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AGRICULTURAL
EXPERIMENT STATION

SOIL EROSION
ARCHER FIELD STATION

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*In cooperation with U. S. Department of Agriculture.
SOIL EROSION
ARCHER FIELD STATION

By A. L. Nelson, Associate Agronomist

Division of Dry Land Agriculture, Bureau of Plant Industry,
U. S. Department of Agriculture

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INTRODUCTION

It is obvious to most everyone that the prevention of soil erosion is of vital importance to the national life. Under average conditions nature produces but one covering of soil in an epoch; therefore, it is important that it be held in place and its productivity maintained.

The natural factors which erode arable lands in this region are continued high winds and, to a less degree, down-pouring rains, generally of short duration. The destruction of vegetation, the small amount of organic matter in the soil, the loose nature of the soil, especially if sandy, and the semi-arid conditions are other factors that contribute to the erosion problem.

1The work at the Archer Field Station is conducted cooperatively by the Division of Dry Land Agriculture, Bureau of Plant Industry, U. S. Department of Agriculture and the Division of State Experiment Farms, Agricultural College, University of Wyoming.

2Appreciation for helpful suggestions is expressed to Dr. C. E. Leighty and John A. Cole of the Division of Dry Land Agriculture, and W. L. Quayle, Director of State Experiment Farms. Acknowledgments are made to Jenkins W. Jones and Victor H. Florell of the Division of Cereal Crops and Diseases; and Leroy D. Willey and W. E. Lyness of the Division of Dry Land Agriculture, who conducted the work reported in this bulletin prior to July 18, 1918, at which time the author took sole charge.
WIND VELOCITY

The 22-year average hourly wind velocity measured at 2 feet above the surface with a 4-cup Robinson anemometer at the Archer Field Station is 8.7 miles per hour. The average velocity is not sufficient to cause severe erosion on tilled soils. The period of highest wind velocity occurs during the driest part of the year, which extends from November to March inclusive; however, wind damage may extend into April, depending on the season. The 22-year average hourly wind velocity for the six months, November-April, is 11.0 miles per hour. Owing to the condition of the tilled soils and the vegetation, severe soil blowing seldom occurs during November, therefore, in Table I, November is placed in the fall group of months.

The wind velocity data, as shown in Table I, were taken from the Archer Field Station records except for four periods when they were obtained from the U. S. Weather Bureau at Cheyenne, Wyoming. The four periods are as follows: March, 1917; November and December, 1917; January, February, and March, 1918; and January, February, and March, 1920. In order that a comparison of the wind velocities at Cheyenne and the Archer Field Station, which is located about nine miles east of Cheyenne by air line, may be made, the following data are given. The average hourly wind velocity at Cheyenne for January, February, March, November, and December, 1934, was 12.34 miles, while the average hourly wind velocity at the Archer Field Station for the same period was 12.20 miles per hour. During this period the anemometer at the station was mounted on a 6-foot pedestal. Therefore, it is obvious that the wind velocities taken at Cheyenne and the Archer Field Station are fairly comparable.

Table I shows that 9 per cent of the days in the winter group of months had a wind velocity of 20 miles or more per hour. It often happens that days with a much lower average hourly wind velocity will have periods of high velocity. From observations, it is probable that days having an average wind velocity of 10 miles per hour will also have periods during which the wind velocity is sufficient to cause soil blowing, provided the soil is in such a condition as to be subject to blowing. Thus during the months of December to April, inclusive, it is probable that
half of the days may have periods of wind velocity which subject susceptible soils to soil blowing.

That portion of the year from May to October, inclusive, and oftentimes November, is marked by rather low wind velocities which give but little or no trouble by soil blowing. Table 1 shows that during August 98.23 per cent of the days have hourly wind velocities less than 10 miles per hour. During the summer period of low wind velocity and more abundant precipitation, preparations should be made to control soil blowing during the winter and early spring months.

**PRECIPITATION**

The seasonal distribution of the precipitation determines to a large extent the effectiveness of the wind in causing soil erosion. The 22-year average annual precipitation at the Archer Field Station is 13.82 inches. Of this amount 10.90 inches or 79 per cent occurred during the months of April to September, inclusive. During the months of greatest wind velocity but little precipitation occurs; therefore, the dry condition of the soil makes it more subject to erosion by wind. The high winds are also a factor in the evaporation of soil moisture. It is therefore apparent that special consideration should be given to the prevention of soil blowing on tilled lands.

At times a portion of the summer precipitation occurs in the form of sudden down-pours of rain or hail. Under these conditions considerable damage in the way of erosion may take place. Figure 1 shows the flood waters of the hail storm of June 29, 1920, the precipitation of which amounted to 1.37 inches. Earlier in the month, June 18, a hail storm occurred, the precipitation of which amounted to 2.36 inches. With such amounts of water flowing over tilled soils located on slopes or in swale bottoms considerable erosion takes place. But since most of the tilled lands are on gentle slopes, such as is shown in Figure 1, the total erosion by water is relatively small.

**OTHER NATURAL CONDITIONS**

In places where the soil supports a good native sod, soil erosion by wind or water is of little or no importance, and even the
### TABLE 1—AVERAGE NUMBER OF DAYS PER YEAR HAVING WIND VELOCITIES OF SPECIFIED CLASSES IN EACH MONTH AND GROUP OF MONTHS, AND THE PER CENT OF DAYS IN EACH VELOCITY CLASS, AT THE ARCHER FIELD STATION, 1913-1934.

<table>
<thead>
<tr>
<th>Velocity group</th>
<th>Fall group—Days</th>
<th>Winter group—Days</th>
<th>Summer group—Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miles per hour hour</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-9.9</td>
<td>30.45</td>
<td>28.09</td>
<td>25.77</td>
</tr>
<tr>
<td>10-14.9</td>
<td>.55</td>
<td>1.68</td>
<td>4.09</td>
</tr>
<tr>
<td>15-19.9</td>
<td>.00</td>
<td>.18</td>
<td>.77</td>
</tr>
<tr>
<td>20 up</td>
<td>.00</td>
<td>.05</td>
<td>.37</td>
</tr>
</tbody>
</table>

### PER CENT

<table>
<thead>
<tr>
<th>Velocity group</th>
<th>Fall group—Days</th>
<th>Winter group—Days</th>
<th>Summer group—Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miles per hour hour</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-9.9</td>
<td>98.23</td>
<td>93.63</td>
<td>83.13</td>
</tr>
<tr>
<td>10-14.9</td>
<td>1.77</td>
<td>5.60</td>
<td>13.19</td>
</tr>
<tr>
<td>15-19.9</td>
<td>.00</td>
<td>.00</td>
<td>2.49</td>
</tr>
<tr>
<td>20 up</td>
<td>.00</td>
<td>.17</td>
<td>1.19</td>
</tr>
</tbody>
</table>
severest of protracted winds raise only a hazy, light-colored dust. The destruction of the native vegetation leaves the soil exposed to erosion by wind. The severity of the erosion is largely determined by the wind, nature of the soil, and the methods of cropping and tillage.

SANDY SOILS UNDER TILLAGE

The light sandy soils of this section are seldom adapted to extensive production of small grains or other drilled crops. Corn, potatoes, and beans thrive best on sandy soils. The tillage of these crops generally leaves the soil in a condition favorable for soil blowing. This is especially true regarding the bean crop. The cultivation of this crop leaves the soil nearly level, and the bean puller, used in harvesting the crop, stirs the soil of the low ridges when it is dry and leaves it in a fine, dry, loose condition without any crop refuse. Thus, the soil is in an optimum condition for soil blowing. In sections where the soil is sandy, most of the soil blowing can be controlled by fall listing rather deep at right angles to the prevailing winds. At the Archer Field Station soil blowing is largely controlled by ridging the soil with sugar beet irrigation shovels attached to the back shanks of the duckfoot or "Field Cultivator." These ridges are not high enough to interfere with field operations the next spring.
The demarcation between those soils that need the lister ridging and those that need the field cultivator ridging lies in the property of the soil to make firm clods. Soils which will make firm clods will, in all probability, resist soil blowing when ridged with the field cultivator. Soils which do not have sufficient clay in them to make firm clods should be ridged more heavily, as by deep listing.

Because of the differences in the tillage and harvesting of the corn and potato crops, soil on which these crops have been produced is, generally, not so subject to soil blowing as bean land. However, corn land from which the stalks have been removed may blow. If the rows of these crops are at right angles to the prevailing winter winds, soil blowing is not so severe as where the rows are parallel with the wind.

Sudan grass stubble rows at right angles to the wind are effective in preventing soil blowing. Drilled crop stubble is also effective in preventing soil blowing. During periods of severe drought a small grain crop may not produce a crop sufficient to make a stubble, or the droughty growth may be eaten close to the ground by animals, in which cases the surface soil generally becomes loose and being unprotected is subject to soil blowing.

HEAVY SOILS

Soils heavier than the sandy soils, such as the sandy loams which have sufficient clay in them to form firm clods, can be tilled with much less danger of severe blowing, but the tillage should be such as to form and conserve a clod mulch rather than a fine surface mulch. This is especially important when the land is to be summer fallowed. The clod mulch also aids in preventing soil erosion by down-pouring summer rains, as it tends to prevent run-off. It also holds the snow, to some extent, from blowing away during the winter months. Ridging the soil is of further aid in this respect.

SOIL BLOWING AND ORGANIC MATTER

Soil blowing is checked by organic matter in the surface soil. From observations, the undecayed or partially decayed organic matter is of greater aid than the decayed. However, the latter is
Figure 2.—A close-up view of winter wheat seeded on fallow land as it appeared May 21, 1916. Only a few plants survived.

also of aid in that it tends to hold the soil particles together, thus making it more difficult for the wind to move them. It is obvious that with field trash and manure mixed with the surface soil there is a greater resistance to soil erosion by either wind or water. Further, the decay of organic matter is much more rapid in the surface soil than when plowed under. This is especially true during dry years. It is, therefore, important to manage crop production so as to leave a considerable amount of organic material in the fields. The tillage should be such as to leave it at the surface or mixed with the surface soil.

SOIL BLOWING AT THE ARCHER FIELD STATION

The greater part of the sod in the experimental field was broken during the summer of 1912 and the spring of 1913. Soil blowing was first reported during January and February, 1915. This is in accord with practical experience, since little or no soil blowing occurs during the first two or three years after breaking native sod. Photographs taken in the spring of 1916 show that severe soil blowing had occurred. Figures 2, 3, and 4 are photographs taken May 21, 1916. The land shown in Figure 2 was plowed in the fall of 1914 and fallowed during the summer of 1915. One series was double-disked three times and harrowed
The other series was double-disked four times and harrowed twice. The annual report for 1916 states that these pieces of land were tilled just enough during the summer to keep down weeds. It is probable that the surface soil was in a very fine condition. The report also states that the winter wheat made a good fall growth and withstood the cold winter but was killed by
severe soil blowing in the spring. Figure 2 gives a close-up view of the wheat plants. Figure 3 shows the effect of soil blowing on to an adjoining stubble plat. It should not be concluded that all the soil which drifted within the bounds of this plat lodged on it, as the lighter particles are carried great distances. Deposits, as shown in Figure 3, often cause decreased yields.

Figure 4 shows the scooped-out condition of the cultivated soil between alfalfa rows. The soil which was not held by the crowns of the plants was blown away. On July 18, 1918, when the writer took charge of the station, these alfalfa rows had the same appearance as shown in the figure. Later experience with this crop in rows indicates that a cross cultivation of the rows with a spring-tooth harrow early in the spring is a better method than cultivating lengthwise of the rows.

The writer used the same methods of tillage, plowing, harrowing, and double-disking the fallow land as his predecessors. The result of much careful work in seed-bed preparation for winter wheat on fallow is shown in Figure 5. Not even a sign of a plant remained. Not only did the fallow land blow, but the soil in the corn fields moved to various protected places as shown in Figures 6 and 7.
These conditions were the incentive for study in an effort to find methods by which the soil could be held in place. As a result, the use of the spiketooth harrow and disk harrow was discontinued on fallow. These implements were substituted by the spring-tooth harrow. While this change did not accomplish all that was
desired, the winter wheat crop of 1921, as shown in Figure 8, followed. Figure 8, is a photograph of winter wheat seeded September 1, 1920. The average yield from this date of seeding on fallow was 33.9 bushels per acre. Figure 9 shows an increase field of winter wheat produced on fallow in 1915. The 1915, 1918, and 1921 winter wheat yields on fallow showed that when
the winter wheat crop survived the winter, good yields were obtained.

In the spring of 1922 experiments were started with different methods of tillage with the objects of checking soil blowing and conserving moisture for the production of winter wheat. University of Wyoming Bulletins Nos. 151 and 161 contain the results of these experiments to January, 1929.

The practical effects of these experiments are expressed in Table 2 in data taken from the Wyoming Agricultural Statistics.

### TABLE 2.—WINTER WHEAT ACREAGE IN GOSHEN, LARAMIE, AND PLATTE COUNTIES AND THE STATE OF WYOMING FOR 1924, 1929, AND 1931.

<table>
<thead>
<tr>
<th></th>
<th>1924 Acres</th>
<th>1929 Acres</th>
<th>1931 Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goshen County</td>
<td>3,000</td>
<td>26,000</td>
<td>72,000</td>
</tr>
<tr>
<td>Laramie County</td>
<td>3,500</td>
<td>21,000</td>
<td>31,000</td>
</tr>
<tr>
<td>Platte County</td>
<td>1,600</td>
<td>11,500</td>
<td>18,900</td>
</tr>
<tr>
<td>Total</td>
<td>8,100</td>
<td>58,500</td>
<td>121,900</td>
</tr>
<tr>
<td>Wyoming</td>
<td>16,000</td>
<td>82,000</td>
<td>161,000</td>
</tr>
</tbody>
</table>
A paragraph taken from Director W. L. Quayle's annual report for 1929-30 relative to the winter wheat experiments at the Archer Field Station is as follows: "While the acreage seeded to spring wheat for the six years ending 1929 has continued to fluctuate with a tendency to decrease, the acreage seeded to winter wheat has gone steadily upward, so that at the end of this particular time the acreage in Wyoming is approximately 700 per cent of what it was in 1923, when the furrow drill was first introduced into the State at the Archer Experiment Farm."

In addition to the success which has attended the use of the furrow drill, the development at the Archer Field Station of improved methods of tillage has also added very materially to the certainty of winter wheat production. Figures 10 and 11 show the contrast in 1923 in winter wheat seeded with the common and the furrow drills. The contrast has not always been so marked, but the average results are in favor of the furrow drill used on land where the cheaper methods of tillage have been employed. Since 1923 other methods of tillage have been introduced. Table 3 contains the average yields of these experiments. These results indicate that the methods of tillage are probably as important as the type of drill used to seed the grain. Further, the cheaper methods of tillage produced the larger yields. Since the duckfoot methods
of tillage produced larger yields of winter wheat than plowing, it was decided to try this method of tillage for other crops. Experiments along this line were started in the spring of 1926.

**Table 3.—Seven-year average yields of winter wheat produced by different methods of fallow tillage and seeding at the Archer Field Station, 1927-1933, inclusive.**

<table>
<thead>
<tr>
<th>Tillage</th>
<th>Drill</th>
<th>Yield Bu.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early spring plowed</td>
<td>Common</td>
<td>11.8</td>
</tr>
<tr>
<td>Late spring plowed</td>
<td>Common</td>
<td>12.8</td>
</tr>
<tr>
<td>Early spring plowed</td>
<td>Furrow</td>
<td>12.4</td>
</tr>
<tr>
<td>Late spring plowed</td>
<td>Furrow</td>
<td>12.6</td>
</tr>
<tr>
<td>Late spring duckfoot</td>
<td>Common</td>
<td>12.1</td>
</tr>
<tr>
<td>Late spring duckfoot</td>
<td>Furrow</td>
<td>13.1</td>
</tr>
<tr>
<td>Fall listed, straw returned</td>
<td>Furrow</td>
<td>15.7</td>
</tr>
<tr>
<td>Late spring listed, straw returned</td>
<td>Furrow</td>
<td>15.3</td>
</tr>
<tr>
<td>Late spring listed</td>
<td>Furrow</td>
<td>14.7</td>
</tr>
<tr>
<td>Early spring duckfoot, straw returned</td>
<td>Furrow</td>
<td>15.6</td>
</tr>
<tr>
<td>Early spring duckfoot</td>
<td>Furrow</td>
<td>16.6</td>
</tr>
<tr>
<td>Late spring subsoiled (not plowed)</td>
<td>Furrow</td>
<td>16.2</td>
</tr>
</tbody>
</table>

A portion of series D, section 4, which had not been plowed since the spring of 1919, was taken for rotation 18-1926. Rotation 7-1926 was started directly to the south on series E, and rotation 19-1926 was started directly to the north on series C. As shown in Table 4, all these rotations have the same crops consisting of corn, potatoes, beans, and spring wheat. In rotation 7-1926 the land was plowed for the corn and duckfooted for the other crops. In rotation 18-1926 all plats were given one 75-bushel load, or ten such loads per acre, of barnyard manure annually, and all plats were duckfooted. In rotation 19-1926 all plats were manured and treated the same as in 18-1926, except that they were plowed instead of duckfooted. Rotation 18-1926 shows less erosion than either of the others, and at the same time, both during drought and favorable years, as shown in Table 4, produced comparatively well.

Since the duckfoot method of tillage for fallow, and seeding with the furrow drill were started in the spring of 1922, the station has not lost a winter wheat crop by soil blowing. The winter
wheat varietal and other experiments were more severely affected by soil blowing than the rotation experiments because of the larger tracts of fallow land. Two factors that were of aid in preventing soil blowing on the land used for the winter wheat varietal and other experiments were: (1) The crop previous to fallowing was millet, which left a coarse heavy stubble; and (2) the land was first worked early in the spring with 4-inch spade shovels on the duckfoot. The spade shovels require less draft, go deeper, and do not clog so easily as 10- and 12-inch shovels. During the latter part of May or the fore part of June the land was tilled with 10- and 12-inch duckfoot shovels. The 4-inch shovels cut the soil into slices and by the first of June these firm slices were, generally, partially dry. Most of the time this method of tillage produced a good clod mulch intermixed with coarse stubble. One and sometimes two more cultivations were required before seeding. Figure 12 shows such a seed bed seeded to winter wheat with the furrow drill.
TABLE 4.—AVERAGE YIELDS OF CORN, POTATOES, BEANS, AND SPRING WHEAT FROM ROTATIONS 7-1926, 18-1926, AND 19-1926.

AVERAGE YIELDS 1927-1934, INCLUSIVE.

<table>
<thead>
<tr>
<th>Rotations</th>
<th>Corn Grain (Bu.)</th>
<th>Corn Stover (Lbs.)</th>
<th>Potatoes (Bu.)</th>
<th>Beans Grain (Bu.)</th>
<th>Beans Straw (Lbs.)</th>
<th>Spring Wheat Grain (Bu.)</th>
<th>Spring Wheat Straw (Lbs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rot. 7-1926</td>
<td>11.8</td>
<td>1,505</td>
<td>64.7</td>
<td>6.1</td>
<td>514</td>
<td>11.4</td>
<td>1,033</td>
</tr>
<tr>
<td>Rot. 18-1926</td>
<td>11.0</td>
<td>1,480</td>
<td>76.9</td>
<td>6.1</td>
<td>599</td>
<td>13.8</td>
<td>1,255</td>
</tr>
<tr>
<td>Rot. 19-1926</td>
<td>9.7</td>
<td>1,826</td>
<td>71.3</td>
<td>6.7</td>
<td>553</td>
<td>11.9</td>
<td>1,209</td>
</tr>
</tbody>
</table>

*AVERAGE YIELDS 1927-31, INCLUSIVE.

<table>
<thead>
<tr>
<th>Rotations</th>
<th>Corn Grain (Bu.)</th>
<th>Corn Stover (Lbs.)</th>
<th>Potatoes (Bu.)</th>
<th>Beans Grain (Bu.)</th>
<th>Beans Straw (Lbs.)</th>
<th>Spring Wheat Grain (Bu.)</th>
<th>Spring Wheat Straw (Lbs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rot. 7-1926</td>
<td>15.3</td>
<td>1,966</td>
<td>85.3</td>
<td>7.6</td>
<td>570</td>
<td>14.2</td>
<td>1,250</td>
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<tr>
<td>Rot. 18-1926</td>
<td>14.5</td>
<td>1,910</td>
<td>101.4</td>
<td>8.1</td>
<td>684</td>
<td>17.8</td>
<td>1,580</td>
</tr>
<tr>
<td>Rot. 19-1926</td>
<td>13.2</td>
<td>2,384</td>
<td>101.9</td>
<td>9.3</td>
<td>688</td>
<td>16.3</td>
<td>1,594</td>
</tr>
</tbody>
</table>

†AVERAGE YIELDS 1932-1934, INCLUSIVE.

<table>
<thead>
<tr>
<th>Rotations</th>
<th>Corn Grain (Bu.)</th>
<th>Corn Stover (Lbs.)</th>
<th>Potatoes (Bu.)</th>
<th>Beans Grain (Bu.)</th>
<th>Beans Straw (Lbs.)</th>
<th>Spring Wheat Grain (Bu.)</th>
<th>Spring Wheat Straw (Lbs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rot. 7-1926</td>
<td>6.0</td>
<td>737</td>
<td>30.4</td>
<td>3.5</td>
<td>420</td>
<td>6.8</td>
<td>679</td>
</tr>
<tr>
<td>Rot. 18-1926</td>
<td>5.2</td>
<td>763</td>
<td>36.1</td>
<td>2.8</td>
<td>457</td>
<td>6.9</td>
<td>713</td>
</tr>
<tr>
<td>Rot. 19-1926</td>
<td>4.0</td>
<td>897</td>
<td>20.3</td>
<td>2.3</td>
<td>327</td>
<td>4.7</td>
<td>567</td>
</tr>
</tbody>
</table>

*Years of about average precipitation.
†Years of drought.

Probably no photographic material illustrates the effect of ridges in checking soil blowing as well as that showing the checking of the drifted snow. Figure 13 shows the snow held by the ridges and furrows made by the furrow drill. Figure 14 shows the small amount of snow held on the same date by a seeding made with the common drill. Drifting soil is held in about the same proportion. Further, the snow collected in the furrows not only protects and furnishes added moisture for the plants, but the snow and moisture also aid in holding the soil in place.
Figure 13.—Furrow drill seeding of winter wheat. Snow shows slight soil blowing. Compare with Figure 14. Photograph taken after storm of December 6 and 7, 1927.

Figure 14.—Common drill seeding of winter wheat. Very little snow left. Compare with Figure 13. Photograph taken after storm of December 6 and 7, 1927.
Figure 15.—An average crop of winter wheat seeded with the furrow drill on duckfoot fallow. 1925 crop.

15 shows a typical crop of winter wheat produced in 1925 by furrow drill seeding on duckfoot fallow.

Figure 16 shows the duckfoot cultivator being used on winter wheat stubble. Figure 17 shows a duckfoot fallow as it appeared August 4, 1924. It is more difficult to obtain a good clod mulch with the duckfoot than with the plow. It is generally an easy matter to obtain a good clod mulch if the plowed land is allowed to lie without tillage three or four days after plowing, in order to let clods form, and then tilled with the duckfoot cultivator. However, the clods on early spring plowing, which is generally done during the fore part of April, do not hold up well during the spring months, and, therefore, the soil becomes more susceptible to soil blowing.

The trash in the surface soil of a duckfoot fallow is a vital factor in preventing soil blowing. Stubble land, with a very short stubble, such as is left by a mowing machine, when fall-disked about 2 inches deep with the oneway disk or wheatland plow, has withstood soil blowing during the last three winters (1932-33, 1933-34, 1934-35). The soil is made very fine, but a large portion of the stubble is only tipped over and is held in place by the weight of the soil on it. The same cultivation is used when a growth of
weeds occurs after harvest. By shallow cultivation with the one-way disk the weeds are prevented from maturing seed, the soil moisture is conserved, and the trash is left at the surface to prevent soil blowing. This method will not hold snow as well as if the stubble were left standing; however, there is but little snow to catch during the winter months. Probably more moisture is conserved by weed killing than by the catching of snow during the winter. Where the wheat crop has been harvested with a combine and then the land fall-tilled with a one-way, the long stubble projects sufficiently above the soil to make a very good snow catch. Such land can generally be cultivated with the duckfoot the following spring, especially if narrow shovels are used.

At the Archer Field Station fall-plowed land left rough is but little affected by soil blowing. As shown in U. S. Department of Agriculture Bulletin No. 1315, fall-plowed land produced smaller yields than spring-plowed land. Figure 18 shows the condition of the fall-plowed land in the spring of 1922. Larger clods than those shown in Figure 18 were produced by the fall plowing of 1934. Land in this condition cannot be blown away, neither can it be made into a good seed bed under most dry-land conditions.
Further, the open condition of the surface allows the subsoil to dry out during the winter. The power required to plow and work soil in a dry condition makes fall plowing impractical.

**Rotations and Soil Blowing Control**

As previously stated, most of the soil blowing in this section occurs on fallow and row-cropped land. Since most of the fallowed land is seeded to winter wheat in the fall, it is obvious that soil blowing is a direct injury to the crop. The system of producing winter wheat on fallow is a 2-year rotation of fallow and winter wheat. Most of the land in row crops is generally followed by spring-drilled crops. This is another 2-year rotation. Table 5 gives the acreage in fallow and the principal crops in the three southeastern counties of Wyoming in 1931 arranged in two groups, one most subject to blowing and one most resistant to blowing. The acreage of the two groups is approximately equal. It is apparent that in practical farm operations row crops, especially corn, are an important factor in farm economy, and that the production of winter wheat on fallow has a place in the operations of a large number of farms. Rotations and systems of farm management which will, to a large extent, control soil erosion
either by wind or water, are not established effectively by unyielding formulas. Each farmer will of necessity have to adapt the fundamental facts to the tillage of his soils and to his managerial system. Each individual farmer must rely on his knowledge of his farm, its soils, local climate, adaptation of the various soils on his farm to various crops, different varieties and strains, and the tillage best suited to his soils.

Soil erosion control is not a casual situation. It does not permit a transitory farm population. The acquisition of the necessary detailed knowledge of an individual farm comes from long and intelligent observations and efforts on the same land and accounts for the success and prosperity of one farmer, while another farmer on similar land in the same neighborhood may receive unsatisfactory returns. The conservation and fertility of the soil and the economy of farm operations in the various branches of farm activities determine the profits of the farm.

Transitory economic and social conditions beyond the control of the homemaking farmer often cause the breaking up and changing of well organized farm operations. Transient farmers, "suitcase farmers," and land speculators, whose operations are generally in the production of wheat, and who jump in and out
of the farming industry, are one of the factors contributing to unsettled farm conditions. These transitory farm operators and some so-called farmers give but little thought to the soil being blown away and thereby causing real damage of a permanent nature to their own and adjoining lands.

Table 5.—Acreage of crops in Goshen, Laramie, and Platte counties, Wyoming, in 1931 which subject the soil to blowing and acreage which protects the soil from blowing.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Goshen County</th>
<th>Laramie County</th>
<th>Platte County</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acreage subject to soil blowing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fallow for winter wheat</td>
<td>72,000</td>
<td>31,000</td>
<td>18,900</td>
<td>121,900</td>
</tr>
<tr>
<td>Corn</td>
<td>45,000</td>
<td>53,000</td>
<td>19,000</td>
<td>117,000</td>
</tr>
<tr>
<td>Potatoes</td>
<td>9,000</td>
<td>8,000</td>
<td>2,500</td>
<td>19,500</td>
</tr>
<tr>
<td>Beans</td>
<td>2,500</td>
<td>2,000</td>
<td>1,500</td>
<td>6,000</td>
</tr>
<tr>
<td>Total</td>
<td>128,500</td>
<td>94,000</td>
<td>41,900</td>
<td>264,400</td>
</tr>
<tr>
<td>Acreage resistant to soil blowing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter wheat</td>
<td>72,000</td>
<td>31,000</td>
<td>18,900</td>
<td>121,900</td>
</tr>
<tr>
<td>Spring wheat</td>
<td>8,000</td>
<td>16,000</td>
<td>12,000</td>
<td>36,000</td>
</tr>
<tr>
<td>Oats</td>
<td>9,000</td>
<td>14,000</td>
<td>8,000</td>
<td>31,000</td>
</tr>
<tr>
<td>Barley</td>
<td>18,000</td>
<td>15,000</td>
<td>9,000</td>
<td>42,000</td>
</tr>
<tr>
<td>Rye</td>
<td>3,700</td>
<td>14,000</td>
<td>800</td>
<td>18,500</td>
</tr>
<tr>
<td>Total</td>
<td>110,700</td>
<td>90,000</td>
<td>48,700</td>
<td>249,400</td>
</tr>
</tbody>
</table>

1 Data from Wyoming Agricultural Statistics, 1932.

The control of soil erosion on tilled lands is, under most conditions, dependent upon stable systematic methods of tillage and crop rotations. A rotation is a systematic sequence of crops and tillage adapted to the production of the crops. In planning the following rotations an effort has been made to incorporate the best sequence of crops and the most economical methods of tillage for the conservation of moisture and the checking of soil blowing. Since it has been fairly well proved that farm operations in this section of the Great Plains should be based primarily upon livestock production, these suggested rotations are presented with this in mind.

The simplest spring crop rotation and one which gives fair security of crop returns is corn and spring-drilled crops. The seed bed for the corn crop may be prepared in two ways: (1) by
plowing, harrowing, and planting; and (2) by double-disking and listing—the plowing and disking to be done during the early spring. The method of listing corn in the stubble has produced much inferior yields to disking and listing. The spring-drilled crop is seeded on disked corn ground. The term disking, when used in connection with spring crops, as above and also hereafter, will mean double-disking, duckfooting, spring-tooothing, or oneway-ing the land 3 or 4 inches deep. It should be borne in mind that in this region most of the corn is picked, after which the stalk field is pastured. Owing to the fine growth of the corn stalks, most of them when pastured are eaten fairly close. The soil is trampled to a fine dust and made subject to soil blowing. Some corn fields are not pastured, in which cases, if a fair stand of corn was obtained, soil blowing seldom occurs.

In the operation of this simple rotation, the tilled land under general conditions would be divided into two fields—one for corn and one for the spring-drilled crop. In this section the corn rows should run north and south to resist better the soil blowing effect of the westerly winds. If the soil is subject to blowing, the land should be farmed in strips varying in width according to the nature of the soil and the tillage method followed. If the land is fairly good wheat land, it has considerable clay in it, and probably if cropped in strips 15 to 20 rods in width, soil blowing would be largely controlled. Sandy soils should probably be cropped in strips 8 to 15 rods in width—one strip being planted to corn and the next strip to a spring-drilled crop, thus alternating across the field. The strips, like the rows, should run crosswise to the prevailing heavy winter winds.

In some sections rye is seeded in the stubble of the spring-drilled crop. If the fall precipitation is favorable, winter rye is to be preferred, but if the soil is dry in the fall, it is a safer practice to wait until spring and then seed spring rye in the stubble. This practice has proved fairly successful. If this procedure is followed, a 3-year rotation is established. This can be lengthened into a 5-year rotation by adding a year of duckfoot fallow and seeding winter wheat on it with a furrow drill.
In this rotation the spring-drilled crop should be an early maturing one, so as to give the soil an opportunity to acquire moisture before seeding winter rye. The reasons for the duck-foot fallow and furrow drill have previously been explained. If the stubble of the spring-drilled crop and the rye crop is left at the surface when the land is fallowed, as is done by the duck-foot, no soil blowing should occur during the winter the land is in winter wheat, unless the soil is sandy. With this rotation and the strips 16 rods wide there would be ten strips to the half mile or two strips of each crop in a square field of 160 acres. In the manipulation of this rotation corn always follows the winter wheat. Figure 19 illustrates the sequence of the crops in this rotation.

If the corn in this rotation is seeded on strips 1 and 6 in 1935, it will be seeded on strips 5 and 10 in 1936. All other crops will move one strip toward the left, and the rotation will thus continue indefinitely. Under normal conditions such a cropping system distributes labor, reduces the risk of ordinary dry years, and protects the soil from blowing. The straw of the drilled crops is often used as a supplemental feed during the winter and is sometimes held for a number of years as reserve feed. It should be borne in mind that any of the drilled crops may be cut for hay to supplement the corn for feed. However, one objection to this rotation is that the winter wheat is in the same field with the other crops which, to a large extent, precludes the pasturing of the field. In this section the pasturing of winter wheat on fallow is a doubtful practice, because the animals trample down the furrow drill ridges and increase the danger of blowing.

Table 5 shows that the total corn acreage of the three southeastern counties (Goshen, Laramie, and Platte) is 117,000 acres, and the total acreage of spring-drilled crops is 109,000 acres. In Laramie County, where there is a better balance between spring and winter cereals, the corn acreage is 53,000 acres and the spring-drilled cereal acreage is 45,000. Thus, it appears that the corn crop is a vital factor in the farm economy of the section. This is further emphasized in sections where winter wheat is produced almost exclusively, in that such farmers are in a more precarious economic condition than those who have livestock and practice a
<table>
<thead>
<tr>
<th>FIGURE 18—A 5-YEAR ROTATION FOR STRIP FARMING.</th>
<th>FIGURE 20—A DOUBLE 5-YEAR ROTATION FOR STRIP FARMING.</th>
<th>FIGURE 21—A 10-YEAR ROTATION FOR STRIP FARMING.</th>
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<tbody>
<tr>
<td>Rotation A</td>
<td>S.P. beans</td>
<td>Grass</td>
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<td>Spring-planted crop</td>
<td></td>
<td>Grass</td>
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<tr>
<td>Winter wheat</td>
<td></td>
<td>Winter wheat</td>
</tr>
<tr>
<td>Corn</td>
<td></td>
<td>Grass</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
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<td>7</td>
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<td>10</td>
<td>Winter wheat</td>
<td>Follow</td>
</tr>
<tr>
<td>Spring-drilled crop</td>
<td>Corn</td>
<td>Corn</td>
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<tr>
<td>Rotation B</td>
<td>Potatoes</td>
<td>Follow</td>
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<td>Spring-drilled crop</td>
<td>Millet</td>
<td>Grass</td>
</tr>
<tr>
<td>Corn</td>
<td></td>
<td>Grass</td>
</tr>
</tbody>
</table>
diversification of crops in which corn predominates. Therefore, it is evident that rotations with a large percentage of corn or other row crops are essential.

Figure 20 shows a combination of two 5-year rotations planned for strip farming where the land is subject to blowing and a large percentage of row-crop acreage is desired. In this arrangement rotation A occupies the odd-numbered strips and rotation B the even-numbered ones. Each crop remains in its own rotation by moving two strips to the left each year. In each rotation there is a row crop following a row crop, but these strips are separated by a spring-drilled crop in the other rotation. In rotation A potatoes follow beans to give them the most favored place in the rotation. In rotation B corn follows corn to increase the surety of a feed crop in drought years. If beans and potatoes are not desired, corn can be planted instead. Where two cultivated crops next to each other make an undesirably wide strip, two to four rows of Sudan grass may be planted between them and allowed to stand over winter as a check to soil blowing.

Figure 21 shows another type of rotation in which grass can be grown for hay and pasture, and which is adapted to conditions where more land has been broken from native sod than is desirable. For those not conversant with domesticated grasses adapted to the Great Plains section of Wyoming it is recommended that copies of University of Wyoming Bulletin No. 195 and U. S. Department of Agriculture Technical Bulletin No. 307 be obtained.

Since corn is the only extensively grown crop that does not decrease in acre yield when continuously cropped on the same land, and since during dry years, like 1934, corn produced the largest yield where seeded on ground continuously cropped to corn, it appears that soil blowing is the limiting factor in determining the extensiveness of the production of this crop.

If the corn rows are at right angles to the prevailing winds, four to six rows of Sudan grass could be planted at suitable intervals instead of corn and would aid in checking soil blowing, especially if the Sudan grass is allowed to stand in compact unbroken rows. It would also cause the drifting snow to lodge in the field and aid in the production of the crop that follows. The
same system could be followed in bean and potato fields. However, it should be borne in mind that there is the greatest economy of total production when spring-drilled crops are planted on disked row-crop land.

The possible number and combinations of rotations are so extensive that it is possible to devise rotations and methods of cropping and tillage to meet the needs of most cultivated productive soils that are subject to blowing.

**TILLAGE MACHINERY**

Tillage implements are important in establishing conditions which make the soil subject to blowing or that aid in its prevention. The soil conditions that resist are those that affect the surface (1) as to roughness and (2) as to the presence of undecayed organic matter. Under natural conditions the sod holds the soil, but under tillage probably the best substitute is undecayed organic matter mixed with the surface soil. Clods and a ridged surface are supplements to the organic matter mixed with the surface soil.

The moldboard plow and the disk and spike-tooth harrows are examples of tillage machinery of past agricultural development. The moldboard plow was designed to cover barnyard manure and field trash, and the two harrows were used extensively to break the clods and fine the surface. Deep plowing was emphasized and compared with "scratching," as shallow tillage was called. It is now apparent that "scratching" in a systematic manner is preferable, not only to prevent soil blowing but for more economic tillage and better production, as shown in Tables 3 and 4.

It appears that the very old method of stirring the soil with a "crooked stick," when adapted to modern mass production, more nearly approaches the correct method of soil tillage for this region. This method left the land rough with the trash mixed with the surface soil. Probably the tillage of no implement of modern type more closely resembles that of the "crooked stick" than that of the duckfoot or "field cultivator." This is especially true when the bull tongue or spade shovels are used. The main objection to the duckfoot cultivator is that it clogs rather easily if there is an abundance of coarse trash. The oneway, also called the disk-
harrow plow or wheatland plow, handles this condition; but, when used as the only implement in the tillage of fallow land, the soil becomes fine and subject to blowing, which, in turn, endangers the production of the winter wheat crop. Therefore, it is important, when it becomes necessary to use the oneway in order to handle the trash on the land, that the remainder of the tillage necessary to control weeds during the season be done with the duckfoot or a similar implement which will preserve clods and leave the trash mixed with the surface soil.

Probably no implement, after the land has received the season's primary tillage, is better adapted to the clean tillage of fallow than the rotary rodweeder, but, like the oneway, its continued use leaves the soil fine and subject to blowing. The tillage work of the spring-tooth harrow approaches that of the duckfoot, but the spring-tooth harrow clogs more easily. The spring-tooth harrow is better adapted to shelter belt tillage work, because it has no side wheels which cause considerable damage when cultivating close to the trees.

The lister has been used on some extensive winter wheat farms with success. The land was listed early in the spring, and later in the season, when the weeds again began to grow, the ridges were leveled with large sweeps attached to the beams in place of the lister bottoms. The remainder of the fallow land tillage was done with the duckfoot. This method will handle a large amount of field trash, leaving it quite thoroughly mixed with the surface soil. It also tends to make a rather rough, cloddy fallow mulch. Where it is necessary to list the land in the fall, in order to prevent soil blowing during the winter, the ridges can be leveled with the sweeps in the spring; and, with but little tillage to smooth off the rough places, the land is ready for the spring crops. The selection and proper use of tillage implements are vital factors, not only in the control of soil blowing but also in farm economy. For instance, the oneway must be used with care on land that is to pass the winter without the protection of a trash covering, but it can be used extensively in the spring for spring crops after the soil blowing season is over.
GRASSES

No crop is so effective in preventing soil blowing as grass, and the native grasses have proved their value in this respect. When the native sod is plowed but given no further severe tillage, and is then left, as it sometimes has been on the homesteads, it requires from fifteen to twenty years before a fairly good sod is again established, which consists mainly of buffalo grass (*Buchloe dactyloides*), blue grama grass (*Bouteloua gracilis*), and western wheatgrass (*Agropyron smithii*). Under these conditions, the sod is rather bumpy. Some of the early breakings were cultivated for several years by diskimg or other shallow methods of tillage and then left. Under these conditions the buffalo grass and blue grama grass disappeared, and the western wheatgrass is practically the only growth. Where cultivation was of such a nature as to kill the native grasses before it was abandoned, weeds often grow in sufficient numbers to prevent soil blowing, but the native grasses are slow to reappear.

Probably it would prove more advantageous to seed such lands to grasses such as crested wheatgrass (*Agropyron cristatum*), bromegrass (*Bromus inermis*), or slender wheatgrass (*Agropyron paucilorum*). A combination of these grasses with sweet clover would be a good mixture.

It is probable that cultivated land would prove more resistant to soil blowing if it were cropped to grass for three or four years in every eight or ten-year period. Bromegrass and western wheatgrass are probably to be preferred for seeding in places where the grass is liable to be covered with drifted soil.

Alfalfa is often recommended for dry-land areas. No doubt it is unsurpassed as a roughage feed, and, if properly tilled or left untilled, it will under most conditions prevent soil blowing while the stand lasts. But when broken up it leaves the soil very fine and therefore subject to soil blowing. On the other hand the grass sod, especially if care is taken to preserve the sod clods, will be of aid for several years in checking soil blowing.
SHELTER BELTS

Trees and Shrubs

Shelter belts of trees and shrubs will check soil blowing for a short distance on the windward side and a greater distance on the leeward side—the distance depending on the nature, density, and height of the shelter belt. From observations at this station, the protected distance on the leeward side ranges from 20 to 35 rods. It is probable that with a good shelter belt the effects may be carried even farther.

It is quite possible that certain shrubs or trees could be planted at intervals in rows through the fields and thus check soil blowing. If adapted to it, the shrubs could be used for browse, especially during drought periods.

Annual Plants

The Mammoth Russian sunflower planted in rows, the same as corn, makes a very good snow catch and checks soil blowing on the leeward side. Sudan grass has also proved very good. A couple of rows planted at intervals, at right angles to the prevailing winds, across fallow fields to be seeded to winter wheat would probably be a practical and economic method in aiding the checking of soil blowing in the winter wheat region. Owing to the uncertain growth of the sorgos at the Archer Field Station, they have not been used for checking soil blowing, but reports are that at lower altitudes they serve better than Sudan grass. Corn, while used to a considerable extent, does not stand up as well. It tends to fall over during snow storms. The grain, however, is a vital factor to the producer, which accounts for its being used more extensively than any other crop in the strip farming area.

MEASURING SOIL EROSION

It is a vital and practical problem to civilization to know the rate of soil erosion and the rate of soil formation from the underlying strata. In order to determine this problem, careful measurements will have to be taken over considerable periods of time with various methods of tillage and systems of cropping. If new soil is formed as fast as the old soil is removed, will it be more or less productive than the old soil?
That soil is being eroded under certain methods of tillage and cropping, and that soil has been collected under other methods of tillage and cropping, has been observed and measured, but this does not answer the problems mentioned in the previous paragraph. Suffice it to say that when civilized people become indifferent to the erosion of their soils there is but little care of fertility, in which case it is only a matter of time until the region reverts to a barren, wasted wilderness. Soil erosion is measured in terms of civilization. Therefore, the prevention of undue soil erosion revolves around the question as to whether there is a proper respect for the past, which produced the soil, and the future effects on those who will depend on the soil for their existence.

However, man is not given to exert himself greatly because of experiences long past or to react to distant future events until there is a definite tangible pressure which excites some instinctive emotion; therefore, soil erosion has not received sufficient serious consideration in the past. It appears that the present agitation is, for the most part, justified and therefore will receive attention from all who, under civilized conditions, have a respectable degree of consideration for the source of life's necessities.

CONCLUSIONS

Soil blowing takes place in damaging amounts, but, with a degree of care adapted to practical operations, most of the productive soils can be farmed without undue damage by soil blowing.

The greatest danger from soil blowing occurs on fallow land, generally seeded to winter wheat, and on row-cropped land, especially if sandy.

Factors that aid in the control of soil blowing are shallow tillage of a nature that produces clods and leaves the organic matter at the surface, ridging the soil at right angles to the prevailing winds, strip farming, the growing of sod crops, and providing shelter belts or windbreaks.
The following publications of the Wyoming Experiment Station may be had upon request: (Revised list, October, 1935.)

**ANNUAL REPORTS**—
18th to 44th, inclusive (1907-8 to 1933-34, inclusive.)

**INDEX BULLETINS**—
C, E, and G.

**STATE FARMS BULLETINS**—
4. Some Results from Agricultural Stations over the State from 1923 Report.
7. The Service of the State Experiment Farms.

**CIRCULAR**—
17. Feeding Yearling Steers.
18. Abortion Disease in Wyoming.

**BULLETINS**—
101. Zygadenine, the Crystalline Alkaloid of Zygadenus intermedius.
110. Sweet Clover.
112. The Poisonous Properties of the Two-Grooved Milk Vetch (*Astragalus bisulcatus*).
113. The Effect of Alkali upon Portland Cement.
116. Winter Grains.
134. Wintering Range Calves.
139. Climatological Data for Wyoming.
158. Use of Calcium Cyanide in the Apiary.
163. Results with Tree Planting at the Sheridan Field Station.
171. Varietal Tests with Wheat at Sheridan Field Station.
176. Mexican Bean Beetle.
177. Bacterial Wilt of Alfalfa.
180. Vegetable Cookery at High Altitudes.
182. Grain Mixtures Supplementary to Wyoming Native Hay for Milk Production.
185. Barley Tests at the Sheridan Field Station.
190. Drifting of Honeybees.
193. Arrow Grass—Chemical and Physiological Considerations.
194. Three Species of Zygadenus (Death Camas).
195. Grasses, Alfalfa, and Sweet Clover at the Archer Field Station.
196. Wool Inheritance in Hampshire-Rambouillet Crossbreds.
198. Influence of Storage upon the Bread Making Qualities of Wyoming Hard Wheat Flours.
199. Factors Influencing the Palatability of Hay.
200. Plants Poisonous to Livestock.
201. Infectious Abortion.
203. Poultry Feeding, Housing, and Lighting Experiments at the Wyoming Experiment Station.
204. The Micrometer Caliper for Measuring the Thickness of Wool Fibers.
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