy himself in regard to whether it will bring a profit on his land by making small trials. Our results can not be said to indicate that subsoiling in regions which depend on irrigation will materially assist in saving the moisture or make irrigation less necessary. It is true that subsoiling apparently mitigated the effects of drought somewhat in Wheatland, though the increase in the value of the crop was not sufficient to pay for the expense incurred. It is possible that, where water for irrigation is scarce, and other conditions are favorable, subsoiling might make the water which is available go farther in maturing a crop, though we have been unable to prove any valuable saving of moisture where the subsoil is made porous.

SUMMARY.

The expense of subsoiling to depths of sixteen or eighteen inches is from three to six dollars per acre.

Subsoiling is probably more valuable in semi-arid or humid regions than where irrigation is practiced.

The effects of once subsoiling the land may continue for three or more years and under our conditions are more apparent the second season after the subsoiling is done than they are the first.

If subsoiling is to be practiced, we recommend doing it in the fall.

Subsoiling does not produce a uniform effect on the grains. Under certain conditions it may pay for wheat raised by irrigation. We have not found it profitable for oats, barley, or corn.

Grain takes longer to mature on subsoiled land. At high altitudes where the season is comparatively short it is doubtful if subsoiling for grain is advisable.

The quantity and quality of root crops are greatly improved by subsoiling the land. Subsoiling can be generally recommended in this state for potatoes.

Under our conditions subsoiling has increased the amount of water needed to irrigate the land and apparently is of little value in conserving moisture. However, if no water could be applied by irrigation during the summer, the filling with moisture in the winter or spring by rainfall or irrigation of the reservoir formed by subsoiling, would be beneficial.

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