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THESIS FOR
DEGREE OF MASTER OF AGRICULTURE

THE SOIL SURVEY AND ITS RELATION TO AGRICULTURAL DEVELOPMENT

by
Warren J. ^WGeib

To the Committee on Advanced Degrees
of the
Michigan Agricultural College,
East Lansing, Michigan

1915

THESIS

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CHAPTER I

INTRODUCTION

Of all lines of industry which are followed in the United States agriculture is without question the most important. The farmers of this country supply the bread for the nation, and the prosperity of our people as a whole depends more largely upon agriculture than upon any other one industry. When the hot winds from the southwest sweep over Kansas and destroy the wheat crop; when a cold wet spring delays planting and cuts short the yields of corn and oats; or when any condition prevails which causes a material reduction in the supply of farm produce the whole country suffers. When the farmers have a bumper crop the whole country considers itself blessed; the buying power of all classes is increased, and the merchant is happy, the banker smiles, and the manufacturer works over time. Agriculture may well be considered the foundation upon which the rapid and substantial growth of this country is based, and upon which continued prosperity depends.

In order that a permanent condition of prosperity may prevail throughout the land, and that the proper balance be maintained in the Nation's growth, it is necessary that agricultural production should keep pace with the increase in population. Statistics indicate, however, that population is increasing more rapidly than agricultural production, and that if some method cannot be devised to improve this condition,

and make our crops grow as rapidly as our boys and girls, the feeding of the people will finally become a problem of grave concern to the Nation.

In 1900 the population of the United States was approximately 76 million, while in 1910 it was 92 million, or an increase of about 21 per cent in ten years. Basing the increase at the same rate it is estimated that at the beginning of the year 1915 there were in this country slightly over 100 million mouths to feed. Continuing at this rate for half a century the population will be over 200 million, and it is only reasonable to expect that this growth will actually take place. The question of providing a continuous food supply for this vast multitude, and insuring a steady increase that will keep pace with the growth in population is a problem which should be given most serious consideration.

From a careful study of the United States Census Reports it will be observed that during the period from 1900 to 1910 there was a slight increase in the total acreage devoted to the growing of corn, but the total yield in bushels in 1910 was 4.3 per cent smaller than in 1900. The total yield of wheat increased 3.8 per cent, but the acreage was reduced by 15 per cent. The yield of oats increased 6.8 per cent. The acreage of cotton increased 32 per cent, but the total yield increased only 11.7 per cent. Taking into consideration all cereals the total acreage in 1910 was 3.5 per cent greater than in 1900, but the total yield was only 1.7 per cent greater. This means that the average yield per acre

during the ten year period was slightly reduced. The total value of all farm products in 1910 was greater than the total value of any preceding year, and also slightly greater than the value of the farm products of 1911. The value of farm produce for 1900 was also greater than the value of any preceding year, and both years cited are normal so that the comparison here made is just and fair. The prices paid for farm produce in 1910 were considerably higher than those paid in 1900, as is indicated by the fact that the total value of farm produce in 1910 was 83.3 per cent greater than in 1900, whereas there was a total increase in the amount of farm produce for the same period of only 10 per cent. By comparing this total increase in all farm produce of 10 per cent, with the total increase in population for the same period of 21 per cent, we find that the population of this country is increasing slightly more than twice as fast as is agricultural production.

In considering this question the study would not be complete without a survey of exports and imports of agricultural products. In 1900 the value of all agricultural exports was equal to approximately 16 per cent of all products of the farm for that year. In 1910 the total exports had dropped to 9.6 per cent of the total production. During 1900 the value of all agricultural imports was equal to about 49 per cent of the exports, and in 1910 this figure had increased so that the imports equalled 78 per cent of the exports. During this ten-year period the agricultural exports increased only about 3 per cent, while the total agricultural imports increased

slightly over 6 per cent. For the year 1910 the difference between exports and imports, which is in favor of exports, was equal in value to only about 2.1 per cent of the total agricultural production for that year. It is very evident, therefore, that with the present rate of increase in imports and a continuation of the same conditions in crop production, it will be but comparatively few years until the imports of agricultural products will equal and exceed in value the exports of agricultural products.

It is not the intention to imply through these figures that when the value of imports equals the value of exports that there will be a shortage in the food supply, but it is very evident that unless some method or plan is devised whereby agricultural production may increase more rapidly than it is at present, that the time will come when the feeding of our rapidly increasing population will be a most serious problem.

Wherever there has been an increase in the total yields of crops from year to year the increase, in most cases, is the result of an increased acreage, rather than an increase in the yield per acre. An increase in agricultural production which is brought about in this way can never, of itself, solve this great problem. The total land area of the country is limited, and this source of increase will, therefore, in time be eliminated. The total land area of the United States is approximately one billion, 900 million acres. In 1910 there were 878,000,000 acres, or 46 per cent of the whole in farms, and of the land in farms 54 per cent, or near-

ly 25 per cent of the total area was improved land. In 1910 there were 40 million acres more in farms than in 1900. Should this rate of increase continue, and if all the land area were adapted to some line of farming, every acre of land in this country would be in farms in less than 25 years. But there is a very large amount of land which is too rough and mountainous to have any agricultural value, and there are extensive tracts of arid land where there is no water available for irrigation. On the other hand, the percentage of improved land on each farm will continue to increase until every acre of land suitable for crop production or grazing will be fully utilized.

It would be impossible to state with any degree of accuracy just when all available land will be farmed, but with the present rate of increase in population, and with no greater yields per acre, it will be necessary, in order to produce sufficient food to supply the home demand, to have all available land under cultivation within the next 50 years. The present war in Europe will doubtless check immigration and possibly delay for a time the most serious aspect, but this is only a delay and should be considered as an opportunity for this country to better prepare itself to meet the problems of agricultural production which we know the future will present.

As the total land area is limited, it is very evident that there must be some other way of increasing the food supply than merely by increasing the number of acres under cultivation. This other way to which it is desired to call

attention is by improving the efficiency of each farm by increasing the productivity of the soil as a whole. But the soil as a whole will not reach its highest degree of productivity until all different kinds, classes, and types of soil have been carefully studied as individuals, and only those crops grown, rotations followed, and methods of cultivation and fertilization used which are best adapted to the individual soils. Former Secretary of Agriculture Wilson once stated that the object of the United States Department of Agriculture was to make two blades of grass grow where but one grew before, but if this great problem of food production is to be solved it will be necessary to do even more than this. It will be necessary to make two blades of grass grow where nothing grew before, and to make a stalk of corn or a hill of beans grow where there is now a thistle or a sand bur.

While the situation which is now developing was foreseen by some fully a half century or more ago, and while various movements were then started to encourage the higher development of agriculture, it is only within recent years that the magnitude of the problem is beginning to be really appreciated. When all vacant lands suitable for some form of farming are included in farms, when a higher proportion of each farm is improved, and when the population is nearly double what it is at present, the seriousness of the situation will be clear to all, whereas at present only those who are giving some thought and study to such problems realize what is certain to develop.

Various organizations have been established from time to time for the purpose of advancing agricultural interests, and all of these have appreciated, to some degree at least, the important place which the soil itself holds as a factor in agricultural advancement. Among these organizations are the Federal Department of Agriculture, State Departments of Agriculture, Agricultural Colleges, and Experiment Stations.

One object to be attained by such institutions is to advise the farmer as to the lines along which his energy can be most profitably and effectively expended: to help him determine, among other things, how best to use and not abuse our most valuable resource--the soil. But the soil is a very complex factor, and we may also say a composite factor, being made up of many individuals which often differ widely from each other. Instructions for the improvement and management of the soil on one farm may not apply to the soil on an adjoining farm--in fact it may not apply to all of the soil on one farm or even in the same field. The differences in soils, and especially in their physical characteristics, are very great, and but few investigators, scientists, or practical farmers fully appreciate the variations in the soil, and the relation of these variations to soil management and improvement. As a result of this condition a large amount of misleading information has been given out and many farmers have come to look with distrust upon the work of scientific investigation. Before the most intelligent and useful instructions can be given

concerning the management of any particular soil it is necessary to have at hand a number of facts concerning that soil. The texture, structure, color, and topography should be known. It is necessary to know the location, extent, and distribution of the soil before the type of farming best adapted to it can be selected. Conditions relative to the origin of the soil, soil acidity, organic matter supply, and the content of mineral plant food elements should also be thoroughly understood. The collection and distribution through printed reports and published maps of this and much additional information concerning the soils of the United States, is the mission of the Soil Survey.

Soil surveys have been made by the Federal Government in every state and territory within the United States, Alaska included. At present most of the work of the government is being concentrated within those states which are willing to cooperate. Among the states which have been, or are now, cooperating in carrying forward the Soil Survey are Florida, Georgia, Alabama, Mississippi, North Carolina, West Virginia, New Jersey, Pennsylvania, New York, Ohio, Wisconsin, Iowa, Missouri, Nebraska, North Dakota, Washington, and California. Other states are entering into a co-operative agreement with the United States Department of Agriculture each year for the extension of this work and it is the plan to ultimately cover the whole country with surveys of this kind. The knowledge thus acquired cannot help but be of very great value in the higher development of agriculture and in solving the great problem of a more rapid increase in agricultural production.

CHAPTER II

A SOIL SURVEY DEFINED

The classifying and mapping of soils as now carried on has developed in this country practically within the past 20 years. Previous to this time considerable valuable work had been done in this and other countries, and before taking up the description of the work as now organized it will be of interest to briefly review the history of the development of this line of work. The following historical notes have been taken largely from a paper prepared by Dr. George N. Coffey and published in the Proceedings of the American Society of Agronomy, Vol. 3, 1911, under the title "The Development of Soil Survey Work in the United States With a Brief Reference to Foreign Countries".

In France the study of soil classification has been carried on for many years. The first map showing soils and agricultural regions was published in 1843. This was by M. de Caumont, and it covered the Department of Calvados. In Germany the study of Geology in its relation to soil conditions has been carried on for over 40 years. In the British Isles the detailed mapping of the superficial deposits is considered as an excellent basis for soil maps, but no true soil maps have been made. The soil surveys simply carry further the work of the Geological Survey as regards surface formations. The Japanese have made a study of the characteristics of the soils of their country and have published a number of agricultural maps. These are based upon geology which is

shown in colors, while the physical characteristics are indicated by means of hatching over the colors. A systematic study of the soils of Russia has been carried on so vigorously and so ably for the past 40 or 50 years that probably more is known of the nature of the soils of Russia than of any other country of such large geographic extent.

The first attempt at classifying soils in this country was probably by Amos Eaton and T. Romeyn Peck who prepared a report on the soils of Albany County, New York. This was published in 1820. The first map in this country which claimed to show the different character of soils was that of Massachusetts by Edward Hitchcock, published in 1841. In the Natural History Survey of New York, Part V, Agriculture, 1845, Emmons discusses the characteristics of the soils of New York and also gives an agricultural map of New York, which is the first map of the kind published in this country. Owen in Kentucky, Hilgard in Mississippi, and Smith in Alabama all did pioneer work along this line. In 1882 Chamberlain published a soil map of Wisconsin, and this appears to be the first soil map published in this country based upon the physical properties of the soil. In 1891 Whitney made an investigation of the soils of Maryland. The practical importance of this work was recognized by Congress and as a result a Division of Soils was organized in the United States Department of Agriculture. In 1899 actual field mapping was begun and since that time a large number of areas have been surveyed by the Bureau of Soils. These represent the first detailed soil maps published in

this country.

Before going further in this discussion it may be well to define what is meant by a soil survey, and describe the classification that is followed in carrying forward work of this kind. A soil survey consists of making a careful examination of the soil in the field, and classifying it into various divisions according to certain established rules. It includes a study of the peculiar characteristics of the various soils, processes of formation, sources of origin, etc., but the most important study that is made is that of the physical properties of the soil, and the chief factor in this connection is texture. A soil survey includes the making of a map which shows the location, extent and distribution of all different kinds of soil. It also includes a writing of a report in which all soils are fully described. An account is given of the extent of agricultural development in the community covered, the methods of farming followed, crops grown, yields obtained, marketing facilities, transportation, and in fact all factors are studied which have a direct bearing upon the agricultural development of the area. In brief a soil survey may be considered as an inventory of the soil resources of a given region.

In making a study of the soil under field conditions, and over extensive tracts of country, it is necessary that there should be some uniform method of study and classification. The classification here outlined is the one which has been developed by the United States Bureau of Soils, and it is now in use in all of the soil survey work which is

being carried forward by the Bureau of Soils. It is also followed by all of the states which are cooperating with the Federal Government along this line of work.

Soil fertility depends upon two factors: first, upon the physical characteristics of the soil, such as water-holding capacity, workability, etc., and second, upon the chemical composition of the material composing the soil. The chemical composition depends upon the mode of origin of the soil, and the source of material from which the soil is derived.

Water-holding capacity, and other physical properties of soil all depend chiefly upon texture, which refers to the size of the individual soil grains, or particles, and the texture of the soil is the most important single factor to be considered in soil classification. A coarse sandy soil, for example, will not retain moisture so long as a loam soil, or clay loam, because the finer the soil grains, the greater will be the total soil-grain surface area to which moisture may adhere. Texture is determined in the field by rubbing the soil between the thumb and fingers, and with experience one soon becomes expert at judging the size of soil grains. This field judgment is verified in the laboratory by a mechanical analysis, which is made by a simple method of separating soil grains into different groups, of which there are seven. These are known as clay, silt, very fine sand, fine sand, medium sand, coarse sand, and fine gravel.

The following table shows the size of soil particles in each of the seven groups, which are known as "separates".

Fine gravel:	Coarse sand:	Medium sand:	Fine sand:	Very fine sand:	Silt:	Clay:	
m.m.	m.m.	m.m.	m.m.	m.m.	m.m.	m.m.	
2-1	1-0.5	0.5-.25	.25-.1	.1-.05	.05-.005	.005-.0001	

Another factor which is considered in classification is the structure of the soil. This refers to the arrangement of the soil particles. A soil may be loose and open in structure, or it may be compact. The color of the soil is important as indicating the organic matter content. The origin of the soil and its method of deposition is also important. The topographic position which a soil occupies is often a factor which determines how a soil can be utilized. The chemical composition of soils is also important, but this is not given as much consideration as is the physical character of the soil material.

A chemical analysis shows whether the soil contains a large store of plant food, or only a small quantity, and it indicates which kinds of plant food will probably be needed first. The amount of organic matter in the soil is also determined, and tests are made to show conditions relative to soil acidity.

Soils are grouped according to texture into soil classes, a soil class being made up of soils having the same texture, though differing in other respects. A fine sand, for example, may be light colored and of alluvial origin,

while another fine sand may be dark in color and of residual origin, while a third fine sand may have been blown into sand dunes by the wind, yet all of these soils would belong to the same class, because the greater proportion of the soil grains have the same size or texture. Thus we may have different kinds of clays, loams, sands, etc., and the class to which any soil will belong depends upon the size of the individual soil grains of which it is composed, and not upon its color, origin, topographic position, or agricultural value.

Soil Classes

Soils Containing Less than 20% Silt and Clay

Coarse sand.--Over 25% fine gravel and coarse sand, and less than 50% of any other grade of sand.

Sand.--Over 25% fine gravel, coarse and medium sand, and less than 50% fine sand.

Fine sand.--Over 50% fine sand, or less than 25% fine gravel, coarse and medium sand.

Very fine sand.--Over 50% very fine sand.

Soils Containing Between 20-50% of Silt and Clay

Sandy loam.--Over 25% fine gravel, coarse and medium sand.

Fine sandy loam.--Over 50% fine sand, or less than 25% fine gravel, coarse and medium sand.

Sandy clay.--Less than 20% silt.

Soils Containing over 50% of Silt and Clay

Loam.--Less than 20% clay, and less than 50% silt.

Silt Loam.--Less than 20% clay, and over 50% silt.

Clay loam.--Between 20 and 30% clay, and less than 50% silt.

Silty clay loam.--Between 20 and 30% clay, and over 50% silt.

Clay.--Over 30% clay.

Soils may be grouped in another way. Where soils are closely related through similar sources of the material from which derived, mode of origin, topographic position, etc., so that the different soils constitute merely a graduation in texture of otherwise uniform material, such a group is called a soil series. It corresponds to the family which is made up of different individuals having the same parentage. The Miami series, for example, includes light colored, glacial material where the soils have been derived largely from the underlying limestone, and the soils in the series range in texture from a clay loam to sand and gravel. The Plainfield series includes light colored soils in regions where no limestone is present, and where the material occurs as outwash plains or stream terraces. The soils in this series also have a wide range in texture. The name used for a soil series usually indicates the locality where that particular series was first recognized and mapped by the Soil Survey.

By uniting the name of the soil class, which refers to texture, with the name of the soil series, which refers chiefly to origin, we get the soil type, which is the basis or unit of classifying and mapping soils. A soil type, thus, is a soil which is uniform throughout its entire extent in texture, color, topographic position, and other physical properties, and having a distinct agricultural unity, that is, being adapted to the same crops, and requiring the same treatment. It is also uniform in the source of material from which it is derived, and the mode

of origin which, taken together, determine the chemical composition. Since the soil type is the unit in classifying and mapping soils, and the basis upon which experimental work should be conducted, every farmer should be familiar with the soil types on his farm, and their leading characteristics.

The work of classifying and mapping soils may be divided into two general groups. One of these may be called a general, preliminary, or reconnoissance survey, and the other a detailed survey. The name indicates the difference between the two lines of work. In making a reconnoissance, or preliminary survey the region in question is covered in a much more general way, and much more rapidly than in a detail survey. The amount of detail which may be shown will vary within certain limits in both classes of work, depending upon a number of factors to be considered later and each class of survey has a particular field of usefulness which will be brought out in the following chapters.

CHAPTER III

METHODS OF MAKING A SOIL SURVEY

As indicated in the preceding chapter there are several factors which go to determine what class of survey shall be made of any particular region. Most of the reconnaissance or general surveys which have thus far been conducted have been in newly developing sections of the country, where but little settlement has been made. One object of general work of this kind is to indicate which land is suitable for farming, and which has but little or no value for agricultural purposes. In some cases the object has been to determine which lands were suited to agriculture and which suitable for forestry purposes. Where a region is thickly timbered, or in a cut over condition and thickly grown up with a dense second growth, the making of a detail survey would be so costly as to be prohibitive. In such cases a general survey answers the purpose for a number of years until the country becomes settled, after which a detail survey can be made. In semi-arid regions extensive reconnaissance surveys have been made, and these have outlined the various soils so that it could be determined which sections would permit the development of dry farming or irrigation projects. General surveys are also being made in some cases of entire states in order that a broad general knowledge of the soils and their distribution may be gained quickly, before the detailed classifying of the soils is undertaken. The general

knowledge acquired in this way is of great assistance in developing the agriculture of a state by directing settlement first to the most desirable regions, in helping to study soil problems in old settled regions, and it is also of great value in the follow-up work of the detail soil survey.

Detail soil surveys can be made to best advantage in sections which are well settled, and where all portions of the region are readily accessible. While general surveys usually cover six or eight counties as one group, or in some cases, nearly half of an entire state, a detail survey is usually confined to the limits of a single county. The chief object of a detailed survey is to make a very careful study of the soils in such a way as to determine the character of the problems which will be met with on each soil type, and to assist in the solution of these problems, in so far as that is possible.

Different standards are used in these different classes of surveys. In the general survey the unit of mapping may range from 1/4 square mile to several square miles, which means that these sized tracts would be the smallest variations which could be indicated by a general survey. Maps of general surveys are published on the scale of three miles to one inch, six miles to one inch, or sometimes on a still smaller scale. In a detailed survey, on the other hand, the unit of mapping is 10 acres, which means that any variation of ten acres or more in extent would be shown on a detailed soil map. Frequently even smaller tracts are indicated. Detail maps are usually published on a scale of

one mile to one inch.

The methods which are followed in the reconnoissance and detail surveys differ somewhat, and of the two the general survey is usually the more difficult to make. Survey parties usually consist of two men, though within any area there may be several parties of two each, both in the general and in the detail work. A brief description of an outfit used by a party of which the writer was a member will give an idea of how reconnoissance work in a semi-arid region is conducted. The party was made up of two soil survey men, each supplied with a saddle horse. A large covered wagon, with a team of mules attached was in charge of a Mexican driver who served as cook, driver, and handy man about camp. The wagon carried tent, cots, bedding, camp stove, survey equipment such as soil augers, plane-tables, etc., food supplies, and hay and grain for horses and mules. Camp was established about every ten or fifteen miles, and was kept in each place from one to two days. While proceeding from one camping place to the next the road or trail was traversed by the use of an ordinary plane table. The distance was measured by an odometer attached to the wagon wheel. The soils were examined and mapped as the camping outfit moved along. The base map with which we were supplied was very inaccurate and many corrections were necessary. When camp was established the Mexican was left to look after the outfit and each of the soil men went in different directions from the camp. If roads or trails existed these were followed. Where no roads could be found a course was decided upon and followed by the use of the compass. In such cases

the distance was estimated by timing the horse, after first having determined as carefully as possible at what rate the horse would travel. The direction was kept, and the mapping was done by the use of a small army sketching case which can be used while riding, it only being necessary to stop to examine the soil at various places. An effort was made to cover the country over lines approximately three miles apart. In some places we could get over a region more closely than this, while in others it was impossible. The growth of cactus was in places so large and so dense as to make it impossible to get into certain localities. In such places field glasses aided in gaining an idea of the character of country which could not be visited.

The country was very sparsely settled, the grazing was very limited, and it was necessary to haul along sufficient hay as well as grain for horses and mules. Roads were often poor, and as the mule team was light it became necessary to supplement our original outfit with a three-yoke team of oxen and an extra wagon with Mexican driver, to carry along feed. Their only food was cactus (prickley pear) from which the spines had been burnt. The moisture in the heavy leaves often enabled the oxen to go without water for two days at a time, when the supply was limited. With this outfit we were for a time over 70 miles from the railroad. The food which we ate consisted chiefly of beans, bacon, rice, corn bread, ⁶bisuit and coffee, all of which our Mexican cook was good at preparing. Quail and rabbits were plentiful so that we were often enabled to have fresh meat, as the outfit was always supplied with

guns and plenty of amunition.

Our work in the semi-arid region of Texas extended over a period of nearly six months, during which time we covered an area of 4000 square miles, or at the rate of approximately 160 square miles per week.

An account of the outfit and methods of work on a reconnoissance survey in northern Wisconsin will also be of interest at this point, since the conditions in the two sections of country are radically different. The region referred to here consisted of new country either in virgin forest, or cut-over land which had grown up with a dense second growth of popple and birch. Swamps were also numerous, and over extensive tracts forest fires and heavy wind storms had swept, leaving the country in an almost impassable condition. Wagon roads were scarce, but wherever these were found they were used as the starting points for the work. The small towns scattered through the region, and the logging camps supplied a base from which supplies could be readily secured. After the wagon roads were traversed the only way of getting over the remainder of the country was to walk, and the lightest camping outfit obtainable was selected, and the area was so divided up that by taking camping trips of from one to two weeks each all portions of the region to be surveyed could be reached, and a sufficient food supply could be carried along for each trip.

Each party consisted of two men who worked together the greater portion of the time. One member of each party was a soil expert and the other a compassman. Each man was supplied with a pack sack in which was carried a food sup-

ply sufficient for the proposed trip of from one to two weeks. In addition there was one light weight tent, blankets, hand ax, frying pan, and a small bucket for boiling rice, etc. Note books, compass, soil auger, and maps were also necessary in the conduct of the work. When starting out on a camping trip each pack would weight from 40 to 60 pounds. The first camp could usually be established at from 8 to 10 miles from the base of supplies and work carried on from such a point for a couple of days, when camp would be moved several miles again.

In this work an effort was made to see something of every section of land, which made it necessary to go over parallel lines two miles apart. Work was started each day from some section corner, and by the use of the compass the section line was followed, and as many as possible of the section corners were located. The compassman attended to keeping the proper course, and counted paces to keep the location, and the soil man examined and mapped the soil. While in camp each man did his share of cooking, making fires, washing dishes, etc.

Travel through this region was often very difficult. Slowest progress was made while crossing swamps in which there was a dense growth of alder or cedar, or where fires had run through, and where there was a dense tangle of fallen trees, stumps, brush, and vines. Over such a course it would sometimes take one hour to go half a mile. In the open virgin forest two miles an hour was considered about the maximum rate of progress that could be kept up all

day. In the making of a general survey of this kind under such conditions it will be readily understood that it requires good judgment, as well as a strong healthy body, and the good nature of an optimist. Progress in reconnoissance work in wooded regions such as northern Wisconsin is much slower than in semi-arid regions as southwestern Texas. Under the Wisconsin conditions, which are typical of a very large scope of country in Michigan, Wisconsin, and Minnesota, the soil survey progressed at the rate of from one to two townships per week, depending upon the distance from the base of supplies, and the character of country being surveyed.

In detail work of the soil survey an area usually consists of a county, and the unit of mapping is 10 acres. The work is usually conducted by parties of two. Headquarters are established at some central place, usually the county seat, and the surveying operations started from this point. If there is no reliable base map of the area one must be constructed by the use of the plane table as the soil mapping progresses. The amount of detail which is shown varies somewhat, but some portion of every 40-acre tract of land should be seen. Usually every section line is followed, and one trip taken across on a quarter line. Side trips from these courses are taken whenever surface features of other factors indicate that there is some variation in the soil back from these lines of travel. Where extensive open marshes occur, or where there are large areas of uniform soil, as in prairie regions, the necessity for getting over the country in this amount of detail is not so great as where the soils are

complicated and change radically within short distances. In making a detail survey of a region a team and buggy can be used to advantage. The soil in the fields along the roads can be examined by the man with the team while the other man crosses the section. It is customary for the men to alternate in the taking of these cross section trips. The men can usually return to town each night, but when the distance becomes too great, accommodations can usually be secured with farmers, and thus the field work carried on without the loss of time in taking long drives. Trips of several days or a week out from headquarters can usually be planned to advantage after the work is well under way. All the equipment necessary, for detail work such as soil auger, plane table, sacks for taking samples, etc., can readily be carried in the buggy.

The progress possible in a detail survey will depend upon the uniformity of the soils, and the character and number of the roads over which it is possible to drive. Where soils are uniform as in a prairie region the progress may be as rapid as in reconnoissance work where the difficulties are most numerous. On the average 36 square miles per week is considered a fair rate of progress for a party of two men, while it may vary all the way from 10 to 40 square miles per week.

The taking of samples for laboratory study is important, and in both detail and general work several samples of both soil and subsoil are taken from each type mapped. These are selected so as to be typical of the soil they represent.

CHAPTER IV

VALUE, USES, AND COST OF A SOIL SURVEY

While the Federal Government has been making soil surveys and soil maps for the past 16 years, the large number of uses to which such maps can be put, and the great value of work of this character is just now beginning to be fully appreciated by both the practical and scientific men throughout the country. It would be impossible to estimate with any degree of accuracy the value to the country in dollars and cents of such soil investigations as are now being carried on. While the object of soil survey work is primarily to aid in the agricultural development of the country, there are a number of lines quite distinct from agriculture along which the results of the soil survey work are being found very useful.

In the first place, a soil survey provides an accurate, up-to-date map of the region covered. This map shows all cultural data, such as roads, streams, houses, schools, churches, town and county boundaries, and frequently the contour lines indicating the elevation, and configuration of the surface of the land are also shown. In addition the soil map shows in colors the location and extent of all the different classes and types of soil which occur in the region surveyed.

A soil survey of a newly developing region is of value to a prospective settler, since from it he can learn the character of the soil, extent of settlement and development, crops which are being grown, cost and methods of clear-

ing land, something of the transportation facilities, climatic conditions, labor problems, and other factors and conditions prevailing in the region to which he may desire to go. It would not be advisable to purchase land entirely on the strength of a soil survey report, but such a report and map will direct a man and be of valuable service in selecting a farm in a location best suited to the line of farming which the prospective settler may wish to follow. It gives reliable, unbiased information concerning the soil and its crop-producing powers which could not be supplied in any other way. A satisfied homeseeker is a valuable asset to a region, and if soil maps are consulted by prospective settlers they will know to what kind of a country they are going.

In regions which are well settled the soil survey is of value to the resident farmer by pointing out and assisting to solve the problems with which he may meet on his farm. The survey is often able to detect difference in the soil or subsoil which the land owner did not know existed, and these differences sometimes account for the variation in crop yields.

The survey outlines the extent of each soil type, determines conditions relative to soil acidity, makes a study of the physical properties of the soil, and their relation to crop production. The soil report brings to the farmer not only a description of his own soil, but it also brings to him results which have been obtained by experiments conducted on the same type of soil. If one line of farming, for example, has given especially good results on one type of soil in a given county, it is reasonable to assume that wherever the

same type of soil occurs under similar conditions it will respond to the same line of treatment as in the first instance. The farmer would learn through the results of the soil survey work that his soil was adapted to the same system of farming, and by following this up his yields and net returns could be materially increased.

The soil map and soil survey report of any region stimulates within that region a greater interest in the study of the soil and all agricultural problems. When the owner of a farm receives a map of the county in which his land is located, his first thought is to see how his farm has been mapped. It may be that the mapping will not in all cases conform to his judgment of how the soil should have been mapped. He will turn to the report to see how the various soils are described, and he may go into the field and examine the physical properties of the soil to which attention may be called by the report. If soil maps and reports were to do no more than to stimulate and encourage this closer study of the soil they would, through this avenue alone, much more than pay for their making, for when one has sufficient interest in the soil on his farm to make a careful study of its properties and behavior, the result is certain to be seen in the development of better farming.

A comparative study of soils can only be made to best advantage when the soils have been classified and mapped according to some uniform established rule. Home-seekers, real estate men, farmers, students, scientists,

and experiment station workers are all more or less interested in comparing soils in one section of the country with soils in some other region. The results of soil survey work provide about the only means through which such a comparative study can be made. This comparative study is necessary in applying results of experimental work.

There are a number of special uses which are coming to be made of the results of soil survey work, and a few of these may be mentioned here. Where detail surveys have been made it has been found that the soil map is of great value in making tax assessments. Assessments are often made without any regard to the character of the soil and its producing power. Heavy soils which produce profitable crops have often been assessed the same as lighter soils which have a lower producing power, which of course is unjust. The soil map shows the extent and distribution of the various soils and indicates something of their relative value. Such information should therefore be of value to all communities in properly adjusting the taxes.

Manufacturers of drainage tile frequently make use of soil maps in determining the amount of land in various regions which would be improved by tile drainage. It would be useless to carry on a campaign of advertising drain tile in a region where there was no land that required drainage. In Jefferson County, Wisconsin, the soil map indicates that 19.7 per cent of the county consists of Peat, all of which requires drainage. In addition it indicates that the soils of the Clyde series occupy 25.4 per cent of the county, and

all of these types in this series are low lying and require drainage before the most profitable crops can be secured. By adding these two amounts we find that in this county there is over 45 per cent of the area which requires drainage, a fact which the tile manufacturer is very glad to know.

Large lumber companies are making use of these soil reports. When the purchase of an extensive tract of timber is contemplated the prospective buyer not only wants to know how much timber and what kinds can be cut from the tract, but he also wishes to know what value for agricultural purposes the land will have when the timber has been removed. This knowledge will have considerable to do with the price he can afford to pay for the land and timber.

Bankers and loan agencies make use of the soil maps in placing loans and in determining the value of securities offered.

Not long ago the Board of Normal School Regents of Wisconsin called upon the Soils Department of the University of Wisconsin for a map showing the character of the soils in the northeastern portion of the State where it was proposed to establish a new Normal School. There is much undeveloped territory in that section, and it was thought that the school should be located so as to be readily accessible to the portions of the area which would ultimately be the most highly developed. This, of course, meant that a knowledge of the soils and their distribution would be taken into consideration in the establishing of the school.

Fortunately the State was able to supply a general soil map of the region in question. Numerous other instances could be indicated where special uses are being made of soil survey reports and soil maps, but the above will suffice to point out the extensive field in which work of this character is useful.

The most valuable and the most permanent use which can be made of work of this character, however, is in connection with agricultural experiment station work. The soil survey is basic work and the facts which are collected through this channel must be at the foundation of all experimental work if the greatest possible good is to be attained. It should be evident to all that a thorough knowledge of the soil is essential to the intelligent application of experiment station work. The fact that this one point has not been fully appreciated is believed to be responsible in a large measure for the lack of sympathy which many farmers have for efforts which are being made by experiment stations. Many early investigators were inclined to largely disregard the variations in soil texture, and when certain crops, rotations, and methods of farming gave good results on a test farm, these results were recommended to farmers regardless of the character of soil on the individual farms. Failure can in many cases be traced directly to this disregard of the physical character of the soil.

One great need in agricultural work today is more general recognition of the individuality of soils, a fuller realization of the true meaning of soil differences. Much valuable time and money have been wasted trying to draw

conclusions from experiments conducted upon entirely dissimilar soils. Many of the contradictory and seemingly inexplicable results obtained by different investigators, or even by the same investigator, are undoubtedly due to fundamental soil differences which would have been evident from a comparative field study.

Bulletin 121 of the Illinois Experiment Station reports the results of variety tests of wheat. These were conducted in three sections of the State--northern, central, and southern. The first two were located on a black prairie silt loam of marked fertility; the last upon a white, very acid silt loam of much lower agricultural value. As a result of three years trial it is stated that the Turkey Red variety stood first or among the very best upon the prairie soil, not only in Illinois but also in Iowa. However, upon the light colored silt loam this variety yielded 5.2 bushels per acre less than the Fulcaster, a variety which has been grown on this soil for a number of years. If these wheat variety tests had been conducted upon the "black soils" alone and the Turkey Red, which proved to be the best yielding variety on these soils had been distributed to the farmers situated upon the "white soils" in southern Illinois, it would have resulted in the loss to them of approximately one-third of their wheat crop, as the Turkey Red gave a yield of 11.4 bushels compared with an average of 16.6 for the Fulcaster. This experiment brings out very forcibly the necessity for testing out the variety upon the soil upon which it is to be grown.

It is very interesting to note in this connection that the Turkey Red wheat, which gave the largest yields at the Illinois Experiment Station is one of the poorest yielders on the Ohio Experiment Station at Wooster. This variety has also been tried in North Carolina and Pennsylvania and has proved one of the lowest yielders in both states. The only soils in Ohio upon which this variety has given anything like satisfactory yields are the black soils, which are not very different from those in Illinois.

The fact that some soils are better adapted to certain crops than others is coming to be more fully appreciated each year, but our knowledge of the adaptation of soils to particular crops, or varieties of crops, is yet very incomplete. This lack of knowledge along this line doubtless results in the loss of millions of dollars every year to the farmers of this country. Such knowledge, however, cannot be obtained until the individual soils have been carefully studied in the field, and their extent and distribution determined. It is this class of information that the soil survey is collecting from all parts of the country, and the great value of this work in the higher development of agriculture cannot well be over-estimated.

As experimental work advances it will doubtless be found that varieties of all crops can be developed which will give better results on some one type of soil than upon any other soil. In fact, results already obtained point definitely in this direction, and it will only be a question of time when the farmer will consider what variety of corn he can grow on Carrington silt loam to best advantage, ra-

ther than whether the soil is adapted to corn. It is not only a question of the crop which is best suited to a particular soil, but also the rotation of crops, methods of cultivation and fertilization which are best suited to that soil. Before the best systems of farming can be worked out it is evident that the peculiar characteristics of each soil must be understood. In the large manufacturing establishments the question of the division of labor has been carefully worked out, and each individual has some particular duty to perform. Each individual is making his part of the whole better than he could make any other part, and out from this condition has developed the high efficiency of large manufacturing concerns. Just so there must be a division of labor in the soil, and each soil must be kept busy making the particular crop or series of crops to which it is best adapted. But it can be readily appreciated that before an efficient system can be perfected it is necessary to have a thorough knowledge of each soil and its peculiarities. The supplying of this knowledge for all soils is the mission of the soil survey. It will therefore be seen that the relation of the soil survey to agricultural development is not only an important one, but also a very intimate one, and one which must be given most serious consideration by all interested in the solution of problems rising out of the rapid increase in population, and the necessity for a more rapid increase in the production of food supplies.

The expense of making a soil survey will vary greatly, depending upon the amount of detail which it is desired to

indicate, upon the character of the country in which the work is done, and also upon the uniformity of the soil itself. The Soil Survey of Northwestern Wisconsin, which was made entirely by the State, and which was of a very general character, cost \$.84 per square mile for the field work. This area covered approximately 7000 square miles. Marinette County, Wisconsin, which included 1413 square miles cost approximately \$2 per square mile. This work was done in cooperation with the Federal Government and was in considerable more detail than the area above referred to. Both of these regions were covered by a reconnoissance survey. The general survey of South Texas referred to earlier in this paper cost less than \$1 per square mile for the field work, and this area covered approximately 16,000 square miles. The detail surveys are, of course, more expensive to make. The detail survey of Columbia County, Wisconsin cost approximately \$4.50 per square mile, and the area covers 799 square miles. Kewaunee County which contains only 341 square miles cost slightly more to survey. Where the soils are more uniform than in glaciated regions, such as is represented by these last two areas, the cost is often much less, and a number of detail surveys have been made where the cost for field work did not exceed \$1.50 per square mile. It is seldom that any of the detail work has exceeded a cost of one cent per acre. The cost of publication will bring the total cost of the survey up to a somewhat higher level. A report and map covering a county of average size will cost from 10 to 15 cents per copy. Where the edition is large, say 10,000 or over, the cost per copy

will be several cents less than where the edition is a thousand or less.

When the total cost of this class of work is compared with the great good which it is possible to accomplish it will be seen that the expense is small. The cost of the work, however, must be met at the time when the survey is made and the money must come from funds appropriated for use from year to year. This concentrates the expense within a short period, whereas the benefits to be derived will continue for an indefinite period. Were it possible to spread the cost of a survey of any region over a period of a number of years, and have the region itself elect whether or not such a survey should be made, it might tend to overcome some of the difficulties which now arise in securing appropriations from legislatures for the extension of this class of work.

CHAPTER V

THE SOIL SURVEY AS A BASIS FOR NEW LINES OF USEFUL INVESTIGATION

The work accomplished thus far by soil surveys has directed a great amount of attention to a more careful study of the soil, both by individual farmers and also by scientific workers interested in agricultural development. The management of the soil, so as to secure the greatest possible yields, and at the same time increase the fertility of the land, is a complicated problem, and there is an unlimited field for investigation. The more interest that can be created in this subject the more quickly will the nation be able to meet the demand for a larger food supply.

As a direct outgrowth of the work being accomplished by the soil survey investigations, the State of Wisconsin has recently established what is known as the State Soils Laboratory, and a brief account of this will indicate the extent of the field throughout which this new line of work may develop. While Wisconsin is the only state now taking up work of this kind, it would seem that every state in the United States could well afford to follow in Wisconsin's steps.

The object of the State Soils Laboratory is to make a careful examination and study of individual farms, make a chemical examination and analysis of the soils, and to give instructions and advice as to how the soil

may be permanently improved and its fertility increased.

It is the object to help the farmer become thoroughly acquainted with his soil, its texture, structure, chemical and physical composition, and the methods of cultivation, fertilization, crops best adapted to the different kinds of soil which may be found upon his farm. This line of work has been made possible through legislative action which established the State Soils Laboratory as a part of the Soils Department of the College of Agriculture. Prior to the enactment of this law the college was not in position to analyze soils for private individuals.

The law provides (1) that a representative of the College of Agriculture shall make an examination of individual farms, studying the soils, methods of cultivation, fertilization, crop rotations, etc., (2) Samples of soil are taken, a chemical analysis made, and a written report sent to each farmer giving the results of the examination and soil analyses, and outlining methods for the permanent improvement of the soil. (3) When five or more in a neighborhood unite in requesting this work the representative of the college will make a second visit to the community for the purpose of meeting those interested and fully explaining the results of the analyses, and working out with the farmers or owners detailed plans for the improvement of the soil.

Any farmer or landowner may secure this service by applying to the College of Agriculture. The charge for the work as outlined by the law is considerably less than the actual cost of the work, the difference being made

up by a direct appropriation of state funds.

The cost for the field examination and the chemical analysis of the soil of any tract of land not to exceed 160 acres, when requested by one person is five dollars. If the individual wishes more than one tract examined each additional tract and sample together will cost three dollars. Where five or more persons in one community club together the cost for the first soil analysis for each member of the group is three dollars, and for each additional sample and examination, two dollars.

The call for this class of work has been so great since the establishment of the State Soils Laboratory that the demand cannot be met by the present organization. The aim is to be of direct service to the individual farmer, and to help him solve his soil problems in such a way as to increase the fertility of his land and put dollars and cents into his pocket.

There is another phase of soil survey work which might well be carried on in conjunction with the State Soils Laboratory, but for which no provision has as yet been made. As indicated previously in this paper there are now two well established classes of soil surveys--the general or preliminary, and the detail survey. The only difference between the two is in the amount of detail shown. Ten acres is considered as the unit of mapping in the detail survey, though in some cases smaller variations are sometimes indicated. While this amount of detail is sufficient for outlining the soils of a whole county, and for directing the study of the different soil types,

it is hardly sufficient detail when the soils on an individual farm are considered. Within an area of ten acres there may be several distinct types of soil, all of which would require somewhat different lines of treatment to increase their producing power. It is therefore suggested that there may be a place for a third class of soil survey to be known as the "Farm Soil Survey".

The Farm Soil Survey should include somewhat more than either of the other two classes of surveys and might more properly be called a Farm Survey. It should include a topographic survey of the farm as well as an accurate soil survey. The farm soil map should be in sufficient detail to show all variations of one-fourth acre, and the soil types as now recognized should be split up, possibly into phases, so as to recognize and map variations which are now included with the typical soil. The lines of tile which would be required to drain low, marshy places, should be indicated, and the report should estimate the cost of installing any drainage system which would be required to give the farm proper drainage. Samples of all soils on the farm should be taken and a mechanical and chemical analysis made. A complete history of the farm and its management should be secured, covering the time from when the land was cleared and first cultivated down to the present time. This history should include the crop rotations followed, the methods of cultivation and fertilization, and all facts which might have some bearing upon present condition of the soil and its state of productive-

ness. The cost of such work could be met by charging the farmer a small fee, and by making up the remainder from a direct appropriation, as in the case of the Soils Laboratory.

With such complete data as this in the hands of the soil expert and experiment station worker very definite systems of soil and farm management could be worked out, and it is this class of service which will have to be supplied if the agricultural interests of the country are to attain their greatest possibilities.

As soil survey work advances, and as the demand for specific information concerning the management of different soils increases, it is becoming apparent that there should be at hand a larger fund of facts concerning the most extensive soil types which occur in any state. Each experiment station has a number of branch stations located at various points, and these are doing excellent work. In many cases, however, the location of these stations did not take into account to a sufficient extent the character of the soil, and the extent of the region which the branch station would represent. As a result there are extensive types of soil in nearly every state upon which no systematic experiments are being conducted, and when advice for soil management is given for such soils it must be based largely upon results obtained from other soils, which may differ from the soils in question.

The establishing of branch station farms is expensive, and usually involves more or less political discussion which is often harmful to the cause which should be ad-

vanced. The suggestion is therefore made that a somewhat different system might be followed. When soil surveys have been completed over enough of any state so that a fair estimate can be made of which will be the most important soil types the following plans might be found desirable:

Four or five farms should be selected which are located on a soil which is typical of a large area. These farms should be made up largely, or possibly entirely of this one soil, and the farmer should be an intelligent man willing to cooperate and interested in the plan of work. This set of farms should be kept under very close observation and records taken of all farm operations. The system of farming to be followed should be worked out by the observer in conjunction with the farmer, and but little small plot work attempted. Everything should be on the usual scale of the average farm. The observer should visit every farm every couple of weeks, and remain on each a sufficient time to keep in close touch with all operations, and the development of the crops. A similar set of farms should also be established on another extensive type of soil, and in many localities these could be so selected that one man could inspect two or three sets of farms on as many types of soil. The data which it would be possible to collect in this way should be of great value, and it would also present an opportunity of being of service to each community. Each Soil Test Farm, as it might well be called, would become the center of interest and if properly conducted should be the means of increasing the productivity

of the soil on surrounding farms, as well as on the test farm itself. The data collected would also be of service to the Experiment Station by providing the best systems of farming which could be recommended in other portions of the state where the same soil types were found, and where other conditions were similar.

Since the development of the agricultural interests of the country are essential to the welfare of the nation it is important that every effort should be made to improve the soil, for the soil is the nation's greatest asset, and forms the corner stone upon which our present and future prosperity is based. The foregoing is therefore submitted with the hope that it may aid in some small degree in perfecting methods for the permanent improvement of the soil, and in helping to solve the problems of agricultural production.

SUMMARY

Agriculture is the most important industry of this country. Our population, however, is increasing more than twice as fast as is agricultural production, and this fact presents a problem which should be given most serious consideration. An increase in the acreage devoted to crop production will assist in meeting the situation, but the problem cannot be solved in this way alone, for the total land area is limited, and this limit will soon be reached. Probably the only way in which the development of a most serious situation may be avoided will be to perfect systems of farming which will insure a gradually increasing return from each acre of land. In order that this end may be attained and the nation's food supply made to keep pace with the increase in population, a thorough knowledge of the soil is essential. But the soil is a complicated factor and varies greatly, so that all differences, gradations, and phases must be carefully studied before efficient methods of soil improvement can be devised. The making of a careful study of the soil, outlining the extent of all soil types on published maps, and preparing reports covering the soils and agricultural possibilities of any region is the mission of the Soil Survey. This is basic work and should precede and serve as the foundation for all agricultural experimental work undertaken.

Briefly stated a soil survey may be considered as an inventory of the soil resources of a given region. The soil is studied in the field and classified into types,

classes, and series, chiefly on the basis of texture, structure, color, origin, and chemical composition, and maps are constructed which show the extent and distribution of the different soil types.

Soil surveys are of two kinds, reconnoissance and detail. The reconnoissance may be considered as only preliminary or very general, while in a detail survey the country is covered much more closely, and a very careful study is made of all soil variations. Tracts as small as ten acres are mapped.

In the field the soil is examined by means of a three-foot auger, and tests are made a sufficient number of times to keep account of the soil variations. Maps are constructed as the field work progresses, by the use of plane table, odometer, etc., and the various soil types are represented on the map by means of different colors. Samples of all soils are collected for mechanical and chemical analysis.

The results of soil survey work are of value to prospective settlers, to the resident farmer, the real estate dealer, the agricultural student, experiment station workers, to various manufacturing concerns, and to men engaged in various lines which depend largely upon the agriculture of a region. Probably the most important use which can be made of the soil survey of any region is to aid the experiment station workers in perfecting methods of cultivation, crop rotation, and fertilization best adapted to each soil type. Through this avenue yields per acre should be increased and the food supply for the nation maintained.

The cost of soil survey work varies with the amount of detail to be shown and the character of the country in which the survey is made. Detail surveys seldom exceed one cent per acre, while the general surveys will doubtless average less than one-fifth of a cent per acre.

The soil survey also forms the basis for new lines of investigation and service. One of these is the work of the State Soils Laboratory which has been established in Wisconsin. This provides for making a careful study of the soils on individual farms, the making of chemical analysis, and the working out of plans for the permanent improvement of the soil.

In this same connection it has been proposed that detail farm soil surveys could be made to advantage, and simply carry the soil survey work already established, one step further by mapping individual farms on a large scale so as to show variations of one fourth acre. A topographic survey would also be made to outline lines of tile required to drain low places. The history of the farm, and all methods of cultivation, etc. would be recorded. With such a fund of information the soil expert and experiment station worker would be enabled to outline methods of soil improvement which should be of great value.

In addition to the above, Soil Test Farms are proposed. This would mean having several farms on each important typical soil type in a state, all under careful observation. The methods of farming followed to be worked out by the observer and the farmer and careful records kept of all operations, yields, cost of production, etc., so as to assist the scientific workers in perfecting the methods and types of farming best suited to each important soil.

