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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 215.

B. T. GALLOWAY, *Chief of Bureau.*

AGRICULTURE IN THE CENTRAL PART OF THE SEMIARID PORTION OF THE GREAT PLAINS.

BY

J. A. WARREN,

Assistant Agriculturist, Office of Farm Management.

ISSUED JULY 19, 1911.

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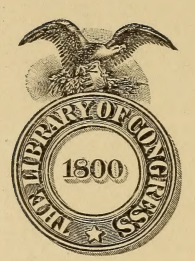

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., March 20, 1911.

Sir: I have the honor to transmit herewith a manuscript entitled "Agriculture in the Central Part of the Semiarid Portion of the Great Plains," and to recommend that it be published as Bulletin No. 215 of the series of this Bureau. This manuscript was prepared by Dr. J. A. Warren, Assistant Agriculturist, under the direction of the Agriculturist in Charge of the Office of Farm Management, of this Bureau, who for a number of years past has been studying the management of "dry farms" and the problems confronting the farmers of the region, besides having had some previous practical experience there. The author wishes to acknowledge his indebtedness to Mr. J. E. Payne, superintendent of the experiment station at Akron, Colo.; Prof. W. P. Snyder, superintendent, and Mr. W. W. Burr, assistant, of the substation at North Platte, Nebr., each of whom has read the manuscript and offered valuable suggestions.

For some time prospective settlers have made a strong demand upon the Department for reliable information concerning this region. There has also been a strong demand from persons already located there for suggestions for the better management of their lands. This manuscript is intended to fill the former want and in a measure also the latter.

Respectfully,

Wm. A. Taylor,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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AGRICULTURE IN THE CENTRAL PART OF THE SEMIARID PORTION OF THE GREAT PLAINS.

INTRODUCTION.

Since the earliest period of settlement in this country the surplus population has migrated westward. This movement will doubtless continue till all the varied resources of the West are as fully utilized as their respective values warrant—till the return for efforts expended and the advantages to be obtained are balanced with those of other parts of the country. The relative profitableness and agreeableness of agricultural enterprises in different sections are by no means stable quantities. For this reason there must always be more or less shifting of population, but this shifting will naturally grow less as the whole country becomes more fully occupied and its possibilities more fully developed.

Agriculture, like every other human activity, is not dependent upon natural surroundings alone, but is changed and swayed by every change in economic conditions. Factors in agriculture may be divided into two classes, natural and artificial. Over most natural forces man has little or no control. Artificial factors are produced and controlled by man, though not necessarily by the individual. Natural conditions are the results of forces so superhuman that man may not even hope to change or modify them. All he may hope to do is to fit himself to meet those conditions and prosper under them by learning to counteract the adverse effects, to supplement deficiencies, and to make the most of every favor nature grants.

Climate and soil are the total natural agricultural resources of any country. Favorable conditions with respect to both are absolutely necessary to successful crop production. A fertile soil is essential, yet an infertile soil may be built up and improved; but a fertile soil is absolutely useless without a favorable climate. "What a nation shall raise depends upon the climate of the region in which that nation happens to be located, and what is produced influences the laws, habits, and customs of the people. North America owes more to its variety of climate than to its variety of soil. A temperate climate,

with its recurring periods of heat and cold, is responsible for our being the busy, hustling nation that we are."[1]

Settlers in new countries, and especially in the dry regions, have often been misled by giving too little attention to climatic conditions. They have found a fertile, easily tilled soil, and without regard to climate have assumed that good crops must be the reward of cultivation.

NATURAL FACTORS OF PLANT GROWTH IN THE GREAT PLAINS FIXED.

Of the climatic factors, rainfall and evaporation are the most important in the semiarid region, because the most faulty. The saying that "rainfall follows the plow" has, in its effect, been one of the worst deceptions ever foisted upon a credulous public. This idea has been the undoing of more plains settlers than has drought itself. If the people had realized that the dry country would always be a dry country many who have settled in the semiarid regions would never have gone there, and those who did go, understanding the hard conditions, might have risen to the emergency and long ago have met the necessity, as did the settlers in Utah and Washington, instead of waiting in the vain hope that Nature would take pity on them and reward their puny efforts by an increase in precipitation. Space does not permit a discussion here of the fixedness of climate, but all students of meteorology now agree that the climate is unchangeable, at least within the limits of a single generation.[2] There are fluctuations from year to year and more or less cyclical changes which give periods of dry years followed by periods of wet years, but the average of a long period of years is practically stable. These fluctuations, although very irregular, lie between fairly well-defined limits as regards total variation.

The main factors affecting evaporation from an open water surface are the relative humidity of the atmosphere, or the proportion of moisture in the air compared to what it can hold, the wind velocity, the temperature of the air and of the water at the surface, and the air pressure. Evaporation from the soil, however, is affected not only by these factors, but also by the character and condition of the soil and by the plant growth thereon. Soil conditions and plant covering are largely under the farmer's control.

The soil in its native state is, like the climate, unchangeable so far as the ordinary limits of time are concerned, but under cultivation very important temporary changes may be brought about.[3]

[1] Ball, Frank Morris, of the department of geology, University of Minnesota, in Monthly Weather Review, May, 1906.

[2] For a discussion of this subject the reader is referred to the Yearbook of the U. S. Dept. of Agriculture for 1908, p. 289; Bulletin D, U. S. Weather Bureau; and Monthly Weather Review, May, 1906.

[3] See Bulletin 55, Bureau of Soils, pp. 61, 71, and 76.

Climate,[1] soil, and topography [2] are the factors determining the native vegetation. As these factors are all fixed and unchangeable to any appreciable extent, the native vegetation is also fixed and unchangeable so far as one lifetime is concerned, except for the limited effects of overgrazing and the effect of increased or diminished burning by fire.

Yet along with the idea of change of climate goes the belief that the plant growth of the native prairies of Nebraska and Kansas has changed decidedly as successful agriculture has pushed its way westward. This notion prevails especially with reference to the long grasses, many believing that even eastern Nebraska and eastern Kansas were covered with buffalo and grama grasses 40 years ago, and that settlement has caused the bluestem to drive the short grasses westward 200 miles. This opinion has, however, no foundation in fact. When the Plains were first settled there were no elements in the flora that had not assumed their proper places. Neither the long grasses nor the short grasses were newcomers. Both had fought the battle for supremacy and each held its chosen ground—the ground which it still holds, except as overgrazing or burning has disturbed the equilibrium. If the stock is removed, the floral covering even on the overgrazed land again assumes its original character, showing conclusively that the character of the plant growth is a fixed resultant of natural causes and is not determined or changed by any obscure and intangible force following in the wake of civilization.

The appearance of the prairies changes noticeably in wet seasons. The wheat-grass and other tall grasses and weeds are much more in evidence, the buffalo and grama grasses grow much taller, and annual plants are more conspicuous; but the real and permanent characters of the flora are unchanged by even half a dozen wet years. The relative sizes of plants, but not the kinds of perennials, change with the season.

The same native flora which existed on the Plains when they were first settled occupies them to-day; the same climatic conditions which caused the ruin of the early settlers must be met by the settlers of to-day; the same soil conditions which the homesteader then found confront the "dry farmer" of the present; the same grass mixture which pastured the first homeseeker's stock and in some cases furnished hay for the winter is still there. As man has not changed the climate, neither has he changed the plant growth on the prairies.

ECONOMIC CONDITIONS IN THE GREAT PLAINS CHANGED.

What has just been stated is not that the farmer on the semiarid Plains to-day has the same combination of conditions to meet that he had 25 years ago when the region was first invaded. It has

[1] See Bulletin 55, Bureau of Soils, pp. 31 and 35. [2] Idem, p. 30.

been pointed out that agricultural factors are of two classes, natural and artificial, and one of these sets of factors is as important as the other. It is just as essential to have a market as to have a crop. While the forces of the first group are fixed, those of the second are constantly changing. Whatever differences there may be between the conditions that surround the settler on the dry lands to-day and those that faced the settler of a generation ago on the same land, these differences are not in soil, climate, or native vegetation. They are economic and industrial differences—differences in the machinery available, the methods of cultivation practiced, the varieties of crops at hand, and the prices of products. The changes in these respects are great, so great that the total combination of all conditions make, as it were, almost another country. The improvement in machinery is so great that Prof. Snyder, of the substation at North Platte, Nebr., has said, "Take away the disk, the press drill, and the corn machinery and western Nebraska would still be a place for the cattleman." A parallel statement with regard to the crops that have been introduced during the last 15 years may be made, but great as is the effect of these changes the advance in prices of products is of still greater importance.

Where success has been attained it has in almost every instance been due to more than normally favorable seasons combined with high prices. There does not appear to have been any great and general revolution in methods of cultivation except what has been brought about by the introduction of new machinery. In spite of the fact that many periodicals have published glowing accounts of a wonderful revolution in methods that has turned the dry region into the most prosperous of farms, there is little foundation for such stories. Otherwise than to use new machinery, the average farmer of the dry country has improved his practices but little. His increased prosperity is due more to unusually favorable seasons and to high prices of grain and stock than to better methods of cultivation or management.

Nevertheless, a very few exceptional farmers, unusually progressive men, who study their work and the conditions to be met, have changed their methods radically and have met with better success.

EXTENT OF THE SEMIARID REGION.

Some writers and experimenters consider the semiarid region as including all the Plains as far east as the ninety-eighth meridian, and thus include a large area of land receiving an average of as much as 27 or 28 inches of rainfall annually, which has supported a prosperous agricultural population for a generation, and in many portions of which farms are readily salable at $70 to $100 an acre. Some of the greatest winter wheat, corn, and hog producing counties in Kansas

and Nebraska lie west of this line. To include this territory seems manifestly unjust and misleading, if it does not make the term "semiarid" actually meaningless. It is impossible to fix a positive and definite line on the one side of which we shall say the country is humid and on the other semiarid, or, as some prefer to say, "subhumid," for there is no sudden dropping off in precipitation, but a fairly uniform decrease from east to west across the two States. As generally used, the term refers to a country receiving an average of between 10 and 20 inches of melted snow and rain annually, but in determining aridity or humidity evaporation is of equal importance with precipitation. In southern Texas much more than 20 inches of precipitation may be required to make a humid country, but 20 inches of rainfall in the Red River region of North Dakota makes a distinctly humid climate. With reference to Kansas and Nebraska the writer prefers to consider the western limit of 20 inches average annual precipitation as the eastern limit of the semiarid region, although in southern Kansas this limit may be too far west and in some other places too far east. So far as the records for Kansas and Nebraska now show, this line in most places lies 20 to 30 miles west of the one hundredth meridian.

The accompanying map (fig. 1) shows the region to which this discussion is intended to apply and the average annual precipitation as shown by records of the Weather Bureau.

CLIMATE.

The climate of the Great Plains region has been thoroughly discussed by several able writers and for that reason it seems unnecessary to give more than a brief summary here. It is a region peculiarly subject to high winds, driving storms, and sudden changes in temperature. The light is intense and the air usually very dry. At least in a large proportion of it hail is of frequent occurrence and does much damage to crops. The native flora and even the soil[1] attest the general dryness. To the careful student of nature these tell a story of perennial dryness over which the myth of changing climate could have no appeal.

PRECIPITATION.

All plants for proper development require a reasonable supply of plant food in available form, favorable temperature, an adequate supply of moisture, and an abundance of sunshine. Given a fertile soil, the yield of the crop depends upon the relative distribution of heat, moisture, and light throughout the season. But a chain is no stronger than its weakest link. Given favorable conditions with respect to all the foregoing except one, that one becomes the limiting factor of success—the all-important question. In most of the Great

[1] Bulletin 55, Bureau of Soils.

FIG. 1.—Map of the central part of the semiarid portion of the Great Plains, showing the average annual precipitation. In the region shown in the unshaded part of the map there is less than 16 inches of precipitation during the year; the lightest shading shows from 16 to 18 inches; the medium shading, from 18 to 20 inches; the heaviest shading, more than 20 inches.

Plains region all these conditions but one, moisture, are favorable for crop production. Thus it is that the amount and distribution of rainfall become the question preeminent, and moisture conservation becomes the vital problem to all farmers.

As has been said, there is a fairly uniform decrease in precipitation from east to west across the Plains to some distance into Colorado and to about the Wyoming boundary line. (See map, fig. 1.) This decrease is 1 inch to about 17 miles along the south line of Kansas, 1 inch to about 21 miles along the north line, and 1 inch to about 40 miles along the north line of Nebraska from the Missouri River west. Over most of the region 70 per cent or more of the precipitation falls during the growing season. This, it is often argued, makes a much smaller annual precipitation necessary than if much of it came during the winter. The truth of this supposition may at first seem self-evident, but there is grave doubt whether our small-grain crops may not with proper tillage succeed better with a small amount of precipitation which comes in the winter than with the same amount of rain coming in the summer. At least, the regions which are producing satisfactory crops on the least rainfall are regions of winter rain, and there summer rain (after July) is considered a misfortune, except when falling on fallow land.[1]

It seems, however, fairly well established that late-maturing crops, such as corn, must have considerable rain during the middle and latter part of the growing season.[2]

The rainfall of the region is very uneven in distribution, a large part of it falling in the form of local showers which cover but limited areas and are often torrential in character. This makes the rainfall extremely variable, both as to annual precipitation and distribution through the season. Instead of calling the region "semiarid" it would be more properly described as varying from year to year between arid and humid. This variability is the most serious feature of the climate. If dry seasons came with any regularity the settler could be prepared for them, but coming as they do with no regularity and without warning they are the constant dread and often the ruin of the homesteader. If the precipitation were fairly uniform and favorably distributed the conditions might be easily met, but this variability has always been the limiting factor of success. It is this, more than the scarcity of moisture, that must be overcome.

EVAPORATION.

From an agricultural standpoint evaporation is of equal importance with precipitation, although few people appreciate this fact. It is this factor which determines the amount of water needed to

[1] Thatcher, R. W., Director of the Washington Agricultural Experiment Station, in address at Corn Exposition, Omaha, 1909.

[2] For a further discussion of this subject, see Bulletin 85, U. S. Weather Bureau; Yearbook, U. S. Dept. of Agriculture for 1903, p. 215; Annual Report, Nebraska State Board of Agriculture, 1909, p. 312.

produce a crop. The water actually contained in the crop at any time is so small as not to be worth considering. It is the water that passes through the plants into the air and the amount lost from the soil which determine the amount necessary for the welfare of the crop. The amount of water within reach of the roots of plants is of no greater importance than the rate at which it escapes through the leaves and stems. The water used by the plants is that which passes through them and the small amount retained in their bodies. The balance of the precipitation in this region is nearly all lost by evaporation directly from the surface of the soil, very little escaping through seepage.

The amount of water used by plants is far from uniform for all parts of the region, being greatest in the warmest and windiest parts and growing less as temperature and wind velocity decrease. For this reason an inch of water in the Panhandle of Texas is not comparable with an inch of water in North Dakota.[1] The amount of water lost through plants in the semiarid region, or, in other words, the amount of water necessary to produce a crop if all loss from the soil could be prevented, is not very well known. It is, however, known to be far in excess of that required in more humid sections. Experimenters in several States have determined the amount of water lost by various plants in their particular localities and in publishing the results have usually stated that they applied to their particular conditions only; but, in spite of this, results obtained in Wisconsin have frequently been quoted to show what a small quantity of water was needed on the dry Plains. Records indicate that in the drier portion of the Plains the air is about twice as dry as at Madison, Wis. Obviously, results in Wisconsin have no relation to Plains conditions. At the Utah Agricultural Experiment Station it has been found that about 50 tons of water passed through wheat plants for every bushel of grain produced, or the equivalent of 12 inches of water actually passed through the plants to produce 27 bushels of wheat to the acre. To this must be added the water lost from the soil by evaporation and by seepage in order to determine what was required to produce the crop.

The loss of water is controlled mainly by the same factors as the evaporation from an open water surface, namely, the dryness of the air, the temperature of the evaporating surface, the wind velocity, and the lightness of the air. From these facts it is plain that the amount of water necessary for a crop is very variable and is not likely to be the same in the same field in any two consecutive seasons. It must vary from season to season approximately as the dryness of the air, the wind velocity, the temperature of the air, the soil, and the plants vary.

[1] Bulletin 188, Bureau of Plant Industry.

The evaporation of water from an open water surface is not an exact measure of the demands made by the atmosphere upon plants; yet it is a relative measure and the best we have at present. Experiments have shown that the loss of water by plants varies. In southeastern Colorado the evaporation from an open water surface is about 50 inches during the growing season, and diminishes to the northward, on account of the decrease in temperature, to about 35 inches in northwestern Nebraska.

The demands for water during critical periods, which may be only a few hours in duration, are often as important as those for the season; in fact, during dry periods the greater part of the injury to crops is often done within a few extremely trying hours. These demands are frequently excessive and often beyond belief. At Lincoln, Nebr., August 26, 1909, Profs. Montgomery and Kiesselbach found that a single corn plant standing in a field of corn lost 9½ pounds of water in eight and a half hours. August 26 was not nearly so hard a day on the corn as was August 23, when the temperature was higher, the wind more than doubled, and the relative humidity only about two-thirds as high. Judging from the record of August 26, the same plant must have lost about 15 pounds in the same length of time on August 23. Even August 23 was not nearly so trying a day as some that have occurred in southeastern Nebraska during very dry seasons. What the demands upon plants in still drier regions may be at times we can only imagine. In a large part of the region the demands are much greater than at Lincoln.

WINDS.

The semiarid portion of the Great Plains is the windiest extensive area in the United States. There are not many records that fairly represent the wind sweep on the smooth prairies. The following data published by the Weather Bureau are the best available on the subject and are included here as being at least suggestive:

Average wind velocities on the semiarid plains.

Station.	March.	April.	May.	June.	July.	August.	September.
Amarillo, Tex.	19.8	20.2	18.9	18.8	16.1	13.4	16.9
Dodge City, Kans.	12.8	14.2	13.7	13.8	11.8	10.9	11.9
North Platte, Nebr.	10.8	12.6	11.8	10.9	9.0	8.6	9.3
Valentine, Nebr.	11.6	13.4	12.2	12.2	10.3	9.5	10.9
Peoria, Ill. (3 years)	11.0	11.0	9.7	8.6	7.1	6.7	7.9

Dodge City, Kans., North Platte, Nebr., and Valentine, Nebr., are near the eastern limit of the semiarid area, and are in valleys which apparently must protect them from the full force of the wind, or at

least prevent as high wind velocities as prevail on the level prairies. Amarillo, Tex., is on a level plain and receives the full sweep of the wind. The conditions at this station may be more representative of the open country under discussion than those at the other stations, yet it seems probable that if there were records on the open prairies farther north they would lie between the figures given. For comparison, the record at Peoria, Ill., is also given.

EFFECT OF WIND ON AGRICULTURE.

High wind velocity has an important bearing on agriculture. It has a positive value as a source of power for pumping water and is occasionally utilized to run feed grinders and other small machinery. It also enables the farmer to cure feed quickly and in excellent condition, but the beneficial results fade into insignificance when compared with the damage done. On many days it is a great hindrance to labor, especially if hay or grain is to be handled; it blows the soil badly, sometimes removing several inches from bare fields in a short time. This drifting absolutely prohibits summer tillage on light soils; the blowing sand cuts off crops and the wind does much damage by whipping and splitting the leaves. All of these facts mentioned, however, are of small importance when compared with the effect of wind on the evaporation of water from the soil and from plants.

The significance of high wind velocity becomes more apparent when its effect upon the rate of evaporation and the consequent drying effect upon soil and plants are considered. Everyone knows that the air takes up water much more rapidly on a windy day than on a calm one, but to get any definite relation between evaporation on a still day and on a windy one is very difficult. Prof. Thomas Russell's experiments with instruments constructed for the purpose gave the following results for evaporation from a water surface:[1]

With the wind at 5 miles an hour evaporation is 2.2 times as rapid as during a calm.
With the wind at 10 miles an hour evaporation is 3.2 times as rapid as during a calm.
With the wind at 15 miles an hour evaporation is 4.9 times as rapid as during a calm.
With the wind at 20 miles an hour evaporation is 5.9 times as rapid as during a calm.
With the wind at 25 miles an hour evaporation is 6.1 times as rapid as during a calm.
With the wind at 30 miles an hour evaporation is 6.3 times as rapid as during a calm.

While the wind can not affect the loss of water from the soil to any great depth at anything like the ratios specified, there is no question that the amount of water required for the best development of plants increases materially as wind velocity increases.

[1] Report of the Chief Signal Officer, War Department, 1888, p. 176; also Monthly Weather Review, U. S. Signal Service, 1888, p. 235.

LIGHT.

The whole semiarid country is a region of intense sunlight. On account of the clearness of the air, the small amount of cloud, and the rarity of the air caused by the high altitude, the sun's rays lose much less energy before striking the earth. Although this is a subject not usually considered it is undoubtedly an important one—how important no one knows. It is known that plants use more water when exposed to strong light. With fairly favorable conditions of heat and moisture the quality and yield of grain depend largely on the intensity and duration of light. It seems comparatively certain that this is one of the main factors responsible for the uniformly high quality of grain produced in the semiarid region and the large yields obtained whenever an adequate supply of moisture is available.[1]

IRRIGATION WATER.[2]

The extent of territory in this region that can ever be irrigated is, indeed, an extremely small proportion of the whole. At best, the water in the streams is sufficient for only small patches in comparison to the whole, or narrow strips along the streams. This water is supplied mainly by the precipitation in the mountains. The amount of water lost by surface run-off in the semiarid region itself is comparatively small and is commonly much exaggerated. It would in reality make only a thin covering over the entire surface. We see water flowing in a draw and think of its volume, but do not stop to think how far apart the watercourses are, and from what a large area the little stream collected the water. Of course, there is considerable movement of water from higher to lower ground, especially during driving storms, so that much more water goes into the ground on one part of a field than on another. Some water also accumulates in low places, where it remains till evaporated, being thus lost to agriculture. Occasionally too, considerable water finds its way into the streams. A considerable but unknown quantity is also lost by seepage.

The Republican River, which rises in the plains of Colorado and has most of its drainage basin in the semiarid region, though its mouth is in a region of much heavier rainfall, has an average annual discharge of only about three-fifths of an inch for its entire basin. In other words, if all the water discharged by this stream during a year were spread out on the land from which it was collected there would be but three-fifths of an inch over the entire area. It must

[1] For a further discussion of this subject, see Bulletin 36, U. S. Weather Bureau.

[2] It would be unnecessary to mention this subject here except to warn persons from accepting statements concerning future irrigation on land where there is no hope for irrigation.

be remembered that this includes not only the storm water but the seepage water also, the only considerable loss not included being the evaporation from the surface of the stream itself.

The North Platte River and its tributaries gather most of their water from mountain areas where the precipitation is generally greater than on the prairies, and in all of which the evaporation is much less and the run-off much greater; yet the amount of water in these streams is sufficient to cover the area from which it has been collected to the depth of only 1.5 inches in a year.[1]

SOILS.

The soils are, in a measure at least, characteristic of the climate. They are strictly dry-climate soils. Little difference in texture between soil and subsoil is found. There is nearly everywhere a high percentage of soluble salts, and in many of the valleys an excess of alkali. This is due to the fact that there is not sufficient rain to leach out the salts. The soil is not often wet to any great depth, and over much of the region there is no seepage whatever, all the water which gets into the soil returning to the air. There is then no means by which these soluble mineral compounds can get away. In nearly all the region a slightly whitish zone is observed at from 1 to 3 feet below the surface. This is due to the accumulation of salts which have been carried down by the rain water and left behind when the water was evaporated to the air. This zone marks the limit below which the soil is not often wet.[2]

The soils are mostly fine sandy loams or silt loams, containing little clay. These soils are locally called "hard land." There are limited areas of dark-colored tillable sands, which, under ordinary tillage withstand drought better than any other soils of the region. Such soils are found north of Haxtum, Colo., north of Oshkosh, Nebr., and in other places. There are large areas of sand hills on which agriculture is out of the question, but within these areas are numerous small valleys where the soil contains some humus and is quite productive. In many of the valleys water is within reach of the plant roots, and here large crops of native hay and some cultivated crops are produced. In many places on the Plains there is more or less gravel, and considerable areas of adobe are found. The adobe is heavy and hard to work, but most of the soils are porous and easy to till when sufficiently moist.

On account of the dryness of the climate there is usually a large store of mineral plant food in the soil, but for the same reason it has

[1] See Bulletin 205, Office of Experiment Stations, U. S. Dept. of Agriculture, entitled "Irrigation in Wyoming," by C. T. Johnson, State Engineer.

[2] This does not refer to the deposits of soft, impure lime rock locally called "magnesia and native lime."

been impossible for any large amount of organic matter to accumulate. The aridity of the climate has not permitted a heavy growth of vegetation and has hastened the burning out of the decomposed matter. No large quantity of organic matter is usually present, much less than is found in soils of humid sections.[1] There is, however, in all the better soils of the region, where the rainfall is 15 inches or more, sufficient humus and nitrogen to produce a number of large crops. As yet the question of fertility has usually not entered into the problem of crop production in the semiarid region. The amount of moisture has not been sufficient to enable the farmers to use the fertility present. Lack of moisture has been the one problem. The writer does not say that if general farming becomes successful and well established fertility will not very soon become a problem or that it might not now be a problem if an abundance of water were available, but that in the past lack of moisture has been the one limiting factor. Under the heavy cropping of irrigation farming, fertility has in many sections become a problem within a very few years after breaking the sod. In fact, in some of the more arid regions more organic matter is needed from the start, as at Wheatland, Wyo. Any system of agriculture to be permanent must provide for the maintenance of the fertility of the soil, but in the territory here discussed the average farmer has not learned how to exhaust this, so its maintenance does not give him any immediate concern. The problem now at hand for the average farmer is to learn how to use profitably the fertility already present and how to produce crops with the limited amount of water received. When this is done, when he has learned how to utilize the native fertility of the soil under the prevailing climatic conditions, then attention may well be given to soil maintenance and improvement. It is altogether probable, however, that the addition of humus would so change the water-holding properties of the soil as to enable a crop to be produced with less rainfall.

The large crops produced in wet seasons and the large crops grown under irrigation all attest the value of the soil. The size of these crops is probably due in no small measure to the very dryness of the climate, contradictory as this may seem.

> A severe and long-continued drought * * * usually leaves the soil in excellent shape for a crop the following season, indicating that a complete drying out of the soil for a prolonged period brings about beneficial changes in the soil. Indeed, in keeping soils of poor or average fertility in an air-dry condition in the laboratory for several months they are usually found more productive when tested with plants again.[2]

[1] Bulletin 55, Bureau of Soils, pp. 27 and 28.

[2] Bulletin 55, Bureau of Soils, p. 63.

HISTORY OF THE SETTLEMENT OF THE REGION.

For 40 years, at least, the history of the settlement of the Plains has been one of periodic advance and retrogression. Periods in which settlement was rapid, energetic, and general have alternated with periods when abandonment, desertion, and return were almost as rapid and often prosecuted with as little judgment. But each wave of settlement pushed permanent agriculture farther west. The recoil never forced it back to its former limits, nor were the desertions ever complete. After each exodus, scattered settlers remained all over the territory that had been occupied.

The first wave that really populated the semiarid region was at its height in 1886. This wave carried settlement across the western counties of Kansas and Nebraska and well into Colorado. There was, however, a wide strip of public land still vacant east of the foothills across Colorado and farther north, in Wyoming, and in some of the extreme western counties of Nebraska. Not only did the settlers fail to appreciate the difficulties before them but many were wholly unprepared to face any hardships. They came, not only without any knowledge of the country, but without money with which to establish themselves—without means of maintenance till crops could be grown, to say nothing about stock and machinery. They had little or no working capital. They believed that if they could only get a "claim" they would succeed some way.

A few good crops came, then poor seasons, and the return commenced. Dry seasons and the panic of the nineties struck together with disastrous results. Lands which had been priced at from $5 to $20 or more per acre were offered for taxes, and often without a bidder. Under these conditions much of the land naturally fell into the hands of loan companies and far-seeing speculators. In one county several thousand quarter sections were allowed to revert to the county for taxes. These were finally all sold to a single company at $30 per 160 acres.

The abandonment was so complete in places that towns once of several hundred inhabitants were marked only by the empty school buildings, the cellars, and the hydrants remaining from the city water systems. Even within the last few months newspapers have reported the moving of one of these towns during a single night to escape the payment of bonds for over $30,000 voted during boom days to provide a water system.

At the time these lands were first taken little or nothing was known by the average settler concerning the climate. If there was a suspicion that rainfall was deficient it was entirely lost sight of in the delusion that rainfall followed the plow. The homesteaders confidently expected that in a few years the short-grass country would

prove itself the equal of eastern Nebraska and Iowa, and that the same methods of farming would be equally successful. They finally awoke to their mistake and, not knowing any way to meet the hard conditions, returned, generally to the region from which they had come. In many cases they carried with them an opinion of the dry country which was as much worse than the truth as their expectations had been too high. For these reasons the man who left the semiarid regions 15 or 20 years ago is likely to undervalue the possibilities which they possess.

As has been said, this desertion took place during the period of the lowest prices which a generation has known and during the most severe series of dry seasons experienced in 40 years, if not in the entire history of the country; years when farmers in the best agricultural sections of the country were obliged to sell horses, cattle, and hogs for anything they would bring, for lack of feed to keep them. Economic factors were as potent in bringing about these conditions as natural ones.

CONDITIONS THAT HAVE BROUGHT ABOUT RESETTLEMENT.

With the return of normal financial conditions and the increase in demand for agricultural products, prices began to rise and continued to rise till now they are at a point scarcely dreamed of 15 years ago. Favorable seasons returned large crops and the result has been the greatest period of prosperity that farmers have ever known. Farming became a very profitable business. In consequence, land values rose enormously, and of necessity rents also. Men who had failed to secure a foothold for themselves and those who thought their farms too valuable for what they produced, began to seek cheaper lands. New crops and new machinery had been introduced into the dry country and the few settlers who had remained produced good crops at a good profit. If any other influence was needed to bring about the settlement of the dry lands it was furnished by the land speculators and other promoters who took advantage of the opportunity and made every effort to give impetus to the movement, many of them using the most unscrupulous methods. Magazine writers, speculators, and enthusiasts heralded what was said to be the discovery of new methods of tillage which were certain to produce enormous crops every year. It has been commonly stated that such methods were in general practice on the Plains and that the good crops of recent years were entirely due to them, when as a matter of fact these crops have in most cases been due to more than normal rainfall. There is no marked improvement in the methods of tillage practiced on the majority of farms. This does not mean that nothing better can be done. Reference is here made only to what has been

done and is now being done on the overwhelming majority of farms in the region under discussion. There are a very few farms on which improved methods have been followed, and these farms indicate that much better crops are possible than the average farmer has secured.

Seeing the movement to the dry lands gaining momentum, speculators bought large ranches and employed agents in all parts of the country to parcel out the lands at a large profit. The result was an organized campaign for settlers. This could not have been condemned if the advertisers had been content with describing the semiarid region as it really is, but much of the advertising has been misleading and much of it positively untrue.

Railroads have been important factors in promoting settlement in all the western country. It was a good business proposition for them to increase the population of the country through which they had built, and, furthermore, many of them had large tracts of land which they were anxious to sell.

Strange as it may seem, the establishment of experiment stations in the region has had a strong influence in bringing in settlers. Somehow people seem to take the location of an experiment station as a guaranty that farming will be successful in the vicinity. The location of a station has almost always immediately increased the demand for and enhanced the price of land in the neighborhood. It should not be forgotten that most of the experiment stations in the region have been established only a few years, during which more than the usual number of favorable seasons have occurred. Many of the heavy yields produced at these stations have been largely due to abundant rainfall, as has sometimes been stated in their bulletins, but people frequently lose sight of the climatic conditions and attribute the results entirely to the methods and the seed used.

FARM PRACTICES IN THE REGION.

A very common method of putting in grain has been to go into a field which has received no preparation whatever since the last crop was harvested and with a seeding attachment on a disk cultivator, go over the ground once, and perhaps give one harrowing with a spike-tooth harrow afterwards. The writer has seen thousands of acres treated in this way, till so much perennial grass had gained a footing that it was often difficult to tell just where the field ended and the virgin prairie began.

Most of the land has seldom been plowed. Corn and sorghum have generally been listed in without any previous preparation of the soil and have been cultivated one to three times, the ground being treated the same way year after year or alternated with small grain disked in on the stalk ground. Since disk drills came into use it has

been common to drill grain right into the stubble without any soil preparation.

Shiftless as these methods may seem, it is hardly safe to so characterize them. These old settlers are not, as a rule, shiftless, but are energetic, practical, and optimistic. Many of them before going to the semiarid country were good farmers in more humid sections; the methods which they use have been reluctantly resorted to after long experience and are not without some merit. Their methods are to be considered as adaptations to the existing conditions. In reply to questions concerning these practices a common response is, "If the season is good anything will produce a crop, and if it is bad nothing will do any good. If I do good work I lose it either way." So far as the methods of cultivation common in humid sections are concerned, this statement is not without at least a coloring of truth. The principle has been to cover the largest possible acreage with the least possible work and expense. Some failures, many light crops, and a few large crops have been obtained; yet the evidence is that where the rainfall is from 18 to 20 inches corn and wheat have been produced at about the same cost per bushel as in eastern Nebraska and eastern Kansas. It must not, however, be concluded from this that farming has been as profitable on the average as farther east. There are many disadvantages connected with crop failure besides the loss of the crop itself. It is a great disadvantage to have to tide over one or two seasons at any time without a crop. There are also many social disadvantages connected with living in a sparsely settled country, often at long distances from markets, schools, and churches.

These conditions and practices make large areas necessary for the support of a family; but large areas have usually been available. Grazing land has been free or obtainable at a nominal rental, and very little feed has been used, even during the winter. Yet on the whole the condition of the settlers has been far from satisfactory, especially when the rainfall is less than 18 inches. If these men had been confined to the use of their own lands existence would hardly have been possible.

Within the last few years a number of important changes have taken place. Larger and better machinery has come into use; the hand separator and the centralized creamery have made a market for cream at every station; new crops have been introduced. Durum wheat, which gives a better average yield than other spring wheats and a much better yield in dry seasons, has become a common crop from Kansas north. Turkey Red winter wheat has advanced into the dry country and by the use of the press drill and better methods of cultivation is made, in many counties, a much more productive crop than spring varieties ever were. This is especially true of a

number of counties in Kansas near the eastern limit of the region. Emmer and new varieties of oats have helped. Sorghum and, in Kansas and southeastern Colorado, kafir and milo have become important crops. A very few farmers are using what are generally considered good dry-land methods. Most of the region has had an unusual number of wet seasons during the last 10 or 12 years, especially that portion north of the north line of Kansas, most of which has now had five or six unusually favorable seasons in succession.

But the most potent factor in bringing about more prosperous conditions has been the great advance in prices of products, while there has been but slight advance in the farmer's necessary expenses. A few years ago wheat sold at 30 to 40 cents a bushel, where it now brings 80 cents to $1, while the cost of production, aside from rent, has remained almost the same, if it has not actually decreased. Without considering rent, 8 bushels of wheat to the acre is a profitable crop at present prices. There is more than a living in it. But what was such a crop at 30 cents? Then, 25 bushels to the acre was not as good as 8 bushels now. During several years, when there was a surplus, corn was worth more to burn than to sell. It was cheaper fuel than coal. In fact, there were times when, if the grower were obliged to stay overnight on the trip to market, his load would have scarcely more than paid his expenses if he stayed at a hotel and put his team in a barn, as he does now. Cattle were correspondingly low; hogs were $2 to $3 a hundredweight; and eggs and butter were scarcely salable at all.

Interest is another factor of great importance to the man short of money. Fifteen years ago 2 to 3 per cent a month in advance were common rates of interest on chattel loans. The writer once saw a banker attempt to lend a farmer $64 in return for a note for $100 due in one year. This amounts to over 56 per cent interest. Now, very reasonable rates can be secured, though not as low as farther east.

THE AGRICULTURAL FUTURE OF THE REGION.

The hopes for better results in the future than have been secured in the past lie in (1) the continuance of high prices of agricultural products, (2) the general adoption of better methods of cultivation especially adapted to the conservation of moisture, (3) the introduction and development of more drought-resistant varieties of grains, forage crops, grasses, and vegetables, (4) the more careful and systematic management of the farm as a whole, (5) a change of attitude among the people from that of sojourners and speculators to that of permanent home builders, and (6) the fact that there is now a considerable population of "drought-resistant" settlers.

FUTURE PRICES OF PRODUCTS.

In the light of the history of agricultural development throughout the country it would seem comparatively certain that prices of farm products must average higher in the future than they have during the last 25 years. All prominent industrialists and political economists appear to be agreed upon this point. Therefore, it seems comparatively safe to assume that smaller yields of grain than have been required in the past will be sufficient to produce a living profit.

IMPROVED METHODS OF TILLAGE.

In the Great Plains region by far the largest portion of the precipitation comes during the warm months, and it is probably impossible to conserve as large a proportion of the rainfall as can be saved in the regions where the heavy precipitation occurs during the cooler weather; but the work at North Platte, Nebr., and other stations in the Plains region shows that on summer-tilled fields probably 40 or 50 per cent of the summer rainfall can be gotten into the first 6 feet of soil and held there for the use of the next season's crop.

It has been frequently asserted that all the rainfall of one year may be imprisoned in the soil and retained there for the use of the following crop. This, however, is a serious mistake. It requires about 3 or 4 inches of dry surface mulch to prevent serious loss of water from the soil below. All the water which does not get through this mulch into the lower layers of soil will be lost to the air by evaporation and not be available for storage. It is evident that, in a region where a large part of the rainfall comes in light showers during the warm weather, a very large proportion of the precipitation serves only to wet the surface mulch and is evaporated from it directly into the air. Ordinarily, showers of one-third of an inch or less coming in the warm part of the year are utterly useless as far as storing water in summer-tilled land is concerned and not infrequently are a source of positive loss, as, being only sufficient to wet the surface mulch and cause a crust to form, they make cultivation necessary for no other purpose than to break the crust thus produced, in order to prevent the loss of water already stored in the lower layers of soil and to prevent the growth of weeds that would immediately spring up. These statements must not be understood as applying to growing crops. Light showers may be of great value to a growing crop, but for the storing of water by summer tillage light showers are often not only of no value, but are a positive damage.

In the Great Plains region, then, it seems fair to assume that not more than 40 to 60 per cent of the rainfall can be gotten deep enough into the soil of a summer-tilled field to be retained there. Most of

the soils are capable of holding between 10 and 17 inches of water in the first 6 feet, but it is not always possible to get them filled to their full capacity, nor can plant roots draw all the water out of the soil. There will always be a considerable amount of water remaining in the soil when plants cease to grow, and even when they die on account of drought. The more rapid the evaporation, the greater will be the quantity of water in the soil when plants begin to suffer, because plants can not draw water as rapidly from a comparatively dry soil as from a wetter one. The amount of water which soil still contains when plants have ceased to grow normally varies with the character of the soil, being greatest in clay and least in sand. In most of the Plains soils it is from 4 to 7 per cent of the dry weight of the soil, or approximately that number of inches of water is distributed through the first 6 feet of soil. On the other hand, plants will live, though they will not grow much, till they have reduced the water content of the soil nearly, though not quite, as low as the dry air will be able to reduce it. Hence, it may be assumed that one-half to three-fourths of the water which is stored in the soil is actually available for normal plant growth. In a season, then, of 16 inches of rainfall, if one-half of it is stored in the first 6 feet of soil there will be 8 inches of water conserved. Probably 4 to 7 inches will be actually available for the use of plants; that is, a reserve of 4 to 7 inches of water is carried over to supplement the rainfall of the succeeding season or to start winter grain and keep it growing till spring rains come. This stored water, however, is much more valuable to growing crops than an equal amount of rainfall, because it is down so far in the soil that a much smaller percentage of it is lost by evaporation from the surface than of the rain which falls upon the crop. A small amount of water is often invaluable in enabling a crop to pass successfully through a dry spell which it would not otherwise withstand. In this way even a very small reserve may determine the fate of the crop.

From this it will readily be seen that there are many places on the Great Plains where it would not seem probable that summer tillage would conserve sufficient moisture, together with the rainfall of the succeeding season, to produce a profitable crop.

How much rainfall is absolutely necessary to produce one crop in two years is largely a matter of speculation. At present, however, it does not seem that in the region under discussion profitable crops can be expected without a precipitation of at least 15 or 16 inches in one of the two years; that is, either while the ground is being summer-tilled or while it is growing the crop. When a season with only 8 or 10 inches of rainfall is followed by one equally dry it does not seem possible that even summer tillage will produce a paying crop. But

if the summer tillage is conducted through a season of considerable rainfall followed by a dry season, it may be altogether possible to produce a profitable crop. When a dry season is followed by a dry season, the prospects for success seem small indeed.

In all the region under discussion, even in the eastern part, seasons of much less than 16 inches of rainfall are likely to occur. Where the average is only 15 or 16 inches, fully half the seasons will have less than this amount, and presumably, even with the best known methods for the conservation of moisture, many light crops and a considerable number of failures must be expected.

Statements have frequently been published by uninformed or unscrupulous persons which leave the impression, if they do not actu-

FIG. 2.—A field of wheat on summer-tilled land, Phillips County, Colo., 1909.

ally say, that 40 to 60 bushels of wheat per acre can be produced every other year by summer tillage wherever the average precipitation is 10 inches. Such statements must be considered as purely visionary and without any foundation in fact.[1] So far as the writer is aware, the best yields of wheat obtained on summer-tilled land anywhere in the Great Plains region for a period of years have been secured by one farmer in Logan County, Colo., and one in Phillips County, Colo. (See fig. 2.) The first reports an average of 28 bushels to the acre for five years and the second 35½ bushels to the acre for

[1] In the State of Washington, where the conditions are especially favorable for wheat growing, and where summer tillage has reached a high development, the yield of wheat in those regions where there is an annual precipitation of 10 to 12 inches seldom exceeds 20 bushels to the acre. The yields usually obtained with that amount of rainfall will run from 7 to 15 bushels, depending on conditions.

seven years. These crops were all produced on land that had been thoroughly summer-tilled and during a period of seasons more favorable than the average. It must be remembered that each of these crops required two years for its production.

In the matter of summer tillage for the conservation of moisture there is considerable variation in the practices of the best dry-land farmers. The best method appears to be to double-disk the land in the summer as soon as possible after the grain is cut (if a small-grain crop was grown), and again in the spring as early as the ground can be worked, and then disk or harrow as often as is necessary to keep down the weeds and to keep the crust broken till about June; then plow as deeply as the available horsepower will permit, disking or harrowing each half-day's plowing before leaving the field, or, better, using a revolving pulverizer attachment on the plow. After this the ground must be double-disked, harrowed, or worked with some other surface cultivator as often as is necessary to keep the crust broken, maintain a good surface mulch, and keep the weeds down till time for seeding winter wheat. A field tilled in this way is shown in figure 3, while the crop grown on an adjoining field similarly tilled the preceding year is shown in figure 2.

The depth of surface mulch required will vary somewhat with different soils and other varying conditions, but will generally need to be 3 or 4 inches. This should not be a dust mulch but a mulch of granular soil or small clods. A dust mulch is not only less effective in conserving moisture than a mulch of small clods but is a very uncertain thing to hold in a region of high winds. A dust mulch of 3 or 4 inches might be blown off the entire field in a single day. In maintaining the mulch it is best to vary the depth of cultivation so as to prevent the formation of a crust below the mulch.

Before time for seeding, that part of the soil between the surface mulch and the bottom of the plowing should be well firmed in order to reestablish connection between the furrow slice and the soil below, enabling the water to rise by capillarity to within easy reach of the young plants and form a firm seed bed, which is an absolute necessity for the best development of the small grains and grasses. This condition may be secured by subsurface packing immediately after the plow, but the subsequent working will usually give the required condition. When considerable rain falls between the time of plowing and the time of seeding this will serve to firm the lower part of the furrow and connect it with the soil below. Packing will insure the filling of the air spaces left in the soil as it falls from the moldboard of the plow and will bring the moist soil in contact with whatever stubble or trash may be turned under and hasten its decay—an important point. Packing will show the greatest benefits on light soils in dry

seasons and on late plowing. It may be of no benefit in a wet season and may be harmful on heavy soil.

There are various types of corrugated rollers and special subsurface packers made for this purpose, and the work may be done with the common disk by setting it straight and weighting it to make it run deep. Subsurface packing is important not only on summer-tilled but also on spring-plowed land that is to raise a crop the same season.

In western Kansas and eastern Colorado the lister is very much in favor and the farmers use it for every possible purpose. Most of the few who have done any summer-tilling do not plow the ground but list the land that is to be summer-tilled just after they get through

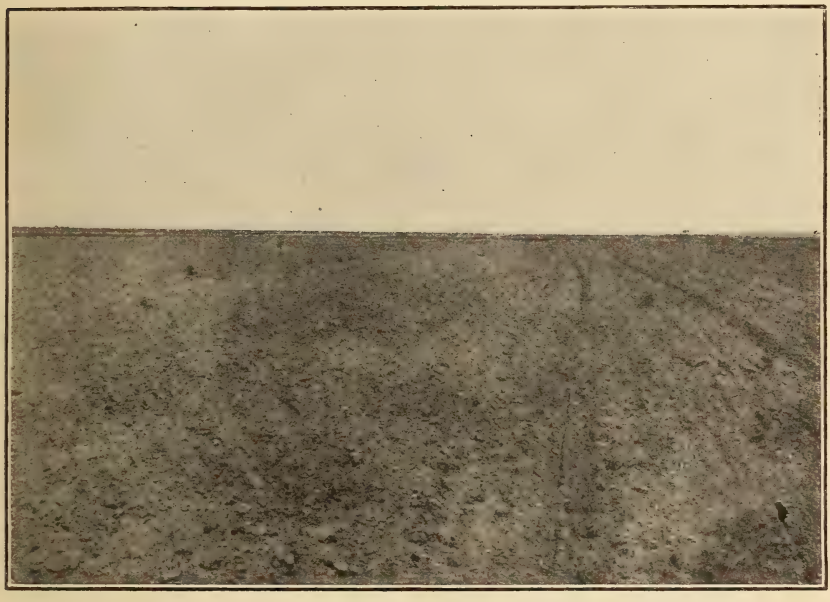

FIG. 3.—A summer-tilled field where winter wheat will be grown, adjacent to the field shown in figure 2.

planting corn (fig. 4), then throw down the ridges. About the last of June or the first of July they list again, splitting the middles left by the first listing. They then throw down the ridges and do whatever additional cultivation is necessary to keep down the weeds and maintain the surface mulch. This is a cheaper way of doing the work than plowing, because less cultivation is required. It has an advantage also in the fact that if the weeds attain any considerable size (which should never be allowed), the ridges enable the farmer to kill the weeds without plowing the ground. It does not seem to the writer, however, that this method can, on the average, produce as favorable results as that previously described, although there are no data at hand to show the comparative values of the two methods.

Conservation of moisture is not the only benefit derived from summer tillage, although it is one of the most important reasons for the good results following. Such tillage puts the ground in very much better physical condition for plant growth, aside from the more favorable moisture content. There is abundant evidence also that there is more available plant food in the upper layers of soil and within easy reach of the plant roots. This, however, must not be interpreted to mean that fertility has or has not been added to the soil. The temperature and moisture conditions secured by the clean and thorough cultivation given are favorable for changing the condition of the plant food already in the soil so that plants may use it, while it was previously in unusable form.

FIG. 4.—A field summer-tilled by listing instead of plowing, Rawlins County, Kans., 1909.

One of the very important effects of summer tillage on winter wheat is that it enables the wheat to start at once with a vigorous growth and so enter the winter in good condition. It thus comes through the winter strong, well rooted, and ready to take advantage of any opportunities for growth. In this condition it is able to withstand considerable hardship, when wheat on land less thoroughly prepared suffers in the winter and comes through weak or dies. It will often happen that the field which was summer-tilled the preceding season will contain little, if any, more moisture in the spring in the first 3 feet of soil than a field which grew a crop and was plowed and seeded to wheat, but the wheat on the summer-tilled land will have so much better start that it will go on and make a crop under conditions that would cause the other to fail. It appears also that grain on summer-tilled land, either by virtue of better root systems or because

of the better capillary condition of the soil, is able to draw water from a greater depth.[1] Summer tillage is not practicable on all soils nor for all crops. Soils which are likely to blow, especially very sandy soils, can not be bare tilled because they will blow away.

Summer tillage has proved a success for winter wheat and by this method of cultivation winter wheat becomes the surest crop in the region; but without summer tillage winter wheat is as uncertain in much of the region as spring grain. Summer tillage considerably increases the yield of spring grains also. It is still uncertain whether it is profitable to summer-till for spring grain or whether all the summer-tilled land should be utilized for winter wheat and potatoes.

There are now sufficient experimental data at hand to show conclusively that summer tillage is not profitable for corn, all results indicating that corn on spring-plowed land will outyield that on summer-tilled land. With all cultivated crops frequent, thorough, and shallow cultivation is of the utmost importance. Unless the season is unusually favorable the harrow should be used frequently on corn, potatoes, and small grain until the plants are so large as to be damaged by this implement.

Up to the present time the methods employed in the semiarid plains have, for the most part, been merely a makeshift. That these methods must and will be changed for the better is certain. General agriculture can never have a substantial foundation in this region until tillage for the conservation of moisture is generally practiced. In the face of the fact that so much has been done in the way of tillage for the conservation of moisture in parts of Utah, Oregon, Washington, and Canada, it is a wonder that so little has been done on our semiarid plains. The work of the agricultural experiment stations and of the progressive farmers in the region has now gone far enough to prove that by the use of methods for moisture conservation which have accomplished so much in the far northwest a considerable amount of moisture can be conserved and used for crop production in all portions of the semiarid region.

INTRODUCTION AND DEVELOPMENT OF DROUGHT-RESISTANT CROPS.

As regards the introduction and development of drought-resistant crops, much is to be expected. The Department of Agriculture has experts scouring all parts of the world in search of plants which may prove valuable in the various sections of the United States. There are many regions in the Old World where the climatic conditions are very similar to those of our semiarid Plains and upon which civilized men have maintained themselves for thousands of years. Many varieties of drought-resistant plants adapted to our semiarid

[1] See "Some Soil Studies in Dry-Land Regions," by Dr. F. J. Alway, in Bulletin 130. Bureau of Plant Industry, 1908, p. 38.

regions have already been discovered in such places and introduced to the decided advantage of the Plains farmers. Among these may be mentioned durum wheat, brome-grass, alfalfa, milo, kafir, and sorghum. It is to be expected that many other useful varieties will yet be discovered and introduced.

The development of new varieties requires in most cases a considerable period of years, and yet since the semiarid region was first settled marked improvements have already been made in many of our crops. Some of the varieties of corn, for example, which have been developed on the dry lands by selection are much more capable of producing crops under the severe conditions existing than was the original stock from which they have descended. Milo a few years ago was a tall plant of irregular height and produced drooping heads, but careful breeding has developed a quite uniform dwarf strain with erect heads. Hardy varieties of winter emmer, barley, and oats may be expected in the near future, each of which would be of great value to the dry country as well as to many other sections.

As nearly all our common grains have been developed from plants which in their early history were adapted only to much more humid climates than those in which we now grow them, there is no reason for thinking that varieties and strains of these plants may not yet be produced which will succeed with far less water than is required by the present varieties. With the rapid advancement which has been made in agricultural science and plant breeding within the last few years it would seem only reasonable to expect results to be obtained in much less time than has been required in the past. There is work now going on at some of the agricultural experiment stations which indicates that it may be possible within a few years to breed a variety of corn which will produce an equal amount of grain with perhaps only two-thirds as much water as is now required. To what extent drought-resistant varieties may be developed and how much may be accomplished in reducing the water requirements of plants is purely a matter of speculation, but the work has already gone far enough to give assurance of considerable success in this line. A word of caution to the individual may be necessary here. Plant breeding, while it will surely play an important part in the future development of the region, is too slow a process for the individual to wait for or to depend upon. It is a regional rather than an individual proposition.

Over all the region in question the only winter wheats that have proved themselves sufficiently hardy are of the Crimean type, such as Turkey Red and Kharkof. Common spring wheat is largely grown on the table-lands south of Wray, Colo., and also in eastern Wyoming and the adjacent parts of Nebraska. It seems comparatively certain, however, that with good tillage, winter wheat will far outyield the common spring varieties, even in these sections.

Durum, or macaroni, wheat is giving better yields than the common spring varieties in nearly all sections north of the Kansas-Nebraska line, but south of this line it has not been so satisfactory. The yields of durum wheat commonly approach those of winter wheat when given similar advantages of cultivation. Durum wheat, however, is at a great disadvantage, because it is commonly discriminated against on the market to the extent of 5 to 20 cents a bushel. The lower price frequently offsets the higher yield and makes the crop no more profitable than other spring varieties. Experiments at North Platte, Nebr., indicate that durum wheat will produce more feed to the acre than either oats or emmer. There would seem, then, no good reason why it should not be grown in preference to either of these crops unless the straw of oats and emmer is enough better feed than the wheat straw to overcome the difference in favor of the wheat.

Early varieties of oats are much more certain than late varieties in all the southern part of the area under discussion, and are at least as productive in the northern portion. The late varieties, however, succeed much better north of the South Platte River than they do farther south.

Barley is a valuable feed crop throughout the region, but in most places is not so popular as other grains. It has generally been more satisfactory in the northern than in the southern sections. California feed barley appears to be one of the best varieties for feed and the common six-rowed the best for market.

Emmer, commonly called spelt, is quite generally grown as a substitute for oats. While this is one of the most drought resistant of our spring grains it does not appear to be able to produce any more, if as much, feed to the acre than oats, barley, or durum wheat.

South of the Rock Island Railroad milo is one of the surest and most productive grain crops, and at the same time it makes considerable fodder, though for fodder it is inferior to sorghum and kafir. Kafir is also grown in the same territory, but it requires a longer season and produces less grain to the acre than milo, though it is a much better fodder plant.

Sorghum stands without a rival as the most important fodder crop of the semiarid region as far north as the South Platte River, and may be used to advantage throughout the limits of the territory under discussion in these pages.

Millets are of more or less importance throughout the region, but are much less productive and less drought resistant than the sorghums. They have the advantage, however, of being able to mature in much less time.

In a large portion of the region, especially that receiving the heaviest rainfall, alfalfa can be produced with more or less success, but

in the drier parts its production on uplands by the use of ordinary methods is doubtful. Moderately successful small fields have been maintained for a number of years in many localities, as at Santa Fe, Kans.; Vernon, Colo.; Colby, Kans.; and Sextorp, Harrison, and Alliance, Nebr. Most of the large yields of alfalfa reported from the region have been grown on subirrigated valley land, but the public has commonly credited them to the upland. There are still many subirrigated patches growing buffalo grass that ought to be seeded to alfalfa. A number of fields of alfalfa seeded in rows 30 to 36 inches apart and thoroughly cultivated, very much as corn and potatoes are cultivated, have produced very profitable crops for several years. The promise for the production of alfalfa seed by this method is very bright for the entire region.

PROMISING SYSTEMS OF FARM MANAGEMENT.

It does not seem advisable for anyone to attempt to do exclusive grain farming in this region and expect to make it a permanent success. In the past this has proved inadvisable here, as it has nearly everywhere else. On the other hand, it has also been proved by the majority of old settlers that for the man with limited means it is precarious to depend on stock alone. At least, the most certain means of securing a more or less constant income is to give attention to a number of different products. This also enables one to accomplish much more with the same number of laborers, because it furnishes more constant employment.

As has been mentioned previously, the growth of grass is comparatively small in this dry country. For this reason a large area is required for pasturage. In most places somewhere from 8 to 20 acres of native grass, together with 2 tons of rough feed, though often this amount of rough feed is not used, are required to carry one grown horse or cow the year round, or 1 square mile will commonly pasture from 30 head on the drier and sandier lands to 80 head on the best lands. This, together with the frequent light crops, makes it essential that settlers own or control larger areas of land than are required to maintain a family in more humid regions.

It is impossible to say definitely what the farm unit should be or on how small a tract a family can live. The acreage required must necessarily vary much with the local conditions, but it will vary even more with the man. There is much truth in the old saying "Thar's more in the man than thar is in the lan'." However, some general statement on this subject may serve to give those unfamiliar with the conditions a better idea. It is the writer's opinion that on the better lands near the eastern limit of the territory 320 acres should be sufficient to support a family, but near the western limit for general agriculture two to four sections will be needed. In most cases only

150 to 200 acres should be broken and the rest used for pasture. These figures must be taken as only suggestive. It will appear to many that the area here allowed for the pasturing of one animal is excessive, but it is none too much. It will also be suggested that cultivated grasses can be sown which will very much reduce this area; but experience has not yet proved it advisable to make a general practice of plowing up the native grass with the expectation of making a better pasture by sowing something else. It must be remembered that the higher rate of evaporation in the southern portion of the territory makes the conditions there more severe and the acreage required larger than is necessary with the same rainfall farther north.

On the heavier lands it now seems that the most promising system of management is about as follows: Leave a large portion of the farm, probably three-fourths, or all but 100 to 200 acres, in native pasture, and keep all the dual-purpose cows the pasture will carry, along with the young cattle, horses, and colts. Butter or cream is one of the surest sources of income and profit. There should be pasture enough to feed one animal for every 1 to 2 acres of land under cultivation; in the best portions of the region, however, the farmers have not always found it most profitable to keep so much stock. There should always be a large flock of poultry. Hens will lay in dry seasons as well as in wet. One of the first objects on the farm land, then, must be to raise feed for the stock. In seasons of good crops the farmer must stack feed to carry over and to tide him through dry years. He must reverse the old adage learned in his youth, "Lay by something for a rainy day," and in this country must learn, both with regard to himself and his stock, to lay by something for the dry day. Of the farm land one-fifth to one-third should be summer-tilled each year for winter wheat and potatoes for money crops, these to be followed with corn or some fodder crop, and the third year with spring grain or summer fallow.

Assuming that the farm contains 640 acres, one-fourth of which is under cultivation, the foregoing plans would call for one of the following rotations on each field:

Rotation for farm of 640 acres, one-fourth under cultivation.

THREE-YEAR ROTATION.	FOUR-YEAR ROTATION.	FIVE-YEAR ROTATION.
First year, summer-tilled.	Summer-tilled.	Summer-tilled.
Second year, winter wheat and potatoes.	Winter wheat and potatoes.	Winter wheat and potatoes.
Third year, corn and rough feed.	Corn.	Corn.
Fourth year, summer-tilled.	Spring grain and rough feed.	Spring grain.
Fifth year, same as second.	Summer-tilled.	Rough feed and corn.
Sixth year, same as third.	Winter wheat and potatoes.	Summer-tilled.

These rotations would give the following acreages of each crop on the farm each year:

Acreages in different crops for farm of 640 acres, one-fourth under cultivation.

THREE-YEAR ROTATION.	FOUR-YEAR ROTATION.	FIVE-YEAR ROTATION.
53 acres summer-tilled.	40 acres summer-tilled.	32 acres summer-tilled.
53 acres in winter wheat and potatoes.	40 acres in winter wheat and potatoes.	32 acres in winter wheat and potatoes.
53 acres in corn and rough feed.	40 acres in corn.	32 acres in corn.
	40 acres in spring grain and rough feed.	32 acres in spring grain.
		32 acres in corn and rough feed.

In the southern part of the territory winter barley and in the northern part winter rye may replace a part of the winter wheat. No one of these systems, of course, could be followed on all farms, but some one of them can easily be varied to meet almost any of the local conditions. On the sandier lands summer tillage can not be practiced and winter wheat does not do well. On such lands corn, sorghum, emmer, and rye must be the main crops.

In the best part of the area the five-year rotation will probably give the largest net returns, while in the western part the three-year rotation will best fit the conditions. It should be noted that winter wheat and potatoes follow summer tillage in all rotations. That is because summer tillage has proved more profitable for these crops than for any others. Summer tillage has not proved profitable for corn, and therefore this crop follows winter wheat. The thorough cultivation which corn requires leaves the soil in good condition for spring grain; in fact, many tests have given as good yields of spring grain following corn as on summer-tilled land. Sorghum is the most vigorous feeder and the most drought-resistant crop of all, and for that reason is placed last in the series. Sorghum also dries out the ground so completely that the following crop is entirely dependent upon the rainfall of the current season, there being little or no available water left in the soil by the time the sorghum is mature. For this reason any crop following sorghum is almost sure to give a low yield unless timely and abundant rains occur. Following the sorghum with summer tillage gives an entire season in which to replenish the soil moisture before another crop is planted.

If the manure is cared for there will be enough to give each field a light dressing at least once in the rotation. The writer is well aware that farmers in the dry country are generally afraid of manure, but he is convinced that the trouble is mostly due to too heavy applications. Manure should be spread as evenly as possible and great care should be taken that no large bunches are left. The thinner

it is spread the better. It should always be disked or otherwise worked into the soil before the ground is plowed. If these precautions are observed, only good results should be expected. The best place in the rotation to apply the manure is probably just preceding the sorghum. The sorghum will generally be listed, and so the roots will be below the manure. What manure is not incorporated with the soil is near the surface and will help conserve moisture instead of burning out the crop, as it is very likely to do if a heavy dressing is plowed under before it has time to rot. Summer tillage following the sorghum gives another full year for the manure to rot before a small-grain crop occupies the land. If the land is poor manure may be spread very thinly on the winter wheat to good advantage, but if the land is rich and a wet season follows the wheat is almost sure to lodge. Manure may safely be applied on ground that is to grow corn, or it may be spread lightly on the stalk ground before it is disked for spring grain. When used in this way it is often of great benefit in preventing the soil from blowing.

None of these rotations provides for a protein feed, but no satisfactory high-protein feed crop is available. Any land that will grow alfalfa should be seeded to it, and probably with proper care this crop can be grown to some extent on every farm. The experiments with alfalfa in rows 3 or 3½ feet apart and cultivated as regularly as corn are giving flattering results, and where it is too dry for the ordinary seeding it seems almost certain that this method will produce valuable seed crops and at the same time some feed.

Most of the soils of the dry region are short of nitrogen and humus, and if alfalfa can be grown for a few years the land will produce better crops of other kinds. The writer is personally familiar with a small field of alfalfa in northeastern Colorado which died in 1894. In the summer of 1908 the native grasses which had taken possession were more than twice as thick and tall as on the remainder of the field. In irrigated fields on the plains of Colorado yields of grain are frequently doubled where alfalfa has been grown. Alfalfa, however, leaves the ground very dry, and for that reason the first crop following it often suffers severely from drought and makes a light yield unless the season is very favorable.

In much of the sand-hill country and on some of the rough land nothing but stock production seems possible; but even here, where in reach of a market, the small stockman will find it almost necessary to sell cream. In the sand hills hay is usually plentiful, and where the settler has valleys that will grow alfalfa or peas milking should be profitable. In many of the better valleys potatoes may be produced, but in some places the difficulty in getting them to market makes them impossible as a market crop.

To make the homestead more attractive and to furnish shade and windbreaks, everyone wants some trees around the house. Besides the comfort secured from trees nothing adds more to the appearance of a place, and in the whole region nothing is more conspicuous by its absence from the settler's home. This is unnecessary. There are hardy trees that can be kept growing anywhere in the region where crops can be grown if they are given proper care. Windbreaks are valuable for the protection they afford to growing crops and stock as well as about the house, and may also be made to yield material for fuel, fencing, and farm timbers. They should be kept thoroughly cultivated, at least for several years, and fenced from stock at all times. The honey locust is one of the best varieties to use, and has generally succeeded in the drier portions of the region. The green ash is very hardy and may be kept growing, but should be planted in the moister situations. In places it may be attacked by borers sooner or later. The white elm is also very hardy, and while not equal to the honey locust, is in general a more desirable and more satisfactory tree. The black locust is quite hardy and a rapid grower, but it is almost sure to be destroyed by borers. In some portions of the Central Plains region it might be advisable to plant Russian mulberry, Russian olive, and Osage orange. The Forest Service also recommends the western yellow pine, the jack pine, and the Austrian pine for this region. So far as present knowledge goes this about exhausts the list of forest trees adapted for planting in this section.

Fruit growing on a commercial scale is not to be recommended, but every farmer wants some fruit even if it costs him more in labor than it would to buy it. Small fruits, including Early Richmond cherries, plums, and currants, can be grown if a little special care is given them. Strawberries may also be produced if a little water can be secured. Frequently enough water can be spared from the well to help a great deal in the garden or on the small fruit. On most farms there are slopes where a deep furrow would collect considerable storm water and run it to the garden, even when there was only a light shower. Advantage should be taken of every such opportunity offered. Without a garden and some fruit it is hard to call a place home. Where ground water is available a windmill may supply water for a garden.

Two of the most prosperous and painstaking farmers of northeastern Colorado have worked out on their farms almost exactly such systems as here outlined and have followed them for a number of years with marked success, while a considerable number of progressive farmers scattered over the region are partially following such systems.

OPPORTUNITY FOR FARMERS IN THE GREAT PLAINS.

The Great Plains is not a region where a farmer should expect to make large profits with a small investment if he is to confine his operations to his own lands. Large profits have been made, but in most cases they have been the result either of speculating in lands or of running cattle on free grass. More capital is needed to start to advantage than in a more humid section, because there is more danger of failure. One must often wait till the second year before he has any certainty of a profitable crop, for it takes a full season to get land in shape for a good crop of wheat. If the season is unusually favorable the spring crops may be very profitable, but the risk in depending on them is great. Spring or early summer breaking is almost equal to summer-tilled land for small grain if the land has not grown many weeds.

No man should go empty handed into this country, but many men with limited means who are willing to endure some privations will be able to secure a foothold and establish homes. We are often asked how much capital is necessary and whether the land is too high priced. Obviously, these are questions which the individual must answer for himself. In the Great Plains, as anywhere else, it is not necessary that one have sufficient capital to enable him to start free from debt. In general, we may say that in our opinion from $6,000 to $8,000 should buy enough land to support a family of average size, and that where it is mainly a stock proposition $50 should buy enough land to pasture one cow. It is evident that one can not afford to pay $10 an acre for land where 4 square miles are required to give one family a moderate support. By comparing these statements with those concerning the necessary size of the farm, the reader may draw his own conclusions.

No man should think of "dry farming" by what are generally considered improved methods as an indifferent or lazy man's job. Dry farming, to be successful and permanent, is necessarily good farming. The indifferent farmer will get a few good crops, many poor ones, and many almost complete failures. The man who has failed in a more humid region should not expect to succeed in the Great Plains. In a humid region any kind of cultivation is almost sure to bring some kind of crop, but not so in the dry country. It is only the best and most systematic farming that can be expected to give even moderate returns in unfavorable seasons, and in some seasons even this will fail.

That there will be many failures among the settlers now locating in the drier parts of the region goes without saying. In many places inexperienced men are crowding in too thickly and are expecting to make a living on far too small an area. They are trying to farm by

the same methods used in more humid sections or by more careless methods, and are depending on timely rains to bring results. Then, too, among the immigrants to any undeveloped country there is a relatively large proportion of individuals who do not go with a fixed purpose to establish a home but expect to sell at the first opportunity. In fact, in many sections it is difficult to keep from gaining the impression that land speculation is receiving more attention than crop production. Far too many, whether their holdings are deeded lands or merely homestead entries, are hoping to sell at a profit rather than to establish homes. To such this discussion makes no appeal. It is written not as a guide to speculators but as an aid to home seekers. The writer does not wish to be understood as condemning land speculation, but land speculation does not develop the agricultural possibilities of a region or support a stable population. What is needed in the semiarid region is not speculators but home builders—not a shifting but a stable, producing population. There probably are many people both in this country and in Europe who could be happier, freer, more healthy, and more prosperous on the semiarid Plains than in their present situations.

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