Bulletin No. 158 - Soil Moisture Studies Under Dry-Farming

F. S. Harris

J. W. Jones

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Soil Moisture Studies Under Dry-Farming

BY

F. S. HARRIS and J. W. JONES

Logan, Utah, July, 1917.
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STATION

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SOIL MOISTURE STUDIES UNDER DRY-FARMING
BY F. S. HARRIS and J. W. JONES*

I. INTRODUCTION

Profitable cultivation of land under dry-farm conditions is dependent on the efficient use of precipitation. Soil fertility is not at present the limiting factor in crop production on most arid lands, but insufficient moisture to make available the fertility of these dry-lands is not only a limiting factor, but in most cases the controlling factor in crop production. The rainfall in the principal dry-farming areas of Utah varies from 12 to 15 inches a year. During different years it may range from 10 to 22 inches; therefore the best use must be made of the water that falls.

The major portion of the precipitation in Utah comes during the winter and spring months which makes a deep soil with great water-storing capacity essential if the moisture is to be retained for crop use. This bulletin treats primarily the problems of accumulation and use of the soil moisture.

The results herein presented were obtained under field conditions and should be applicable to areas with similar soil and climatic conditions, but the conclusions could not be applied unless conditions were the same.

These data were obtained in co-operation with the Office of Cereal Investigation and Biophysical Investigations of the U. S. Department of Agriculture.

In studying these deductions it is urgently requested that the soil type and climatic conditions be constantly kept in mind so that erroneous conceptions or conclusions may not be drawn. Studies to determine the most efficient and economical methods of storing water in the soil as well as moisture movements in the soil have been made since the spring of 1908 at the Nephi Sub-station.

*The authors wish to acknowledge their indebtedness to F. D. Farrell, P. V. Cardon, and A. D. Ellison, former superintendents of the Nephi Sub-station, and to A. F. Bracken and H. W. Turpin, all of whom took many of the samples and made many of the moisture determinations reported in this bulletin.
The Nephi Sub-station is located in Juab Valley in about the central part of the state on a transverse rise in the land called the Levan Ridge. The water table on this ridge is several hundred feet below the surface. Sub-irrigation is impossible, due to absence of any canals and a general water shortage throughout the section. Ideal conditions for studying the storage and use of moisture are presented because all crops are absolutely dependent on the normal precipitation.

1. Precipitation

Records of the moisture falling for the past 19 years first at Levan, Utah, and later at the Nephi Sub-station show that the annual precipitation varied during this period from 9.08 inches in 1910 to 18.48 inches in 1906. Similar and even greater variations are observed for the different months of these years. During May in 1898, 5.57 inches of rain fell, while records of the same month in 1902 show only .16 inches. In 1914 the rainfall for June was 1.94 inches, while in 1916 no rain was recorded during this month.

![Figure 1](image-url)

Fig. 1.—Diagram showing the annual precipitation at Nephi, Utah, for the years 1898 to 1916 inclusive. The normal rainfall is presented by cross line.
SOIL MOISTURE STUDIES UNDER DRY-FARMING

About 85 per cent of the precipitation at Nephi falls between October and May inclusive; May, June, and July are the three months during which winter wheat, the leading dry-farm crop, makes practically all its growth. It is essential since most of the precipitation comes during the non-growing season, that every effort be made to catch and retain this moisture until needed by the growing crops. If the moisture is not saved low yields are the result. (See Table 1 and Figure 1).

TABLE I.—PRECIPITATION BY MONTHS FOR THE 19 YEARS BETWEEN 1898 AND 1916 AT THE NEPHI SUB-STATION.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
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<td>0.25</td>
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<td>0.00</td>
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<td>1.09</td>
<td>1.91</td>
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<td>1900</td>
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<td>0.12</td>
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<td>0.03</td>
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<td>0.02</td>
<td>0.22</td>
<td>0.20</td>
<td>0.91</td>
<td>0.52</td>
<td>1.43</td>
<td>1.72</td>
<td>12.49</td>
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<td>2.26</td>
<td>0.48</td>
<td>0.47</td>
<td>0.15</td>
<td>0.92</td>
<td>1.56</td>
<td>0.24</td>
<td>0.52</td>
<td>12.58</td>
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<td>1.44</td>
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<td>3.10</td>
<td>0.02</td>
<td>0.36</td>
<td>0.17</td>
<td>0.20</td>
<td>1.05</td>
<td>0.00</td>
<td>0.97</td>
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<td>1.57</td>
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<td>1.39</td>
<td>0.21</td>
<td>0.31</td>
<td>0.60</td>
<td>3.17</td>
<td>0.08</td>
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<td>0.57</td>
<td>12.63</td>
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<td>2.92</td>
<td>0.43</td>
<td>0.80</td>
<td>1.57</td>
<td>0.61</td>
<td>T</td>
<td>1.47</td>
<td>1.82</td>
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<td>1.58</td>
<td>0.32</td>
<td>1.46</td>
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<td>1.11</td>
<td>1.13</td>
<td>0.20</td>
<td>3.64</td>
<td>0.67</td>
<td>0.52</td>
<td>3.41</td>
<td>2.28</td>
<td>1.73</td>
<td>0.46</td>
<td>0.62</td>
<td>16.57</td>
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<td>1.70</td>
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<td>2.21</td>
<td>0.68</td>
<td>0.17</td>
<td>0.95</td>
<td>2.84</td>
<td>0.68</td>
<td>0.32</td>
<td>1.53</td>
<td>1.51</td>
<td>16.19</td>
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<tr>
<td>1910</td>
<td>0.61</td>
<td>0.61</td>
<td>0.81</td>
<td>0.46</td>
<td>0.72</td>
<td>0.03</td>
<td>0.38</td>
<td>0.10</td>
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<td>0.58</td>
<td>0.84</td>
<td>9.98</td>
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<td>1911</td>
<td>1.92</td>
<td>0.61</td>
<td>1.05</td>
<td>0.56</td>
<td>0.24</td>
<td>0.76</td>
<td>1.77</td>
<td>0.28</td>
<td>1.07</td>
<td>0.75</td>
<td>0.44</td>
<td>0.66</td>
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<td>0.29</td>
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<td>0.47</td>
<td>1.05</td>
<td>0.17</td>
<td>0.48</td>
<td>0.62</td>
<td>0.47</td>
<td>2.07</td>
<td>1.52</td>
<td>0.90</td>
<td>11.33</td>
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<tr>
<td>1913</td>
<td>0.59</td>
<td>1.45</td>
<td>0.78</td>
<td>0.86</td>
<td>0.30</td>
<td>1.08</td>
<td>0.16</td>
<td>1.68</td>
<td>1.12</td>
<td>1.30</td>
<td>1.81</td>
<td>1.21</td>
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<tr>
<td>1914</td>
<td>2.94</td>
<td>1.00</td>
<td>0.43</td>
<td>3.20</td>
<td>0.71</td>
<td>1.94</td>
<td>1.74</td>
<td>0.29</td>
<td>0.04</td>
<td>1.35</td>
<td>0.15</td>
<td>0.65</td>
<td>14.44</td>
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<td>1915</td>
<td>1.27</td>
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<td>1.04</td>
<td>0.02</td>
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<td>0.49</td>
<td>0.30</td>
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<td>1916</td>
<td>1.95</td>
<td>1.75</td>
<td>2.96</td>
<td>0.28</td>
<td>0.96</td>
<td>0.00</td>
<td>1.14</td>
<td>0.78</td>
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<td>2.54</td>
<td>0.20</td>
<td>1.26</td>
<td>14.32</td>
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<tr>
<td>Total</td>
<td>23.59</td>
<td>24.94</td>
<td>32.34</td>
<td>32.07</td>
<td>32.73</td>
<td>16.79</td>
<td>11.80</td>
<td>17.98</td>
<td>18.33</td>
<td>23.33</td>
<td>16.80</td>
<td>19.78</td>
<td>257.57</td>
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<td>Avg.</td>
<td>1.24</td>
<td>1.31</td>
<td>1.70</td>
<td>1.32</td>
<td>1.72</td>
<td>0.57</td>
<td>0.63</td>
<td>0.95</td>
<td>0.96</td>
<td>1.23</td>
<td>0.88</td>
<td>1.04</td>
<td>13.55</td>
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</tbody>
</table>

2. Evaporation

It is important that as much of the annual precipitation be induced to enter the soil as possible, but it is of no less importance that this moisture be retained until needed by crops. The first problem is how best to catch, and the second how to retain, the moisture. Moisture is lost from the soil by surface evaporation, and by transpiration from plants.

In Table II is given the monthly evaporation from a free water surface during the seven-month period from April to October inclusive, for the years 1908 to 1916 inclusive. While the evaporation varied during different years the averages for the seven-month period for 9 years was 47.6 inches. Investigations show that high evaporation diminishes the effectiveness of the annual precipitation. Regions in which evaporation is great require a higher annual precipitation to produce the same results than in a more favored locality.
TABLE II.—TOTAL MONTHLY EVAPORATION AT THE NEPHI SUB-STATION FOR THE MONTHS APRIL TO OCTOBER FROM 1908 TO 1916.

<table>
<thead>
<tr>
<th>Year</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>Aug.</th>
<th>Sept.</th>
<th>Oct.</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1908</td>
<td>4.800</td>
<td>6.980</td>
<td>7.879</td>
<td>10.343</td>
<td>9.331</td>
<td>6.234</td>
<td>2.410</td>
<td>47.977</td>
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<tr>
<td>1909</td>
<td>3.645</td>
<td>5.990</td>
<td>8.803</td>
<td>9.466</td>
<td>7.036</td>
<td>5.600</td>
<td>4.428</td>
<td>44.968</td>
</tr>
<tr>
<td>1913</td>
<td>4.350</td>
<td>7.474</td>
<td>8.313</td>
<td>9.526</td>
<td>8.252</td>
<td>5.250</td>
<td>2.742</td>
<td>45.907</td>
</tr>
<tr>
<td>Total</td>
<td>39.714</td>
<td>64.619</td>
<td>79.595</td>
<td>84.835</td>
<td>82.855</td>
<td>57.230</td>
<td>31.063</td>
<td>439.911</td>
</tr>
</tbody>
</table>

In Figure 2 is shown graphically the average monthly precipitation and the corresponding monthly evaporation for the seven-month period at the Nephi Sub-station. June, July, and August are the months with the lowest precipitation and highest evaporation.

![Diagram showing the average monthly precipitation and evaporation from April 1 to October 31, during the years 1908 to 1916 inclusive at Nephi, Utah, Sub-station.](image-url)
3. Wind

Wind is not a serious menace to crop production at Nephi. Records of wind velocity during the past 8 years for the seven-month period from April 1 to November 1 show that the average velocity was about 4.5 miles an hour. Velocities as high as 10 miles an hour for an entire day was seldom experienced.

4. Temperature

Temperature records at Nephi show that July and August are the months of greatest heat; the temperature ranging from 85 to 97 degrees Fahrenheit. The nights are usually cool and pleasant. In the winter temperatures of 20 degrees below zero have been recorded, but at this time the ground is usually covered with snow which protects the tender crops. Low temperatures without a protective blanket of snow usually result in severe winter-killing of fall-sown cereals.

5. Type of Soil

The soil of the Nephi Sub-station is a deep alluvial clay loam derived from the weathering of the adjacent mountain ranges. Considerable limestone and gypsum as well as small deposits of phosphorus and potassium minerals have been found in these mountains. The soil is reddish brown in color and varies in texture from a clay loam to a sandy loam. Above the 4-foot level the sandy loam is seldom encountered. The workable part of the soil is rather heavy (about 15 per cent clay) making it sticky when wet, and very hard when thoroughly dried. Crusting and baking of the soil after heavy storms and the resulting moisture losses due to crop growth and dry weather are common.

### TABLE III.—PHYSICAL COMPOSITION OF SOILS OF THE NEPHI SUB-STATION.

(Results Expressed as Per Cent of Dry Soil.)

<table>
<thead>
<tr>
<th>Depth in feet</th>
<th>1st</th>
<th>2d</th>
<th>3d</th>
<th>4th</th>
<th>5th</th>
<th>6th</th>
<th>7th</th>
<th>8th</th>
<th>9th</th>
<th>10th</th>
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<td>29006</td>
<td>29014</td>
<td>29015</td>
<td>29019</td>
<td>29026</td>
<td>29030</td>
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<td>5.29</td>
<td>8.94</td>
<td>4.43</td>
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<td>2.20</td>
<td>3.64</td>
<td>3.93</td>
<td>4.54</td>
<td>5.38</td>
</tr>
<tr>
<td>Fine matter</td>
<td>90.41</td>
<td>94.71</td>
<td>91.06</td>
<td>95.87</td>
<td>94.15</td>
<td>97.89</td>
<td>96.36</td>
<td>96.07</td>
<td>95.46</td>
<td>94.62</td>
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<tr>
<td>Medium sand</td>
<td>8.93</td>
<td>8.99</td>
<td>8.73</td>
<td>11.56</td>
<td>15.69</td>
<td>8.93</td>
<td>16.28</td>
<td>12.60</td>
<td>23.57</td>
<td>15.48</td>
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<tr>
<td>Fine sand</td>
<td>20.05</td>
<td>16.48</td>
<td>12.38</td>
<td>18.97</td>
<td>19.48</td>
<td>27.40</td>
<td>25.00</td>
<td>22.52</td>
<td>26.09</td>
<td>21.45</td>
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<td>Medium silt</td>
<td>15.23</td>
<td>16.78</td>
<td>17.53</td>
<td>17.25</td>
<td>15.43</td>
<td>13.51</td>
<td>13.73</td>
<td>17.03</td>
<td>10.04</td>
<td>15.77</td>
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<tr>
<td>Fine clay</td>
<td>15.73</td>
<td>16.93</td>
<td>18.62</td>
<td>20.68</td>
<td>12.41</td>
<td>16.03</td>
<td>12.19</td>
<td>13.29</td>
<td>20.95</td>
<td>18.38</td>
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<td>Real Sp. Gr.</td>
<td>2.62</td>
<td>2.67</td>
<td>2.52</td>
<td>2.62</td>
<td>2.62</td>
<td>2.66</td>
<td>2.61</td>
<td>2.64</td>
<td>2.61</td>
<td>2.63</td>
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<tr>
<td>Apparent Sp. Gr.</td>
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<td>1.32</td>
<td>1.41</td>
<td>1.43</td>
<td>1.46</td>
<td>1.41</td>
<td>1.48</td>
<td>1.44</td>
</tr>
<tr>
<td>Water, Sol. mat.</td>
<td>0.09</td>
<td>0.702</td>
<td>0.02</td>
<td>0.04</td>
<td>0.11</td>
<td>0.07</td>
<td>0.11</td>
<td>0.13</td>
<td>0.05</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Little difficulty is experienced, however, in preparing a good seed bed if the soil is not too wet or too dry. Working this type of soil when too wet results in a baked condition which necessitates
exposure to weathering agencies before it again becomes friable

The surface soil is relatively low in humus making it desirable to increase this constituent, but the addition of humus should not be too rapid. In Table III are presented the results of a mechanical analysis of the soil by foot-sections to a depth of 10 feet. This table shows that the soil is composed largely of fine sand, coarse, medium, and fine silt, and fine clay. A soil of this nature retains water well.

6. Depth of Sampling

Most of the soil moisture work at Nephi has been done to a depth of 6 feet, although one series of plats was sampled 10 feet deep. The plats were sampled in foot sections with a soil tube in the spring, summer, and fall. Each foot section, as soon as obtained, was placed in a tightly covered soil can. The samples were dried at a temperature between 105 degrees and 110 degrees F. for 12 to 14 hours, and the percentage moisture calculated on the dry basis.

II. EXPERIMENTAL RESULTS

1. Stubble Treatment

a. Effect of Disking after Harvest on the Moisture Content of Fall-plowed and Spring-plowed Fallow

In the fall of 1911 a test was begun to determine the effect of fall double disking on the moisture content of the fall-plowed and spring-plowed fallow plats. Four plats were included in the test, two of these being cropped to winter wheat each year and two fallowed.

After producing a crop of wheat both stubble plats were double disked soon after harvest. Later in the season one of these plats was fall plowed and left rough until spring; the other was spring plowed. Throughout the summer both plats received identical treatment.

Moisture determinations in 1-foot sections to a depth of 6 feet were made in April, June, and September on these fallow plats during the 5 years from 1912 to 1916 inclusive. Each sampling included 2 borings for each foot on both plats and the average percentage of moisture in the two determinations was used.

In Figure 3 is shown graphically the average percentages of moisture stored in these two plats for the 5-year period. In the spring sampling the fall-plowed plat contained slightly more moisture in the upper 2 feet, while the next 3 feet showed slight
advantages in favor of the spring-plowed plat. The fourth to sixth feet were about equal for both plats.

Slightly more moisture was found in the summer sampling of the first 3 feet of the fall-plowed plat than the spring-plowed one, but in the fourth to sixth feet the percentage of moisture in the spring-plowed plat was distinctly higher than the corresponding depth on the plat fall plowed. The fall sampling shows that at depths of 3 and 4 feet the percentage of moisture favors fall plowing to a slight extent while the other feet favor spring plowing.

The first sampling shows the average moisture content of the upper 6 feet of the spring-plowed soil to be 17.31 per cent while the fall-plowed plat contained an average of 17.65 per cent. The averages for the summer samplings were 16.96 per cent moisture in the upper 6 feet of the spring-plowed plats, and 16.59 per cent in the fall-plowed plat. In the fall the averages were 16.55 and 16.31 for the spring- and fall-plowed plats respectively.

It is evident from these results that spring and fall plowing are about equally effective in holding moisture after fall disk ing. When the moisture percentages found in the two disked plats, which were fall- and spring-plowed, are compared with similarly treated undisked plats, it is found that disk ing in the fall was not beneficial to moisture storage. Plats not disked but otherwise treated as those disked contained the higher average percentage of moisture in the upper 6 feet of soil.
The data show that working the surface soil in the fall after harvest held the fall and winter precipitation nearer the surface than where the soil was left untreated during the winter. It is probable that stubble holds the snow better than a disked or plowed surface, and it appears that fall cultivation destroys surface "cracks" thus hindering the percolation of water to the lower depths.

During the 5 years under discussion the soil has not been saturated to a depth of 6 feet. The greatest seasonal fluctuations were found in the second to the fifth feet; the second and third contained the highest percentages of moisture.

b. Effect of Burning Stubble on the Moisture Content of Fall-plowed Fallow

In the fall of 1911 a test was begun to determine the effect of burning wheat stubble on the moisture content of fall-plowed fallow. In this test four plats were used; two fallowed and two cropped each year. Both fallow plats were fall plowed on the same date to the same depth and received uniform treatment throughout the fallow year, except that the stubble was burned before plowing on one plat, while on the other it was plowed under.

Three years' moisture data are available on this test. Sampling was done as before—in the spring, summer, and fall—for the years 1912, 1913, and 1914. The results are shown graphically in Figure 4.

In the spring the average moisture content of feet 1, 3, 4, and 5 was higher for the

![Fig. 4.—Diagram showing the effect of burning wheat stubble after harvest on the average percentage of moisture found in fall-plowed fallow in the spring, summer, and fall. Average for the years 1912, 1913, and 1914.](image-url)
plat on which the stubble was burned, while 2 and 6 were exceeded by the plat on which the stubble was plowed under. For the upper 6 feet of the plat on which the stubble was burned there was an average of 17.70, while in the ordinary fall-plowed plat there was an average of 17.22 per cent of moisture.

The summer sampling showed a rather marked benefit to the moisture percentages in favor of burning stubble before plowing in all but the first and sixth feet; the first foot of the two plats being about equal, and the sixth foot distinctly in favor of plowing the stubble under. The average moisture content of the upper six feet of soil on the burned stubble fallow was 17.63 and that of the unburned plat 16.72 per cent, or nearly 1 per cent more moisture in the stubble burned plat.

Although the moisture was lower on the plats where the straw was allowed to decay, it is probable that the continual addition of organic matter would decidedly increase the water holding capacity of the soil.

2. Plowing

a. The Moisture Content of Fall- and Spring-plowed Fallow

In the fall of 1908 two adjacent plats that produced a crop in 1908 were laid off to determine whether more moisture could be stored in fall-plowed than in spring-plowed fallow. One plat was fall-plowed—the usual depth being 8 inches—and left in the rough until spring, while the other was plowed as soon as it was possible to work the land in the spring. Both plats received uniform treatment during all seasons and alternate plats were added in 1909. There are available, therefore, moisture data for the 8 years, 1909 to 1916 inclusive, on the comparative merits of fall- and spring-plowed fallow. The fallow plats as shown graphically in Figure 5 were sampled in the spring, summer, and fall of each season to a depth of six feet.

In the spring sampling the average moisture content of the first and second feet favored the fall-plowed fallow 5 years, and the spring-plowed fallow 3 years. The moisture of the fourth and fifth feet was higher in the spring-plowed fallow every year, and in that of the third every year except 1914. The moisture content of the sixth foot favored spring-plowed fallow 5 of the 8 years.
Fig. 5.—Diagram showing the moisture content for the spring, summer, and fall for fall-plowed and spring-plowed fallow in foot sections to a depth of 6 feet during the years 1909 to 1916.
SOIL MOISTURE STUDIES UNDER DRY-FARMING

Referring to Table I it is observed that a high annual precipitation usually resulted in a high moisture content in the soil and vice versa. The effect of a high annual precipitation may be more noticeable the following season than the year in which it occurs. The spring sampling for practically every year showed that land plowed in the fall absorbed winter precipitation less readily than stubble land. The results show a tendency for the fall-plowed plat to retain the moisture in the upper two or three feet, while on the stubble the moisture penetrated more readily to the lower depths. Fall cultivation of any kind at Nephi destroys cracks in the ground and pulverizes the soil so much that it readily runs together and holds the moisture that falls near the surface while the undisturbed cracks permit the water to penetrate deeply.

Fall samplings show the moisture content of the first and third feet to favor spring plowing 5 years, the second foot every year, the fourth and sixth feet 6 years, and the fifth foot 7 of the 8 years. Considerable moisture was lost, probably both by evaporation and percolation, each year during the interval be-

Fig. 6.—Diagram showing the average percentage of moisture found in fall-plowed and spring-plowed fallow in the spring, summer, and fall for the 8-year period 1909-1916.
between spring and fall. Some years a loss occurred from each of the 6 feet, while in other seasons it was largely from the upper and lower depths.

b. **Average Moisture Data on Spring- and Fall-plowing**

In Figure 6 is presented the 8-year average moisture data of the fall-plowed and spring-plowed fallow that are presented in detail in Figure 5.

It is observed in the spring sampling that the average moisture content of the first and second feet was higher in the fall-plowed than in the spring-plowed fallow, while the lower 4 feet were considerably higher in the spring-plowed soil. The spring-plowed fallow admitted the moisture to lower depths than the fall-plowed fallow. Fall plowing held the moisture nearer the surface, particularly high percentages being recorded in the first and second feet. Two explanations for this have presented themselves either of which may answer in part:

1. Stubble on a plat may catch and hold the snow better than plowed land, and thus result in the plat having a higher per cent of moisture in the spring.

2. The soil at Nephi when producing a crop of winter wheat usually cracks at the surface; these cracks aid in taking up moisture. Fall plowing would hinder the stubble from catching the snow as well as breaking up and destroying all cracks.

Whether or not these explanations are correct makes little difference as the data show that spring-plowed fallow at Nephi contained more moisture than fall-plowed fallow in the upper 6 feet of soil.

In the summer sampling, although the sixth foot of the two plats were identical, the average moisture content of each of the upper five feet were all considerably in favor of spring-plowing. The moisture had distributed itself fairly evenly throughout the upper 6 feet of soil, when the summer samples were taken.

Between the spring and summer sampling proportionately more moisture from the second and third feet was lost than from the fourth and fifth, showing that there was a downward movement, while a large decrease was experienced in the first foot. Each foot of the spring-plowed fallow and the upper four of the fall-plowed lost moisture between the dates of spring and summer sampling, although the lower two feet of the latter plat gained.
Only for the fourth and fifth feet of the spring-plowed fallow and the fifth and sixth feet of the fall-plowed was the loss of moisture between the summer and fall noticeable. Each of the six feet of the spring-plowed plat contained more moisture than the corresponding depths of the fall-plowed.

c. Effect of Depth of Fall and Spring Plowing on the Moisture Content of the Soil

It is usually necessary to re-plow or double disk fall-plowed fallow in the spring in order to kill weeds and volunteer grain. To determine the effect on the moisture of plowing deep in the fall and shallow in the spring (8 and 3 inches), shallow in the fall and deep in spring (3 and 8 inches), deep in both the fall and the spring (8 and 8 inches), a test was started in the fall of 1911 on plats 25 A, 26 A, and 27 A respectively. Subsequent treatment was the same on all plats and in the fall of 1912 duplicate plats on series "C" for the alternate years were added. Except for the plats plowed 8 inches deep in the fall and spring where only 2 years moisture data are available, the results given are for 3 years. The average moisture data on this test is shown graphically for each foot on the 3 dates sampled in Figure 7.

In examining the figure it should be remembered that the plat plowed 8 and 8 inches is not comparable with the other two plats, since the data were obtained during different years and is an average of two years only.
The moisture content of the two comparable plats was practically the same in the upper 4 feet at the time of spring sampling, but the fifth and sixth feet favored the plat plowed deep in the fall and shallow in the spring. The average, however, shows only about 0.5 per cent more moisture in the upper 6 feet of soil in the plat plowed 8 and 3 than in the one plowed 3 and 8 inches. The average percentage moisture for the upper 6 feet of soil was 17.67 for 8- and 3- and 17.15 for 3- and 8-inch plowing.

In the summer sampling the plat plowed 8 and 3 inches had more moisture in all but the third and fourth feet than the plat plowed 3 and 8 inches. The average per cent of moisture in the upper 6 feet of soil, for the plat plowed 8 and 3 inches was 16.21 per cent, and for the plat plowed 3 and 8 inches 15.59, a difference of about 0.6 per cent in favor of deep fall and shallow spring plowing.

The fall determinations show the plats were practically the same as in the summer. The moisture content of the first foot in both plats increased over the previous sampling due to fall rain; the other feet were influenced to only a small extent.

The average per cent of moisture in the upper 6 feet of soil for the plat plowed 8 and 3 inches was 16.44, and for the one plowed 3 and 8 inches, 15.95 per cent. Both plats lost about 1.25 per cent of moisture from the upper 6 feet of soil during the summer but largely from the surface foot. In addition to this loss, all summer rains, usually amounting to about 3.75 inches between the spring and fall, were lost.

These data show that it was better to plow deep in the fall and shallow in the spring, than vice versa. It is not necessary however, at Nephi to plow in the fall and again in the spring, because spring plowing is just as efficient in holding the winter precipitation and in eradicating weeds as both fall and spring plowing.

d. Effect of Depth of Fall Plowing on the Moisture Content of Fallow Soil

In the fall of 1908 a depth of fall-plowing test was started on plats which prior to 1908 had been uniformly cropped and fallowed. In this test plats 16, 17, 18, and 19 A—all tenth-acre plats—were fall-plowed as follows: Plats 16 A and 17 A were
SOIL MOISTURE STUDIES UNDER DRY-FARMING

subsoiled 18 and 15 inches deep respectively; and plats 18 A and 19 A were plowed 10 and 5 inches deep respectively.

Alternate plats on series "C" similar in number and treatment were added in the fall of 1909. By using alternate plats in this manner each season, it was possible to study yields and moisture content of fallow plats for each treatment each year.

In presenting the 8-year moisture data now available on this test, plat 17 subsoiled 15 inches was omitted, because (1) it was not sampled in 1915 and 1916 making only 6 years' data available; and (2) the moisture data obtained was very similar to that of plat 16 subsoiled 18 inches.

The average percentages of moisture in plats fall-plowed 5 and 10 inches, and subsoiled 18 inches deep respectively, for the 8-year period 1909 to 1916 inclusive on three different dates, is shown graphically in Figure 8.

Plat 19 plowed 5 inches had a higher percentage of moisture in all but the third and fourth feet in the spring than the plat subsoiled 18 inches deep. The plat plowed 10 inches had considerably more moisture than either the subsoiled or shallow plowed plats in all feet except the second. The average per cent moisture to a depth of 6 feet, in the spring, for the plat plowed 5 inches was 18.62, for the plat plowed 10 inches 19.38, and for the plat subsoiled 18 inches 18.48 per cent. Expressed in inches of moisture this shows that the plat plowed 10 inches deep stored 0.77 of an inch more water in

Fig. 8.—Diagram showing the percentage moisture found in fallow land fall-plowed 5 inches and 10 inches, and sub-soiled 18 inches deep respectively for the 8-year period 1909-1916.
the upper 6 feet of soil than the plat subsoiled 18 inches, and 0.65 of an inch more than the plat plowed 5 inches deep. The plat plowed 5 inches deep stored 0.12 of an inch more water than the plat subsoiled 18 inches.

In the summer sampling the moisture had distributed itself more uniformly throughout the upper 6 feet of soil. The moisture content of the second to fifth feet shows little variation due to the depth of plowing, all plats being fairly uniform. In the first foot the 10-inch plowing was high and the subsoiled plat low; in the sixth foot the subsoiled plat was high and the 5-inch plowing low. The average per cent of moisture in the summer, in the upper 6 feet of soil, was for the 10-inch plowing 18.45, for the subsoiled plat 18.29, and for the 5-inch plowing 17.99 per cent. The greatest difference was equivalent to 0.39 of an inch of water. Most all plats lost moisture between the spring and summer sampling although most of this loss was from the upper foot of soil.

A decrease of moisture in the first and second feet of all plats since the summer was noted in the fall determinations, while the lower 4 feet remained practically as in the summer. Considering the 6-foot section, it appears that deep plowing increased the percentage of moisture in the sixth foot. The average per cent of moisture found in the upper 6 feet of soil in the fall sampling was 17.68 for 10-inch plowing, 17.57 for subsoiling, and 17.40 per cent for 5-inch plowing. The second and third feet carried most moisture. During the interval between the spring and fall sampling the plats plowed 10 and 5 inches deep lost from the upper 6 feet 1.7 and 1.2 per cent moisture respectively, while the one subsoiled lost only 0.91 per cent in addition to the summer rainfall of 3.75 inches.

These averages are all very close and show rather conclusively that deep fall plowing was not necessary to store winter precipitation at the Nephi Sub-station. The difference in the amount of moisture after subsoiling, deep plowing, and shallow plowing is not sufficient to warrant the practice of subsoiling or deep plowing for fallow.

3. Cultivation of Fallow

a. Effect of Cultivation on the Moisture Content of Fall-plowed Fallow

A test was started to determine the effect of cultivation on
the moisture content of fallow in the fall of 1908. Two plats were
fall-plowed to the same depth on the same date and left in the
rough during the winter. From the spring throughout the fallow
season one plat was kept free from weeds by diskng and harrow-
ing, while the other received no cultivation, although weeds and
volunteer grain were clipped before reaching maturity.

The average moisture content of these plats for the 6-year
period, 1909 to 1914 inclusive, is shown graphically in Figure 9.

In the spring determinations each foot of the cultivated plat con-
tained a higher percentage of moisture than the uncultivated, the
differences increasing somewhat with depth. The average moisture
content for the spring sampling in the upper 6 feet of soil of the cul-
tivated plat was 18.32, and the uncultivated plat was 17.12 per cent.

Summer samples show that each foot of the cultivated plat contain-
ed considerably more moisture than the corre-
sp0nding depth in the uncultivated plat, the
greatest difference be-
ing in the upper 4 feet. The average moisture content for the
upper six feet in the summer was 18.02 per cent for the cultivated
and 14.91 for the uncultivated plat or a difference of about 2.5
inches of water. Weeds and evaporation used considerable
water from the top four feet of the uncultivated plat.

By fall the differences in moisture content of each foot were
still more strikingly in favor of the cultivated plat, the uncultivated
soil having lost much more moisture from all 6 feet than had the
cultivated. This loss was later found to be primarily due to

Fig. 9.—Diagram showing the percentage moisture in cultivated and uncultivated fall-
plowed fallow in the spring, summer, and fall. Average for the 6-year period 1909-1914.
volunteer grain and weed growth on the uncultivated plat. The conditions were similar to a cropped plat and a clean fallow plat. In the upper 6 feet of the cultivated fallow there was an average of 16.77 and in the uncultivated fallow 12.94 per cent moisture for the fall determinations or the equivalent of 3.25 inches more water in the cultivated than in the uncultivated plat. The differences in favor of cultivation increased as the season advanced. This test shows the great necessity of checking weed growth that moisture may be conserved in the upper 6 feet of soil. Later determinations show the real function of cultivating fallow is to keep weeds down, maintaining a mulch being secondary in importance so far as moisture conservation is concerned. Preserving a clean fallow at a minimum expense for cultivation is the most practicable and profitable method. Frequent cultivation of a weedless fallow in Nephi soil is neither profitable nor practicable when the margin of profits is as narrow as it is under dry-farm conditions.

b. Effect of Cultivation on Spring-Plowed Fallow

To determine the effect of cultivation on the moisture content of spring-plowed fallow, the stubble on two plats that were cropped in 1911 was left until the spring of 1912. As soon as it was possible to work the land in the spring, these two plats were plowed to a depth of 8 inches. After plowing one plat was harrowed and summer-fallowed as usual during the summer while the other was untouched after plowing. Alternate plats were used in this test.

Fig. 10.—Diagram showing the percentage moisture in cultivated and uncultivated spring-plowed fallow in the spring, summer, and fall for the 3-year period 1902-1914.
SOIL MOISTURE STUDIES UNDER DRY-FARMING

As graphically shown in Figure 10 although the upper feet of the uncultivated plat were highest in the spring, both plats were about equal in moisture content in the lower 4 feet. The moisture content of the first, third, fourth, and fifth feet in the summer was higher in the uncultivated plat, than in the cultivated. The average 6-foot moisture content of the cultivated plat was 17.37 per cent, and for the uncultivated 17.46 per cent; practically identical.

In the fall sampling the percentage moisture in the first, second, and the sixth feet favored the uncultivated plat. The average per cent of moisture in the upper 6 feet of soil on the cultivated plat was 17.30 per cent, and for the uncultivated 17.42 per cent.

Each of the three dates on which samples were taken show the second, third, and fourth feet to carry more moisture than other feet.

It appears from these data that it is not necessary, nor even good practice in moisture conservation, to cultivate spring-plowed fallow at Nephi.

c. Effect of Cultivation and Hoeing on the Moisture Content of Fall-plowed Fallow

To compare the moisture in a mulched soil with one unmulched but having the weeds eradicated with a sharp hoe, a test was begun in the fall of 1914. These 2 plats were fall-plowed and left in the rough until spring. In the fall of 1915 an alternate pair of plats were added. One plat received normal fallow treatment, while the other was left as plowed except that as often during the summer as was necessary to keep growth checked the weeds were hoed carefully so as to disturb the soil as little as possible. An average of the 2 years' data with the usual samplings are presented graphically in Figure 11.

In the spring the moisture content of foot 1 and 5 were the only depths higher in the hand-hoed plat than in the machine-weeded one.

The percentage moisture in the first foot was markedly and
the sixth foot noticeably in favor of the machine-weeded fallow, while the second to fifth feet were higher for the hand cultivation in the summer period.

During fall the machine weeded fallow was best for each of the six feet. The greatest difference, about 1.25 per cent, was in the third foot. The difference in moisture content between the two plats in the fall was much smaller than would be expected. This shows that one of the most important functions of cultivation is to kill weeds. Whether it is profitable to cultivate solely to maintain a soil mulch, except after rather heavy storms, is a problem for further investigation.

Fig. 11.—Diagram showing the effect of machine weeding vs. hand weeding on the percentage moisture in fall-plowed fallow in the spring, summer, and fall. Average for 1915-1916.

4. MULCHES

a. The Effect of Straw Mulch, 2 Inch Earth Mulch, and No Mulch on the Moisture Content of Fallow Land

In the fall of 1915 a test was started to determine the effect of various mulches on the moisture content of fallow land.

Plats 0 to 11 on series A and B, or 24 tenth-acre plats representing twelve mulch treatments in duplicate were used. Previous to this test all plats had been alternately cropped and fallowed, 1915 being a cropped year. The treatments of the plats were as follows:
SOIL MOISTURE STUDIES UNDER DRY-FARMING

Series | Treatment
--- | ---
A 0 | Never plowed; weeds pulled or hoed.
A 1 | Fall plowed; straw mulch.
A 2 | Fall plowed; subsoiled (18 inch); mulch 4 inch.
A 3 | Fall plowed; disked once in spring.
A 4 | Fall plowed; weeds pulled.
A 5 | Fall plowed; mulched 2 inch.
A 6 | Fall plowed; mulched 4 inch.
A 7 | Fall plowed; mulched 6 inch.
A 8 | Spring plowed; weeds pulled or hoed.
A 9 | Spring plowed; mulched 2 inch.
A 10 | Spring plowed; mulched 4 inch.
A 11 | Spring plowed; mulched 6 inch.

The cultivated plats were harrowed after each rain to restore the mulch. Weeds were also kept in check. The plats were sampled as frequently as possible, determinations being made about every 10 days.

Samples were taken to a depth of 6 feet. The holes in the soil were filled after sampling to prevent rapid downward percolation of water and air movement. The plats were sampled during the periods between: May 22 and 29; June 6 and 10, 16 and 19, 26 and 29; July 12 and 15, 17 and 19, 27 and 29; August 7 and 9, 17 and 19, 28 and 30, 1916. In all 2,880 samples were taken.

In Figure 12 is shown graphically the average percentage moisture from the 10 sampling dates in plats A 1 and B 10 that were straw-mulched 4 inches deep; A 5 and B 6 that were earth-mulched 2 inches deep;
and A 4 and B 7 that were not mulched but weeds pulled. Straw mulch was most and no mulch least effective for conserving soil moisture. Mulches apparently affected the moisture only in the upper three feet of soil; below this depth all plats were practically the same. The two-inch cultivation was not enough better than no cultivation to justify its use.

b. Effect of Depth of Mulching on the Moisture Content of Fall-plowed and Spring-plowed Fallow

These data were obtained in 1916 from the experiment on the effect of mulches on the moisture content of fallow land.

From the 10 sampling dates, 240 determinations for each treatment shown in Figure 13 were made. That each of the twelve treatments contained at least 19 per cent of moisture in the upper six feet of soil throughout the season indicates that mulches are not very important in moisture conservation on a weedless soil.

The moisture of the fall-plowed and spring-plowed plats receiving like treatment was practically the same in all cases. The percentage moisture of the spring-plowed plats increased slightly with depth of cultivation, while the fall-plowed plats
slightly decreased inversely with depth of cultivation. Although on fall-plowed land the straw mulch was the most efficient moisture conserver, the unplowed plat on which the weeds were pulled ranked second. The fall-plowed plat disked once in the spring, and the spring-plowed plat mulched six inches deep both ranked high. Even the uncultivated fallow-plats on which the weeds were pulled or hoed, lost little more than the most intensive treatment, showing again that the chief purpose of cultivation is to kill weeds.

c. Effect of Mulches on the Movement of Moisture in Fallow.

The data presented in Figure 14 showing the distribution of moisture by foot sections to a depth of 6 feet on ten different dates, were obtained from the same plats discussed in the last 2 sections.

Fig. 14.—Diagram showing distribution of moisture each week throughout the season in fallow soil to a depth of 6 feet. Each column is the average of 24 samplings.

Each column indicates the average percentage moisture in the 24 plats. The rainfall during the sampling periods is given below:

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<th>Date</th>
<th>Precipitation</th>
<th>Inches</th>
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<td></td>
</tr>
<tr>
<td>June 26-28</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>July 27-29</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td>Aug. 22-29</td>
<td>0.22</td>
<td></td>
</tr>
<tr>
<td>July 27-29</td>
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<td></td>
</tr>
<tr>
<td>Aug. 28-29</td>
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</tr>
<tr>
<td>July 27-29</td>
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<td>July 27-29</td>
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<td>Aug. 3</td>
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<td>Aug. 5</td>
<td>0.26</td>
<td></td>
</tr>
<tr>
<td>Aug. 7</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>Aug. 16</td>
<td>0.10</td>
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</tr>
</tbody>
</table>
It is observed in Figure 14 that all depths decreased in moisture from May 22-29 to July 12-15, then increased slightly until August 7-9 after which it again decreased. Marked variations occurred in the first foot, and while the fluctuations were small in the lower depths and decreased with depth for the 6 feet, they were real and correspond with the fluctuations in the surface soil. Apparently a fluctuation in the surface foot influenced the moisture in the lower depths. The increase in moisture in late July was undoubtedly due to rains of .16, .11 and .30 of an inch respectively. One-tenth of an inch of rain did not effect the moisture content of even the first foot.

5. CROPS

a. Effect of Continuously Cropping Land to Winter Wheat on the Moisture Content of the Soil

One of the first tests started by the Utah Experiment Station on the Nephi farm was to determine the relative yields from land cropped continuously, two years in three, one year in two, and one year in three. The experiment was conducted on four fifth-acre plats until 1907 when five tenth-acre plats were added so that a crop might be produced each season for each cropping method.

In the spring of 1909 it was thought advisable to study the moisture content under the treatments. From 1909 to 1916 inclusive, composite foot samples were made on these plats to a depth of ten feet. For the years 1909, 1910, 1915, and 1916, the plats were sampled three times during the season and from 1911 to 1914 inclusive twice.

The moisture content on the continuously-cropped plat for the eight-year period is shown in Figure 15. The moisture at the time of spring sampling in 1909, 1910, 1912, 1915, and 1916, for the upper four feet was relatively high; in 1913 and 1914 high for the upper three feet; and for 1911 rather low throughout. In the spring determinations, the sixth to ninth feet were usually low in moisture. The precipitation from the fall of one year until the spring determinations of the next in dry years was usually only sufficient to affect the moisture of the upper three
Fig. 15.—Diagram showing the annual moisture content for the spring, summer, and fall in foot sections to a depth of 10 feet in land continuously cropped to winter wheat during the 8-year period from 1909 to 1916.
or four feet of soil, while in very wet years the effect was noted as deep as seven feet.

The summer sampling of 1909, 1910, 1915, and 1916 shows that the moisture content of the cropped plats decreased rapidly in the upper soil sections as the season advanced. Until after the summer determinations were made, the crops fed largely on the moisture in the upper four feet of soil.

Comparing the moisture in the fall and spring shows rather conclusively that winter wheat on continuously-cropped land at Nephi draws most of its moisture from the upper four feet of soil. Changes did occur at depths below 5 feet, but whether the moisture of the lower depths was used by the crop, or moved below their reach is not known.

In four of the eight years the fifth foot had gained moisture while during the other four it lost between the period of spring and fall sampling. Practically every year the ninth and tenth feet were higher in moisture than the seventh and eight.

Between the fifth and ninth feet the soil is lighter than that above or below, making the sixth, seventh, and eighth feet usually much lower in moisture than the feet above. This light soil between two clay layers at Nephi makes it practically impossible for moisture to move up by capillarity from the lower to the upper feet; if the moisture is used the roots must penetrate the lower strata. Experiments show that a sandy soil can not draw moisture from clay, unless the clay has a very much higher percentage than the sand. The data show further that the ninth and tenth feet have not been saturated at Nephi.

b. Effect of Cropping 2 Years in 3 to Winter Wheat on the Moisture Content of the Soil

Unfortunately the moisture data obtained on this test have been from winter wheat plats in 7 of the 8 years for which data are available.

In 1909, 1910, 1913, 1914, and 1916 when the spring determinations were made Figure 16 shows that each year at least the upper 5 feet of the plats contained a higher percentage of moisture than lower depths. The upper foot sections were relatively low in moisture for 1911, 1912, and 1915. Generally the per cent moisture of the seventh to ninth feet was lower than
the upper foot sections, and the tenth foot was relatively high. Percipitation was apparently not sufficient in the fall and winter.

Fig. 16.—Diagram showing the moisture for the spring, summer, and fall in foot sections to a depth of ten feet in land cropped two years in three during the 8-year period 1909 to 1916.
of 1911 and 1912 materially to affect the moisture content of the lower soil depths.

The summer sampling for 1909, 1910, and 1915 shows that the crop used considerable moisture from the upper four feet of soil during the interval between spring and summer. The fallow year 1916 lost some moisture from the upper four feet but not nearly so much as the cropped plats.

Determinations for the fall period compared with the spring indicate that winter wheat uses moisture to a depth of from 5 to 7 feet, as a rule, and sometimes possibly deeper. The most erratic changes in moisture content, however, were noted in the upper 6 feet of soil.

c. Moisture Content of Land Alternately Cropped to Winter Wheat

In 1909 the moisture data presented in Figure 17 were from fallow, in 1910 winter wheat, etc., alternately.

From the spring determinations in 1909, 1910, 1913, 1914, and 1916, each of the upper six feet of soil were relatively high in moisture; those in 1912 and 1915 high in the upper 4 feet; and those of 1911 low in the upper 6 feet. The seventh, eighth, ninth, and tenth feet were low in percentage moisture nearly every year in the spring. In 1916 the moisture content in the lower four feet was the highest recorded for these depths during the past eight years. Wherever the blue clay was encountered (the ninth foot in 1910 and tenth foot in 1911 for instance) the moisture percentage was usually high.

In the fallow years, 1909 and 1915 between the spring and summer, the moisture apparently moved downward and tended to distribute itself more evenly throughout the upper ten feet of soil in the summer than in the spring. This distribution, however, was confined primarily to the upper seven feet.

During the crop years, 1910 and 1916, the moisture content decreased materially in every foot except the seventh in 1910 and the ninth in 1916, between the dates of spring and summer sampling. The greatest loss in moisture was from the upper five feet of soil. The moisture content of the fallow plats in 1909, 1911, 1913, and 1915 had not increased between spring and fall but the moisture had distributed itself more uniformly throughout the upper seven feet and in several cases had penetrated to
SOIL MOISTURE STUDIES UNDER DRY-FARMING

PERCENTAGE MOISTURE

Fig. 17.—Diagram showing the moisture content for the spring, summer, and fall in foot sections to a depth of ten feet in land alternately cropped to winter wheat during the 8-years 1909 to 1916.

the lower depths of the soil. In 1911 there was a loss of 2 percent of moisture, besides the rainfall, from the upper ten feet of soil between spring and fall. The small rainfall in 1910 and
1911 accounts for the low moisture content of the upper 6 feet of soil in 1911. Moisture decreased in practically all of the

Fig. 18.—Diagram showing the moisture content for the spring, summer, and fall in foot sections to a depth of ten feet in land cropped one year in three during the 8-year period from 1909 to 1916.
upper ten feet of soil between the spring and fall of the cropped years 1910, 1912, 1914 and 1916. The greatest loss was from the upper five feet.

The active feeding zone for winter wheat is the upper 6 feet of soil; below this depth only occasionally does the crop draw heavily for water. It is believed that at Nephi moisture fluctuations below the seventh foot are due largely to soil variations. In very wet years water enters fallow soil to a depth of 10 feet (note for instance the fall sampling of 1915 and the spring sampling of 1916), but it is doubtful whether this moisture is recovered by winter wheat. It probably continues to move down through the soil.

d. Effect of Cropping 1 Year in 3 to Winter Wheat on the Moisture Content of Land

Conclusions from Figure 18 are that the moisture percentage in the spring determinations fluctuate greatly. There was a slight decrease in the moisture content of the fallow plats, and a marked decrease for cropped plats, in the upper feet between spring and summer. The fall sampling shows decreases in the moisture content of fallow plats in the upper feet between spring and fall and striking decreases on cropped plats even to a depth of ten feet in 1916. During such years as 1910 the moisture was either lost from each of the ten feet by evaporation at the surface or by movement to lower depths.

c. Effect of Kind of Crop on the Moisture Content of the Soil.

From 1909 to 1914, inclusive, moisture determinations were made on corn, potato and pea plats grown in rotation with winter wheat. The plats were sampled to a depth of 6 feet in the spring, summer, and fall of each year. The average percentage moisture of the cultivated plats are compared graphically with the same data for winter wheat in Figure 19.

In the spring the moisture in all plats was about the same for all depths although a little more was found in the wheat plat. The moisture was rather evenly distributed throughout the entire 6 feet on all plats.

The corn, potato, and pea plats, when sampled in the summer, showed a distinct loss of moisture from the surface foot of soil, and slight losses from some of the lower depths. The wheat soil showed that relatively large quantities of water were used
Fig. 19.—Diagram showing the average effect of different crops on distribution of moisture in the spring, summer, and fall for the years 1909-1914.

from each of the six feet of soil, with the greatest loss in the upper four feet. A comparison of corn, potatoes, peas, and winter wheat soils at this period shows plainly that intertilled crops do not use the soil moisture so rapidly, nor so deeply, as winter wheat.

Between spring and fall all four plats lost some moisture from each of the upper six feet, while corn, potatoes, and peas took most of their moisture from the first four feet, wheat used considerable moisture from each of the top six feet, although the upper four feet showed the greatest loss. Peas absorbed the least water from the soil and wheat a great deal more than any of the intertilled crops. It is evident from these data that winter wheat was much more efficient than corn, potatoes, or peas, in extracting moisture from the upper six feet of soil.

f. Moisture Content of Intertilled Crops and Fallow

Figure 20 shows graphically the 5-year average percentage moisture for intertilled crops and fallow. In May only the first and sixth feet of the fallow contained more moisture than the intertilled plats. Since all plats grew a crop of winter wheat the previous summer and were subsequently all given the regular
fall and spring treatments, about the same percentage moisture was expected in each plat at this time.

The June sampling shows the cropped and fallowed plats to be practically identical in moisture content with the highest percentages at the second and third feet. That very little growth is made by intertilled crops at Nephi until after June 16 partly explains the uniformity in the moisture content of the cropped and fallowed plats on this date.

By July 21 the fallow plat had more moisture in each of the upper 5 feet of soil than the corresponding depths in the cropped plats. The cropped plats had lost most of their moisture from the upper, especially the first, foot sections.

In October the loss from the upper 5 feet of the cropped plats was still more pronounced than in July, but there was undoubtedly a great deal of available moisture remaining in these sections. The intertilled crops did not exhaust the moisture from the soil nearly so completely as did wheat. The low yields obtained from the intertilled crops was not due to a lack of available moisture in the upper 6 feet of soil, but to the inability of the cultivated crops to use the moisture. Larger yields of intertilled crops would undoubtedly mean the use of
more moisture, and hence a greater difference in the moisture content of intertilled and fallowed plats.

g. The Effect of Spring Cultivation on the Moisture Content of Winter Wheat Plats.

From 1909 to 1914 inclusive two adjacent plats of winter wheat—one harrowed in the spring, the other not harrowed—were used in a test to determine the effect of spring harrowing on the moisture content of the soil. The average moisture data are shown graphically in Figure 21.

The spring sampling was usually taken before the cultivated plat was harrowed; consequently, the percentage of moisture present was practically the same for both plats. However, there was some difference in the fifth and sixth feet in favor of the plat not cultivated.

The four-year average data in the summer shows all feet, except the second, had a higher moisture content in the uncultivated plat than in the plat that was harrowed. The difference between the two plats was relatively small, the greatest divergence occurring in the third and fourth feet. Again in the fall, as on the previous dates, there was little difference in the moisture content of the cultivated and uncultivated plats. As a result of this test it seems logical and reasonable to believe that spring cultivation of winter wheat does not conserve the moisture in the upper six feet of soil.

6. MANURE

a. Moisture Content of Cropped and Fallow Plats

In the spring of 1915 an experiment was started to determine the effect of various amounts of farm manure on the percentage moisture in cropped and fallowed land. The manure
was added in the spring and the plats spring-plowed for fallow. The twentieth-acre plats sampled in this test were: 36F East and West, 39F East and West, and 41F East and West. The east plats are cropped, while the west plats are fallowed in alternate years. Plats 36F East and West were not manured; and plats 39F and 41F East and West were manured at the rate of 10 and 20 tons per acre respectively.

A crop of Kubanka spring wheat was produced on the west plats in 1915, while the east plats were fallowed. Turkey Red winter wheat on the east with the west plats fallowed was the arrangement in 1916. The average moisture data in the fallowed and cropped plats, manured and unmanured, on three different dates are shown graphically in Figures 22, 23, and 24.

In the spring the moisture content of the cropped and fallowed plats differed little and inconsistently. The three pairs of plats, i.e., 36, 39, and 41 F. East and West, all contained an average of about 19 per cent of moisture in the upper 6 feet of soil in the spring. The plats that received 20 tons of manure per acre contained more moisture in the first foot than the other plats.

At the time of the summer sampling the moisture content of the cropped plats had decreased materially in the upper 4 feet and a great deal in the fifth and sixth foot. The percentage moisture of the plats manured at the rate of 20 tons was greater than those manured at the rate of 10 tons. The fallow plats lost moisture largely from the upper foot.

Fig. 22.—Diagram showing the effect of cropping spring plowed land on the moisture content in the spring, summer, and fall to a depth of 6 feet. Results for 1915-1916.
By fall the cropped plats had lost still more moisture at all depths but especially in the lower sections. The fallow plats had practically the same moisture content as in the summer. The plat manured at the rate of 10 tons lost moisture from every, but most noticeably from the lower, depths between the summer and fall.

The cropped plat (41) manured at the rate of 20 tons per acre maintained its moisture better than the one unmanured or manured at the rate of 10 tons. These studies show that winter wheat in maturing uses considerable moisture from the sixth foot of soil. However, the moisture of the sixth foot was not reduced nearly so much as that in the upper feet. The addition of manure has not as yet greatly increased the water-holding capacity of the soil.
Beginning with Figure 25 and ending with Figure 33 is shown graphically the storage of moisture during the winter of 1915-16, and the use of moisture by winter wheat on plats that received different cultural preparations. In the various figures rather marked differences are noted in the amount and depth to which moisture was stored, and similar differences are noted in the quantities and depth from which moisture was used by the wheat crop on different plats.

Fig. 24.—Diagram showing the effect of cropping spring-plowed land that had been manured at the rate of 20 tons per acre, on the moisture content in the spring, summer, and fall. Results for 1915-1916.
7. STORAGE AND USE OF WATER BY WINTER WHEAT IN 1915 and 1916

a. Use of Moisture by Winter Wheat and Storage of Moisture in Spring-plowed Fallow

In Figure 25 a wide difference is observed between the moisture of cropped and fallow plats in the fall of 1915. By the spring of 1916, however, the plat that was cropped in 1915 contained more moisture in the upper six feet than the plat that was fallow. A great loss of moisture to a depth of 4 feet, between spring and summer, and a heavy loss from all 6 feet between the summer and fall determinations was noticed for the plat cropped in 1916. The fallow plat lost about 2 per cent of moisture, largely from the first foot, during the summer, in addition to the seasonal rainfall.
SOIL MOISTURE STUDIES UNDER DRY-FARMING

b. Use of Moisture by Winter Wheat and Storage of Moisture in Spring-plowed Fallow Disked in Fall after Harvest for Years 1915 and 1916

That there was a great inequality in the moisture content of stubble land and fallow in the fall of 1915 is observed from Figure 26. In the spring of 1916 the first, second, and third feet were practically the same on both plats, but the moisture content of the fourth, fifth, and sixth feet favored the fallow plat or plat that was cropped for 1916. Between the spring and summer, and summer and fall determinations the moisture content of the cropped plat decreased in all feet. The fallow plat lost about 1.5 per cent of moisture during the season. It appears that disking caused the moisture to be held near the surface, when Figure 26 is compared with Figure 25.

Fig. 26.—Diagram showing the effect of cropping land disked in the fall, then spring-plowed, on the moisture content in the fall and again the following spring, summer, and fall under the alternate treatment. Results for 1915-1916.
c. Use of Moisture by Winter Wheat and Storage of Moisture in Fall-plowed Fallow for the Years 1915 and 1916

A wide difference in the moisture content of cropped and fallow land in the fall of 1915 is shown in Figure 27. By spring in 1916 the plat that was cropped in 1915 contained practically the same amount of moisture in the upper six feet as the plat that was fallow. The plat cropped in 1916 used considerable moisture to a depth of 4 feet between the spring and summer sampling dates, and to a depth of 6 feet between the spring and fall. Less moisture was used from the lower than from the upper feet.

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![Diagram showing the moisture content of cropped and fallow fall-plowed land in the fall and again the following spring, summer, and fall under the alternate treatment. Results for 1915-1916.](image-url)
d. Use of Moisture by Winter Wheat and Storage of Moisture in Fall-plowed Fallow, Disked after Harvest for the Years 1915 and 1916

As in the last charts, Figure 28 shows the large variation in the moisture of cropped and fallow land in the fall of 1915 to have disappeared before the spring of 1916, although in this case the lower feet did not approach each other as closely as in the previous treatments. The figure shows clearly that moisture was absorbed more quickly and penetrated deeper in moist soil than in a relatively dry one. From spring to fall the moisture content of the cropped plat diminished rapidly in all feet. The fallow plat gained in some feet and lost in others, the average loss being about 1 per cent. Moisture was held nearer the surface on plats that were cultivated in the fall.

![Diagram showing the effect of cropping land that had been disked and plowed in the fall, on the moisture content in the fall and again the following spring, summer, and fall under alternate treatment. Results for 1915-1916.](image)

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Fig. 28.—Diagram showing the effect of cropping land that had been disked and plowed in the fall, on the moisture content in the fall and again the following spring, summer, and fall under alternate treatment. Results for 1915-1916.
Use of Moisture by Winter Wheat from Fall-plowed Fallow, Frequently Cultivated During Fallow Season, in 1915 and 1916

Figure 29 shows that the moisture content of the stubble plat in the fall of 1915 was low in all feet. Although the moisture content of the stubble plat had increased in all six feet by the spring of 1916, it was much lower than the fallow plat or the plat that was cropped in 1915. The wheat crop had used moisture from all six feet, but largely from the upper four feet during the season. The moisture of the fallow plat moved deeper into the soil between the spring and summer determinations.
Use of Moisture by Winter Wheat and the Storage of Moisture on Fallow, Plowed 8 Inches Deep in the Fall, and Replowed 8 Inches Deep in the Spring

Figure 30 shows that in the spring of 1916 the moisture content of both plats had increased considerably in the upper 6 feet of soil and the difference between them lessened since the fall of

1915. The stubble plat held more of the winter precipitation than the fallow plat in the upper six feet. Moisture was used by the crop to a depth of six feet in 1916 as shown in the fall determinations. The fallow plat lost some moisture in both the upper and lower feet.
g. Use of Moisture by Winter Wheat and Storage of Moisture on Fallow, Fall-plowed 5 Inches Deep for the Years 1915 and 1916

There is observed in Figure 31 a wide difference in the moisture contents of stubble and fallow land in the fall of 1915, and in the spring of 1916 the small differences in moisture between the plats still show the effect of the high moisture in the fallow plats of the fall before or the cropped plats of 1916. Moisture decreased materially in all feet of the cropped plat during the intervals between spring and fall. The sixth foot of the fallow plat in 1916 was practically the same in the fall of 1916 as it was in the fall of 1915.
Use of Moisture by Winter Wheat and Storage of Moisture on Fallow, Fall-plowed 10 Inches Deep, for the Years 1915 and 1916.

Despite the noticeable contrast in the fall-before, Figure 32 shows that the moisture of these 2 plats in the spring of 1916 was about the same. From spring to fall the cropped plat lost considerableness moisture from all depths, although most was lost from the upper five feet. The fallow plat lost about 2 per cent and the cropped about 5 per cent of moisture in addition to the summer rainfall.
i. Use of Moisture by Winter Wheat and Storage of Moisture on Fallow Subsoiled 18 Inches Deep for the Years 1915 and 1916

The same relation between the moisture in these plats in the fall of 1915 and the spring of 1916 is noticed in Figure 33 as was seen in Figure 32. Most of the moisture used by wheat during the season was taken from the upper four feet. The fallow plat lost about 1 per cent of moisture during the fallow summer in addition to the rainfall.

![Diagram showing the effect of cropping land that had been fall-subsoiled 18 inches deep, on the moisture content in the fall and again the following spring, summer, and fall under the alternate treatment. Results for 1915-1916.](image-url)
III. SUMMARY

1. The limiting factor in crop production on dry-lands is water.

2. This bulletin reports results of soil moisture studies at the Nephi, Utah, Sub-station from the years 1908 to 1916 inclusive.

3. For the past 19 years the normal precipitation at Nephi was 13.48 inches. About 85 per cent of this fell during the non-growing season between October and May. The 9-year average evaporation from a free water surface for the 7 month period, April to October inclusive, was 47.6 inches.

4. The average wind velocity at Nephi was about 4.5 miles an hour for the summer months, while the temperature seldom reached 100 degrees F.

5. The soil on the sub-station is a deep alluvial reddish-brown clayey to sandy loam.

6. Disking stubble before fall-plowing or after harvest before spring-plowing was not beneficial in moisture storage.

7. Burning stubble before fall-plowing slightly increased the moisture content of fallow.

8. More moisture was held in the upper six feet of spring-plowed than of fall-plowed fallow.

9. In years of high precipitation, moisture was stored to a depth of 7 feet in summer fallow, while in dry years it accumulated only to a depth of 3 or 4 feet.

10. Plowing both in the fall and in the spring did not store more moisture than either spring- or fall-plowing alone.

11. Practically the same amount of moisture was found in land plowed shallow, deep, and subsoiled.

12. Cultivation of fall-plowed fallow by eradicating weeds and volunteer grain conserved a great deal of moisture, but the cultivation of spring-plowed fallow was of doubtful value.

13. Mulched fallow retained only slightly more moisture than fallow on which the weeds were killed with a sharp hoe but not mulched; hence, destroying weeds is more important than maintaining a mulch in conserving moisture in fallow land.

14. Straw mulches were more efficient in preventing evaporation than soil mulches.
15. Deep mulching was more effective in retaining moisture in spring-plowed fallow than in fall-plowed fallow.

16. Fallow soil lost from 0.5 to 2.0 per cent in addition to the rainfall between spring and fall of the fallow summer.

17. Continuously cropping to winter wheat did not deplete the moisture supply to a depth of 10 feet more thoroughly than alternate cropping.

18. Although the intertilled crops—corn, peas and potatoes—used moisture to a depth of 5 feet, they did not dry the soil so thoroughly nor so deeply as did winter wheat.

19. Manure, especially when as much as 20 tons to the acre were added, increased the water-holding capacity of cropped soil and slightly increased that of the second foot in fallow.

20. Winter wheat used moisture to a depth of 6 feet.

21. Stubble and fall-plowed soils gained considerable moisture to a depth of 6 feet between the fall of 1915 and spring of 1916.

22. Moisture penetrated deeper and more quickly in moist than in dry soil.

23. Summer tillage aided materially in conserving soil moisture.

24. At Nephi about 18 inches of water can be stored in the upper 6 feet of soil.

25. Indications are that crops extend their roots into the lower soil layers for water, but that little moisture is raised from great depths by capillarity in this soil.

26. It required from 0.50 to 1.0 inch of rain in the fall to connect the dry surface soil on fallow with the moist soil below.

27. The minimum point to which winter wheat used water from the soil was about 10 per cent. Hence, water above 10 per cent is available for this crop.

28. From 54 to 65 per cent of the precipitation falling between September 20th one year and the following September was found in the upper six feet of soil.

29. Fallow land at Nephi averaged 17.5 per cent water in the upper six feet of soil in the fall. At seeding time about 6.4 inches of this moisture was available for plants.
30. During the winter after the fallow there is usually about 4 per cent, or 3.5 inches, of available moisture stored.

31. Probably never more than 10 inches of water in the upper six feet of this soil is available for plant use. Even in the best years following a fallow considerably less than one year's precipitation was available for crops in the first six feet of the soil.

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