DRY-FARMING

ITS PRINCIPLES AND PRACTICE

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Illustrated

LONDON

T. WERNER LAURIE

CLIFFORD'S INN

CROSSING WHEAT, MINNESOTA EXPERIMENT STATION

By this means new drought-resistant wheats can be developed

TO ALL THOSE
WHO BELIEVE IN THE DRY-LANDS OF THE
UNITED STATES AND THE BRITISH EMPIRE
THIS VOLUME IS RESPECTFULLY
INSCRIBED

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PREFACE

The aim of this volume is to set forth in a plain way the salient facts of that new branch of agricultural science which is now universally known as dry-farming. The writer has taken special care to deal only with the data obtained by reliable farmers, experiment-station workers, together with the results of his own experience. It is therefore hoped that this little manual will form a safe and useful guide to those thousands of settlers who are ceaselessly pouring into the great semi-arid plains of the United States and Western Canada and be of genuine value as well to all those interested in the study and practice of agriculture.

PREFACE

The author wishes to express his indebtedness for much valuable aid to the following: Messrs. E. C. Chilcott, L. J. Briggs, and William M. Jardine of the National Department of Agriculture; Dr. John A. Widtsoe, Professor Lewis A. Merrill, and Professor J. C. Hogenson of Utah; Professor F. B. Linfield and Professor A. Atkinson of Montana; Mr. H. W. Campbell of Lincoln, Nebraska; Dr. V. T. Cooke of Wyoming; Mr. Gifford Pinchot, Chief Forester, Washington, D. C.; and Professor E. W. Hilgard of California. Nor must he fail to thank Mr. John T. Burns of Colorado, Secretary to the Dry-Farming Congress, for much kind assistance.

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DRY-FARMING

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CHAPTER I

HISTORY OF DRY-FARMING

IN the study of dry-farming we are naturally led at the outset to ask what is the real meaning of the term "desert." The dictionary defines it as "a barren tract incapable of supporting population, as the vast sand plains of Asia and Africa, which are destitute of moisture and vegetation." Such a definition is apt to mislead us unless we constantly bear in mind that what is now a desert region may be transformed in a few years into a country of fertile fields capable of sustaining a large population. The most striking illustration of this fact is to be found in America. Spread out an old map of the United States, of just forty years ago, and you will see that vast region marked "The Great American Desert" which stretched from the Missouri to the Rockies. What has happened? In the space of a single generation, a vast army of settlers has invaded this region and six transcontinental railroads[1] bring food and the daily paper to the farmer's door. Next turning to the British Empire we note that great desert region of Australia so quaintly called the "Never-Never-Country" on the fringe of which farmers even now are settling. Lastly, coming to South Africa, we can mark out the Kalahari Desert, or, as it is termed in the

[1] On the 10th of last May forty years had elapsed since the rails of the Union Pacific moving westward met the rails of the Central Pacific moving eastward at Promontory Point, near Ogden, Utah, and the first transcontinental railway was finished. To-day the United States possesses 230,000 miles of railroads, or forty-seven per cent. of the railway system of the whole world.

native tongue, the "Great Thirst Country," which is destined in our own lifetime to become the happy and prosperous home of hundreds of energetic colonists. The lesson of all this is plain. In our dry or desert lands we possess a priceless heritage; and if there are any persons who still think that there are no more good farms to be had, you may remind them of that fine saying of Emerson: "The last lands are the best lands."

Definition.

The term "dry-farming," or, as some writers prefer to say, "dry-land farming," is a new term which originated in western America. In Utah and some other portions of the Great Basin it is common to speak of arid-farming. Still another term is "scientific soil culture," but it is far too cumbersome for the ordinary farmer and is hardly worth discussion. For the sake of uniformity it would be well if all experiment stations, farmers' societies, and the agricultural press in general would agree to speak of "dry-farming" and "dry-land agriculture." Dry-farming may be defined as the conservation of soil moisture during long periods of dry weather by means of tillage, together with the growth of drought-resistant plants. It is not, of course, farming without moisture, for that would be clearly impossible. The phrase is now widely and loosely applied to a particular form of farming in all places where the normal rainfall ranges from zero to 30 inches per annum. That is to say, a farmer in a certain district of Utah might speak of dry-farming with 9 inches of rain; while his neighbor in eastern Nebraska with a rainfall of 29 inches might equally well propose to conserve his surplus moisture by proper tillage

along dry-farming lines. But although the fundamental principles would be the same, the details of the two operations would be vastly different. For the Utah farmer would require to accumulate a two years' rainfall to produce a satisfactory crop; whereas his more fortunate brother in Nebraska would doubtless demand an annual crop from such an abundant supply of moisture. Nevertheless, the Utah farmer has one distinct advantage over his friend in Nebraska, namely, that his rain falls during the winter months when evaporation is not excessive; whereas in Nebraska much of the rain falls during the hot summer months when a very large percentage is likely to be lost through evaporation.

An Ancient Practice.

It is sometimes said that dry-farming is a new agricultural practice. But it is not so. Even in America the farmers of Utah have been raising crops on their dry-lands with a rainfall of less than 15 inches for over half a century. More than that: dry-farming has been practised since the dawn of civilization in Mesopotamia in Egypt, and in northwestern India. And, as Hilgard has pointed out, the great depth of soil in arid regions as compared with that of humid climates undoubtedly explains largely why the ancient agriculturists could remain in the same country for thousands of years without having any knowledge of scientific agriculture. Most farmers are aware of the fact that the roots of plants go far deeper in dry regions than they do in damp climates. Now if the roots of plants can penetrate to great depth, so surely must both moisture and air. It would thus seem that an all-wise Providence had amply compensated the agriculturist of the semi-arid region by giving him in many parts of the globe great depth of soil combined with an almost inexhaustible fertility. Such at least is the lesson of history.

An English Agriculturist.

The starting-point in our story may be said to be the publication of that agricultural classic entitled "The New Horse-Hoeing Husbandry" or "An Essay on the Principles of Tillage and Vegetation" by Jethro Tull. This very remarkable man, who was born in the year 1674, may be justly called the "Father of the Experimental Method in Agriculture." He was also the foremost preacher of his time of the gospel of good tillage. The great value of Tull's writings is that they are founded not upon mere theory, but upon actual experiments in the field. At that time, in the south of Europe, it was customary for the peasant to till the rows between the grape-vines. This practice attracted the attention of the English traveler, who on his return began to carry out the same system on his own estate; and as a result of his studies and experiments he published his agricultural classic in the year 1731. Tull's idea—which was that by tillage soils might be constantly and forever re-invigorated or renewed—is summed up in his famous epigram "Tillage is Manure." He believed that the earth was the true and the sole food of the plant; and, further, that the plant feeds and grows by taking in minute particles of soil. And since these particles are thrown off from the surface of the soil grains, it followed, therefore, that the more finely the soil was divided the more numerous the particles and the more readily the plant would grow. Although

THEIR FIRST HOME ON A DRY FARM, JUAB COUNTY, UTAH

Tull's theories were wrong, his practice has been followed by all progressive farmers down to the present time. We now know that plants do not absorb particles of earth, but take in food in solution. Consequently, the more the particles of soil are broken up and refined, the more plant food the roots can absorb. Before Tull's day, seeds were sown broadcast and but little subsequent tillage was given. He recommended a more thorough preparation of the land. He advised that wheat, oats, and other crops be planted in drills to admit of tillage with a horse-hoe. He devised a number of tools to perform this work. For all these things, he was bitterly abused and opposed by his contemporaries. His system met with much opposition from the farmers themselves. In the third and fourth editions of this work the editors affirm that "what is still more to be lamented, these people [farmers] are so much attracted to their old customs that they are not only averse to alter them themselves, but are moreover industrious to prevent others from succeeding, who attempt to introduce anything new." And again: "The Hoe-Plough has been complained of as cumbersome and unwieldy to the horse and ploughman." With Tull we see the beginning of modern farm machinery; and as Professor Bailey remarks: "Every commonwealth might well raise a monument to the memory of Jethro Tull." He died in the year 1740.

Dry-Farming in the United States.

In the United States, the history of dry-farming may be said to date back to 1849, the year of the gold discovery in California. At that time men crossed from the Eastern States, passed over the deserts, and settled along the Pacific

Coast. As was natural, the early pioneers in the State of California, just as in South Africa, established themselves along the sides of rivers; but in process of time they became bolder and began to till the land which lay away from the water courses. It is probable that the first farming on dry land in California was done in connection with orchard cultivation. Several years ago Hilgard of California called attention to the vast potentialities of the arid lands of the West and by his brilliant researches in the laboratory and in the field he clearly proved that they possess certain distinct advantages over the more humid soils of the East. He has always laid special stress on the two fundamental principles of dry-land farming, namely, deep initial preparation of the ground, and constant shallow after-cultivation. He has also observed that in selecting virgin land for dry-farming, the farmer should not rest content merely with the chemical analysis of his soil, but should carefully examine the nature of the native vegetation, and probe or dig to a depth of five or six feet before passing final judgment on the capability of such ground for this type of farming. Hilgard's investigations on the subject of alkali land have also been of the greatest value to the farmers of California.

In Nebraska.

So far as Nebraska is concerned, the first settlements were a hopeless failure, and indeed it was not until three great tides of settlement had washed this State and receded in disaster that success was finally won. The pioneers of Nebraska mostly came from the humid regions of the Eastern States as well as from Europe. And it was but natural that, if they had any knowledge of farming whatsoever, it was of farming in a damp climate. Thus it happened that both their methods and their seeds were totally unsuited to the drought-stricken plains of the Sunflower State. Nevertheless, the best of the colonists remained, and, being taught a bitter lesson by their continual losses, finally changed their methods, adapted themselves to their arid surroundings, and so eventually established prosperous homesteads. The influence of two men in this State had much to do with concentrating attention upon the possibilities of dry-land farming. The one, Mr. Hardy W. Campbell, of Lincoln, Nebraska, has introduced what is widely known as the "Campbell method" of cultivation throughout the Western States. The other, the late Mr. J. Sterling Morton, the father of Arbor Day, was for some time Secretary of

Agriculture. Mr. Morton was also a Nebraska pioneer, and it is to his influence that most of the homesteads of that State are surrounded by groves of trees and, furthermore, that Arbor Day has spread throughout the whole world. The advantages of trees in the conservation of moisture are well known to all who have farmed on the wind-swept prairies.

In Utah.

Utah, which takes its name from the Indian tribe "Eutaw," is a land of snow-clad mountains and desert places. Now although the agricultural and industrial development of this important State has undoubtedly been due to the practice of irrigation[1]—which has been raised to a higher art here than anywhere else on the American Continent, with the possible

[1] It is said the first irrigation canal in the United States was built in Utah in the year 1847.

exception of California—it is also of interest to note that the colonists of Utah have also been the pioneers in dry-farming. The total area of the Mormon Commonwealth is 82,190 square miles; but the holdings are small; the average size farm being about forty acres; while five and ten acres are not uncommon. This, of course, refers to farms under irrigation. At the present moment, however, only 988 square miles are irrigated, or a little more than one per cent. of the total land of the State. For the sake of argument, increase the irrigated area to 10,000 square miles, and yet only a trifle more than twelve per cent. of the State will be under irrigation farming, leaving 72,000 square miles, or nearly 45,000,000 acres of arid lands. The soil of these millions of acres is fertile; the rainfall is low; they are covered with sage-bush, greasewood, and sunflowers;

there is no possibility of irrigating those deserts, but they form a priceless though as yet undeveloped part of the State, in the opinion of many far-seeing citizens. The problem of arid-farming in Utah is not new. Even at the building of the first canal the pioneers wistfully put the question: "What can be done with the deserts?" And the story of the conquest of these deserts is a romance of the past half-century. The first settlers passed through Emigration Canyon and entered the Valley of the Great Salt Lake on July 24, 1847, when they at once applied themselves to the digging of irrigation ditches. As time wore on new irrigation canals were built and more and more land was brought under cultivation. Sometimes, however, the full supply of water failed to reach the farmer; yet here and there fair but small crops were reaped. This fact did not escape the

SAGE-BRUSH, DESERT OF UTAH

notice of the more thoughtful settlers and several attempts were made to grow wheat without irrigation even as early as the year 1855. These efforts failed because they were made mostly on irrigated farms. But the farmers of that day were not aware of the fact, now so well understood, that farming without irrigation cannot be practised on soils which are now and then flooded with irrigation water. Ten years later an experiment was made on a much larger and bolder scale. It was then that a little band of immigrants—most of whom hailed from Scandinavia—had settled on what is now known as Bear River City. They drew the water for their farms from the Malad River. Now the water of this stream is heavy with alkali, and it was only a matter of a few years until the lands had become so impregnated with noxious salts as to be unable to sustain a crop. In despair the settlers swung their plows into the hopeless sage-brush lands, planted their wheat, waited, watched and prayed. To their amazement the seed sprouted and the young plants stood up bravely in the scorching sun and yielded a bountiful crop. This was the first great victory for dry-farming in the State of Utah. For several years the practice was confined to the northern part of the State—notably the Cache Valley—and it has only been spread to the central and southern counties within the past decade or so. But as far back as the year 1879 Major J. W. Powell in his volume entitled "The Lands of the Arid Region" speaks of the strange sight of these dry-farms. And Brigham Young often predicted that the time would come when the lands above the irrigation canals would produce vast crops of grain. It was only however, as the rivers passed into private ownership, and the population increased that the people themselves seriously turned to dry-farming. Be that as it may, with forty years' experience[1] it is but little wonder that the farmers of this State can speak as those having authority on the fundamental principles of dry-farming.

Dry-farming in Utah is thus no mere theory, but an actual fact, and if any further proof were needed it would be found in the latest statistics, which show that the acreage under the plow and the harrow is already far greater than that under the irrigation furrow.

In Utah Dr. John A. Widtsoe, Director of the State Agricultural College at Logan, was the first publicly to advocate

[1] Recently, the writer visited a farm in the Cache Valley which had yielded wheat continuously for the past forty years without the use of manure. The usual practice had been followed, viz., wheat one year, summer fallow the next; and the last crop was making an excellent growth.

the reclamation of the deserts by the scientific study of the soil. In this cause he has been ably assisted by Professor Lewis A. Merrill, Superintendent of the Farmers' Institutes and Editor of the *Deseret Farmer*. Dr. Widtsoe's *gospel of* dry-farming, as applied to Utah, may be summed up in the following terms:

1. Plow deep.

2. Plow in the Fall; there is no need for Spring plowing.

3. Cultivate the soil in early Spring, and as far as possible after every rain.

4. Fallow the land every other year, under a rainfall of 12 to 15 inches; every third year, under a rainfall of 15 to 20 inches.

5. Grow crops that are drought-resistant.

6. To make dry-farming successful among practical men stick to a few crops, preferably such staples as wheat, oats,

DRY-LAND WHEAT IN UTAH

barley, rye and alfalfa, and then when they are established go on to others.

The first dry-farmers on the bench[1] lands of Utah soon learned to plow deeply and to cultivate often in order to provide a natural soil reservoir for their scanty rainfall and, at the same time, to retain it as long as possible. They also found out, through long experience, that light seeding and the cropping of the land every second year gave the biggest harvests on dry soils. This particular practice led to the development of moisture-saving summer fallows, of which I shall speak later.

Other States.

Although I have only touched upon three States, it must not be supposed that dry-farming is purely a local problem.

[1] In agriculture a "bench" is "the nearly level or gently sloping land rising above the adjacent low region and forming a part of a terrace or wash, disunited from the remainder by erosion.—*Century Dictionary*.

For it has been successfully tried to a greater or less degree in every State in the West. Twenty years ago a beginning was made in dry-farming in eastern Wyoming near the Black Hills. During the same period settlers were pouring westward over the Dakotas, Kansas, Colorado, Montana, and the drier sections of Oregon.

Experiment Stations.

It is said that the first experiment farms in the semi-arid country were started by the State of Colorado in the year 1894. But for lack of funds these stations were abandoned and it is to the State of Utah that the honor belongs of having first established and successfully maintained a series of dry-land experiment stations. Since the year 1895, the reclamation of the deserts without irrigation has been the subject of much discussion among the officers of the Utah Experiment Station. In 1901, a systematic investigation was begun, and in 1903 the Governor recommended in his message to the Legislature that arid experimental farms be established. Such is the brief history of the Arid Farm Bill. In the State of Utah, five experimental farms have been established. They consist of forty acres each. Each county in which a farm was placed donated the land, cleared the ground of sage-brush, and so forth, gave it a first plowing, and inclosed it with a rabbit-proof fence. Numerous citizens took a personal interest in the work and greatly simplified the inauguration of the experimental plots. These farms are under the direction of the Agricultural College. The results of the Utah Dry-Land Experiment Farms may be summed up as follows:

They have already demonstrated,

(1) The great value of tillage in dry-farming.

(2) That by proper methods a certain percentage of moisture can be carried over from one season to another.

(3) That the finest wheats are those grown on dry lands.

(4) That the area of dry-farming can be greatly extended by the introduction of drought-resistant cereals.

Furthermore, the *publications* of these stations have been the means of attracting hundreds of new settlers to Utah. All this has been accomplished with an extraordinarily low State appropriation of $12,000 per annum. Meanwhile, the United States Department of Agriculture, through the Bureau of Plant Industry, has established a chain of experiment stations in the semi-arid region for the purpose of testing the best meth-

DRY-LAND WHEAT, U. S. EXPERIMENT DRY-FARM, CHEYENNE, WYOMING ods of conserving soil moisture and raising dry-land crops.

Dry-Farming Congress.

Lastly must be mentioned the part played by the Dry-Farming Congress. This conference was started three years ago in the City of Denver as a sort of "side-show" to the Live-stock Exhibition; but it was soon found that many more farmers were interested in the subject of dry-farming than in the pedigrees of cattle, horses, and sheep. And the country at large awoke to the fact that dry-farming was no mere theory but a subject of vast economic importance. A year later the Trans-Missouri Dry-Farming Congress met in Salt Lake City; and this year at Cheyenne, Wyoming, when several foreign delegates[1] were

[1] The following countries sent their representatives to this Congress: Australia, Canada, Mexico, Russia, Brazil, Transvaal, and Great Britain.

present and took part in the proceedings. The fourth Congress will meet in Montana. In the past dry-farming has suffered from the attempts of unscrupulous land dealers to use it as a means of selling worthless land. But the Congress has always stood out against such misleading statements; and at Cheyenne a resolution was passed denouncing in the strongest terms all fake and sensational advertisements. The future of dry-farming is assured. It will take its place alongside the sister science of irrigation, and through the combined efforts of the farmer and the expert it is destined to exercise an enormous influence on the future development of the United States and the British Empire.

CHAPTER II

SOME POINTS IN PRACTICE

IN dry-farming the most important factor is the nature and quality of the soil. One man may fail to "make good," in the expressive language of the West, although the rainfall of his region is ample, by reason of the poorness of the soil; another may raise splendid crops in a country of a small average precipitation."[1] In the selection and purchase of dry-farms, many serious mistakes might have been avoided if the farmer had known: first, that the most important thing is depth of soil; second, that sandy or silty loams are the best soils for dry-farming, and third, that the character of

[1] A term which includes rain, snow, and sleet.

the soil can readily be determined by simply digging a pit or examining a railroad cutting. Having satisfied himself on this score the intelligent and energetic dry-farmer can go in and possess the land and be reasonably sure of success.

All soils are not suitable for dry-farming. They may be too shallow or too loose, or too compact. The soil must be looked upon as a sort of reservoir for the storage of water over periods ranging from a few weeks to many months. With that in mind, the question is, "what soils will best retain the rainfall?" And the answer is, "sandy loams having a good supply of well decomposed vegetable mold." Besides, such soils are warm, mellow, and easy to plow. In dry-farming as a general rule, soils ought not to be too heavy. For example, clay soils are unsuitable as the moisture does not rise fast enough to supply the plant during spells of very dry weather. Furthermore, such soils prevent the downward penetration of the roots of the plant, and are therefore to be avoided. Again, soils containing a large quantity of humus (decaying vegetable and animal matter) are much better than those which are lacking in this quality. Humus not only increases the moisture-holding capacity of soils, but also improves their mechanical texture. Although arid soils are usually comparatively poor in humus, they are much richer in nitrogen than the soils of humid regions, and so, smaller amounts suffice. It has also been recently found that the nitrifying germs are present in large numbers in the soils of the drier regions and in a very active state. Soils known to be poor in lime should be avoided, or supplied with marl or quicklime, preferably with marl. Of course, naturally poor soils can be greatly improved and made good dry-farming soils by green-manuring or merely the application of barn-yard manure. But the application of commercial fertilizers is seldom of much practical benefit to the ordinary dry-land farmer who needs more especially a moisture-retaining soil rather than a temporary artificial stimulant to plant growth. The nature of vegetation is a very important matter. In a new country the prospective farmer should first of all look out for any wild leguminous (pod-forming) plants. For two reasons: first, because they indicate the presence of sufficient lime to justify dry-farming; and, secondly, they nearly always have deep roots showing a good depth of soil. Another point to be noted on viewing all agricultural lands is the development of trees. Are they well developed and of fairly normal form—

not low or *stunted?* It is not so much a question of species as a problem of normal or abnormal growth. Certain trees indicate good land provided they are of normal growth.

But the most essential point is to bore to a depth of not less than five or six feet in order to see what is the nature of the subsoil. For in dry-farming the amount of moisture which will rise to the plant roots depends upon what sort of soil is below and its depth. Gravel will effectually hinder water from getting up from below. Further, if the water-table (that is, the point at which water is found by digging) is too shallow, the roots will be prevented from feeding properly and may be drowned. For example, a water-table of five feet is too little for alfalfa (lucerne) though it would do well enough for clover; alfalfa should have at least from ten to fifteen feet for its long tap-root to strike down and fully develop. Again, you can often get a good idea of the true nature of the subsoil by noticing how deep ants and burrowing animals go and what kind of soil they bring up. Perhaps a single case which Professor Hilgard mentioned to the writer will make this clear. Some time ago, in the State of Washington, Hilgard noticed a tall luscious grass growing in a particularly arid region. He could not understand how the grass happened to thrive there until he observed that it invariably grew in the burrows of badgers. The badgers had subsoiled the land and so made a natural soil reservoir which was moist enough for that particular species of grass. Here the badgers[1] proved a true beacon to the farmers who afterwards went in and possessed the

[1] In South Africa the presence of ant-hills is usually a reliable sign of good dry-farming country.

land. Subsequently, the same land grew excellent crops of potatoes. It is always well to look carefully at the roots of native grasses; to follow their depth and then to find out by simple feeding tests, chemical analysis, or inquiry, the nutritive value of each grass. Some grasses are so full of flinty matter that cattle will not thrive on them; others again, growing on very dry lands, often make very good fodder. Furthermore, animals usually prefer the grass growing on hilly lands to the green vegetation on low or bottom lands, which is apt to be more or less salty, especially in arid regions.

Finally, in case of doubt as to the real nature of the land, you can go to the nearest bluff and look at the geological formation of the country. A gentle slope is the best land for dry-farming, as hilly land is likely to be more or less irregular, with very uncertain soil strata.

Moisture and Fertility.

In dry-farming, then, the two fundamental problems are the conservation of moisture and the maintenance of soil fertility. Moreover, it may be said in a broad way that while the farmer of the East is most interested in the question of fertility, the farmer of the semi-arid West is much more interested in the saving of moisture. Nor is the reason far to seek. In the Eastern States there is a plentiful supply of moisture, but the soils of many farms have been exhausted by injudicious cropping year after year and the land will no longer yield a profitable crop. The Eastern farmer is therefore confronted with an impoverished and ill-used soil. And so he tries to restore the early fertility of his soil by the use of commercial fertilizers,[1] barn-yard, or

[1] The farmers of a single State, Maine, spent last year $5,000,000 on the purchase of commercial fertilizers.

DRY LAND BROWN GRASS, 1½ TONS PER ACRE, FORSYTH, MONTANA green manures. But the farmer of Utah, Montana, and Arizona is working on different land. He knows that if he can conserve his moisture he will reap an abundant harvest.[1] His problem then is how best to store up his small annual rainfall. Show him how to do that and he is fully satisfied. Indeed, it is more or less useless to urge the conservation of fertility on men whose real need is more water. I do not wish to minimize the great value of fertility or the necessity of keeping the essential plant-foods from being used up: but simply to emphasize the fact that the farm must be made to pay, and it is more important for the Western farmer to concentrate his mind on the conservation of soil moisture than on the possible exhaustion of his land in ten years' time. There are, of course,

[1] This is also largely true of South Africa, where the problem of moisture supply is much more important than the question of fertility.

districts in the West, notably in Oregon and in Minnesota, where the continuous cropping of wheat over periods of ten to thirty years has seriously injured the land. The only rational way of restoring the fertility to such soils and increasing the yields on these old grain lands is by rotation of crops, and the use of barnyard and green manures so as to return vegetable matter to the soil. One of the very best crops to use for this purpose is clover which has given such excellent results on the exhausted wheat soils of the Red River Valley and southwestern Minnesota. Clover is a nitrogen-gathering crop and is unrivaled as a soil-renovator. In dry-farming, commercial fertilizers are of little practical use and should be avoided. For they do not increase the store of humus—vegetable mold—which is so important an agent in conserving the soil moisture. Furthermore, being so expensive, they are only suited to intensive farming on limited areas close to the large markets.

Mixed Farming.

The most successful dry-land farmers are those who are engaged in mixed farming—that is, growing grain and raising stock at the same time. This is easily understood when we remember what an important bearing manure has on soil improvement, fertility, and the retention of moisture. Where crops are fed to stock on the farm and the manure and refuse, such as corn stalks, returned to the land, the loss of soil fertility is comparatively small. The feeding of cattle, lambs and hogs on the dry-farm will bring in to the energetic farmer ready money, while the manure will help to improve his soils and sustain his crops in seasons of drought.

Implements for Dry-Farming.

In order to carry out the principles of dry-farming, it is not necessary to purchase expensive implements; and many farmers raise good crops on dry lands with a very few tools. Indeed, the writer has seen more than one farmer ruined through the extravagant purchase of costly agricultural machines which, when not in use, were allowed to remain rusting in rain and snow-storm. As far as possible simple sheds should be erected for all farm implements, or they may be covered with tarpaulins and greased from time to time. The dry-farmer should possess the following: Two-furrow plow, single-furrow plow, disc harrow, steel-tooth harrow, chain harrow, acme harrow, spring-tooth harrow, alfalfa (lucerne) harrow,[1] weeder, float or drag, corn-

[1] Note the number of harrows. All of use in making the soil mulch.

planter, press-drill, potato-planter and digger, horse-hoes and cultivators, roller, sub-surface packer,[1] mowing-machine, wagon, hay-rake, etc.

Size of the Dry-Farm.

The question is often asked, "How large should a dry-farm be?" This is a purely local or personal question governed by the land laws of individual States. If it were practicable it should depend on the family unit. That is to say, can a farm of a quarter-section, 160 acres (Homestead Law), afford a sufficient acreage to support the farmer, his wife and four or five children; or does it require half a section, 320 acres, as under the new Mondell Law,[2] or a whole sec-

[1] A sub-surface packer is not essential, and should be used with great care on wet or heavy soil.

[2] This Act, which was approved February 19, 1909, provides for an enlarged homestead. This Act provides for the making of Homestead entry for an area of 320 acres

tion, 640 acres, as out among the sand-hills of Nebraska. All this naturally depends upon the energy of the husbandman, the nature of his climate, and the productivity of his soil. At farmers' meetings it is usual to hear this matter debated, with much earnestness, from two different points of view. On the one

or less of non-mineral, non-timbered, non-irrigable public land in the States of Colorado, Montana, Nevada, Oregon, Utah, Washington, Wyoming, and in the Territories of Arizona and New Mexico. This Act is construed to mean land which requires the application of dry-farming methods to make it produce agricultural crops. Final proof must be made as in the ordinary Homestead, and further, at least one fourth of the whole area must be shown to have been continuously cultivated to agricultural crops, other than native grasses, beginning with the third year of the entry and continuing to date of final proof. Furthermore, commutation is expressly forbidden. An interesting additional clause is inserted in this Act in regard to the State of Utah, to the effect that on lands which have not sufficient water upon them for domestic purposes, continuous residence is not necessary, but the entryman may reside at such distance as will enable him to farm successfully. Further, he must show that he has cultivated not less than one half of the total area during the fourth and fifth years after entry.

hand it is said, with much truth, that the great need in America to-day is better tillage; that the Red River farmer should produce not 7 or 8 bushels of wheat, but 14 to 16; and that this could be done by better cultivation on smaller holdings. On the other hand the Westerner justly remarks: "I am a pioneer, far removed from the comforts and pleasures of civilization. Land is cheap and abundant. I can live more easily and feed more stock on 320 acres than I can on 160." The writer has an open mind on this subject and does not care to dogmatize. But the following is possibly a fair statement of the case. For farming under irrigation the small farm unit 40, 80, or 160 acres are the figures to be considered; but a much larger unit, 160, 320, 640 is essential to the dry-farmer. At any rate every one should possess twice the amount of land he proposes to put in crop and at least as much again for stock pasture. Undoubtedly, a section—640 acres—of land would bring in a more certain livelihood than a smaller holding, and half that amount, where little or no water is available for irrigation, is small enough to make a comfortable living in many parts of the semi-arid West.

The Lesson.

The development of dry-farming is teaching the old but too often forgotten lesson of the value of proper tillage. The most common and fatal error in Western farming is the careless preparation of the ground. Poor, shallow plowing and the lack of after-cultivation of the soil are the two factors to which crop failure is mainly due. It is impossible for any plant to withstand a severe drought when its roots lie in hard, dry soil. But put the same seed in deep mellow earth, with a

DRY LAND MELONS GROWN ON THE BENCH LANDS OF MONTANA

HARVESTING DRY-LAND POTATOES

individual soil grain is more or less surrounded by a film of moisture, as will be seen hereafter, it is evident that, other things being equal, the largest aggregate area of earth grains will retain the most water per cubic foot. Let us make this plain by a simple sum. Suppose that a cubic foot of marbles one inch in diameter has a total surface of 27.7 square feet. Now, for the sake of argument, reduce these marbles to one thousandth of an inch in diameter, and you will find that the total area per cubic foot is increased to 27,700 square feet. From this little problem it is clear that the total amount of water capable of being absorbed by a soil which is cloddy and lumpy must be very small in comparison with that in a finely divided state, and not only is the absorbing power of the soil much less, but its capacity for holding moisture is likewise greatly diminished.

Free Water or Well Water.

It is well known that all fertile soils contain many tons of water, which is usually present in three forms as (a) free water or well water, (b) film water or capillary water, and (c) hygroscopic water.

Free water is frequently called well water, ground water, standing water, or first water. It comes to the surface in the form of springs, and is usually the source of the supply of wells. If you dig a hole in any ground, you will generally strike water at a certain depth, which may be several inches or many feet below the surface. This point is termed the "water-table." Now the surface of the water-table follows, roughly, the general contour of the land; that is, it stands highest where the ground is highest, and lowest where the land is lowest. In digging wells, therefore, the farmer must take

EASTERN SECTION OF WYOMING, NEAR LUTHER

Cattle Range until 1907

A DRY-FARM IN NORTHERN WYOMING

care to sink the bottom of his well so far below the level of the water-table that seasonable changes will not cause it to go dry. As a recent authority remarks, "We must consider, then, that beneath all farm soils, at some depth, there is standing water, and that we plow and harrow above subterranean lakes." This is a most important fact, because if it is only a matter of one or two feet from the surface of the land to the level of the so-called soil-lake, there is evidently not enough dry soil for the plants to grow and thrive in, and consequently they are liable to sicken and die off. The depth of standing water most favorable to crops cannot be definitely stated, since so much depends upon the nature of the soil and the roots of the crop. Thus, while lucerne needs a fairly large amount of water to do well, its deep-rooting habit renders it undesirable that the "first," or standing water, should be as near as three feet from the surface of the soil, whereas the shallower-rooting cereals may be successfully grown with a water-level of this depth. But in no case should free water come within eighteen inches of the surface. Tap-rooted plants descend to an extraordinary depth in sandy loams, and for such crops a high permanent water-level is not good, since they can obtain their moisture supply at great depths and demand a feeding area vast in comparison with the soil mass at the service of shallow-rooted herbs. Thus lucerne roots frequently penetrate to the depth of twenty feet, and double this distance is not unknown.

Film Water or Capillary Water.

But the most valuable water in the soil and, at the same time, the most important for the dry-land farmer, is that elementary precaution of examining his sub-soil before planting an orchard or a vineyard, and should at the end of five years find his trees a dead loss in consequence of an unsuitable sub-soil." Again Hilgard says: "Eastern emigrants, as well as a large proportion of Californian farmers, do not realize the privileges they possess in having a triple or quadruple acreage of arable soil under their feet, over and above the area for which their title-deeds call."

Hygroscopic Moisture or Water Vapor.

We now come to the third way in which water may occur in a soil. This is as water vapor or hygroscopic moisture.[1] The surface-soil absorbs water vapor from the air, and more especially during heavy dews and mists or in cool, damp

[1] If you take a tumbler of cold water into a warm room the glass becomes coated with a thin film of hygroscopic moisture produced by condensation.

nights. Thus it is that in some parts of the United States, notably California, summer fogs have a markedly good effect upon vegetation. And although this moisture is of but little value save in times of severe drought, it is not to be despised by any means. During the hot days of summer a soil of a high absorptive power such as a well-tilled clay loam, will retain its moisture for a much longer time than a soil of low absorptive power, such as a shallow sandy soil, whose store of moisture will be exhausted in a few hours, while the surface of the land itself is heated up to the scalding point, thereby searing the stems and root-crowns of the growing crop. It is also worthy of note that, generally speaking, soils of high absorptive power are also those of high capillary power.

Hilgard summarizes the effect of hygroscopic moisture as follows:

CHAPTER IV

RAINFALL AND EVAPORATION

THE agricultural productivity of any region is primarily governed by the nature of the climate and the quality of the soil. For example, the rainfall may be so scant or the growing season so short, or frosts so frequent as to make farming even on fertile land more or less impracticable. On the other hand, no matter how favorable the climate may be, if the soil is so compact as to retard the free movement of air, and water; or if it lacks one or more of the essential elements of plant-food, crops cannot be successfully grown. Now the climatic factors which are involved in crop production are temperature, rainfall, and evaporation. With regard to the first it may be stated that wheat and oats will stand a much lower temperature than corn (maize) or sorghum. Again, some regions are found in which the temperature is so high that wheat does not thrive. For this reason only those plants should be selected which are well adapted to the temperature range of the particular region in which they are to be grown. Now in dry-land farming the most important problem is naturally the amount and distribution of the rainfall. The rain falling in the course of a year is usually measured in the form of inches. This amount ranges all the way from nothing or a mere fraction of an inch, as in portions of the Andes and the great African and Asian deserts, to as much as 600 inches, or fifty feet, at Cherapundji in eastern India. In studying a rainfall map of the world it will be seen

DRY-LAND, GOLD-COIN FALL WHEAT, 55 BUSHELS PER ACRE that a large portion of the earth's surface is arid. This term is commonly meant to imply an annual average of less than 20 inches. The arid region thus defined would include, in the United States, most of the country lying west of a line drawn through North Dakota and Texas, extending northwest into Canada and southward into Mexico; while in South Africa it would be found in the Kalahari Desert and in some portions of the Transvaal. The different sections of the United States comprise an Arid region,[1] with a rainfall of from zero to 20 inches; a Semi-arid region from 20 to 30 inches; and a Humid region of 30 inches and upward. About two fifths of the United States is more or less arid and must be irrigated or cultivated by dry-farm methods. But as Professor Elwood Mead remarks: "If every drop of water

[1] The driest and warmest State is Arizona.

which falls on the mountain summits could be utilized, it is not likely that more than 10 per cent. of the total area of the arid West could be irrigated, and it is certain that, because of physical obstacles, it will never be possible to get water to even this small percentage." This statement clearly shows what a vast tract of territory in America still remains to be reclaimed by dry-farming.

Now, although it would appear that a great deal of the West is more or less arid, it must not be forgotten that there is a heavy fall of snow during the winter over a very large area, which has a most beneficial influence on the physical condition of the soil. Furthermore, the rainfall which in any given region may be ample for certain drought-resisting plants, will be quite inadequate for seeds which have come from more humid countries, and which demand a much larger amount of water for their full development. Hence the term "dry-land crops" simply means certain plants that are able to thrive and give good returns in regions where the rainfall is low or irregular. Again, it is commonly said that the climate of the Great Plains region is changing and becoming drier and the same is popularly supposed to be true with regard to the rainfall of South Africa.[1] But is this really so? The records compiled by Mr. E. C. Chilcott and Dr. L. J. Briggs of the Department of Agriculture, are worthy of the close at-

[1] In the Transvaal, South Africa, the rainfall varies from about 15 inches at Bloemhof to 60 inches in the Woodbush Forest. The dry-land farmer in this colony has therefore a good rainfall as compared with the dry-land farmer in America. With regard to the total amount of rain, the Transvaal has nothing to complain of. But it is its unfortunate distribution that creates farming difficulties. The only certain rainfall occurs during the period of *November to March.* Rains are indeed common in October but sometimes do not come. In this part of Africa there is no snow.

tention of every dry-farmer. The figures are taken from the records of the Weather Bureau for the Great Plains area for the past thirty years. In the year 1905, a season of excessive rain, the annual average for the Great Plains as a whole was 27 inches; but for the year 1907 the total precipitation for the same year had sunk to a little less than 18 inches. Notwithstanding this apparent decrease, Briggs emphatically states that "there is no foundation for the statement which has been made so often that the climate of the Great Plains as far as precipitation is concerned is permanently changed." Further, he clearly shows that if we divide the precipitation into ten-year periods and take the average for these periods that the rainfall during the years 1895–1905 exceeds the rainfall for the previous ten years 1885–1894, which includes the great drought of 1898 and

A DRY FARM IN SOUTH AFRICA, SHOWING TWO MILES OF MAIZE

1894 (annual average 15–16 inches), by only half an inch. Thus the only safe criterion of the rainfall of any region is the average amount for a period of at least ten years. And it is satisfactory to reflect, as Briggs remarks, that the Settlement of the Great Plains has been made on a normal rainfall which is far better than an agriculture established during a series of abnormally wet or dry years.

Evaporation.

So far as the writer is aware, Dr. Briggs of Washington was the first to call attention to the enormous importance of evaporation in relation to dry-farming. And this is a matter of equal if not greater importance to the South African farmer in a land of hot suns, bare veldt, and dry, sweeping winds. To watch a terrific thunder-storm, to see rivers of water pouring over the land, and a few hours later to walk over perfectly dry ground is a phenomenon familiar to every farmer in the semi-dry zone. This appalling waste is mainly due to hard impenetrable soil—in a word to surface run-off; and, secondly, to the sucking power of a summer sun.

Evaporation therefore is a factor which should not be ignored in passing judgment on the agricultural productiveness of any region. By the term *evaporation* is meant the number of inches of water which vaporizes or evaporates from a clean water surface in a freely exposed open tank during a given period. Thus the annual evaporation is the total number of inches of water which evaporates during the year, just as the precipitation is measured by the total number of inches of water falling into the tank, as rain or snow, during the year.

Evaporation depends upon the temperature of the evaporating surface, the dryness of the air, and the velocity of the wind. The hotter the day, the greater the evaporation; the drier the day, the greater the evaporation; the harder the wind blows, the greater the evaporation —the ceaseless sucking up of moisture. The amount of evaporation from an open tank of water is thus a measure of the *evaporation of that locality.* The higher the evaporation from the tank, the greater is the moisture demand made upon the soil. Briggs says: "Settlers looking into the possibilities of a new country inquire only regarding the rainfall. The evaporation is not considered. This is doubtless largely due to the unfortunate fact that evaporation data are not yet generally available. Such records would be of great value to the settler. In dry-farming the most favorable region, other factors being equal, is obviously the one with the lowest evaporation. The demands upon the soil are here the smallest and in times of scanty rainfall the settler has a proportionately better chance to mature a fair crop." A series of evaporation determinations has been made recently by the Department of Agriculture at various points throughout the West during the six months of spring and summer. These tests were made by means of a freely exposed tank set in the soil, and some remarkable results were obtained. At North Dakota, with a summer rainfall of 13 inches the evaporation was 30 inches and at Amarillo, Texas, during the same period, with a summer rainfall of 13 inches, the evaporation was 54 inches. Summarizing these experiments, Briggs says: "In other words, with the same rainfall in North Dakota and at Amarillo, during the

CROP-ROTATION PLOTS, EXPERIMENT STATION, EDGELEY, NORTH DAKOTA growing season, the man at Amarillo would be working under conditions which are practically twice as severe as those in North Dakota. Under those conditions, why are we justified in talking of precipitation alone? What does precipitation alone mean in connection with such figures as those? If we assume that the precipitation required is in proportion to the evaporation, then the man at Amarillo, in order not to have to work harder to conserve the moisture than the man in North Dakota would need practically twice the rainfall." In the well-known desert region called the Staked Plains of Texas, the evaporation is very much higher. At El Paso it is 58 inches, and at Yuma, Arizona, it is 56, while in New Mexico at the boundary between upper and lower California it reaches the startling figure of 72 inches. The dry-*land farmer must therefore realize that* the annual rainfall is not the only factor to be considered in selecting his homestead, since the greater the evaporation in any given locality, the harder will it be for him to conserve enough moisture to produce his crops.

Finally a matter which should be carefully studied in dry-farming is the effect of a mountainous locality on the rainfall. The following sketch will make this plain.

The town of Deseret, Utah, lies well out in a broad valley, which is too dry for farming except with irrigation. About thirty miles southeast of Deseret is the town of Fillmore, which lies close to the western slope of a mountain range, the crest of which is 10,000 feet above sea level. The total annual rainfall at Deseret is 7.7 inches and at Fillmore 13.8 inches, a difference due to the effect of the mountains. Richfield is situated only sixteen miles from Fillmore, but on the opposite side of the mountain range, and here the average annual rainfall is only 5.5 inches. These figures clearly show what a difference the intervention of a mountain range may make upon the rainfall of two places only a few miles apart.

CHAPTER V

THE PROBLEM OF TILLAGE

TILLAGE is the most important operation in dry-farming, and upon it will mainly depend the success or failure of the crop. The modern plow is the product of many centuries of slow improvement, and during this time it has evolved from a crooked stick to an implement of marvellous efficiency. One of the main objects of plowing is to leave the soil in such a condition that but little subsequent tillage will be needed to fit the land for the crop. A good plow should turn over the furrow slice in a loose and crumbling condition and at the same moment bury the weeds, stubble and trash. In this way the labor of harrowing is greatly reduced; whereas flat-furrow plowing requires a great deal of harrowing before the field is left in fine and mellow tilth.

Depth of Plowing.

The dry-land farmer often asks, "How deep should I plow?" and again, "What is deep plowing?" This is a hard question to answer without some precise knowledge of the local conditions and the nature of the soil; but as a general rule in dry-farming it may be emphatically said: Plow deep. Usually deep plowing means anything from seven to ten inches and over. Of course on the Plains it is not always possible to plow deep. The ground may be too hard, or perhaps the farmer has too few horses or the wrong kind of plow. But deep plowing is strongly to be recommended for several reasons: it increases the water-holding capacity of most soils; admits sunlight and air; extends the root-feeding area; prevents light soils from being blown away; encourages the growth of soil-bacteria; prevents surface washing after heavy rains, and, lastly, enables plants to successfully withstand long periods of drought. Broadly speaking, a soil that is best suited to dry-farming is also one that may be plowed deeply, but the most successful results have been obtained in the case of deep uniform sandy loams. Deep plowing is strongly advocated by the dry-farmers of Utah, Montana, Kansas as well as by their brethren in South Africa.

In some cases, however, deep plowing is undesirable, as for example where the soil is very shallow or consists of a cold and heavy clay. Turning up this sort of sub-surface soil may result in retarding, if not entirely checking, the germination

FALL WHEAT, TURKEY RED, FORSYTH DRY-FARM, MONTANA of the seed. In fact it may be a fairly long time before such raw land becomes transformed into a mellow seed-bed. But this seldom occurs in dry-farming, as the summer fallow affords ample time for the weathering of the ground, and so the soil is generally well aërated before the crop is planted. If the land is plowed year after year at the same depth the sole of the furrow becomes packed by the smoothing action of the bottom of the plow, as well as by the tramping of the horses. This results in the formation of what is commonly known as a *hard pan* or plow-sole. A hard pan is injurious for three reasons: it decreases the water-holding capacity of the soil; retards the growth of the roots; and checks the capillary rise of moisture from the deeper layers below. It is thus a sound plan to vary the depth of plowing every two or three years. Another point worth noting is to have the plowed land as long as possible so as to avoid delay in turning and too much tramping at the corners.

When to Plow.

On every dry-farm the work should be so arranged that the plowing can be done at the best and the most convenient time of the year. In most States it is impossible to plow during the winter season and again during the summer when the ground has become so hard and dry that it cannot be turned over. Moreover, other imperative farm operations, such as seeding and harvesting, may preclude plowing. Plowing, therefore, must be done when the work of the farm and the physical condition of the soil will permit. Nevertheless, with good management *there is ample time in the three seasons of* the autumn, spring, and summer. In dry-farming fall plowing usually gives the heaviest crops and has several distinct advantages over spring plowing:

(1) It enables the land to absorb the winter rains and snow, and so retains a great deal of moisture.

(2) It exposes the soil to the disintegrating action of the frost, setting free plant-food.

(3) It permits the ground to settle and so tends to form a mellow compact seed-bed.

But spring plowing will remain a universal practice because in the rush of harvesting, threshing, and hauling to market, the farmer seldom has time to finish the whole of his plowing in the fall. In the springtime the land is generally in a capital condition for plowing, but for the best results two things are essential: (a) packing the seed-bed and (b) following with a harrow to form a soil-mulch. Summer plowing may be done after the seeding is over and before the harvest begins, if the ground is in a suitable state. In Montana, as well as in some other sections, the rainy season makes early- to mid-summer a favorable time to plow for the summer fallow and fall grains. It is also a particularly good season for breaking up new ground. In breaking care should be taken to lay the furrows down evenly and then to roll or pack them close to the sub-soil, following immediately with the harrow to fill up the spaces and form a surface-mulch. This will tend to check the excessive evaporation which goes on during the hot days of summer. Sod ground can be plowed with safety when considerably wetter than old land.

On Plows.

The ordinary moldboard plow does better work than the disc plow and should be used for breaking the prairie. But disc plows are now widely used and have a recognized place on the dry-farm. They do good work in old lands, the draft is lighter, and they can be used in drier soil than is practicable with the moldboard. A disc plow, if run deep, is of special value in breaking up the plow-sole which is apt to be formed by the too constant use of the moldboard plow set at the same depth year after year. Many farmers, however, try to cut too wide a furrow with their disc plow, which results in a poor job. Gang plows save much time and labor and enable one man to keep several horses at work. Rod-breaker plows in which steel rods take the place of the solid moldboard have been found useful in turning over virgin land. Subsoil plows are intended to loosen and pulverize the subsoil without inverting it or bringing it to the surface.

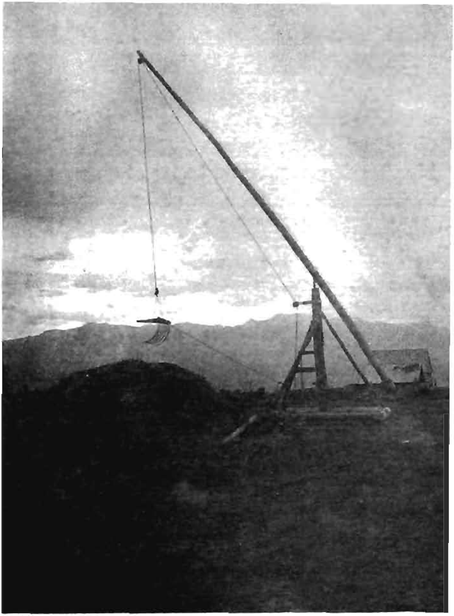
But at the present time they are not much used in dry-farming. Nevertheless, such plows are sometimes used to good purpose. For example, heavy clays that require underdrainage are generally benefited by subsoiling, or they may be used for breaking up a hard pan or plow-sole. In subsoiling it is customary to turn the surface with a common stirring plow and to follow in this furrow with the subsoil plow. This loosens the soil to a depth of 18 to 24 inches from the top of the ground.

In subsoiling dry fields, however, it will often be better to use a plow with a subsoiling attachment, running it a few inches below the bottom of the furrow and so gradually getting to the desired depth by plowing year after year. By this method an excellent seed-bed may be secured.

Harrowing.

After plowing the most important operation in the dry-farm is the constant use of the harrow. The land should always be harrowed the same day that it is plowed. The chief objects of harrowing are: to make a fine and mellow seed-bed, to warm the soil, to kill weeds, to prevent the evaporation of soil moisture, to retain the rains, and to encourage the germ life that is so essential to fertility. In harrowing and plowing, let me state again, the soil should be taken at the right time, that is to say, when the land is moist—neither too wet nor too dry. Harrowing land that is inclined to be wet, or having furrows with a glazed appearance, will injure the mechanical texture of soil. It is better, therefore, to lose some of the water in the soil by evaporation rather than to run the risk of harming the land. All over the West it is a common practice to harrow the small grains—wheat, oats, etc.,—in the spring. This is especially beneficial if heavy rains have firmed and puddled the soil, destroying the mulch of mellow earth. The weeder is better suited for harrowing wheat or other small grain than the common straight-tooth or slanting-tooth harrow; but if the ground is reasonably firm the ordinary light harrow will do good work. Every farmer should have a harrow with levers by which he can regulate the slant of the teeth.

Mr. George L. Farrell, who has grown wheat for forty years in the Cache Valley, Utah, was once asked at a farmers' institute what he would do if the grain were too thin. "Harrow it," he replied. "But what would you do if it were too thick?" "Harrow it," came the same reply. And he was right in both cases. If the grain is too thin, tilt the teeth of



A HAY AND GRAIN DERRICK

Used for Stacking Hay and Wheat in the Cache Valley, Utah the harrow backward, and the harrowing will tend to make the wheat plants "stool" out better and give a much better stand. If the grain is too thick, run the sharp iron teeth straight, cut out some of the plants, and at the same time form a mulch, which cannot fail to be of benefit to the crop. In Utah it is usual to harrow the grain from three to five times during the growing season and thus the surface soil is prevented from caking and the fields kept free from weeds. It does not pay to use a two-horse harrow on large fields. Four-horse tools of all sorts are far more economical. With a three-section harrow and four horses a man or boy can cover over thirty acres a day, which makes it possible during spring and summer to till a fairly large area of land.

There are several excellent implements for harrowing, the most noted being the disc harrow, the Acme harrow, the spike-tooth and spring-tooth harrow. The disc harrow is an absolutely indispensable tool for dry-farming. Under ordinary conditions discs of fourteen inches diameter do much better work than those of eighteen or twenty inches. The disc should be used to break up the surface-sod or stubble immediately after the harvest, for where this is done it will be found that plowing will produce a much better seed-bed. Turning under the disked surface also leaves less air space and the seed-bed is made more compact and mellow. The disc is also useful in killing weeds on summer fallow lands, but it must be used when the weeds are small, for it will merely stimulate the growth of the larger weeds. Always lap the disc one half, which double-discs the ground and leaves it level. The disc is especially useful in cleaning old alfalfa (lucerne) fields; and the new alfalfa renovator—an implement consisting of a series of spikes arranged in disc form—has given excellent results. Other types of harrows such as the Acme and the spring-tooth are useful in forming the soil-mulch. The former is desirable for shallow surface cultivation and the latter for harrowing compact and tough soils.

In dry-farming it is not necessary to harrow the land after every small rain, but it should not be delayed until the ground becomes baked and hard; and it must certainly be done after every heavy rain or melting snow as soon as the soil is in a fit state to be tilled. In short, there are few crops that will not be vastly improved by timely harrowing. Corn, and any of the small grains, may be harrowed until they are four inches or even more in height. In South Africa, McLaren, who raises large quantities of corn (maize) by steam cultivation, has given up cultivation between the rows in favor of harrowing. This means a great saving of time and labor. He harrows until the corn is 8 to 10, or even 12 inches in height with most satisfactory results. Furthermore the harrow may be profitably used for many different sorts of farm work, such as harrowing native ranges, meadows and pastures to encourage the growth of the finer and sweeter grasses, and also such lands as may be infested with cut-worms, army-worms, corn grubs, or grasshoppers. As a Western writer well remarks: "When you cannot think of any more important work, go to the field and harrow."

Listing.

In Kansas the practice of listing for corn is very common in dry-farming. The lister is simply a right- and left-hand plow joined together at the bar which throws the soil out each way, leaving an open furrow. The corn is sown in the bottom of this furrow either by a drill attachment or by a separate drill. It is most successful in dry years. In wet years listed corn suffers from washing and from the rain gathering in the furrows. The first cultivation is given with a spike-tooth harrow as soon as weeds start on the top of the ridges. This rolls a little fine soil down into the furrows. Later tillage sends more of the soil into the furrows until they are finally filled and the ground is left quite level. This filling of the furrows places the root-system several inches deeper than it would have been had the ground been plowed in the ordinary way and the planting done on a level surface. While listed corn stands the drought better than that planted on level, plowed ground, this practice is not adapted to dry-farming in a region where the rainfall is fairly heavy;[1] since the injury caused by standing water may be greater than the gain from deep planting. Further, as the seed is planted in the bottom of the freshly turned furrow where the soil is not as warm as close to the surface, listing should not be begun before the seed-bed is sufficiently warm.

Cultivation.

Cultivation is a very important operation, especially with such crops as corn, and it should be continued until late in the season, but the first cultivation may be deeper than the later ones. How often to cultivate depends upon the nature of

[1] It is sometimes said that in localities where the rainfall is over 15 or 20 or 25 inches per annum it is incorrect to speak of dry-farming. This is clearly a misconception, for dry-farming is a relative term and may be followed with advantage whether the annual precipitation be 15, 25, 30 inches or over.

the soil, the dryness of the season, and the prevalence of weeds. It is a local and personal problem, but few farmers fully realize the loss of moisture caused by the growth of weeds. It is easy to tell when it will pay to cultivate. You have only to examine the surface soil. If it has a hard, baked appearance, or even a thin crust, cultivation should be done at once, for soil water is passing off rapidly into the air wherever the surface soil is hard. There is no hard-and-fast rule for the number of cultivations to be given in a season. Cultivate often enough to make the surface soil mellow, weedless and free from a crust. This may take six cultivations or twelve. Note when the corn leaves begin to curl in the heat of the day, or the potatoes to shrivel. Then is the time for prompt and energetic cultivation. Finally, all cultivation should be directed to establishing a moisture-saving fallow which may be maintained for periods of three months, six months, or one year. Such a fallow is to be well plowed in the first place and then kept constantly tilled to prevent the formation of a soil-crust. This fallow results in four things: (a) storage of rainfall, (b) destroys weeds, (c) admits sunshine and air, (d) encourages beneficial soil-germs.

Weeding.

The weeder is a modified harrow having one row, or more, of long curved, flexible teeth which stir the ground after the manner of a hay-rake. It is a most valuable implement for rapid and easy harrowing and should find a place on every dry-farm. Weeders can be employed on wheat fields where the plants have become too large for the safe use of the ordinary steel-tooth harrow. On large farms it is customary to use four-horse gang weeders which cover the ground very rapidly. Weeders are useful for three purposes—(a) to kill very young weeds, (b) to preserve a shallow mulch, (c) to cover broadcasted seed. A weeder is not effective unless it is used often enough to prevent any weeds from getting too large to be destroyed. Since the weeder stirs the soil only an inch and a half to two inches deep, it should be supplemented by the cultivator, whenever the soil gets hard.

Rolling.

In dry-land farming rolling is very important, because it compacts the surface soil and brings the particles closer together, so that the film water passes up more readily by capillary attraction. While passing upward it comes in contact with the roots of the plants and is absorbed by them, but this water will pass away from the surface unless it is harrowed to establish a soil-mulch. The soil in a field that has been rolled is more moist on the top than if it had not been rolled, but the soil below the compacted portion is much drier than it would have been had the surface been left loose. That is to say, the upper five or six inches of soil have been made more moist by rolling, but at the expense of the soil beneath.

Part of the loss of moisture from rolled soil is due to the fact that the surface is left very smooth and level, and offers less obstruction to the wind. The velocity with which the wind passes over rolled ground may be nearly twice as great as that over rough unrolled ground. This means that much more moisture is sucked up from the soil by the wind. The chief purpose of rolling in dry-land farming is to increase the

A DRY-FARM HOME NEAR NEWCASTLE, WYOMING

The oat-field in the foreground shows how luxuriantly grains will grow without irrigation when deep plowing and intense cultivation are practised supply of moisture for the seeds, but, of course, it is also useful in crushing lumps on soils which become cloddy. Great care, however, must be taken not to roll clayey soils when they are wet, as they are liable to become cemented into hard clods. In general it may be said that rolling accomplishes three very useful purposes: (a) it increases the water-holding capacity of light soils, (b) it aids the germination of seeds, and (c) crushes the lumps in cloddy soils. A tendency to-day, in America at least, is to restrict the use of the roller to light soils in order to make the soil firm, and to use the implement called the *planker* on heavy soils where fining the soil is the end desired.

Planking and Packing.

The planker is made by bolting four 8-inch planks to two cross-pieces so as to present the sharp edge of each plank to the ground. This implement is very useful in smoothing the surface and crushing clods. Its action is somewhat like that of a roller, but instead of pressing down vertically it slides along the field shaving off the uneven places and filling up the hollows. As a pulverizer and clod crusher it is superior to the roller, but its packing action is not as great. The principle of packing combined with the soil-mulch is seen when the gardener presses down the soil around his vegetables and covers them then with loose soil, when the fruit-grower stamps the earth around the roots of the fruit tree but leaves it loose on top, and when the florist presses his seed into the soil, but scatters a little loose earth in the pot. The special implement called the sub-surface packer which has been devised for this work is described in the next chapter.

Seeding.

Having secured a good seed-bed by deep plowing, harrowing and packing, it is now time to take up the question of seeding. In dry-farming all cereals are now put in with the drill and broadcasting has been entirely discarded. With a drill the seed can be placed evenly and the depth to which it is to be sown regulated at will. If the land has been summer-fallowed there will usually be an earth-mulch on the surface of from three to six inches in depth. In this case the seed should be sown down below the mulch and placed in the moist soil. The young plants can easily strike upwards through several inches of loose earth, and if the seed is sown deep the roots enter at once into the moist soil. There are a number of excellent drills on the market and the choice of a seeder is largely a matter of personal opinion. The Montana Experiment Station has invariably secured the best results with a disc press-drill which puts the seed in very deeply and presses down the soil. A press-drill, which firms the moist earth about the seed will give quicker germination, and a better stand of grain than a drill which simply sows the seed in loose soil. Again, with the press-drill there is a great saving of seed and where a large area is being sown this is an important item, more especially if first-class seed is used. The farmer who sows alfalfa broadcast often sows from 20 to 40 pounds per acre, whereas, if he employed a press-drill, from 8 to 12 lbs. would be ample. The press drill has also given good results on the Wyoming dry-farms. Dr. V. T. Cooke of Cheyenne writes: "The press-drill is one of the essentials in dry-farming. This may be either of the shoe or the disc type. The disc-drill has some advan-

WHEAT GROWN CONTINUOUSLY, THIRD CROP. YIELD 4 BUSHELS PER ACRE. FORSYTH DRY-FARM, MONTANA

Showing evil effect of constant cropping without summer fallowing or rotation

WHEAT AFTER A MOISTURE-SAVING FALLOW. YIELD 25 BUSHELS PER ACRE. FORSYTH DRY-FARM, MONTANA tages where there is much stubble or refuse, like coarse manure on the ground, but on well-prepared summer-fallow ground the shoe-drill with press wheels following to firmly pack the seed probably does the best work. In places where there are heavy clay soils to contend with a double press wheel should be used instead of the single press wheel ordinarily placed on these drills. If the soil bakes the double press wheel will leave a crack or opening in the center directly over the seed through which the germinating plantlets can push their way out of the ground."

In the case of a drill that does not press the soil about the seed, germination may be hastened by following the seeder with a roller and then harrowing to check evaporation and prevent blowing. The proper depth of seeding will naturally depend on the character and condition of the soil. But as a general rule in dry-farming the writer recommends deep seeding. However, land that is fall-plowed and well-settled need not be seeded as deep as loose spring-plowed ground. Again, the subsurface packer makes it possible to sow shallower than where it is not used. The best depth is the nearest point to the surface at which perfect sprouting is possible, or, in other words, where the right degree of warmth and moisture is present. But whether the seed is put in 2, 4, or 6 inches deep is a purely local problem of which the farmer himself must be the best judge.

Lastly, thin seeding. It would be interesting to try and compute the enormous annual waste of seed in the semi-arid regions of the West. Unfortunately, not only does this superfluous seed represent a large loss in ready cash,

BARLEY GROWN CONTINUOUSLY, THIRD CROP, YIELD 6 BUSHELS PER ACRE, FORSYTH DRY-FARM, MONTANA

Showing evil effect of constant cropping without summer fallowing or rotation

BARLEY AFTER A MOISTURE-SAVING FALLOW, YIELD 25 BUSHELS PER ACRE FORSYTH DRY-FARM, MONTANA but it also means that the soil is robbed of its much needed moisture, which too often results in crop failure. In dry-farming light seeding almost always gives the heaviest yields: and the old custom of sowing 1½ to 2 bushels of grain to the acre is altogether wrong. In a recent experiment carried out by the Montana Experiment Station with spring wheat, oats, and barley, it was found that three pecks of seed (45 lbs.) gave better results than larger quantities. Again, in Utah, the heaviest yields of grain have been obtained with from two to four pecks (30–60 lbs.) of seed, while Campbell recommends the following amounts for well-fitted summer-tilled fields: winter wheat 18 to 20 pounds; spring wheat 20 to 25 pounds; barley 35 to 40 pounds per acre. Further, Cooke of Wyoming writes: "It is a recognized fact that we have been making the very serious mistake of sowing too much seed per acre. The experience of the most intelligent farmers shows that by sowing thirty to forty pounds of wheat per acre in the fall better results will be obtained than with more seed." In short if the farmer has carefully selected his seed and properly tilled his ground, he will usually find that from two to three pecks of seed are ample for semi-arid lands.

CHAPTER VI

THE CAMPBELL SYSTEM

THE Campbell system of scientific soil culture, or as it is more commonly called the Campbell method of dry-farming, originated with Mr. Hardy W. Campbell of Lincoln, Nebraska. Campbell has done much to popularize dry-farming, but he must be ranked as an agricultural evangelist rather than as an experimenter. Both on the public platform and in the pages of his periodicals his statements at times are somewhat loose and misleading. And to contend that the Campbell system is the sole method of dry-farming is of course absurd. Nevertheless it is not just to disparage Campbell's missionary work among the farmers of the West. It is often said, and truly so, that Jethro Tull was the first exponent of the so-called Campbell system of soil culture; but it should not be forgotten that Tull did not work under semi-arid conditions, and, secondly, that although his practice was successful his theories were erroneous. Be that as it may the fact remains that a great number of western farmers believe in Campbell's teaching and many have followed his system or like methods with success.

The machine called the Campbell subsurface packer, under certain conditions, gives good results; but it must be used with care. It is seldom of much use on soil that has had time to settle and become packed. It is therefore more valuable on spring than on fall plowing, and where loose manure has been applied to the land. On wet, clayey ground it may seriously injure the mechanical and physical texture of the soil.

The story of the origin of the Campbell system[1] of dry-farming is as follows: In the year 1879 Mr. Campbell migrated from New England and settled in what was then known as the Territory of Dakota—since divided into the two States of North and South Dakota. His agricultural career was not startling, merely the hard, grim struggle of the prairie farmer; wheat-growing year in and year out; alternate failure and success, and always the fear of drought, the blizzard, rust, hail, and frost. At that time it was widely stated that the common failure of the wheat crop was due to the exhaustion of the fertility of the soil by the heavy crops of the first few years,

[1] The following account of this particular method of dry-farming is taken from Campbell's *Manual of Scientific Soil Culture*, an interesting but diffusely written volume.

and, further, that these lands would never yield large crops again. Mr. Campbell was convinced that this was a false notion, and that the true explanation—the key to the problem—would be found in a better and a more scientific system of soil culture. It was not until the year 1892 that any definite results were obtained. This was a period of great activity in the study of the soil, and Campbell was able to make use of the investigations of Hilgard of California, of King and Goff in Wisconsin, and of the illuminating writings of Roberts and Bailey of Cornell.

The Sub-surface Packer.

The invention of the Campbell sub-surface packer may be traced to a simple observation. In very dry seasons Mr. Campbell perceived that the growth of the grain was always better and thriftier in certain places; as, for example, where the soil was compacted when a horse stepped over the plowed field leaving the impress of its hoof-prints on land which was afterwards sown to wheat; or, perchance, where the wheel of a heavy farm wagon had rolled over the furrow-slice, there the growth of the grain was always taller, darker, healthier in color, wide-leaved, giving a greater stooling and larger heads. This was the first great principle, namely, that the soil in the lower part of the furrow had been made firm and fine—in a word, compacted. But Mr. Campbell also noted that wherever the horse had lifted his foot a little loose earth was left behind; just as, in like manner, the rolling of the wagon wheel let fall a little loose soil. Here was the second great principle, namely, the formation of the "soil" or "earth-mulch." Thus the purpose of the Campbell sub-surface packer was simply to imitate the horse-foot track in the entire field by firming the lower part of the furrow-slice and leaving the top portion loose to form a soil-mulch. The effect of sub-surface packing, therefore, is to draw the moisture from the deeper strata below, just as is the case with the ordinary roller; but, further, and most important, to check the evaporation of the moisture from the surface by the formation of an earth blanket or soil-mulch. This upward passage of water brought about by sub-surface packing is of the highest importance in the long dry periods so common in western America and South Africa.

Mr. Campbell writes: "When we reach a point in the extreme heated portion of the last afternoon prior to a heavy rain, when our supply of moisture is beginning to shorten, the fact that we have by this sub-surface packing been able to lift the water stored below a little faster may be the means of doubling or trebling the yield."

In a word the proper use of the subsurface packer puts the soil into a firm and mellow state, whilst the harrow forms a fine loose mulch of some two or more inches deep, and the drill sets the seed in a fine, firm, moist, mellow bed—an ideal place for rapid and vigorous sprouting. According to Mr. Campbell, any one who hreaks prairie lands and plants them without first devoting a full season to careful cultivation in order to get the soil in the proper physical condition for the promotion of plant growth, and also to store a sufficient amount of moisture within reach of the plant roots to carry the growing crop through a protracted drought is simply inviting failure, should a season of unusual dryness follow. Summing up, it may be said that sub-surface packing or the fine firm fitting of the lower portion of the furrow-slice results in three things: (1) The water-holding capacity—or soil reservoir—where the main roots grow is enlarged; (2) the movement of the moisture from the lower and deeper soil layers to the roots of the plants is quickened; (3) the area of the feeding roots is greatly extended. These three factors usually result in carrying a crop successfully through a long, hot, dry period; whereas a crop grown under the ordinary methods would be seriously stunted in growth if, indeed, it survived at all.

Summer Culture.

More important, however, than the invention of the sub-surface packer is the method advocated by Mr. Campbell for the conservation of soil moisture over a period of from six months to one year, and what he terms "Summer Culture."[1] The credit, however, of introducing this system undoubtedly belongs to the agriculturists of Utah, who have successfully used moisture-saving summer fallows in dry-land farming for over forty years.

In the springtime, as soon as the frost is well out of the ground, land that has already been plowed is gone over twice with a disc harrow. This produces a mulch which prevents evaporation; it also opens and loosens the surface, so that the rains quickly percolate into the soil. The land is then harrowed after each rain with an ordinary harrow. If the rain is so heavy as to pack the surface of the soil, the disc harrow must again be used. Naturally, the kind of tool for each subsequent cultivation will depend upon the state of the land, the rainfall, and the

[1] This name is rather vague: summer tillage and summer tilled are better terms.

weed growth. But, *since the main object is to store water in the soil,* two things must be constantly kept in mind: first, to prevent the surface of the soil from forming a hard crust, and, secondly, to prevent the growth of weeds. This tillage may continue for a matter of two or three months.

Then at the beginning of the rainy season comes the plowing, which is done to a depth of 7 or 8 inches—the deeper the better. If the above plan has been properly followed out the soil will be moist and easily pulverized by the plow. Furthermore, the surface having been made fine, there are no clods to turn to the bottom of the furrow. If you have a sub-surface packer it should be used while the soil is still moist, making the lower half of the furrow fine and firm. Next, follow with an Acme or a common harrow which will form a mellow moisture-saving mulch. From this time on, the field must be cultivated after every rain and often enough to prevent any weeds from growing. It is then seeded to winter wheat or left over for the following spring crop. It will thus be seen that two decided benefits accrue from Mr. Campbell's method of summer tillage: (1) The storage of the rainfall of part of the season. Experiments have shown that with the loam soil and clay sub-soils of the western prairies but little moisture is lost by percolation. (2) By maintaining a loose mulch on the surface and so preserving the moisture underneath and by allowing the sunshine and air to permeate into the ground the activity of the beneficial soil-germs is encouraged.

Regarding the possibilities of summer culture in semi-arid States, Campbell writes:

"It is our opinion, based on practical results and observation of conditions similar to those in western Kansas, that by the summer culture plan, storing the water the entire season and raising crops the following year, much larger average crops may be grown than the present average in Iowa or Illinois. In fact, we do not believe we overdraw when we say that in the more arid portion of the semi-arid belt by the summer-culture plan, only cropping every other year, we can raise more wheat at less cost in ten years than can be grown in the more humid portions of the belt in ten consecutive crops by the ordinary plan. By our method we have the advantage of only seeding half the land. The great value of work along this line lies in grasping fully the idea of storing and conserving the rain waters, and studying carefully the necessary physical condition of the

TALL OAT-GRASS GROWN ON THE DRY FARMS OF MONTANA soil and endeavoring to bring it to the highest degree of perfection."

Mr. A. M. Ten Eyck, Professor of Agronomy at the Kansas State Agricultural College, puts the whole matter concisely as follows:—

"The principle of loosening the surface of the soil and keeping a mulch of mellow soil in order to prevent the evaporation of the moisture is well recognized by farmers generally, and is practised to a greater or less extent in the cultivation of all kinds of crops. In the Campbell system of culture the purpose is to keep a mellow soil-mulch on the surface of the land all the time, not only during the growing of the crop, but in the intervals between harvest and seeding time. Thus, after the crop is planted, the land is kept cultivated with the harrow or weeder in order to break the surface crust and conserve the soil moisture, and, following out the same principle, the harrowing or work with the weeder is continued after the grain or corn (maize) is up, and during the growing period frequent cultivation is practised. After the crop is harvested the cultivation is not discontinued, but the surface of the ground is loosened as soon as possible after the crop is removed by the use of the disc harrow, and thus the soil is kept continually in a condition not only to prevent the loss of the water already stored in the soil, but this same condition and mellow surface favors the absorption of rain and largely prevents the loss of water by surface drainage."

Summer culture is, therefore, different from summer fallowing, for the sole aim of the first is to keep the land constantly stirred to conserve the rainfall, whereas the object of the latter is simply to rest the ground by letting it lie idle. Furthermore, the old idea of allowing the weeds to grow in order to be turned under for green manure, as commonly practised by the summer-fallow system, is condemned by Campbell, who lays special stress on clean and continuous tillage for the conservation of moisture. His experiments clearly show the marked difference in yield between ground that has been summer tilled and land which has had its soil moisture sapped to such a degree by growing weeds that it breaks up on plowing into a lumpy condition, and cannot be made into a moist, mellow, seed-bed. Mr. Campbell lays emphasis on the need of local experience. He says: "The mistake of the pioneer settlers was that they tried to farm in the West as they had done in the East, and the result was disastrous failure." But he also insists on the value of learning. "The ideal farmer is first of all a student, then an investigator, and, finally, a specialist; ever alert for new things and new ideas, open-minded and free from conceit; a man familiar with what is going on around him, and yet intensely devoted to his own work."

That the Campbell method is likely to stand the test of time there can be no reasonable doubt, since it is based on certain fundamental principles of farm practice, which both experience and experiment have shown to be correct. Moreover, it can never become merely a fashionable agricultural fad, for it demands a high degree of manual skill, and hard and continuous toil. Such a system is not likely to attract the rural dilettante or the lazy farmer.

CHAPTER VII

DRY-FARMING ZONES

ALTHOUGH dry-farming is now practised in almost every State in the semi-arid West, it is desirable to recognize three distinct areas each of which has certain peculiarities of climate and soil. The first has been termed the Great Plains; the second, the Great Basin; and the third, the Columbia Basin Uplands.

THE GREAT PLAINS

THE vast territory now widely known as the Great Plains area is bounded on the north by Canada, on the west by the

Rocky Mountains, on the east by the ninety-eighth meridian,[1] and on the south by the thirty-second parallel of latitude.[2]

In the long-settled States of the East, the agricultural industry has been placed on a more or less stable basis; but in the West many problems are still new and unsolved. Writing on this subject, Chilcott says:

"It is therefore within the Great Plains area that most of the great problems of dry-land agriculture must be solved. It is here that experiments must be carried on which shall determine what are the best methods of agriculture for the conservation of moisture, and the maintenance of the fertility of the soil

[1] This line passes through the States of North and South Dakota, Nebraska, Kansas, Oklahoma, and the Panhandle of Texas.

[2] The southern limit of the Staked Plains. South of this line the country changes and slopes rapidly toward the Gulf and the Rio Grande.

under climatic conditions which exist nowhere else in the United States. Experiments must here be conducted that shall determine what portions can be used for general dry-land agriculture and what portions are unfitted for that purpose. And when it has been demonstrated that certain portions of the area are unsuited to general dry-land agriculture, it must be determined how these portions can best be utilized for stock-raising; and where this industry becomes the predominating one, means must be devised for supplementing the natural grasses of the range with forage plants, either annual or perennial."

There are many persons who believe that the climate of the Great Plains is changing. Studies in climatology, however, do not support this theory, and this portion of the United States is likely to remain an area of comparatively light rainfall, which is probably one of the main reasons for its great and sustained fertility. For, while the scanty rainfall has not tended to induce a luxuriant growth of vegetation during ages past, it has served to preserve within the soil such products of decomposition as have been produced; and the evaporation being very great, the plant-foods have been kept near the surface instead of being washed away, or lost by seepage. Again, tbe methods now devised for the conservation of soil moisture and the introduction of drought-resistant plants are enabling farmers to raise satisfactory crops even in severe droughts.

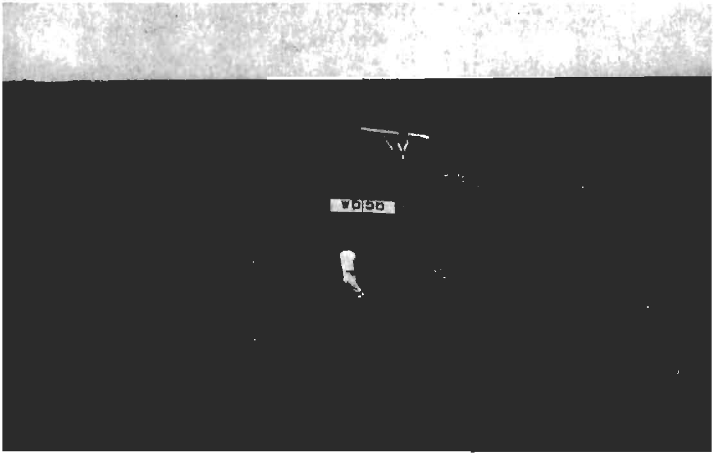
Problems.

The problems to be solved in this region are simple, but none the less important. How can the largest yields of the four staple crops—wheat, oats, barley and corn—be obtained? (1) By raising the same crop continuously by ordinary methods of farming, (2) by continuous cropping with the same crop, using the best methods of cultivation for moisture conservation, or (3) by alternate cropping and summer fallowing. The various Experiment Stations now established by the United States and the State Legislatures will do much to help the farmer in solving these problems.

Early Mistakes.

As I have elsewhere noted the settlers who came from the East soon found that with the fertile and easily tilled lands of the West, it was easy, in good seasons, to raise large crops. This led to very casual and slovenly methods of tillage. Plowing was carelessly done to a depth of only three or four inches. Sometimes, indeed, the land was plowed only once in three or four years, the grain being "stubbled in" on the ground of last year's crop; or the land was prepared for seeding simply by means of the disc harrow. At first this system of farming yielded fairly successful returns, but a series of dry years culminating in the disastrous drought of 1894 taught the farmers a bitter lesson; and, unfortunately, served to depopulate a large part of the Great Plains region. It is commonly said that the failure of these pioneer farmers was owing to the exhaustion of soil fertility; but in the opinion of the writer it was due far more to a lack of moisture. If these early settlers had known how to till their fields in order to conserve the maximum amount of soil water, it is more than probable that, even with continuous cropping to wheat, the soil-germs, growing in a moist, mellow seed-bed, would have supplied the necessary plant-foods

DRY FARM SQUASH, FORSYTH EXPERIMENT STATION, MONTANA



HARVESTING ON A WYOMING DRY-FARM

in the long, hot days of summer; and, consequently, much more sinks into the ground. Moreover, recent experiments have shown that when rain falls on warm, dry ground it takes at least one fourth of an inch to wet the top and to reach the moist soil below, while on heavier lands at least one half inch is needed to penetrate the hard, parched surface-soil.

Furthermore, on a fine-textured soil having a high water-holding capacity slow rains and snow percolate deeply during the cold winter months, and there is but little surface run-off. But in places where the winters are dry and severe and the ground is solidly frozen, rainfalls in winter may be largely wasted by surface run-off, and also by evaporation before the ground has time to thaw out in the spring; while on poor soils of low water-holding capacity, rains are liable to be lost by leaching where the land is bare of crop. This all goes to show that the three factors of climate, season, and soil must be constantly borne in mind when dealing with the subject of summer or winter rainfall.

Tillage.

The usual methods of tillage in the Great Basin consist of deep plowing, frequent cultivation, and alternate-year cropping. Autumn-sown wheat has been so far the chief crop grown on dry lands. The land is then plowed as soon as possible, and left in the rough furrow all winter. As soon as the winter rains have thoroughly soaked into the ground, surface cultivation is begun. This is usually done by means of a disc-harrow. Sometimes a shallow summer plowing is given to turn under any weeds. In the late summer a spike-toothed harrow is used to form a fine seed-bed, and the next crop is sown in the month of September or early in October. As the winter rains tend to compact the soil it is usual to lightly harrow the wheat crop in the early spring, as once it starts to grow nothing more can be done to conserve the moisture. The grain is usually harvested with a header so that there is always a large amount of straw to plow under.

The old agricultural practice of fallowing or plowing land and then leaving it untilled for a time was adopted to render the soil more tender and mellow, and at the same time to destroy weeds. But in the Great Basin, where dry-farming is now much in vogue, the term "fallow" is commonly used to mean land left bare but constantly stirred to conserve moisture. All farmers know that moisture is lost very rapidly from a soil if the surface is not stirred; and so with crops that cannot be inter-tilled, such as wheat, oats, and barley, much moisture is wasted by direct evaporation during the growing season; but with crops that can be inter-tilled during the growing season, such as corn (maize), potatoes, and mangels, a much larger amount of moisture can be held in the soil by means of the soil mulch or dust blanket, as it is commonly called.

Depth of Soil.

Thus it is manifest that the success of dry-farming depends upon the possibility of storing enough water in the soil to carry the crop to maturity; and, consequently, the water-holding capacity of any soil becomes a matter of great importance. The dry-land farmer should, therefore, carefully survey his fields, and unhesitatingly select the deep, rich, mellow lands in preference to the poor, light and sandy soils whenever the storage of water from one season to another is the main object in view.

In general the soils of the Great Basin are deep and retentive and this is especially true of Utah. Prof. J. C. Hogenson writes: "In selecting soil for an arid farm of course we know that we should choose a soil that is quite retentive of moisture. But I believe that above all we should choose a deep soil rather than the kind of soil, for if we have a deep soil, even though it be somewhat less retentive of moisture, we can cultivate it in such a manner as to store the moisture there to a considerable depth, and that is better than a more retentive soil which is poorly cultivated." Again he remarks: "In order to grow wheat successfully on dry land, it is absolutely necessary that the land be thoroughly prepared before the crop is planted. I do not believe that a person can make a success of dry-farming who is not in the habit of thoroughly preparing his land before the crop is sown. In fact, if the land is not thoroughly prepared, more than one half of the profits which might be derived are lost." And finally: "We have found that on an average of a number of years deep seeding has given us better results than shallow seeding, because in the deep seeding the seeds are always put below the dry soil mulch, where they can get the moisture necessary for rapid germination."

Crops.

In the Great Basin wheat and lucerne are the chief crops raised in dry-farming. The varieties of wheat are nearly all light-colored and belong to the class commercially known as "Soft Wheats" of which "Kufoid" and "Gold Coin" are the most commonly grown. Turkey Red is also being largely sown. On the State experimental farms different varieties of Durum wheat, the spring wheat of the Upper Mississippi Valley, such as Fife and Blue-stem, together with some types of hard winter wheats, are being tested.

In general the wheats of the Great Basin are very much mixed, and grading and selection are urgently needed. Public attention has been called to this matter by Mr. William R. Jardine, the United States Agronomist, who has been trying to persuade the farmers to grow one variety for the whole semi-arid belt in order to obtain a better price for a uniform wheat. The Utah wheats have been found to have a fairly high percentage of gluten and so are usually blended with the softer California wheat, and there is but little doubt that with proper care in the selection of seed the Great Basin will become one of the finest wheat-growing countries in the world.

Alfalfa (Lucerne).

Alfalfa is the standard forage crop. At first it was grown only under irrigation, but it is now being widely cultivated on the dry lands. It is important to note that up to the present no serious effort has been made to secure varieties suited to dry-land farming, and so it happens that seed from irrigated land is almost invariably sown on dry lands. It is probable that drought-resistant varieties could be developed in a comparatively short time if proper attention were given to selecting seed that has been grown upon dry lands. Farmers should insist upon seed merchants classifying alfalfa seed thus: (a) Seed from dry lands, and (b) seed grown on irrigated lands.

TWO VARIETIES OF DRY-LAND WHEAT, RED CROSS AND TURKEY RED, U. S. EXPERIMENT STATION, NEWCASTLE, WYOMING

It is highly probable that the method of sowing alfalfa in rows wide enough to permit of inter-tillage will be found to be the best plan for raising forage as well as for seed production. As Mr. Scofield writes in his monograph on this subject: "It is well known that isolated alfalfa plants when allowed to mature on these dry lands produce relatively large quantities of seed. This is probably due, in part, to a better illumination on all sides of the plant, resulting in a larger number of flowers, in part to the drier air surrounding these flowers during the pollenation period, which appears to have some bearing on seed production, and in part to the greater ease of access for insects of various kinds that promote pollenation. It is certainly true that the partial isolation of the plants secured by row planting results in greatly increased yields of seed per plant, and there is strong probability that the yields per acre would be larger, so that experiments to determine this point would be well justified."

Seeding.

In the Great Basin thin or light seeding has been found to give the best results. A large quantity of seed is often the cause of crop failure; because a heavy seeding makes an instant demand on the moisture close to the surface before the young and tender plants can strike their roots down into the deep soil. The result is a severe struggle for existence among the individual plants and crop failure should the drought continue. Speaking on this subject Merrill remarks: "When Bishop Farrell and Mr. Salisbury first started their experiments in the Cache Valley tbey sowed the same amount of seed on their land that they had been accustomed to sow on irrigated land, namely, a bushel and a half (90 lbs.) to two bushels and a half (150 lbs.), and as a consequence there was not sufficient moisture in the ground to nourish the plants which came up and wilted away and died." Thus, in the Great Basin the farmers have learned the lesson of putting merely sufficient seed on the land for the available supply of moisture. Thus, whereas in the more humid regions of the United States farmers sow sixty to ninety pounds of wheat to the acre and fifteen to twenty pounds of lucerne on the dry lands of the Great Basin, far heavier crops are usually obtained when only thirty to forty pounds of wheat and eight to ten pounds of lucerne per acre are sown. But no hard and fast rule can be given; for the same amount of seed will seldom give the same results in different localities.

Rotation.[1]

It is of interest to note that so far crop rotation has not played a prominent part in the agricultural practice of Utah, and Merrill makes this plain in a recent address: "I want to object to the idea that has been advanced here, that we need to rotate our crops. If we grow a crop of corn—maize—on the land, alternating with wheat, it simply means that that corn is going to take so much moisture out of the land."

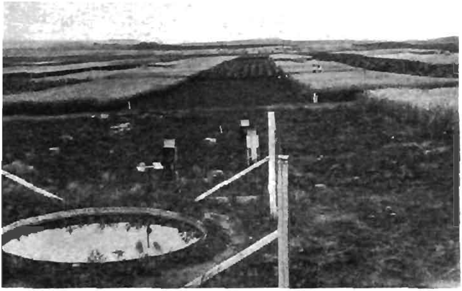
Summing up it may be said that dry-farming in the Great Basin is based on certain fundamental principles which have been worked out by the farmers themselves and their striking success has been mainly due to a combination of five factors: (1) Deep plowing to increase the capacity of the soil for holding moisture.

[1] Second Annual Trans-Missouri Dry Farming Congress, Salt Lake City.

(2) Constant harrowing to form a soil-mulch. (3) The summer fallow to rest the soil, to encourage the nitrifying bacteria, and to carry over the rainfall from one season to another. (4) Fall plowing. (5) A small quantity of seed, so as not to draw too heavily on the limited amount of moisture in the soil before the plants are strong enough to resist drought. In a word, the farmers of this region have concentrated their whole attention on one problem, namely, the conservation of water for the use of the crop. Furthermore, the more progressive settlers are convinced that too many different types of cereals are being grown and an effort is now being made to eliminate all inferior and mixed varieties and to raise one standard sort which will command a ready sale at a high price.

THE COLUMBIA BASIN UPLANDS

During the past few years there has been a rapid development in dry-farming in Idaho, Oregon, and Washington or in other words on the wheat lands of the Columbia Basin. This region is almost entirely surrounded by mountains. The Cascade Mountains lie to the west; the Bitter Root and Cœur d'Alene Mountains to the east; the Okanogan Highlands to the north; and the Blue Mountains to the southeast. The elevation varies from a few hundred feet along the Columbia to as much as 8000 feet in the eastern portion of this region; while the average annual rainfall varies from 6 to 24 inches. Near the Columbia River, where the rainfall is lighter, the dry season extends from March until October. Near the Blue and Bitter Root



ROTATION PLOTS AT THE EDGELEY EXPERIMENT STATION, NORTH DAKOTA

ROTATION PLOTS AT THE EDGELEY EXPERIMENT STATION, NORTH DAKOTA

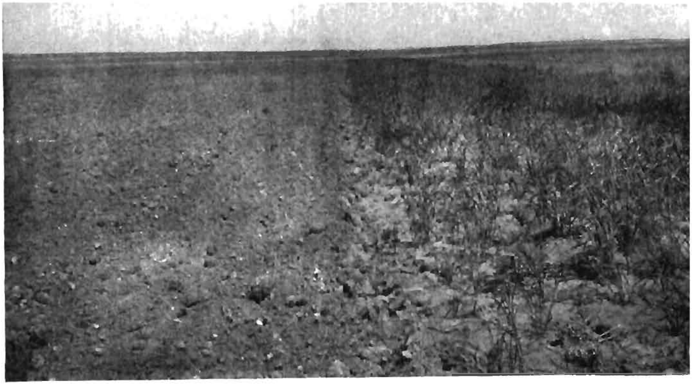
Mountains the dry season is confined entirely to the summer months, while the rainfall is fairly well distributed throughout the remaining part of the year.

There are two distinct agricultural sections in the Columbia Basin. The one consists of the alluvial valleys along the streams where irrigation is practised; the other, the upland prairies—vast undulating treeless hills—where crops are raised by means of dry-farming.

While the central part of the Columbia Basin region is exceedingly dry the eastern portion receives the heaviest annual rainfall. It was natural therefore that the early settlers some thirty-five years ago should take up homesteads within the area of the heaviest rainfall that lies along the foothills of the Blue and Bitter Root Mountains. The remainder of the region was considered only of value for grazing purposes. But the later colonists have pushed cultivation into the dry central region and are producing crops without the aid of irrigation. From the earliest settlements cereal crops have been grown almost exclusively in this region. True, alfalfa, timothy, corn, potatoes, and fruit are now produced in many parts of the country. Yet they all sink into insignificance in comparison with the grains—more especially wheat.

Tillage.

In the Columbia Basin, where the rainfall is light, wheat is grown every other year alternating with the summer fallow; where the rainfall is ample crops are grown every year. Three reasons are usually given in support of summer-fallowing in this region: (a) To conserve moisture. A large amount of wheat being grown with an annual rainfall of



THE OLD METHOD AND THE NEW

Tilled and Untilled Fallow Land in Montana from 8 to 10 inches. So the rainfall of one season is conserved for the use of the next year's crop. (b) To eradicate weeds. The yield of all grain crops is greatly diminished when the land becomes foul with weeds, while the loss of both moisture and plant-food is very great. (c) To renew the fertility of the soil.

The corrugated roller and subsurface packer have been introduced into this region. Farmers in eastern Oregon who use the roller state that their seed germinates much better and that the yield is several bushels more per acre when they use the roller just after drilling in the grain. It also enables them to cut the grain much more easily and cheaply because the ground is firmer at harvest time. If neither the corrugated roller nor the subsurface packer is available the disc harrow is used instead. It is set perfectly straight and weighted to make it cut deeply. Used in this way it does very effective work in settling and packing the bottom of the furrow-slice.

Speaking of the Columbia Basin region Hunter remarks: "There is considerable fall plowing done for spring crops. It is generally conceded that better yields are secured from fall plowing than from spring plowing, provided the land is reasonably clean. There are several reasons for this. Soil left rough and porous as it comes from the plow holds the snow better and rain much better than land that is unplowed. By seeding-time in the spring the winter rains have settled the soil sufficiently to form a good, firm seed-bed. In other words, the winter rains put the bottom of the furrow-slice in practically the same condition as does the subsurface packer or the corrugated roller. When in this condition there is a very much better capillary movement of the moisture than is usually secured from spring plowing. Again, by plowing in the autumn the stubble and other trash on the surface of the ground are covered up and given a better chance to decay."

Varieties.

A great many different varieties of wheat are grown in the Columbia Basin. So many different sorts with their variable milling qualities thrown upon the market make a very unsatisfactory state of affairs. Could this list be reduced to two, four, or even six of the best varieties, it would be much better. Such varieties would then become standardized and the miller would know what he was buying and the producer what he was selling. In selecting the most profitable wheat to grow it is not always possible to satisfy both the farmer and the miller. A wheat of poor milling quality may be a heavy yielder. But undoubtedly the farmers as a whole will secure better results by confining themselves to a few varieties. The following are the best known varieties: Little Club, Red Chaff, Blue-stem, Early Wilbur, Forty-fold and Turkey Red.

CHAPTER VIII

DRY-LAND CROPS

AS we have already seen, the region of the United States which is destined to be reclaimed mainly by the application of the principles of dry-farming comprises the western half of the Dakotas, Nebraska, Kansas, the Panhandle of Texas, and westward to the Pacific Coast range; in other words the Great Plains region, the Intermountain West, and vast tracts of country in the States of California, Oregon and Washington. Now the annual rainfall of this dry-farming zone varies from four to twenty-five inches per annum; and as might be expected wide differences also occur in the altitude, the climate and the soil of this enormous area. It is therefore impossible to say off-hand what sort of crop should be grown or what methods of farm management should be employed. Bearing this in mind, we can now discuss the various crops which have given, or are likely to give, the best results from a dry-farming standpoint.

At the outset it may be said that to raise one crop[1] year after year on the same land is seldom a profitable, and never a safe proceeding, and the dry-farmer must always try, as far as is practicable, to maintain a rational system of rotation in order to preserve the fertility of his soil and at the same time to keep his fields free from insect and fungous pests.

[1] The exceptional fertility of some dry lands after many years of continuous cropping to the same grain should not lead farmers to adopt this practice without very good reasons.

DRY-LAND OAT-FIELD (NEBRASKA WHITE), U. S. EXPERIMENT STATION, NEWCASTLE, WYOMING

DRY-LAND CROPS

Chief Crops.

In dry-farming the chief crops are the cereals, mostly wheat, oats, barley, corn (maize), rye, emmer, spelt, the grain sorghums and millets; but forage plants, such as lucerne, or alfalfa, clover, field peas and other legumes must be grown to feed the live-stock of the farm while hardy drought-resistant trees should be planted for shelter and shade and to make the homestead more attractive.

But of all these crops wheat is by far the most important, and the reason is not far to seek. Wheat is the most widely used grain, and is always in demand. It is also worthy of note that the price of wheat is steadily rising, and as this cereal is generally of a finer quality when raised on dry lands than when it is grown under irrigation, it will probably long remain the principal crop in dry-land farming.

The Great Wheat Groups.

According to Jardine several hundred varieties of wheat, more or less distinct, are grown in the dry-farming region of the United States. The great bulk of these varieties, however, fall into four groups:

I. The Hard Spring Wheats: (a) Common Varieties. (b) Durum Varieties.

II. The Hard Winter Wheats.

III. The Semi-Soft White or Intermountain Wheats.

IV. The Soft-White or Pacific Coast Wheats.

Broadly speaking each group is grown in a particular belt or zone. These wheat zones, of course, are not sharply defined; still certain types predominate in each.

Spring Wheat Zone.

The Hard Spring Wheat Zone takes in North and South Dakota and a portion of northwestern Nebraska. Of the common varieties the two best known are Blue-stem and Red Fife. The famous wheats known as "No. 1 Hard" and "No. 1 Northern" which usually command the highest price on the markets of the world have been developed from these two varieties. The growing of winter wheat is not possible in this zone owing to the long severe winters, light rains in the fall, and severe freezing and thawing in the early spring. But this section may also be spoken of as the home of the durum wheats in America; and as they seem destined to become the leading spring varieties throughout the whole semi-arid West, a short account of their origin may not be out of place.

The Durum Wheats.[1]

For more than forty years there have been occasional shipments into the United States of the hard, glossy wheats of the so-called durum type, chiefly from Russia, but also from Algeria and Chile. But it is only during the past nine years that public attention has been specially directed to them, and this has been due mainly to the publications and efforts of the National Department of Agriculture. In the year 1900 Mr. M. A. Carleton, United States Cerealist, was sent on a mission to Russia. He traveled through the Durum Wheat Zone and secured a large number of varieties which were distributed to the farmers and Experiment Stations in the Great Plains region where the climate and soil conditions are very like those

[1] Also termed macaroni wheats since they are used in the manufacture of macaroni. The term *durum* comes from the Latin word meaning hard.

DRY-LAND WHEAT IN SHOCK, FORSYTH, MONTANA found in Russia and in Algeria, where the macaroni wheats are grown. In 1901 Mr. Carleton wrote on page 16 of his bulletin on Macaroni wheats: "The normal yearly rainfall of the Great Plains at the one-hundredth meridian, where wheat-growing is at present practically non-existent on account of lack of drought-resistant varieties, is nearly three inches greater than that for the entire semi-arid Volga region, which is one of the principal wheat regions of Russia, and which produces the finest macaroni wheat in the world."

At first these grains were received with but little favor, in spite of the fact that they gave excellent yields and showed remarkable rust-resistant and drought-enduring qualities. But the macaroni factories of America were then using the ordinary bread wheats, and neither the mills nor the elevators would accept the durum varieties. Happily this prejudice has entirely died down and it is probable that within the next few years these types will be used exclusively in the manufacture of macaroni. In blending with the softer varieties and as a source of pemolina or "macaroni flour" durum wheats are now acknowledged to be unrivaled. But for the dry-farmer the drought-resisting quality of the durum wheat is the most important point; and in the semi-arid lands of Texas, Montana, Utah, and California, they have surpassed all the spring varieties and are easily preëminent in this respect. Their rust-resistance is also noteworthy. This was first shown in a striking manner during the season of 1900 when the rust epidemic did so much damage to the common varieties. For that reason in some parts of Minnesota, farmers are now growing durum wheats in place of Fife and Blue-stem. But the excessive humidity of the atmosphere makes this section of the country wholly unsuited to their growth. In short, durum wheats are the best spring wheats to be grown where the summers are hot and dry; but they do not give satisfactory yields in humid regions. Durum wheats first became prominent in the commercial world of the United States in the year 1903 when 6,000,000 bushels were produced; the annual harvest has steadily risen until today the total crop is close on 100,000,000 bushels.

Winter (Crimean) Wheat Zone.

The zone in which the hard winter or Crimean wheats are grown includes the State of Kansas, southern and central Nebraska and Oklahoma, the Panhandle of Texas, Montana, Colorado, and Alberta in Canada—the area of maximum production being in central Kansas, 70,000,000 bushels per annum. These wheats originated in Russia and take their name from the peninsula of Crimea, where they have long been grown. They were first introduced into the United States by the Mennonite colonists who came from Russia and brought some seed with them.

The typical varieties of this group are the Turkey—sometimes called Turkey Red—the Kharkof, and the Crimean. They are usually termed "hard red winter wheats." The Kharkof is most valued and has proved very hardy. The wheats of this group are all bearded, and have white chaff and hard, red berries. They do not grow tall, but are very heavy yielders. Although in great demand as milling wheats they are not thought equal to the No. 1 Hard and No. 1 Northern

WHEAT-BREEDING NURSERIES, MINNESOTA EXPERIMENT STATION grades of the Fife and Bluestem of the Dakotas.

Intermountain Wheat Zone.

Passing westward from the Hard Winter Wheat-belt we come to the Intermountain or Great Basin Wheat Zone. The wheat of this region may be considered as intermediate between that of the Great Plains and that of the Pacific Coast. The wheat of this belt is much mixed with, however, a tendency to the production of a white soft berry resembling the grain of the Pacific Coast. Hence, the term semi-soft white wheat.[1]

It cannot be said, as in speaking of the previous zones, that any particular variety is dominant in the Intermountain region, although the winter sorts are chiefly grown. This is due to the fact

[1] It is of interest to know that the finest and cleanest seed is now grown in Alberta, being originally obtained from Kansas.

that the locality in question has up till now been of little or no account in the world's wheat markets. Nevertheless, the rapid development of dry-farming in this section, and the enormous areas which are eminently suited to wheat-growing, must ultimately reduce the number of varieties in favor of one uniform dominant type. As Jardine wisely remarks: "Fruit-growers recognize this principle of uniformity and profit by it. This point has also been forcibly illustrated by the durum wheats in this country. When the durum wheat was produced only locally and in small quantities, it had absolutely no market, but just as soon as the Dakotas began to make a specialty of it, the sale became easier and a market was soon firmly established." In the opinion of the same authority the coming wheats for the Intermountain area will be the Crimean group for winter wheat and the durums for spring. The latter are the only varieties which have proved capable of withstanding the dry, hot summers of this region.

The Pacific Wheat Zone.

This zone comprises the San Joaquin and Sacramento Valley in California, and the Columbia Basin region of Oregon, Washington, and Idaho. The wheats of this belt are the extreme opposite of those of the Kansas region. In other words, they are very soft and white, and very low in gluten—the most valuable constituent of the wheat berry—while the Kansas grains are hard, red, and rich in gluten and hence more desirable. The wheats of the Pacific belt are not readily salable in the Minneapolis and Chicago markets; however, they sell freely on the Pacific Coast, in western

Europe and the Orient. The main varieties are Defiance, Little Club, White Australian, and Sonora in California; Red Chaff and Foise in Oregon; Palouse, Red Russian, and also Blue-stem, in Washington and Idaho. So far all attempts to maintain high gluten content in wheats brought to the Pacific Coast region have failed. As soon as the hard varieties have become acclimated in this region they are found to be starchy and soft and so closely resemble the Pacific Coast types in chemical composition. This is particularly true of the wheat sections of California. It is thus customary for the millers of California to import hard sorts so as to strengthen their own flour. As Jardine points out this is another possible use for durum wheats raised farther east. Such a course would increase the market for the durums and at the same time prove of vast service to the farmers and millers of the Pacific Coast.

Oats.

There are a number of spring varieties of oats that withstand drought to a marked degree. Among the most promising are the following: Sixty-Day, Kherson, Burt, and Swedish Select. These varieties are usually quick growers; they are thus able to use to best advantage the early spring moisture and by maturing soon escape the severe droughts which may occur later in the season. A winter variety, known as the Boswell Winter Oats has given excellent results in Utah and is being tested in the Great Plains area.

Barley.

Tbe most drought-resistant varieties of spring barleys belong to the beardless and hull-less types, and have proved excellent varieties to grow on dry lands. They are highly valued for stock feed, and being spring crops are well adapted to a rotation in which they can follow winter wheat. The Tennessee Winter Barley has given good results in Nebraska and Kansas and is rapidly displacing the spring types in the latter State.

Spelt and Emmer.

Spelt and emmer are less generally known than the other grains as they have only recently been introduced from Russia. There is still some confusion regarding spelt and emmer. They are both generally called spelt. The two are quite distinct, however, but they are alike in the fact that the chaff adheres closely to the berry after thrashing. Botanically, spelt and emmer are closely related to wheat, but economically they might better be classed with oats and barley since they are cultivated in the United States for stock food only. As a mixture with other grains, such as corn, oats, and barley, they are highly prized.

Sorghum.

Sorghum is supposed to have originated in equatorial Africa. At the present time it is more or less extensively cultivated in all tropical and temperate regions of the globe, and forms an important part of the food supply of the human race as well as of domestic animals. It is not too much to say that the sorgbums surpass all other crops in withstanding long periods of drought and hot winds. This fact alone has done much to make them the leading crops in the drier regions of the United States. Sorghum is far superior to corn (maize) in this respect and will remain fresh and green through periods of drought that would entirely destroy a corn-field. Sorghum does excellently on the "red-land" formations of Oklahoma and northwestern Texas. It has also been grown with some success on the alkali soils of California New Mexico, and Arizona.

Effect on the Land.

It is commonly said that Sorghum is "hard on the land" and in a sense this is true. But any crop which produces a large amount of forage or grain tends to exhaust the soil. Sorghum often affords three cuttings a year in the Gulf States and two in the semi-arid regions. It is not surprising, then, that it is hard on the land. On rich soils, however, good crops have been secured for many successive years without any marked decrease in soil fertility. Ball writes on this subject

OATS GROWN CONTINUOUSLY, THIRD CROP, YIELD [illegible] BUSHELS PER ACRE, FORSYTH EXPERIMENT STATION, MONTANA

Showing evil effect of constant cropping without summer fallowing or rotation

OATS AFTER A MOISTURE-SAVING FALLOW, YIELD 57 BUSHELS PER ACRE, FORSYTH DRY-FARM, MONTANA as follows: "It is probable that the observed bad effect on land is due more to the physical condition in which the soil is left than to an actual reduction of fertility. The large quantity of coarse stubble left in the soil, especially where the crop is grown rather thinly in drills, hinders perfect preparation for the next crop. If the land is dry when plowed clumps of stubble are likely to become centres of great clods, which are broken up only with great difficulty. Sorghums also continue their growth later in the autumn than most other crops, and thus continue to remove moisture from the soil until a late date. If the land is then sown to a winter crop there is not sufficient moisture remaining to give it a successful start, and the failure is then laid to the impoverishment of the soil by the preceding sorghum crop. This complaint has been more frequently made against Kaffir corn than against the saccharine sorghums."

Classification of Sorghums.

There are a great many varieties of Sorghums. They hybridize or cross very readily and the number of different sorts seem to be constantly increasing. All forms, however, grown in the United States may be separated into four classes or groups: (1) Broom Corns. (2) Sorgos, Saccharine or Sweet Sorghums. (3) Kaffir corns. (4) Durras.

Of these the broom corns are grown only for their brush, the sorgos for forage and syrup, the Kaffir corns for grain and forage, and the durras almost exclusively for grain.

Broom Corns.

The broom corns have straight stems which do not branch from the upper nodes, or joints, and very long, straight, loose, open seed-heads, usually light-colored, which are used in the making of brooms and brushes. The stalk is dry and pithy, lacking the sweet juice of the saccharine sorghums to which broom corn is most closely related.

Saccharine Sorghums.

The sweet sorghums are popularly known by reason of their sweet sap or juice from which syrup and sugar are made. In general, they are of tall and leafy growth, branching only sparingly at the upper nodes, or joints, and not stooling much at the base. The seed-head or panicle varies from the close, compact "club" head of the Sumac sorghum to the loose and often widely spreading head of the Amber variety. The seeds are red in the Sumac and reddish-yellow in the Orange and Amber sorghums, and usually protrude a little from between the glumes or chaff.

Non-Saccharine Sorghums.

Non-saccharine sorghums have usually a stouter stalk, with a fair amount of juice, which is, however, less abundant and less sugary than in the sweet sorghums. On account of the position of their heads and the shape of their seeds they are readily separated into two great classes namely (a) The Kaffir Corns and (b) The Durras (Dhomas).

The Kaffir group includes Red Kaffir, White Kaffir, Black-hulled White Kaffir, and White Milo or Large African Millet. Kaffir corns are all characterized by erect, rather long and compact, cylindrical heads full of egg-shaped (with the large end outermost) seeds which are either white or red as indicated by the name. White Milo Kaffir corn may be distinguished from Black-hulled White Kaffir corn by its much better growth, longer internodes (with space between the joints of the stem), and larger and lighter colored, yellowish leaves.

The durra group comprises Milo, white durra ("Jerusalem Corn," "Rice Corn," "White Egyptian Corn") and brown durra. ("Brown Egyptian Corn"). The durras are characterized by dry and rather pithy stems and large, oval or egg-shaped, mostly pendent ("goose-becked") heads. The number of leaves on each stalk is only 8 to 10 on the average. This scanty foliage and the pithy stem make them (the durras) of little value for forage in comparison with the Kaffirs and Sorgus. However, the seeds of the durras are larger than the latter. The best known of this group is milo, first known as "Yellow Millo Maize." The adjective "yellow" was applied because of the yellowish color of the seeds and also because a white-seeded sorghum, related to Kaffir corn, was then being sold as "White Millo Maize." It is now commonly known as Dwarf Milo, Yellow Milo and Milo "Maize," but the last name should not be used as it is apt to confuse it with corn. The simple term milo is the best.

Milo was first introduced into the country from Africa about 1880. In the Panhandle of Texas, Oklahoma, and Kansas it is widely grown on account of its drought resistance and comparative earliness. Dwarf milo is merely ordinary milo grown in the dry plains where, owing to lack of moisture, it becomes low in stature. The heads of the common varieties of milo are mostly pendent and consequently hard to harvest; but the improved or selected types developed by the Department of Agriculture have erect heads and consequently may be harvested with grain-headers. The improved *milo* crop is adapted to rapid and economical handling on a large scale by machinery. Milo needs a soil very much like that required for corn. Four pounds of seed to the acre have given the best results in the Texas Panhandle, and the yield varies from 25 to 55 bushels per acre. Milo is mainly used as a feeding grain on the dry-farms of the West; but except for poultry the grain should be cracked or ground before feeding. Milo is now widely grown in western Texas, New Mexico, California, Oklahoma, and Kansas, and is proving of great value as a dry-land grain crop. It seems well worthy of trial in the whole Great Basin region. Lastly, the group of Kowliangs or Chinese grain sorghums are the most promising early strains yet discovered. The best variety matured in the Panhandle of Texas in eighty-five days. This is at an elevation of from 3000 to 4000 feet with an average rainfall of 22 inches.

Rye.

Rye, well known as a good dry-farming crop, can nearly always be relied upon to produce a crop under conditions of drought too severe for wheat or other grain. There are both spring and winter varieties. The spring types are most valuable as green manuring crops, and also for summer forage and pasturage. Winter varieties are most profitable for the production of grain and forage. The value of rye as forage is almost equal to that of timothy if cut at the proper time. Since rye produces a heavy foliage even under very dry conditions, it is specially esteemed as a dry-farm forage crop. Its grain, too, is valuable as a stock food.

Emmer.

Emmer, a species of wheat, has recently attracted much notice as a valuable grain for semi-arid regions. It is largely grown in Russia and Germany and probably was first introduced into the United States by the German and Russian colonists who settled in the Northwest. In Russia it is mainly grown in the Upper Volga region where the annual rainfall is about 16 inches. The name "emmer" is a German word, and should be used instead of "spelt," by which it is often erroneously called. The heads of emmer are almost always bearded; while the spikelets are usually two-grained. The emmer may be distinguished from spelt as follows: the spikelets of spelt are far apart, stand out from the stem, and form a very loose head; while the spikelets of emmer lie close together and form a compact head. Further, the grain of emmer is harder and redder than that of spelt. Emmer is a much harder and quicker growing plant than spelt. It can withstand severe drought, and, to a large degree, leaf-rust and smut. Emmer will produce a fair crop under almost any condition of soil and climate, but thrives best in a dry prairie region, with short hot summers, where it gives excellent yields. It will grow on poor lands, in stony ground, in forest regions, and on the prairie. A dry hot climate seems to produce in emmer a hard, bright, clean grain. In Russia a large amount of this grain is used for human food, such as in porridge and cakes. The high protein content would indicate that it should make very nutritious bread. Moreover, emmer has proved of great value for improving other varieties of wheat. By crossing it with the common varieties, the following characters are secured: (1) Better resistance to fungous attacks. (2) Greater drought resistance. (3) Increase in productiveness. (4) Non-shattering. (5) Stiffness of straw. (6) Increase of gluten content. Crosses with emmer usually show a great increase in general vigor and hardiness.

Corn.

It is rather remarkable that more corn is not grown in the semi-arid zone. It is incorrect to say as a recent writer does that "The West is not a corn country," when we recall the splendid crops raised in Kansas.

Corn, like sorghum, is a drought-resistant crop and if planted in deep, well tilled land will successfully withstand a long period of drought. Corn may be planted in drills or sown in squares with a check-row planter. In Kansas it is usually planted with a lister. Cultivation should begin a day or two after the crop is planted and it is often harrowed until the plants are six to eight inches high in order to keep the soil from getting hard and crusted. Buffum says: "Under dry-farming, with proper tools, one man can plant and tend 160 acres of corn, or of sorghum. He must have plenty of horses, gang-listers, large harrows and gang-weeders." It is impossible to recommend any one variety of corn that would prove adapted to the whole of the West. But the dry-farmer should try to obtain a variety which is likely to suit his particular conditions and grow his own seed-corn. By careful selection for two or three years he can easily increase his annual yield from three to five bushels.

The best corn-breeding work in the United States has been done by the Illinois Experiment Station; and the farmer

DRY LAND WHEAT, CHRISTENSEN RANCH, WYOMING might well obtain one or other of the standard varieties recommended by that station, or such superior corns as Minnesota No. 18 and Wisconsin No. 7, to be obtained from the experiment stations of these States. But the important thing to remember is, as far as possible, to grow only one or two varieties and to plant them far enough apart to avoid mixing or cross-fertilization.

It is not hard to foretell that corn is destined to become one of the most important dry-farm crops in the semi-arid section of the United States, because of its great value as a fodder and as a grain crop.

Alfalfa (Lucern).

Alfalfa[1] is a very valuable crop for the dry-farmer and it is now being grown in

[1] Alfalfa, the Arabic name by which this plant was known in Spain and carried thence to Mexico, California and the western United States. It would be well, how-

every State in the West. It has given excellent yields on the dry lands of Texas, Oklahoma, Utah, Kansas and central Nebraska. Owing to its deep-going tap-root alfalfa will stand a long siege of drought; and the writer has seen splendid fields of lucern in Utah with a rainfall of about 15 inches per annum. Alfalfa grows best in a deep, well-drained loamy soil. It does not thrive in a cold, wet land; nor in loose, sandy soil. Like all other legumes, lucern has the power of absorbing nitrogen from the air. It thus adds fertility to the soil and when plowed under it is valuable as a fertilizer for worn-out lands. It is not, however, so well suited for short rotations as clover, but may be used to great advantage in a five or ten year rotation with wheat, corn, potatoes or sugar beets.

ever, if this name were given up in favor of the synonym ucern, now universally used in Utah, England, Europe, and South Africa.

Lucern should never be grown in orchards as it is apt to withdraw too much moisture from the trees. The cause of the failure of alfalfa is very often due to careless preparation of the soil. New land should be cultivated for one year at least, and better for two or three, before it is seeded. This crop is easy to grow and to keep clean, provided it is sown in a mellow, weedless seed-bed, and no crop responds more generously to good treatment. The effect of frequent tillage is really amazing.

Recently, a new industry has arisen in the semi-arid regions, namely, the growing of alfalfa for seed. It is found that a better quality of seed can be raised on dry lands than under irrigation or in the humid districts of the East. For if too much water is given to the crop during the time of flowering and seed forming, the strength of the plant goes to foliage rather than to seed production. This opens up a new and practically limitless field of work for the dry-farmer. Alfalfa, for seed, should not be sown in quite the same manner as for an ordinary hay crop. To secure strong thrifty plants, prevent crowding, and permit cultivation the seed should be sown very thinly in rows from two and one half to three and one half feet apart and the young plants can be thinned out with a hoe, as for sugar beets, or harrowed crosswise to cut out a portion of the crop. When a small amount of seed, three to six pounds per acre, is used, it may be mixed with ashes to help to spread it evenly. The yield of seed should be from five to seven bushels per acre, but on good soils as high as ten to twelve bushels may be expected. Lucern weighs 60 lbs. to the bushel. In practice the decision as to whether the crop should be used for hay or saved for seed may depend on the weather. If the season is wet, a hay crop is generally harvested; if dry, the field is allowed to go to seed. The best time to cut a lucern crop for seed is when about half the pods have turned brown. For hay lucern should be cut just as it is beginning to bloom. After flowering it loses its feeding-value. If the field is fairly uniform, the proper stage for cutting is when about one tenth of the plants are beginning to flower. Alfalfa is a highly nutritious and palatable fodder for all classes of farm animals. All stock eat it greedily either in the green form or as hay. For the best results, however, it should be combined with some grain, such as corn, barley or oats.

Potatoes.

Potatoes are among the most valuable of dry-farm crops and are now being grown on an extensive scale in the semi-arid regions. It is a well known fact that potatoes raised under irrigation tend to deteriorate, consequently there is a large and growing demand for dry-land seed. In a good, deep sandy loam this crop will thrive with comparatively little moisture. The following varieties are chiefly grown in the West: Ohio, Mammoth Pearl, Rural New Yorker and Burbank.

It is important that a community of settlers who are just starting to farm should plant only one or two varieties in order to supply their market with a uniform product. Potato land should be plowed deep. Usually four horses are put on a fourteen-inch plow and the furrow turned from eight to ten inches deep. If it is sod, the plowing is generally done to a depth of five or six inches the first year, but the ground should be disked before plowing, in order to form a fine seed-bed on turning over.

Potatoes on dry lands should receive deep and thorough cultivation. When the plants are four or five inches high, cultivate deep and near the rows. This may be done each week or ten days, running the cultivator shovels farther from the plants as they grow larger, and throwing the soil toward the rows. If potatoes are to be grown on a large scale, a good potato planter is necessary. The seed should be planted from four to six inches deep in rows three to three and one half inches apart and twelve to eighteen inches in the row. The cultivator and harrow should be used to level the soil and form a moisture-saving mulch. Large potatoes are not desirable and the farmer should strive to raise a medium-tuber, uniform in size, shape and color, free from scab or crack in order to secure the top market prices.

Canadian Field Peas.[1]

This crop has given good results in Montana and elsewhere and should be tried in every dry-farm. Field peas have a two-fold value. The grain and straw furnish valuable food for all classes of farm animals; and the crop is one of the best soil improvers, because of its ability to take free nitrogen from the air and add it to the soil.

The best success in the growing of field peas has been gained on clay loam soils which contained some humus and some lime. Very light, sandy soils do not give enough vine growth; while very

[1] This does not afford an accurate description, since many varieties of this particular strain exist. During the past few years the Montana Experiment Station has grown nineteen different varieties of field peas, all possessing distinctive characters, and yet all belonging to the general class known as "Canadian Field Peas."

rich, black soils produce too much leaf at the expense of the pod. Wet lands are wholly unsuited to the growth of peas.

Peas may be planted either on spring- or fall-plowed land. Usually, fall plowing gives the best results. The soil should be fine and mellow at the time of seeding. Canadian Field Peas should be one of the first farm crops sown in the spring. It is customary to sow with a drill at the rate of from 60 to 100 pounds of seed per acre.

Peas should be cut when the grain is hard in the pods and before the pods have dried sufficiently to crack open. Until a few years ago peas had to be cut with the scythe, making the crop hard and dear to handle. But the introduction of the pea harvester attachment to the ordinary mower has made it possible to handle the crop more cheaply and with much greater ease. Three men and one team of horses with an ordinary mower attachment will cut ten acres of peas in a day.

Leguminous Crops.

Those crops which belong to the pea or pod-forming family are of special value to the dry-farmer, for, in the first place, they may be grown as forage plants or, secondly, utilized for green manuring. Now the plowing under of green crops is one of the oldest methods of maintaining the fertility of the soil. But it was only within the last twenty-five years that the great value of the legume was made clear. Most farmers are aware that the roots of leguminous plants possess small warts, usually termed nodules or tubercles, by means of which they can make use of the free nitrogen of the air. Further, these nodules are caused by certain germs which, while feeding on the legume, provide it with nitrogen drawn from the air.

These nitrifying bacteria vary in size and shape according to the plant. Thus, while in red clover, they are usually small and round, on the bean they may reach the size of a pigeon's egg. Again, every legume has its own special strain of bacteria. For example, the germ on the lucern root is different from that on the clover plant and that on the cow pea is distinct from that of the soy bean. Land may be inoculated with the legume organisms by scattering soil from a field where the crop has been recently grown, or by using artificial cultures of the proper bacteria. According to Piper, there are in the United States fifteen leguminous field crops which are grown more or less extensively for feeding purposes or for green manuring. In the approximate order of their importance they are as follows: Red Clover, Lucern, Cow Peas, Alsike Clover, Crimson Clover, White Clover, Canada Peas, Soy Beans, Peanuts, Vetch, Velvet Beans, Japan Clover and Bur Clover. A few more are cultivated to a less extent, as Sweet Clover, Beggarweed, Grass Peas, Penugreek and Horse Beans. Many others have been tested in an experimental way, but as yet are not grown as crops. From an agricultural point of view legumes may be classified into three groups:

1. *Summer annuals,* including cow peas, soy beans, peanuts, beans, velvet beans and in the North common vetch and Canada peas.

2. *Winter annuals,* comprising crimson clover, bur clover, hairy vetch, and in the South common vetch and Canada peas.

3. *Biennials or perennials,* embracing

red clover, white clover, alsike clover, lucern and sweet clover.

Each of these crops can be grown advantageously only in certain clearly defined regions. Moreover, for the particular purpose in view it rarely happens that a choice of two or more equally valuable legumes is offered. Usually one is so much superior to any other that substitution is practically out of the question. In a few cases, however, the use of one legume in place of another is practicable. Thus, cow peas and soy beans are agriculturally much alike and are adapted to the same States. In a like manner crimson clover, bur clover, and the vetches may be used, one in place of another, over a large area. In some sections of the country the culture of red clover is no longer profitable, owing to various diseases. Alsike clover has been used to some extent as a substitute, but the yield is ordinarily much less. There is also an increasing use of lucern in place of red clover, but with lucern the best practice is to keep the fields in crop for three years or longer.

CHAPTER IX

THE TRACTION-ENGINE IN DRY-FARMING

THERE can be no doubt that the traction-engine is destined to play a prominent part in the development of dry-farming more especially where large areas of virgin prairie require to be turned over. At the same time every sponsive, and what is still worse the fine natural tilth is liable to be injured. Such a condition may last for several seasons. Take, for example, an old traveled road. Plow it up and note how long it will be before such land gives a satisfactory crop. In the same way it may be a considerable time before ground that has been packed hard by the weight of a traveling engine responds to cultivation. Of course where the land is in sod and dry the actual damage done is probably very slight. Another matter which the farmer has to consider in the more remote dry regions is the question of water and coal. If water has to be hauled over two miles, it is doubtful whether one man and four horses will be able to keep the engine supplied. As regards coal, if it has to be hauled six or eight miles, it will require a man and his team for at least three days in the week.

Again, the constant traveling over rough ground, the jarring of the cogs, and the accumulation of dust in the gearing makes it hard to keep this sort of machinery in proper order. Parts are very apt to becomc loose or worn out and the whole outfit may be laid up for several days, pending repairs, at the most critical period of the plowing season. Another trouble is the difficulty of getting efficient engineers—men who have had some experience in running traction-engines for plowing. Stationary or locomotive engineers do not seem to understand how to work these engines, although they are easy enough to manipulate. Notwithstanding all these disadvantages, the manufacturers are constantly striving to improve their machines and the popularity of the traction-engine is growing rapidly. This season a very large percentage of the wheat lands of western North Dakota—where coal is cheap and abundant—will be turned over by the steam plow.

Let us take as a typical example a 25-horse-power engine operating in North Dakota. Such an engine equipped for plowing costs about $2000, while the plows themselves run from $125 to $600 depending upon the make. A 25-horse-power engine with six 14-inch plows generally averages from 18 to 14 acres per day, plowing three to five inches deep. The fuel used in this State is lignite and costs from $2 to $3 per ton in the field, according to the distance from the mine. This size of engine will use about four tons of coal per day. The engineer usually receives from $3.50 to $4.50 per day, and the other men, of whom there are usually three or four, from $1.25 to $1.50. The average total expense is reckoned at about $20 per day. Most of the work of steam cultivation is done by contract; the ordinary price charged for breaking up virgin land is $3.50 per acre, or $4.35 for plowing, disking and seeding. Naturally, the outlay for repairs depends largely on the skill of the engineer, and the care which he takes of his engine. In the Northwest there are from five to six months in the year during which steam cultivation can be profitably employed, and the maximum amount of work which such an outfit as that just mentioned could do, in a favorable season, would be about 1500 acres. Traction-engines intended for steam plowing and thrashing are usually built more strongly than the ordinary traction-engine, both as regards the gearing and the boiler. Steam traction-engines for plowing usually have a capacity of from 25 to 40 horse-power, and new land is generally plowed to a