KANSAS STATE AGRICULTURAL COLLEGE.

Agricultural Experiment Station.

Bulletin No. 199.

CHEMICAL ANALYSES OF SOME KANSAS SOILS.

MANHATTAN, KANSAS.
JUNE, 1914.

KANSAS STATE PRINTING OFFICE.
W. C. AUSTIN, State Printer.
TOPEKA. 1914.
5-2694

FOREWORD.

THE importance of the stored elements of fertility contained in Kansas soils, the value of knowledge concerning its amount, and the necessity for its conservation, has been recognized by those in the Department of Chemistry since the earliest years of the College.

In 1899 the Experiment Station council authorized the department to begin the collection of typical soils of the state, with a view to analyzing them. This work had no more than begun, however, when the chemical laboratory was burned, May 31, 1900, and the lack of facilities of any sort for this kind of work made it necessary to suspend it altogether. Funds were not available to enable this work to be undertaken in a satisfactory manner until 1909, when it was begun in earnest, and has been continued to the present time.

The Bureau of Soils of the United States Department of Agriculture had made a general survey of several typical counties in different parts of the state, and it was thought best, in the first instance, to restrict sampling to these areas, in order to take advantage of the classification and mapping of soils that had been done by that bureau. Some attention has also been given to the geological formation from which the soils have been produced, making use, for this purpose, of the geological map prepared by Prof. E. Haworth of the University of Kansas.

An important part in the plan, which it has not been possible to carry out in every instance, is to make a study of the depletion in the soil fertility that has taken place under tillage. To do this it was hoped that parallel samples might be taken from fields that had been under long cultivation, on the one hand, and from adjacent areas that had been kept in grass, on the other. The difficulties in accomplishing this are such that this feature has not been made as strong as would be desirable.

The entire charge of collecting the samples, including the very important matter of selecting the areas from which samples have been taken, has been in the hands of Prof. C. O. Swanson. He has also had entire general charge of the analytical work, and has prepared this bulletin.

Mr. C. E. Millar has been in immediate charge of almost all of the chemical work recorded in this bulletin, but a few of the earlier samples were analyzed by Mr. H. C. McLean. The manuscript for this bulletin was read by Prof. L. E. Call, of the Department of Agronomy, and Prof. E. C. Johnson, superintendent of Farmers' Institutes, for whose suggestions thankful acknowledgments are hereby made. The undersigned has also read the manuscript and assisted in every way possible.

J. T. WILLARD

TABLE OF CONTENTS.

LIST OF TABLES.

CHEMICAL ANALYSES OF SOME KANSAS SOILS.

By C. O. SWANSON.

CHEMICAL COMPOSITION AND RELATION TO CROP PRODUCTION.

AREAS COVERED BY THIS REPORT.

The systematic sampling of Kansas soils for chemical analysis was undertaken in the summer of 1909. The plan adopted was first to sample those counties or areas which had been surveyed by the Bureau of Soils of the United States Department of Agriculture. The areas surveyed at that time were: a portion of Labette county; all of Allen county; the Wichita area, comprising a portion of the eastern half of Sedgwick county and a portion of the western half of Butler county; all of Brown county; all of Riley county; the Russell sheet, comprising the greater central portion of Russell county; the Garden City area, comprising portions of Finney and Gray counties, the greater section being in the former county. The type names are those given by the Bureau of Soils.

By taking samples first in the areas surveyed, great advantage was gained through work done already by the Bureau of Soils of the United States Department of Agriculture. The work of this Bureau consisted principally in mapping and describing the different soil types, and making mechanical analyses, and the published results were found very helpful in taking the samples and in the discussions which follow.

The areas above mentioned, which were surveyed before the year 1911, have all been sampled for chemical analysis,* and the results of the analyses are included in this report. The counties or portions of counties which had been surveyed before the year 1911 are well scattered over the state. This is a very fortunate situation. The work done is not only

* Samples from Labette county are reserved for a future report.

representative of the areas surveyed but of large sections surrounding these counties. The same types found in these counties are also found in the adjoining counties.

MEANING OF SOIL TYPES AND THEIR FORMATION.

A soil type which is predominant in a county is sampled in several places. Such types present several variations, which are sampled whenever possible. It is impossible to sample all the different shades of the type, and only those are included which are most pronounced. The types which occupy a relatively small area are sampled in only one or two places. Such types may show as much variation as those which are more extensive, but the number of samples must be limited in order that the means available may serve as large a section as is consistent with good work.

All types shade gradually into one another; in some places the line of demarcation is more noticeable than in others. A soil type is determined by the original rock or the material out of which the soil was formed, and also by the method of formation. Granites, limestones, shales and sandstones tend to produce different types of soil because of the fundamental differences in the character of these rocks. This is particularly true of the soils classed as residual. These have been formed in place from the disintegration of rocks. Wherever a residual soil is found the rock out of which it was formed usually lies at some depth beneath the soil. Residual soils are at times shallow as compared with soils classed as transported. In some limestone and sandstone soils the rock lies only a few feet beneath the surface, and on slopes and hillsides soil removal has often kept pace with soil formation, and the soil is so shallow that the land is classed as rock outcrop. Such land will forever remain unprofitable for agriculture. This is true only of small areas. By far the greater portion of the residual soils are of sufficient depth to be fertile.

Transported soils are formed from disintegrated and partially decomposed rock, but instead of remaining in place the material has been carried great distances by water, wind or glaciers. Soils transported mostly by water are called alluvial, those transported by wind are called loess, and those transported by glaciers are called glacial. The glacial soils of the United States lie mostly north of the Ohio and Missouri rivers.

In Kansas these soils are found north of the Kansas river and east of the Blue. In many places the glacial drift is covered with a loess deposit. In a few places the entire glacial drift has been carried away and the soil is either residual or alluvial. Alluvial soils are found mostly in river bottoms. Wind-formed soils, or loess deposits, cover a large part of Kansas. In the same field part of the soil may have been transported by water and part by wind, and in glacial areas part may have been transported by ice in addition to the other two agencies.

Water in motion has carrying power. This is a fact known to every observer in the country. This carrying power increases sixty-four times every time the velocity is doubled. Every streamlet carries soil from higher to lower ground; the size of the particles carried depends on the velocity of the water. This is the great factor in soil erosion or washing. Where the soil is composed mostly of fine clay or silt the amount of material carried by the water is enormous, particularly in hilly sections of the country. As the water approaches the foot of a hill the velocity decreases and some of the material is deposited. The sorting power of water is due to variation in velocity. Because this velocity varies on account of a constantly changing level, the soil on the top of the hill is different from that on the side, and that on the side is different from that at the foot. This effect is very pronounced in some places; in others it is less marked. Alluvial soils, as a class, show a very great variation. This follows from the mode of formation. The lowlands have been enriched by material from the uplands; land at the foot of the hill has been enriched the same way.

The material out of which soils have been formed and the agencies of soil formation have produced the various soil types. The principal materials which determine a type are the varying amounts of gravel, sand, silt, clay, and organic matter. These have various degrees of fineness. The proportions in which these are present determine whether a soil is gravel, sand, loam, silt, clay, or peat. A fertile soil never consists wholly of one of these materials; and the materials, such as sand or gravel, which give the distinctive name to the soil, often comprise much less than half of the total soil. The proportions in which these materials are present in a soil may be determined by inspection and by mechanical analysis.

FACTORS OF FERTILITY.

All the substances in farm crops have come from the air, the water in the soil, and the soil itself. While the portion which the soil contributes is the smallest in amount, yet from the standpoint of soil fertility it is the most important part. Farm produce consists of water, ash, and organic matter. The ash varies from one and a half to two per cent in the corn and wheat grain to eight or ten per cent in hays and coarse fodders, All the substance present in the ash has been obtained from the soil. The water comes from the soil into the plant tissues, and the organic matter is built up from water and from substances present in the air. By organic matter is understood such substances as are produced by plant or animal life. Such organic matter will burn in the ordinary sense of the term, and possesses potential energy. While the bulk of farm substances are built up of such materials as are absolutely free to all, yet it is impossible to grow plants in the absence of certain elements found in the soil.

ELEMENTS FOUND IN FARM PRODUCE.

The organic matter and the ash in plants can be separated into different substances or compounds, and these again into elements. (When a substance is separated into such ultimate components that further separation is impossible, we have elements.) Certain elements are familiar to all. Copper, zinc, silver, gold and mercury are familiar forms of metallic elements. Carbon, the most familiar form of which is pure charcoal, is the basic element in organic material. Oxygen, hydrogen and nitrogen are gases. Ninety-nine per cent of the air is made up of a mixture of oxygen and nitrogen.

The greater portion of the soil and agricultural products is made up of sixteen elements. These sixteen are so predominant that they are in fact the only elements of any consequence in farm produce. They may be divided into four groups: (1) carbon, hydrogen, and oxygen; (2) nitrogen, phosphorus, potassium, and calcium; (3) magnesium, sulphur, and iron; (4) silicon, aluminum, sodium, chlorine, manganese, and titanium. The elements in the first three groups are absolutely necessary to all farm crops. Those in the first group are obtained directly from the air and water, and occur in abundance or the needs of all farm crops. The elements in the second group are obtained directly from the soil by most plants, and are the ones likely to be deficient. Those in the third group are usually supplied in abundance by most soils. The elements in the fourth group are not necessary for the physiological functions of farm plants, but, together with oxygen, they make up the greater portion of the soil, and are important from the standpoint of soil physics. The elements in the first group come from the water and the air, while all the rest come directly from the soil. The legumes form a partial exception to this, in that they can take a part or all of their nitrogen from the air. From ninety to ninety-eight and one-half per cent of all plants is oxygen, hydrogen, carbon, and nitrogen.

ELEMENTS AND COMPOUNDS.

When elements unite they form compounds, or those substances with which all are familiar. Oxygen and hydrogen form water; and if carbon in addition is a part of the compound, such substances as starch, sugar, cellulose and fats are formed. Further, if in addition to these three, two others, namely, nitrogen and sulphur, are in the compounds the proteins are formed. Familiar examples of these are the white of eggs and the curd of milk. Some proteins also contain phosphorus. Four elements, carbon, hydrogen, oxygen and nitrogen, make up the greater part of all agricultural products. When plant or animal substances are burned they largely pass off with volatile products. Some of the sulphur also passes off in the volatile matter, and in case of intense heat a small per cent of some of the others. Practically all the other elements remain in the ash. The carbon, hydrogen and oxygen in the process of burning form water and carbon dioxide, and can again be used directly by other plants, while the nitrogen is not available to any plants but the legumes. Carbon dioxide is also formed by the slow combustion of all plant and animal substances and by the respiration of animals.

Some elements in the ash are united with oxygen and are called oxides, and others in addition to oxygen are also united with carbon dioxide and are called carbonates. Pure limestone or marble is an example of a carbonate, and quicklime an example of an oxide. Most oxides are very soon changed to carbonates if they are exposed to the air. When the ash of plants is added to the soil the elements present in it again become available for the use of other plants.

SOLUBILITY OF PLANT FOOD.

In the soil the ash elements exist as compounds. The greater portion of these are insoluble in water. Before any element can enter a plant the compound in which it is must become soluble. These compounds are slowly made soluble for the use of the plant by the action of physical, biological and chemical forces. Cultivation of the soil, under the control of the farmer, assists these forces. Decay of manure and organic matter does the same.

ESSENTIAL AND NONESSENTIAL ELEMENTS.

The elements belonging to the first three groups named above; namely, carbon, oxygen, hydrogen; nitrogen, phosphorus, potassium; calcium, magnesium, sulphur, iron; are called the essential elements, that is, a plant can not live and produce fertile seed in the absence of any one of them. An essential element forms a part of the building material out of which the plant tissue is made or is indispensable in the building processes. The elements of the fourth group are nonessential to plant life. That is, plants will grow and bear fertile seed in the absence of any or all of them. Their presence in the ash of plants is usually accidental.

Whether or not an element found in the ash of plants is indispensable or not is determined by experiments. A seed bed is prepared in which all but one of the elements are present in proper amounts. If the plant fails to grow to maturity and bear fertile seed the missing element is indispensable for the plant's life. In this way it has been found that nitrogen, phosphorus, potassium, calcium, magnesium, sulphur and iron must be present in the seed bed, while the elements silicon, aluminum, sodium, chlorine, manganese and titanium may be absent. In the absence of any of the elements classed as indispensable the plant will sprout and grow for a while and will then die. This is due to the fact that some of this element is present in the seed itself. The amount of this indispensable element present in the seed and plant is the cause of depletion of soil fertility through the removal of crops.

It should be mentioned that the elements which are classed as nonessential may have some physiological function in plant nutrition of which we are now ignorant. It may be that in the absence of some of them plants would not produce fertile seed after several generations, or the health of the plant might not be maintained. But there is always an abundance of these elements present, and while some of them are very important in soil physics they need not be seriously considered in the problem of soil fertility. There are also present in the soil very small amounts of other elements not mentiond here, but the value of their presence or absence is not known.

PLANT FOOD REMOVED FROM THE SOIL BY VARIOUS CROPS.

In Table I* are given the quantities of each of the elements which ordinary crops take from the soil. Crops vary somewhat in this respect in different places and from year to year, but these amounts represent averages. In the three grains, corn, oats and wheat, the seeds remove a larger proportion of nitrogen and phosphorus than the straw. The other elements are found in greater amounts in the straw than in the seeds. Thus in grain farming nitrogen and phosphorus assume the first importance. When the straw also is sold or removed from the field potassium, calcium, magnesium and sulphur assume much importance.

DEPLETION OF SOIL FERTILITY BY CROPPING.

All crops taken from the land remove plant food. In one hundred bushels of corn there are seventeen pounds of phosphorus. The continuous removal of phosphorus will after a time exhaust the crop-producing power of the land. The plant food which is most easily made soluble is removed first. When this is used up the average crop yields per acre decrease. In systems of farming where the seed crops are removed, and nothing is returned to the soil, the average yield of crops will tend toward an equilibrium. Such is the condition of the soils of southeastern Russia, where the average yield of wheat for twenty years (1883-1902) was eight and one-fourth bushels per acre. Also in India, where land has been cultivated for over two thousand years, and the average is either ten bushels of wheat per acre or one hundred pounds of cotton lint. Such an average and a high scale of civilization is possible only when large areas can be farmed by one man and the population is sparse. But with the increase of population must come an increase of average production per acre if

* These data have been compiled from various experiment station publications.

a high degree of civilization is to be possible. The low average production per acre in Russia and India is responsible for the famine years. A fall from eight and one-fourth to six and one-fourth bushels per acre in Russia produces a famine, the latter being the average for the famine years. With a higher average production per acre, a decrease of two bushels per acre would not cause a famine.

COMPARISON OF ALFALFA AND GRAIN CROPS IN RESPECT TO PLANT FOOD REMOVED.

By many farmers hay crops are not considered as exhaustive of soil fertility as the grain crops. This is contrary to the facts. One season's crop of six tons of alfalfa uses as much nitrogen as four forty-bushel crops of wheat, or four fifty-bushel crops of corn, or eight forty-bushel crops of oats. The same six tons of alfalfa would remove more phosphorus from the soil than two forty-bushel crops of wheat or two fifty-bushel crops of corn, or more than four forty-bushel crops of oats. To remove the same quantity of potassium as six tons of alfalfa would require six forty-bushel crops of wheat, eight fifty-bushel crops of corn, or ten forty-bushel crops of oats. This takes into account not only that which is present in the grain, but in the straw and stalk. Such products, however, are seldom sold from Kansas farms.

It is true that nitrogen is absorbed from the air by the alfalfa, but the maximum, under average conditions, taken from the air is that present in the hay, and nothing is added to the soil to compensate for the very large amounts of phosphorus and potassium removed. If alfalfa is sold off the land it is one of the most soil-exhausting crops raised, while if it is fed on the farm, and the manure produced applied to the land, it is a conserver of fertility. The same argument applies to clover. Clover and alfalfa fail on old, exhausted land for the same reasons as do grain crops. They will not grow on land which has lost its plant food any more than will corn, oats or wheat.

The observation is generally made, that after land has been cropped with alfalfa, even if no manure is returned to the soil, it produces better grain crops than does land not so cropped. This seems true in spite of the fact brought out by chemical analysis that the alfalfa has removed more plant food than would corn, oats or wheat grown on the same kind of land.

TABLE I.—POUNDS OF PLANT FOOD REMOVED BY CROPS.

PRODUCE.	Amount per acre.	Nitrogen.	Phosphorus.	Potassium.	Calcium.	Magnesium.	Sulphur.	Iron.	Sodium.	Chlorine.	Silicon.
Winter wheat, grain	40 bushels.	56.8	9.6	10.4	0.8	3.2	3.4	0.2	0.3	0.1	0.4
Winter wheat, straw	2 tons.	20.0	3.2	36.0	7.6	3.2	4.9	1.2	2.0	3.2	59.9
Totals	....	76.8	12.8	46.4	8.4	6.4	8.3	1.4	2.3	3.3	60.3
Corn, grain	50 bushels.	50.0	8.5	9.5	.7	3.5	4.3	.2	.2	.3	.4
Corn, stover	1½ tons.	24.0	3.0	26.0	10.5	5.0	3.0	2.4	1.2	1.9	18.1
Totals	....	74.0	11.5	35.5	11.2	8.5	7.3	2.6	1.4	2.2	18.5
Oats, grain	40 bushels.	26.4	4.4	6.4	.8	1.6	2.6	.2	.5	.4	8.2
Oats, straw	1 ton.	12.4	2.0	20.8	6.0	2.8	3.4	1.1	2.4	4.3	21.8
Totals	....	38.8	6.4	27.2	6.8	4.4	6.0	1.3	2.9	4.7	30.0
Alfalfa hay, early bloom	6 tons.	300.0	28.0	290.0	130.0	22.8	16.8	....	9.6	22.8	33.6
Red Clover hay, early bloom	3 tons.	120.0	15.0	90.0	87.8	23.3	8.2	3.0	5.0	13.0	4.3
Potato, tuber	100 bushels.	21.0	4.3	30.0	1.2	1.8	.5	.2	1.4	2.2	.6
Apple, fruit	300 bushels.	23.5	2.5	28.5	1.4	1.4	.6	....	5.7	....	.6
Prairie hay	1½ tons.	25.5	3.0	24.9	....	....	....	....	....	....	....

There are two reasons for this temporary improvement in the crop-producing power of the soil: (1) The alfalfa is a very deep-rooted plant. The soil has been made open and porous to a greater depth than is possible with corn, oats or wheat. The subsoil has been stirred, and the same agencies which made the soil out of the original rock have had a chance to make some of the plant food in the subsoil soluble. (2) The alfalfa roots decay very easily; thus humus is formed, and the roots in the process of decay help to liberate more plant food. These roots are rich in nitrogen, phosphorus and potassium in such forms as are rapidly made available to plants. (3) The alfalfa materially increases the quantity of available nitrogen in the soil, and this element is of prime important in grain production. The increased power of crop production on alfalfa land may, therefore, be only temporary unless the alfalfa has been fed and the manure carefully husbanded and returned to the soil.

ULTIMATE SOURCE OF FERTILITY ELEMENTS,

Table II shows the occurrence in the earth's crust of the elements most important in the formation of soils and the growth of plants. It is based on the computations of Prof. F. W. Clarke, of the United States Geological Survey.

TABLE II.—COMPOSITION OF THE EARTH'S CRUST. PERCENTAGES.

Oxygen	47.07	Carbon	0.20
Silicon	28.06	Chlorine	.07
Aluminum	7.90	Phosphorus	.11
Iron	4.43	Sulphur	.11
Calcium	3.44	Manganese	.07
Magnesium	2.40	Nitrogen	Trace
Sodium	2.43	All other elements,	0.64
Potassium	2.45		
Hydrogen	.22		100.00
Titanium	.40		

Table I shows that of the elements obtained by plants from the soil, nitrogen, phosphorus, and potassium are used in the largest amounts.

Table II shows that nitrogen and phosphorus, the elements which are used in the largest quantities in growing grain, are least abundant in the earth's crust. In comparison with the other elements the nitrogen present amounts to only a trace, and the phosphorus only eleven-hundredths of one per cent.

This table gives the average for the earth's crust as a whole. The average quantities in Kansas soils as far as analyzed are given in Table III.

TABLE III.—AVERAGE COMPOSITION OF 117 KANSAS SOILS BY CLASSES. PERCENTAGES.

		Nitrogen.	Phosphorus.	Potassium.	Calcium.	Organic carbon.
Average of gray silt loam	Soil	0.187	0.043	1.42	0.55	2.15
	Subsurface	.119	.045	1.45	.55	1.22
	Subsoil	.067	.038	1.46	.58	.72
Average of limestone clay loam	Soil	.202	.052	1.80	.75	2.39
	Subsurface	.167	.061	1.71	1.03	1.46
	Subsoil	.080	.045	1.72	2.11	.83
Average of alluvial loam	Soil	.158	.051	1.95	.65	1.69
	Subsurface	.113	.048	1.92	.67	1.15
	Subsoil	.071	.047	1.89	1.19	.102
Average of alluvial clay	Soil	.219	.062	2.02	.59	2.34
	Subsurface	.110	.058	1.98	1.71	1.07
	Subsoil	.069	.045	1.92	1.88	.65
Average of sandy loam	Soil	.122	.032	1.46	.95	1.25
	Subsurface	.080	.032	1.48	.42	.72
	Subsoil	.054	.058	1.50	.57	.44
Average of alluvial silt loam	Soil	.199	.062	1.88	1.16	3.03
	Subsurface	.142	.060	2.00	1.19	1.70
	Subsoil	.075	.060	1.92	1.28	.87
Average of brown silt loam	Soil	.166	.053	1.91	.61	1.83
	Subsurface	.118	.053	1.96	.81	1.21
	Subsoil	.065	.051	1.90	1.09	.59
General average	Soil	0.170	0.047	1.78	0.68	1.96
	Subsurface	.122	.047	1.82	.88	1.21
	Subsoil	.068	.046	1.78	1.21	.77

LOSS OF CALCIUM FROM SOILS.

The element which has suffered the greatest loss in soil formation is calcium. Soils formed from limestone are not necessarily rich in lime.* The average per cent of calcium in 26 limestone-formed surface soils of Kansas is 0.75. The average calcium content in 345 limestones given by Clarke is 30.45 per cent. Limestone-formed soils are made up mostly of the impurities found in the original rock. In the eastern humid section of the United States, where limestone is one of the prevailing rocks in soil formation, soils are often deficient in lime, while in the West, where igneous rocks are the prevailing

* Lime is calcium oxide, or oxide of calcium, a compound of calcium and oxygen, and in accordance with views that now are antiquated, compounds of the metal calcium with oxygen and another nonmetal were regarded as formed by the union of the oxide of calcium and the oxide of the nonmetal. They were, therefore, said to contain lime. The expression is still in general use, and may be employed with no disadvantage if it is borne in mind that a soil does not contain actual lime any more than it contains free, uncombined, metallic calcium. In either case we are dealing with compounds of calcium which usually contain oxygen also. The significant element is the calcium, and if this metal were in common use in the metallic state we should doubtless as naturally refer to the calcium of a soil as we do to the iron of a soil, iron, like calcium, existing in soils only in combination with other elements.

ones, the soils are well stocked with lime, Lime leaches out of the soil faster than any other element.

The average per cent of potassium in 345 limestones given by Clarke is 0.27 per cent. The average per cent of potassium in Kansas soils formed from limestone is 1.80. This shows that potassium does not leach as readily as calcium.

SOURCE AND SUPPLY OF NITROGEN.

While the quantity of nitrogen in the earth's crust in comparison with other elements is reported as only a trace, the nitrogen in 117 surface soils of Kansas is 0.17 per cent. The per cent of nitrogen decreases in the subsurface and more so in the subsoil. Most of the nitrogen in the soil is found in the organic matter. This nitrogen has come originally from the air. The average amount of nitrogen found in an acre of Kansas surface soils, as far as analyzed, is sufficient for nearly 3000 bushels of corn, stalk and grain, while that in the air over an acre of land is sufficient for 50,000,000 bushels, or enough for 500,000 years if one hundred bushels were produced every year on every acre of the earth's surface. The ultimate source of nitrogen is inexhaustible.

WHY NITROGEN MAY BE DEFICIENT.

The quantity of nitrogen present is a serious factor in soil fertility, not because the ultimate source of nitrogen is limited, but because the form in which most plants can use it is limited. Most of the soil, nitrogen is found in the organic matter. Before the nitrogen of this organic matter can take part in building the plant tissue the insoluble organic compounds must be changed to soluble forms. The conditions necessary for this to take place are suitable temperature, moisture, and bacteria. For some of the changes it is also necessary that something capable of neutralizing acids be present. Finely powdered limestone is the best for this. The final stages of decomposition in which nitrates are formed do not take place readily in soils deficient in lime. The acids formed as by-products in the decay of organic matter are very beneficial in making soluble such mineral plant foods as the compounds of potassium and phosphorus. In fact the amount of acid liberated in changing organic nitrogen to inorganic is theoretically seven times the amount needed to make soluble the phosphorus needed for the same crop. In the presence of an abundance of decaying organic matter there is no difficulty about available plant food, provided the mineral plant food is there. The decay and nitrification of organic matter will take care of the question of availability.

VALUE OF LEGUMES FOR SOIL IMPROVEMENT.

When legumes have absorbed nitrogen from the air and stored it in the plant tissues it is not available for the use of other plants until these legumes have undergone decay and nitrification. Because legumes are so much richer in nitrogen than other plants, organic matter from this source is much more valuable than that from plants which are poorer in nitrogen. All substances rich in nitrogen undergo relatively rapid decay. For this reason roots from clover and alfalfa and residues from the same undergo relatively rapid decomposition, which contributes to the beneficial effects of these crops.

IMPORTANCE OF CARBON AND ORGANIC MATTER.

The ultimate supply of an element has very little to do with its immediate importance in crop production. The plants obtain their carbon from the carbon dioxide of the air. Over one acre there is enough carbon for the production of two hundred bushels of corn, while there is enough nitrogen for 50,000,000 bushels. Yet carbon is never added to the soil as a fertilizer, while nitrogen is. The carbon is directly available, while the nitrogen must first be changed from the organic to the inorganic form. In the surface soil, according to the average of all analyses in this report, there is enough carbon for about 700 bushels of corn, or 3½ times as much as in the air, yet the plant does not use this directly. An abundance of carbon in the soil is an indication of a plentiful supply of organic matter. The organic matter of soils usually contains about fifty per cent of carbon. Old organic matter contains a larger per cent of carbon than does fresh. As organic matter decays, the more unstable portions are decomposed first, and the rate of decay decreases with age. Old organic matter is by far less valuable than fresh organic matter. Peat and muck have in themselves very little value if added to a soil, but if mixed with fresh manure or green crop residues they are very valuable. In the words of Dr. C. G. Hopkins, "It is not the presence of organic matter which is most important but the decay of organic matter."

AVAILABLE PLANT FOOD.

The same agencies which formed the soil from the original rock are at work now; they are chemical, physical and biological. Their effect is to liberate plant food. While rock ground into powder may contain all the mineral plant food elements in sufficient quantity, yet such a powder would not constitute a good soil. In common language the plant food is not available. The phosphorus and the potassium, as well as the other elements, are in such compounds that the amount dissolved during one season is not sufficient for the needs of the plant. . This rock powder must be changed in chemical composition so that the compounds are more easily soluble. The agencies which bring about these chemical transformations are very closely related to the weather, and the many complex changes which take place in the rock are included in the term weathering. Freezing is a powerful agency in the disintegration of rocks and rock particles. Rain water always contains carbon dioxide, and this substance dissolved in water is a universal though weak solvent for rocks. Lower plant forms find a place to grow. The growth and decay of plant tissues furnish organic acids which dissolve more rock, and in time higher plants can grow and more organic matter is furnished.

In humid sections it is not possible to have a large amount of soluble plant food stored up in the soil, nor is it necessary or desirable. If plant food is made soluble in larger amounts than the plant can use it may be lost through leaching. Soils in humid sections always contain a smaller quantity of soluble plant food than do soils in arid sections.

MAINTENANCE OF FERTILITY BY SOIL RENEWAL.

A low average of crop production is maintained by the constant renewal of the soil. If this were not the case crop production would cease altogether where no fertilizers or manures are used. This renewal consists in the disintegration of the underlying strata and their conversion into soil, while at the same time the older exhausted soil is washed away. This results in an insensible lowering of the total land surface. This lowering has been in progress ever since land began to be formed from rock. It is estimated that the Appalachian mountain system has been eroded about 5000 feet. The present rate of lowering the general level of the Mississippi valley is estimated to be about one foot in 7000 years. This result is brought about by flowing water which carries matter in suspension. On rolling land the lowering is much more rapid than where the land is more flat. Thus the gentle, insensible erosion is not an unmixed evil. When erosion takes place faster than the weathering agencies can render available the plant food in soil brought to the surface, erosion becomes destructive. This happens on almost every hillside where washing is allowed to take place. In the Southern states thousands of acres of land have been completely destroyed in this way. In Kansas the amount of wealth lost in this way every year is equal to a large fortune.

IMPORTANCE OF A LARGE SUPPLY OF PLANT FOOD.

In order that a soil may produce profitable crops for a long time the elements must be present in large amounts. Lands which contain only a few hundred pounds of phosphorus per acre in the surface soil will not produce profitable crops, no matter what is the physical condition nor where they are located. This is the condition of the Maryland barrens. Though they are located within a few miles of the large cities of the country, they are only worth a few dollars an acre. This holds true as a fundamental principle. If, on the other hand, the soil contains at least 1000 pounds of phosphorus per acre, 35,000 of potassium, and 3500 pounds of nitrogen, and is properly located with regard to drainage and has good physical texture, it will produce good crops.

INFLUENCE OF CALCIUM.

It is a well-known fact that soils well stocked with a supply of lime will be more productive under the same conditions of plant-food content than soils not so stocked. That is, if two soils contain the same amount of nitrogen, potassium and phosphorus, the one richer in lime will be the more productive. Lime will influence the physical condition of a soil so as to produce better texture. It renders available small percentages of potassium and phosphoric acid. Soils rich in lime produce good crops of alfalfa and clover if the physical conditions are favorable for these crops. While crops use very small amounts of lime as compared with phosphorus and potassium, yet the presence of a relatively large supply of lime insures crop production. In the words of Hilgard, "A lime country is a rich country."

THE SAMPLING OF SOILS FOR ANALYSIS.

In selecting a place at which to sample a soil one must make a careful study of all factors which have been operative in the formation of the type. Whoever takes the sample must have a mental picture of the type as a whole in all its variations, and the relation of this type to the neighboring types. If the places are properly selected and the sampling carefully done a few samples will represent large areas with sufficient accuracy. To be of general application, and hence of much value, soil samples must be taken from points which represent a soil type of considerable extent. It is impossible to sample and analyze the soil from every field, but it is possible to correlate the soil in nearly every field with types which have been analyzed.

When the place to take a soil sample has been elected, notes are taken concerning the physical characteristics of the soil, the method of cropping, drainage conditions, yield of crops, farming history, and any other items which seem to be of value in connection with the chemical analysis of the sample. These notes are preserved for reference in the files of the chemistry department, and they, together with the results of the chemical analysis, form the basis of the discussion in this report.

The location of a sample is described by range, township, section, and subdivision, as designated in the United States land survey, ten acres being the smallest unit. By this means it is possible to state the exact place in every field where the sample was taken.

In selecting a place to sample, a careful study is made of the type. Frequent borings are made, using a one-inch auger. Cuts along the road are studied, and the character of vegetation is observed. Also, in selecting the location for a sample, preference is given to a place the farming history of which is best known. This information is obtained from the landowner, if possible, or from the farmers of the vicinity. It is not always possible to obtain reliable information on these points, but the general average represents as good information as it is possible to obtain.

METHODS OF TAKING THE SOIL SAMPLES.

A soil sample usually consists of three portions: soil, subsurface, and subsoil. The first is taken to a depth of seven inches, or more exactly, six and two-thirds inches, the second between seven and twenty inches, and the third between twenty and forty inches. This method is the one used by Dr. C. G. Hopkins, of the University of Illinois, and was adopted by this Station. The first depth represents the soil as it is cultivated in good farming practice. The second depth represents what can possibly be moved with a subsoil plow. The third depth represents the lower feeding ground of most agricultural plants. Ordinary soil to the depth of six and two-thirds inches weighs about 2,000,000 pounds per acre; the subsurface, six and two-thirds to twenty inches, weighs about 4,000,000 pounds, and the subsoil, twenty to forty inches, weighs about 6,000,000 pounds. This makes it easy to compute the pounds per acre of any constituent when the percentage composition is known. The calculation only involves multiplying the percentages of the constituent by two, four or six, as the case may be, with due regard for the position of the decimal point. Thus a percentage of one-tenth of any constituent means 2000 pounds per acre for the surface soil, 4000 for the subsurface, and 6000 for the subsoil. With a little practice it is possible to read the percentages of composition in pounds per acre.

For sampling the top soil a tube made of galvanized iron, a little over two inches in diameter and fifteen inches long, has been found very good. By means of this it is possible to obtain a uniform core from the surface down to seven inches, especially where the soil is loose as a result of recent cultivation. For sampling the subsurface and subsoil a one-and-a-half-inch auger is very convenient. Where the soil is so dry that it runs back into the hole a little water may be used. At least five borings are made for each sample, all of the portions from the surface layers being mixed to form the surface sample, and the subsurface and subsoil portions being similarly united, respectively. The soil sample is designated by a whole number and the different portions by the decimals: .1, .2, and .3, placed after the number. Thus soil samples numbered 1013.1, 1013.2, and 1013.3 mean the soil, subsurface and subsoil from sample 1013.

Occasionally, by reason of peculiar local conditions, only one or two depths are taken. In some places the subsurface or subsoil is so full of small stones that boring is impossible. At other places a surface sample is taken from virgin land to compare with one long cultivated.

METHODS OF CHEMICAL ANALYSIS OF THE SOIL.

The methods used in the chemical analysis of soil may be divided into three classes: (1) solution by water or weak acid; (2) solution by strong acids; and (3) solution by fusion. The first method gives the amount available for the plants' use at the time the analysis is made. It is an index to the immediate productiveness of the soil. This method is very valuable in work where methods of handling the soil and systems of cropping are investigated, but it has no value in a soil survey where it is desired to know the duration of the crop-producing power of the land. The method of solution by strong acids has heretofore been followed by most soil analysts. The amount dissolved by strong acids was thought to represent the plant food which it was possible for the plant to obtain. In this method nearly all the calcium is obtained, about 85 per cent of the phosphorus, and about 20 to 25 per cent of the potassium. Most tables of soil analyses published are on this basis. The fault of the method is that it is relative. It represents the amount of plant food soluble at the time the analysis was made, but this condition changes in a few years. The insoluble silicates, which contain the greater amount of potassium, are continually acted on by the weathering agencies. The decay of organic matter, the freezing and thawing of every winter, changes these compounds of potassium into such as are soluble in strong acids. Because of this the absolute method, that of determining the total amount present, is being more and more adopted by experiment-station workers, and is the method followed in Kansas. This is the fusion method.

If the results obtained by the fusion method are to mean anything, the sample must be very carefully taken. The subsurface and subsoil will show very nearly the same amount of phosphorus, lime and potassium as the surface soil. Yet every farmer knows that if the surface is removed by washing, the land will not produce crops. It takes a long time for the lower soil to become weathered enough to liberate a sufficient amount of plant food for the needs of the crop. The sample must be taken in such a way that it represents the actual condition of the soil.

SOILS OF ALLEN COUNTY.

The Bureau of Soils has classified the soils of Allen county into eleven types. Of these, seven were sampled for chemical analysis. 'The four types which were not sampled are of small agricultural importance. While the type classed as "rough stony land" covers over 12,000 acres in this county, it is so lacking in uniformity that it would be almost impossible to sample it. The chief drawback with this type is the lack of depth. The soil which exists in favored spots would have very nearly the same composition as the "Sedgwick clay loam," described later. 'The only agricultural value this "rough stony land" will ever have is for permanent pasture, and even for such purposes it is poor. These statements about the "rough stony land" are true also of the gravelly loam and the rock outcrop. The other type not sampled is the "Yazoo sandy loam." This is found only in a very small area.

The seven types sampled are named as follows: Oswego silt loam, Oswego fine sandy loam, Sedgwick clay loam, Neosho silt loam, Yazoo loam, Yazoo clay, and Sharkey clay. The complete report of the analyses of these samples is found in Table XXVI in the appendix. From the data in this table is calculated the avarage number of pounds of each element per acre in seven inches of surface soil of each type (see Table IV). From this total average can easily be calculated the number of average crops which will use up this amount of plant food. The method of calculating the number of pounds of plant food per acre is explained in the introductory part of this report. The data given below, which can be used for calculating the relation between the number of crops and the amount of plant food present, are obtained from reports published by Dr. C. G. Hopkins of the University of Illinois.

The pounds of elements needed to produce 50 bushels of corn, grain only, are: nitrogen, 50 pounds; phosphorus, 8.5 pounds; and potassium, 9.5 pounds. For the total crop the figures are: nitrogen, 75 pounds; phosphorus, 11.5 pounds; and potassium, 35.5 pounds. The importance of calcium and carbon in relation to soil fertility is not primarily in the amount used directly as plant food, but as soil improvers. The plants use a smaller quantity of calcium for their physiological functions than of nitrogen, phosphorus or potassium, but the soil needs a comparatively large amount of calcium to serve as a corrective for acidity and as a liberator of the other elements. The carbon in the soil is not used directly as plant food. The plants get their carbon from the air, but as the organic matter of the soil is about one-half carbon, the determination of the latter element serves better than any other determination to indicate how much organic matter the soil contains. No satisfactory method has yet been devised for determining the organic matter in the soil. While the total carbon indicates the amount of organic matter present, it does not tell us much about its condition. As was explained in the first part of this bulletin, fresh organic matter in an active state of decay is much more valuable than old organic matter in which decay is very slow. Yet while this is true, the determination of total organic carbon is at present the most valuable, practical method we have for organic matter.

TABLE IV.—ANALYSIS OF SOILS FROM ALLEN COUNTY.

Type as Given in Soil Survey.	Pounds per acre in two million pounds of surface soil (0-7 in.)				
	Nitrogen.	Phosphorus.	Potassium.	Calcium.	Organic carbon.
Oswego silt loam	4,400	960	27,000	13,400	50,200
Oswego fine sandy loam	3,100	520	16,200	4,800	32,600
Sedgwick clay loam	4,340	860	32,000	9,400	48,000
Neosho silt loam	3,320	520	26,400	7,800	31,600
Yazoo loam	3,460	840	37,000	10,600	36,600
Yazoo clay	5,380	1,180	35,400	8,800	53,800
Sharkey clay	5,340	1,160	36,000	13,600	55,800
Average of cultivated soils (omits the last two)	3,724	740	27,720	9,200	39,800

DESCRIPTION OF SOIL TYPES.

OSWEGO SILT LOAM.

The Oswego Silt Loam is known locally as "gray lands" or "white lands." The color varies from an ash gray to a darker gray. This type, on account of its extent, is the most important in the county, covering more than half its area. Most of it is gently undulating; no hilly or very broken land is covered by this type.

The soil is a gray silt loam. Low-lying areas have a darker color than those on slopes or elevations. The most objectionable property of this soil is the nature of its subsoil. This varies in color from a dark drab to a yellow. The lighter color is associated with a more open texture. This subsoil is a silty clay, compact, stiff and impervious. It is locally known as hardpan. It does not well withstand excessively wet or dry weather. The natural underdrainage is very poor. After heavy rains the water stands till it evaporates. This leaves the soil in a very poor condition to withstand a period of dry weather. The great need of this soil is surface and underdrainage with large application of organic matter. The drainage will remove the excess of water in wet weather, and the organic matter will make the soil more open, easier to till, and leave it in a condition to retain the optimum amount of water.

In Table IV it is shown that the average amount of plant food per acre of surface soil is: nitrogen, 4400 pounds; phosphorus, 960 pounds; potassium, 27,000 pounds ; calcium, 13,400 pounds, and organic carbon, 50,200 pounds. In comparison with the brown silt loam of Brown county this type has a larger amount of nitrogen and calcium but a smaller amount of the other elements. As may be seen by a study of Table XXVI, in the appendix, where the complete analyses of all the samples are given, this type varies a great deal. Some samples contain twice as much nitrogen as other samples. The soils which lie low and receive the washings from the adjacent land have the highest amount of nitrogen. One soil has only 3120 pounds of nitrogen per acre while another has 6080 pounds. The phosphorus content is lower than in many Kansas soils, but not as low as in some which are considered good. The difference, however, is this: soils which have a lower content of phosphorus and still have a greater crop-producing power than these gray soils have a more open texture which gives the roots a larger feeding ground. Any operation which will make these soils more open, such as underdrainage, application of organic matter, and lime, increases the feeding area for the roots, and as a consequence larger crops follow.

Potassium and calcium in these soils average high. The average amount of calcium present in the surface seven inches is equivalent to over 15 tons of ground limestone per acre, but the fact that only traces of inorganic carbon were found indicates that the calcium is present in the form of insoluble silicates. In such forms it is not readily available for the use of plants. It is possible, therefore, that the application of one or two tons of ground limestone per acre may prove beneficial. This ought to be tried experimentally, and the outlay for such a trial is very small considering the benefits possible. While the amount of carbon would indicate an abundance of organic matter, more than the average found in Kansas soils, yet because of the close texture of the soil the organic matter is not sufficient to give the desired results; that is, it contains an abundance of carbon, but very little of that energy or life which is associated with fresh organic matter.

These gray lands are potentially fertile. The application of commercial fertilizers is not advised until the physical condition has been improved by farm manure, underdrainage, and possibly by the application of ground limestone. After this is done it may be profitable to apply phosphorus in some form in order to further increase the crop-producing power of this soil.

OSWEGO FINE SANDY LOAM.

The Oswego fine sandy loam constitutes a type known as sandstone soil, and is gray and sandy. The subsurface and subsoil shade to a yellowish or a reddish brown. These soils lie higher than the surrounding land. This type occurs only in small areas. It is considered a poor type of soil, but as the areas which it covers are small, and are bordered by more fertile lands, the general aspect of the country where these lands are found is one of average prosperity. The drainage is good. The soil is well adapted for corn and broomcorn. It is not well adapted to wheat,

Table IV shows that an acre of surface soil of this type contains, as an average, 3100 pounds of nitrogen, 520 pounds of phosphorus, 16,200 pounds of potassium, 4800 pounds of calcium, and 32,600 pounds of organic carbon. In comparison with the other types in this country, it is one of the very poorest. It is similar to the Neosho silt loam, described farther on, in the amount of plant food, but like many soils of a sandy nature, the physical texture is good, and consequently it is more productive than a silt soil with a like amount of plant food. It is very low in organic matter. The analysis for inorganic carbon indicates that the small amount of calcium, equivalent to six tons of limestone per acre, is present not as the carbonates or limestone, but in the form of insoluble silicates. This soil should respond to the application of nitrogen, phosphorus, and possibly limestone. It also needs organic matter, such as would be supplied by farm manures and green manuring crops.

SEDGWICK CLAY LOAM.

A soil locally known as "red lands" is the Sedgwick clay loam. It is an upland type formed from the weathering of limestone. This limestone occurs in layers alternately above and below the shale which formed the Oswego or the gray silt loam described in the preceding pages. Thesurface is a black or dark-brown clay loam. The subsurface shades to a very dark brown, and the subsoil is red. This brown or red is seen in cuts and on roads where the deeper soil has been put on top of the roadbed.

This soil is well adapted for corn, but is not considered as good for wheat as the gray silt loam. In general it has good natural drainage, only low places suffering in this respect. Alfalfa ought to produce well where the soil is of sufficient depth, but alfalfa is not grown to any extent. It is a strong soil, as is shown by the kinds of weeds which grow along the public highways. The failure of alfalfa is probably due to lack of sufficient soil preparation. In some places the soil is shallow, and shallow cultivation is the prevailing practice, even where the soil is deep. With deep cultivation and thorough preparation of the seed bed there is no reason why alfalfa should not produce well on this soil wherever it is of such depth that enough moisture will be stored.

The chemical analyses of five samples of this type give the following amounts of plant food per acre in the surface seven inches: nitrogen, 4340 pounds; phosphorus, 860 pounds; potassium, 32,000 pounds; calcium, 9400 pounds; and organic carbon, 48,000 pounds. In potassium only does it average higher than the Oswego or the gray silt loam. It is a much more variable type than the latter. That it should actually have less calcium than the soil formed from shale emphasizes the point made in the introductory part of this report — that calcium may be so thoroughly leached out that soils formed from limestone are actually poorer in this element than soils formed from some other rock containing a comparatively small amount of calcium.

That this soil produced better than the Oswego or gray silt loam is not due to the presence of more plant food per acre, but to better physical texture and to the presence of more calcium in the form of carbonate. The subsoil being more open affords a larger feeding ground for the roots. The presence of larger quantities of carbonates renders the plant food more available. The greatest difficulty with this soil in places is lack of sufficient depth. In all places wherever possible it should receive deeper cultivation than is at present practiced. When this soil is very shallow it will always be unproductive in dry years.

NEOSHO SILT LOAM.

The Neosho silt loam is an ashy-gray silt loam, locally known as second bottom. It is, without exception, the poorest soil of the seven sampled. The fine silty nature of the soil gives it the poor physical texture of the Oswego silt loam, without the richness in plant food of the latter. In wet weather it is water-soaked and the plants suffer greatly. When it dries out the soil becomes very hard and large cracks are produced. This affords a rapid escape for moisture, and consequently in dry weather the crops suffer greatly.

The chemical analysis of this type gives per acre of surface soil seven inches deep: nitrogen 3320 pounds, phosphorus 520 pounds, potassium 26,400 pounds, calcium 7800 pounds, and organic carbon 31,600 pounds. It is as low in plant food as the sandy loam, but the sandy loam has the advantage of good drainage and more open texture, which affords a larger feeding ground for plant roots. Only a trace of the calcium is present as carbonate. This soil undoubtedly would profit from the application of ground limestone. It is also in need of large amounts of organic matter. It contains nearly twenty tons less organic matter per acre than the Oswego silt loam. To raise profitable crops it also needs application of phosphorus in some form, but this expenditure will be of doubtful benefit unless the drainage conditions are improved and the chemical and physical properties improved by the application of lime and organic matter from legumes.

YAZOO LOAM.

The Yazoo loam is the most extensive and most valuable of the bottom soils. It is formed by alluvial deposits, and because of this varies greatly in texture. It is composed chiefly of silt, fine sand and clay in different proportions. The subsoil is very loose and open. The soil is easy to till. Portions of this type suffer from floods, and this is the worst drawback. The soil is well adapted to the growth of corn, wheat, and alfalfa.

The chemical analysis gives per acre of surface soil seven inches deep: nitrogen 3460 pounds, phosphorus 840 pounds, potassium 37,000 pounds, calcium 10,600 pounds, and organic carbon 36,600 pounds. The amount of phosphorus, organic carbon and calcium is lower than in the main upland types, but this decrease is not so serious on this soil as it would be if it were a silt soil. Being a loam soil it has good physical conditions, which allow a sufficient circulation of air and water, and. consequently use can be made more readily of the plant food present. However, such fields as are not flooded will, if farmed continually to grain, soon suffer from lack of plant food, particularly organic matter, calcium and phosphorus.

YAZOO CLAY AND SHARKEY CLAY.

Two types of small extent and very much alike in physical and chemical composition are the Yazoo clay and the Sharkey clay. Both are alluvial in origin, both suffer from floods. They cover a comparatively small area of the bottom lands. The drainage is very poor, both types being in the lowest part of the river bottom, generally away from the channel and near the upland slope. The soil of the Sharkey clay is a black clay, stiff, waxy, and tenacious. It becomes very hard when dry. It is difficult to till, as it is possible to handle it only when it contains the proper amount of moisture. The surface of the

Yazoo clay is a dark clay loam, but in all other respects it is very similar to the Sharkey clay.

The plant food content, with the exception of calcium, in the Yazoo clay is higher than in any of the other types. If these soils could be protected from floods and properly drained they would make excellent wheat and alfalfa lands.

DURATION OF CROP PRODUCTION IN ALLEN COUNTY.

If the amount of plant food in terms of pounds per acre of surface soil, given in Table IV, be divided by the amounts of these elements used by fifty-bushel corn crops, figures obtained will show that the number of years in which large crops are possible are few when measured in terms of the lifetime of a state or nation, unless plant food is returned to the soil. Nitrogen is the element which will first show a deficiency. Were it not for the fact that nitrogen can be taken from the air and restored to the soil, profitable farming would soon cease for lack of nitrogen. It should be clearly understood, in

TABLE V.-CROP PRODUCTION IN BUSHELS PER ACRE IN ALLEN COUNTY FOR 40 YEARS, 1872-1911.

	Years.	Corn.	Wheat.	Oats.
Ten-year average	1872-1881	30.45	13.00	22.18
Ten-year average	1882-1891	28.50	16.80	30.40
Ten-year average	1892-1901	20.95	15.20	20.12
Ten-year average	1902-1911	20.35	14.15	19.90
Twenty-year average	1872-1891	29.45	14.90	26.29
Twenty-year average	1892-1911	20.65	14.68	20.01
Thirty-year average	1872-1901	26.63	15.00	24.23
Forty-year average	1872-1911	25.06	14.31	23.15

TABLE VI.—AVERAGE AMOUNTS OF NITROGEN, PHOSPHORUS AND POTASSIUM REQUIRED YEARLY BY THE CORN, WHEAT AND OATS CROPS FOR THE 20 YEARS, 1892-1911, CALCULATED IN POUNDS AND IN PERCENTAGES OF THE AVERAGE QUANTITIES PRESENT IN IMPORTANT TYPES OF THE SOILS OF THE COUNTY.

	Corn.		Wheat.		Oats.	
	Pounds.	Per cent.	Pounds.	Per cent.	Pounds.	Per cent.
Nitrogen	31.0	0.83	28.2	0.76	19.4	0.52
Phosphorus	4.7	.64	4.7	.63	3.2	.43
Potassium	14.7	.05	17.0	.06	13.6	.05

studying such figures, that it is an impossibility to use up all of the plant food present in the surface soil; also, that most plants feed to a greater depth than the surface seven inches. But the amount of plant food in the surface soil limits profitable crop production, hence it is not improper to confine such discussion to the plant food present in the surface soil. The presence of several modifying factors makes a direct demonstration of these facts impossible. Any crop removes from the plant food present in the soil only a certain per cent, consequently just as it is impossible to exhaust a bank account if one per cent of the remaining deposit is withdrawn each day, so likewise it is impossible for the crop to remove all of the plant food in the soil if one-half per cent or one per cent, as the case may be, is utilized each year. After a while the amount possible to remove each year is so small that the crops produced will not supply the man who works the land with proper food and shelter. When this stage is reached the land is exhausted, in spite of the fact that probably more than half the original plant food is still present in the soil. The stage when exhaustion is reached will depend on the degree of civilization and the competition of fertile lands within profitable market distance.

The Russian peasants can live on a lower average production per acre than the American farmer. The lands of the eastern states reached a stage of exhaustion sooner because of the competition with the more fertile lands of the Mississippi valley.

DECREASE OF CROP PRODUCTION.

The figures in Table V are taken from the reports of the Kansas State Board of Agriculture, and these data are as reliable as is possible to obtain on this subject. A study of these figures will show that there is an unmistakable decrease in crop production in Allen county. During this time there have been two very potent factors which have worked toward an increase of average production per acre.

These two factors are improved machinery and better-yielding varieties of crops. Notwithstanding this there is no increase but a decrease. If there had not been a steady decrease in the crop-producing power of the soil these two agencies would have been sufficient to increase the average production per acre. We are perhaps not ready to admit that we have reached the limit in improved machinery for preparing the soil or taking care of the crops, and improved varieties of seed is still the hope of the plant breeder. It may be true that many farmers do not take as full advantage of the best seed varieties as they should, but it can not be denied that the general average has improved. That better machinery is used needs no demonstration.

In spite of this improvement in machinery and seeds there has been a decrease in crop production which for corn amounts to ten bushels per acre in the last ten years as compared with the first ten years. Query: What would the decrease have been in case there had been no improvement in seeds and machinery?

AVERAGE AMOUNT OF PLANT FOOD IN THE SURFACE SOIL OF ALLEN COUNTY.

The following are the average amounts of plant food in the surface seven inches cultivated soils of Allen county: nitrogen 3724 pounds, phosphorus 740 pounds, potassium 27,720 pounds, calcium 9200 pounds, and organic carbon 39,800 pounds. The two alluvial clay soils are omitted from this average as these are not under cultivation and do not contribute to the average production of crops in Allen county. Twenty bushels of corn per acre is the average amount produced each year in the last twenty years. This amount of corn, grain and stover, uses annually 31 pounds of nitrogen, 4.6 pounds of phosphorus and 14.4 pounds of potassium. These quantities calculated in percentages of the amounts present in the soil are; 0.8 per cent of the nitrogen, 0.63 per cent of the phosphorus and 0.052 per cent of the potassium. (See Table VI.)

NITROGEN AND PHOSPHORUS THE LIMITING ELEMENTS OF FERTILITY.

On the assumption that crop production could go on indefinitely without renewal of plant food, these figures mean that while these percentages remain constant the quantities of these elements removed each year would be less, and consequently the crops produced would be proportionately smaller. As a larger percentage of nitrogen is used in comparison with the other elements, it follows that the supply of nitrogen in the soil in relation to the amounts used is less than that of the other two. Hence at present nitrogen is probably the limiting element in crop production while phosphorus is a close second.

However, the phosphorus present in the soil may be relatively less available than the nitrogen, and for that reason it may be the limiting element; but if nitrogen is supplied by means of farm manures and legumes the decay of these will make the phosphorus available.

THE PROBLEM OF CALCIUM AND POTASSIUM.

The amount of calcium used by the total crop is about one-third that of potassium. The supply of calcium in the soil is also about one-third that of potassium. Much larger quantities of calcium are lost in the drain water, and for this reason calcium will be lacking in these soils sooner than potassium. Only about one-third to one-fifth of the potassium used by crops is found in the grain. The same is also true of calcium. Hence the return of straw and stover to the soil, preferably in the form of manures, will prolong the supply of these elements. The amount of potassium present in the grain is so small in relation to the large amount present in the soil that with a rational system of using farm manures this element will last almost indefinitely. The function of calcium is not only to serve as a plant food but also to improve the chemical and physical condition of the soil; many soils, therefore, are in need of this element although large amounts, as measured by the quantities found in the grain, may be present.

THE NEEDS OF THE SOILS IN ALLEN COUNTY.

These soils as a whole need farm manure or green manuring crops of legumes, and unless these are used farming will not continue profitable. These will furnish nitrogen and organic matter. When the nitrogen supply has been increased, and the chemical and physical condition improved by drainage where needed, and the application of organic matter on all of the soils which will insure the liberation of plant food, the application of some form of phosphorus will no doubt be profitable. The cheapest form of phosphorus is that; of ground rock phosphate. This will give good results if the above conditions are fulfilled. On very poor land, such as the sandy loam or the poorest phases of the gray silt loam, ground bone meal will be the best form to use at first.

SOILS OF BROWN COUNTY.

The Bureau of Soils has classified the soils in Brown county into five types. Of these only three were sampled for chemical analysis. These are named: Marshall silt loam, Marshall gravelly loam, and Yazoo silt loam. The latter is a bottom soil of alluvial origin; all the others are upland types. The soils classed as "rough stony land" and the "Marshall sandy loam" were not sampled. The former has no uniformity and no agricultural importance beyond its use as pasture land. The "Marshall sandy loam" comprises only 0.7 per cent of the area in the county.

The complete report of the chemical analyses of these three soils is found in Table XXVII in the appendix. The average calculated two pounds of plant food per acre in seven inches surface soil is found in Table VII. This is the average of seven samples of the Marshall silt loam, two of the Yazoo silt loam, and one of the gravelly loam.

TABLE VII.—ANALYSIS OF SOILS FROM BROWN COUNTY.

TYPE AS GIVEN IN SOIL SURVEY.	Pounds per acre in two million pounds of surface soil (0-7 in.)				
	Nitrogen.	Phosphorus.	Potassium.	Calcium.	Organic carbon.
Marshall silt loam	3,620	1,060	38,800	11,200	54,000
Marshall gravelly loam	4,940	740	26,800	12,000	55,800
Yazoo silt loam	3,460	1,300	36,800	14,000	63,600
Average	4,007	1,033	34,133	12,400	57,800

DESCRIPTION OF SOIL TYPES.

MARSHALL SILT LOAM.

(Brown silt loam, glacial and loessal.)

The Marshall silt loam is a soil covering about 84 per cent of the area of Brown county. The surface soil is a dark brown silt loam; the subsurface and subsoil are heavier containing more clay. The color of the subsurface and subsoil is lighter brown, in some places reddish and in other yellowish. This type covers hill and dale alike except where erosion has occurred. The surface drainage is, on the whole, good except where the land is too flat. The largest flat area is found in the southeastern portion of the county. Here the natural underdrainage is poor, and the low, flat fields would be improved by tile drainage. This soil is well adapted to corn, wheat, oats, clover and alfalfa. The aspect of the country denotes more than average prosperity. This soil is derived from loessal deposits. It is in the area covered by the Kansas drift, which in turn was covered by wind-blown materials. The rock underlying the drift is limestone which outcrops in deep ravines and cuts.

The chemical analysis of this soil, as shown in Table VII, shows that it contains in one acre of average surface soil: nitrogen 3620 pounds, phosphorus 1060 pounds, potassium 38,800 pounds. calcium 11,200 pounds, and organic carbon 54,000 pounds, As compared with the gray Oswego silt loam of Allen county, it contains less nitrogen and calcium but more of phosphorus, potassium and organic carbon.

From a study of Table XXVII in the appendix it will be noted that the percentage of nitrogen in the surface soil, is nearly three times that in the subsoil, and that the amount of organic carbon averages twelve times that of nitrogen. The organic carbon shows the same or slightly greater proportional decrease in the subsurface and subsoil as the nitrogen. The percentages of phosphorus, potassium, and calcium do not decrease in the subsoil. That only traces of inorganic carbon were present indicates that nearly all the calcium is present in the form of silicates, and for this reason it may be that, although an average amount of calcium is present, which is equivalent to 14 tons of limestone per acre, this soil may be benefited by the application of limestone. This, however, ought to be demonstrated experminentally. The calcium in some samples shows increase at lower depths.

This soil suffers from erosion both by wind and water. This erosion causes the greatest damage by the removal of nitrogen and organic matter, which are found to the largest extent in the surface soil. From the fact that the subsurface and subsoil contain as much mineral plant food as the surface soil, it must not be inferred that erosion is harmless in respect to these elements. The potential mineral plant food in these lower strata is in an unavailable form. It will take years of weathering to convert it into such forms as are of immediate use to agricultural plants. The removal of the surface soil, and with it large amounts of organic matter, retards this process of plant food liberation.

Insensible erosion, where the soil is removed over the whole surface to the extent of a few inches in a hundred years, is not an unmixed evil. As the surface soil is deprived of its plant food by continuous crop removal, a portion is removed, and the subsoil from below is brought gradually into use. For this reason it will probably never be necessary to apply potassium to this soil. The supply in the surface is sufficient for thousands of years, and in that time new layers of soil are brought to the surface. The same reasoning would be true of calcium except for the leaching which it suffers. But the application of calcium in the form of limestone is not a serious problem since the supply is abundant within easy distance. The problem of maintaining the fertility of this soil narrows down to nitrogen and phosphorus. The nitrogen can be supplied by the growth of legumes, and an abundance of legumes insures the availability of the potassium, and also of the phosphorus as long as the supply of the latter lasts in profitable amounts. The phosphorus problem is helped to some extent by the insensible lowering of the land surface, but not sufficiently to maintain a supply for profitable crop production. The cheapest source of phosphorus is ground rock phosphate, and in this form it will be available for the use of crops if the soil is well supplied with organic matter from farm manures and legumes.

MARSHALL GRAVELLY LOAM.
(Mostly glacial.)

The Marshall gravelly loam is a type of soil which occurs in small areas in the vicinity of streams, It has been developed by erosion, and is generally rolling or hilly. It is used mainly for pasture or native meadow. The soil varies in color from a dark brown to a gray. In places considerable gravel is present, and glacial boulders are found on some of this land. This soil is derived directly from the glacial till, and its area is increasing wherever destructive erosion of the Marshall or brown silt loam is allowed to take place. The situation may be stated thus: The Marshall silt loam consists mostly of the loessal deposit which covers the underlying glacial till. As the loessal deposit is eroded the more gravelly till appears and gradually forms soil. It is for this reason that most of this soil is found near streams where erosion has been more effective.

The chemical analysis of this gravelly loam gives in one acre of surface soil: nitrogen, 4940 pounds; phosphorus, 740 pounds; potassium, 26,800 pounds; calcium, 12,000 pounds, and organic carbon 55,800 pounds. Only one sample of this soil was analyzed and this was taken in a native pasture. This accounts for the large amount of nitrogen present. The calcium and organic carbon are slightly larger in amount than in the Marshall (brown) silt loam, but the phosphorus and potassium are very much less. This indicates that while in the first few feet of the brown Marshall silt loam the supply of mineral plant food is constant, yet as lower depths are reached through destructive erosion, the supply will be diminished not only in what is available but in total amounts.

YAZOO SILT LOAM.
(Bottom Soil.)

The most important of the bottom soils of Brown county is the Yazoo silt loam. It is a dark, heavy silt loam containing a considerable amount of clay. The dark color extends to a depth of about two feet. The deeper subsoil, is a dark brown, heavy silt loam. This is an alluvial soil and is formed from material washed from the surrounding higher lands. It really consists of reworked material of the same kind as makes up the Marshall silt loam. It is modified by the presence of clay and also by gravel from the gravelly loam of the hillsides. Because of this it is variable in texture like all alluvial types. It generally lies flat. Portions of it are water-logged in wet seasons, due to the inflow of water from the surrounding upland, but it is not difficult to tile-drain this land as most of the streams lie several feet below its level.

This is the strongest and best soil in the county when properly drained. When uplands suffer from erosion this soil is benefited, consequently it becomes deeper as the years go on. At present a large portion of this soil is in native pasture, especially where the drainage is poor. This soil was sampled in two places, and the complete results are found in Table XXVII, in the appendix. Sample number 1047 was from a native pasture, and number 1054 was from a field growing wheat and oats. Table VII shows that this type contains in the surface soil an average of: nitrogen 3460 pounds, phosphorus 1300 pounds, potassium 36,800 pounds, calcium 14,000 pounds, and organic carbon 63,600 pounds. Of mineral plant food and organic carbon it has more than the other two types, but it has less of nitrogen. This is probably due to the leaching of diffusible organic material during heavy rains. For crop production it is the strongest soil of the county.

DURATION OF CROP PRODUCTION IN BROWN COUNTY.

A study of the figures in Table VII together with a calculation of the amount of plant food removed by crops will show that permanent agriculture in Brown county will not be possible unless there is a renewal of nitrogen and phosphorus. How such renewal may be made has already been indicated in the discussion of Marshall silt loam.

TABLE VIII.-CROP PRODUCTION IN BUSHELS PER ACRE IN BROWN COUNTY FOR 40 YEARS, 1872-1911.

	Years.	Corn.	Wheat.	Oats.
Ten-year average	1872-1881	36.97	17.13	37.46
Ten-year average	1882-1891	35.99	18.70	38.10
Ten-year average	1892-1901	30.00	16.00	22.78
Ten-year average	1902-1911	30.90	19.80	26.65
Twenty-year average	1872-1891	36.48	17.92	37.78
Twenty-year average	1892-1911	30.45	17.90	24.72
Thirty-year average	1872-1901	34.32	17.28	32.78
Forty-year average	1872-1911	33.62	17.91	31.25

TABLE IX.—AVERAGE AMOUNTS OF NITROGEN, PHOSPHORUS AND POTASSIUM REQUIRED YEARLY BY THE CORN, WHEAT AND OATS CROPS FOR THE 20 YEARS, 1892-1911, CALCULATED IN POUNDS AND IN PERCENTAGES OF THE AVERAGE QUANTITIES PRESENT IN IMPORTANT TYPES OF THE SOILS OF THE COUNTY.

	Corn.		Wheat.		Oats.	
	Pounds.	Per cent.	Pounds.	Per cent.	Pounds.	Per cent.
Nitrogen	45.7	1.13	34.4	0.85	24.0	0.59
Phosphorus	7.0	.67	5.7	.55	4.0	.38
Potassium	21.6	.06	20.8	.06	16.8	.04

AVERAGE CROPS FOR FORTY YEARS.

Table VIII shows the average yield of certain crops in Brown county for forty years. There is a notable decrease in the average production per acre of corn and oats for the forty-year period, while wheat shows a slight increase. The last twenty years, as compared with the first twenty years, show a decrease of six bushels for corn and thirteen bushels for oats. That wheat has held its own is no doubt due to the fact that the soil for this crop is specially prepared, and that it is so often grown after clover or on land that is recently broken. It is the opinion of the farmers of Brown county that it takes more work 'to raise as large crops as formerly. That there is a decrease in the productive power of the soil beyond what the average production shows is evident from the fact that a. decreased average has followed the use of better machinery and improved seed. If that was not true, there should have been an increase instead of the shown decrease in crop production.

THE AVERAGE AMOUNT OF PLANT FOOD IN THE SURFACE SOIL AND ITS RELATION TO CROP PRODUCTION.

The average amount of plant food in an acre of surface soil of Brown county, as far as sampled, contains: nitrogen 4007 pounds, phosphorus 1033 pounds, potassium 34,133 pounds, calcium 12,400 pounds, and organic carbon 57,800 pounds: The average crop production for the twenty years, 1899 to 1911, is: corn 30.45 bushels, wheat 17.9 bushels, oats 24.72 bushels. Table IX shows the average quantity of plant food removed yearly by these crops, and also its relation to the whole amount present expressed as percentages. Of the three crops, corn is the heaviest feeder, and nitrogen is the limiting element. That is, of the total amount present corn uses over 1 per cent of the nitrogen but only 0.67 per cent of the phosphorus. The average wheat crops require 34.4 pounds of nitrogen per year, or 0.85 per cent of the amount present, Of the phosphorus the wheat uses 5.7 pounds a year, or 0.55 per cent. The average oat crop uses 24 pounds of nitrogen per year, or 0.59 per cent of the amount present, but of phosphorus only 0.38 per cent. All three crops use such small amounts of potassium, as measured by the amounts present, that it is purely a question of its liberation. Of the three crops corn removes the largest quantity of plant food and oats the least. The small crops of oats are not so much due to lack of plant food as to lack of availability at the time the plant food is needed. Oats has the shortest growing period of the three crops. Though the time between planting and harvesting corn is shorter than that for wheat, the season in which corn makes its greatest growth is more favorable to the liberation of plant food, and wheat makes its greatest demands upon the soil within a few weeks.

THE NEEDS OF THE SOILS IN BROWN COUNTY.

Comparing the three crops, it is evident that they would all respond first to the application of nitrogen, and that oats would give the greatest increase. Next to nitrogen, they would respond to phosphorus. The cheapest way to apply nitrogen is by plowing under green legume crops or by feeding legume crops and carefully saving all the manure. When the soil is well supplied with organic material rich in nitrogen, phosphorus can be applied in the form of rock phosphate, in which form it is cheapest. When the organic matter containing nitrogen has been supplied, the chemical agencies active in the soil will liberate potassium sufficiently for all the needs of the crops. That these soils show only traces of inorganic carbon indicates that some of them, at least, may be in need of lime. This can best be applied in the form of ground limestone and in connection with a liberal supply of organic matter. Under such conditions ground limestone will decompose rapidly enough for all the needs of crops.

SOILS OF RUSSELL COUNTY.

The Bureau of Soils has mapped five soil types in the Russell sheet. This area comprises the greater portion of the center of Russell county. The types are called: Sedgwick clay loam, Sedgwick sandy loam, Waldo loam, Benton loam, and Lincoln sandy loam. Of these the first four were sampled for chemical analysis. The Lincoln sandy loam was not sampled. It is an alluvial soil and occurs only in small areas along the streams. It is good soil for corn and alfalfa.

DESCRIPTION OF SOIL TYPES.

SEDGWICK CLAY LOAM.

(Dark brown or black clay loam from shale and limestone.)

The most important wheat soil of the area occurs on the upland plateau between the Saline and Smoky Hill rivers, and is the Sedgwick clay loam. It is the typical wheat soil and is devoted almost exclusively to the cultivation of this crop. It

TABLE X.—ANALYSIS OF SOILS FROM RUSSELL COUNTY.

TYPE AS GIVEN IN SOIL SURVEY.	Pounds per acre in two million pounds of surface soil (0-7 in.)				
	Nitrogen.	Phosphorus.	Potassium.	Calcium.	Organic carbon.
Sedgwick clay loam (dark brown or black clay loam)	3,740	1,020	40,800	16,800	42,800
Sedgwick sandy loam (gray or grayish brown sandy loam)	2,820	960	36,000	14,800	32,200
Waldo loam (brown or grayish brown silty loam)	5,380	1,200	38,000	22,200	63,600
Benton loam (light brown to grayish loam)	4,740	1,060	32,400	100,600	58,000
Average	4,170	1,060	36,800	38,600	49,150

is not so well adapted to corn as some of the other types, because during the hot weather of July and August the movement of moisture in this soil is too slow to furnish the needed supply of water to the crops. This soil is derived from shale and limestone. The limestone occurs in thin layers and also in concretions imbedded in the shale. Most of this soil is gently undulating. It is a dark-brown to black silty loam. The subsoil is a silty loam of a slight brown color.

The results of chemical anaylsis of this soil, shown in Table X, give, in pounds per acre of the surface soil: nitrogen 3740 pounds, phosphorus 1020 pounds, potassium 40,800 pounds. calcium 16,800 pounds, and organic carbon 42,800 pounds. In comparison with other soils of the state, it is well stocked with plant food. The nitrogen content is high for a soil in western Kansas. A study of Table XXVIII, in the appendix, will show that continuous wheat farming rapidly depletes this stock of nitrogen. Sample number 1036.1 was from a field which had grown wheat for about thirty years, and sample number 1037 was taken just a few rods away, on soil that had never been broken. The cultivated soil contained 2960 pounds of nitrogen per acre, while the uncultivated contained 4260 pounds—a difference of 1300 pounds. If the average crop of wheat per acre on this soil has been fifteen bushels, which is above the average, this land has produced 450 bushels. If it takes two pounds of nitrogen for the production of one bushel of wheat, the total crop, grain and straw, has removed 900 pounds, leaving 400 pounds which has been wasted in other ways. This takes no account of any nitrogen which has been returned in straw and stubble. If the content of organic carbon of these two soils is compared, 32,200 pounds per acre surface for the cultivated and 40,600 pounds for the uncultivated are found. As no carbon is taken by the plant from the soil, this loss of about eight tons of organic matter per acre has been brought about by oxidation (organic matter = twice the carbon). This illustrates one of the serious problems in connection with continuous wheat-raising in a country that is more likely to suffer from dry weather than from wet. The organic matter is gradually oxidized or burned, and this reduction of organic matter diminishes the power of the soil to withstand drouth. This oxidation of organic matter involves a large loss of nitrogen over and above what is removed in the crop.

SEDGWICK SANDY LOAM.

(Sandy loam from sandstone.)

Another upland type is the Sedgwick sandy loam, which is situated lower than either the Sedgwick clay loam or the Benton loam. In a sense it can be called a bench land. The Sedgwick clay loam occupies the elevation. Where this is eroded, giving a hilly topography, occurs the Benton loam; this Sedgwick sandy loam is situated below this, and above the alluvial soil called Lincoln sandy loam. Consequently this soil is found in the vicinity of rivers. The soil is a light gray to grayish brown sandy loam. The sand in this soil is a medium to fine. The subsoil is lighter in color and its sand content is greater. Some of this land is quite rolling; other areas are more level. This soil, as the name implies, has been produced from sandstone, but on account of its position it has received materials from the higher lying shales and limestones. This soil is better suited to a diversity of crops than the clay loam. It is probably not as strong a wheat soil as the clay loam; but it is a better corn soil.

The chemical analysis of one sample of this soil gave the following results: nitrogen 2820 pounds, phosphorus 960 pounds, potassium 36,000 pounds, calcium 14,800 pounds, organic carbon 32,000 pounds. The soil from which this sample was taken had produced wheat for about 30 years continuously. The low content of organic nitrogen shows the effect of this continuous wheat culture. The content of mineral plant food is slightly lower than that of the clay loam, but this is more than counterbalanced by the more open texture giving the roots a larger feeding area.

BENTON LOAM.

(Erodded and hilly land.)

The Benton loam is light brown to grayish in color and is a residual upland soil derived from shale and limestone. Its topography is very rough, and it is devoted almost exclusively to pasture. Only small areas of this soil can ever be used for anything but pasture. The soil ranges in depth from a few inches to about a foot, and grades quickly to a light colored subsoil which is almost wholly made up of decomposed shale mingled with limestone fragments. It is these which give this soil its high lime content. Because of its rolling topography and stony nature, it retains little moisture. Only a few small areas can ever be farmed. It was near such a tillable area that the sample was taken. Such flat areas where cultivated produce good crops of wheat. The sample was taken in a native meadow.

The chemical analysis shows that this soil contains per acre of surface soil: nitrogen 4740 pounds, phosphorus 1060 pounds, potassium 32,400 pounds, calcium 100,200 pounds, and organic carbon 58,000 pounds. This sample is no doubt richer in nitrogen and carbon than the average of this soil, but the mineral element will probably not average higher.

This soil will not suffer for lack of total mineral plant food, as erosion continually exposes new soil. It is mostly a problem of liberation. As this soil is used almost exclusively for pasture the problem of soil fertility is not important.

WALDO LOAM.

(Brown silt loam, mostly bottom soil.)

The Waldo loam is a brown or grayish brow silty soil the average depth of which is about 12 inches. The subsoil is very similar to the surface soil but has a lighter color. This is an alluvial soil found along the rivers and creeks. The topography is nearly level, having just a gentle slope. The soil is formed mainly from the material washed down from the surrounding hills, which are composed of the Benton loam; consequently it is derived from shale, limestone and some sandstone. It has an excellent physical texture. It is well adapted to corn, wheat, and alfalfa. It withstands dry weather better than any of the other types. Being situated below the hills, crops are protected more from hot winds than on the uplands, The chemical analysis of this soil shows it to contain per acre of surface soil: nitrogen 5380 pounds, phosphorus 1200 pounds, potassium 38,000 pounds, calcium 22,208 pounds, and organic carbon 63,600 pounds. In the elements which are likely to be deficient in most soils it is richer than any of the other types. The percentages of nitrogen, phosphorus, and organic carbon average with the highest in the state.

TABLE XI.—CROP PRODUCTION IN BUSHELS PER ACRE IN RUSSELL COUNTY FOR 40 YEARS, 1872-1911.

	Years.	Corn.	Wheat.	Oats.
Ten-year average	1872–1881	26.87	15.13	24.75
Ten-year average	1882–1891	21.90	16.30	27.10
Ten-year average	1892–1901	15.80	10.30	16.40
Ten-year average	1902–1911	19.60	11.20	18.30
Twenty-year average	1872–1891	24.39	15.72	25.93
Twenty-year average	1892–1911	17.70	10.75	17.35
Thirty-year average	1872–1901	21.52	13.91	22.75
Forty-year average	1872–1911	21.04	13.23	21.64

TABLE XII.—AVERAGE AMOUNTS OF NITROGEN, PHOSPHORUS AND POTASSIUM REQUIRED YEARLY BY THE CORN, WHEAT AND OATS CROPS FOR THE 20 YEARS, 1892-1911, CALCULATED IN POUNDS AND IN PERCENTAGES OF THE AVERAGE QUANTITIES PRESENT IN IMPORTANT TYPES OF THE SOILS OF THE COUNTY.

	Corn.		Wheat.		Oats.	
	Pounds.	Per cent.	Pounds.	Per cent.	Pounds.	Per cent.
Nitrogen	26.6	0.62	20.6	0.48	16.8	0.39
Phosphorus	4.1	.38	3.4	.32	2.8	.26
Potassium	12.6	.04	12.5	.03	11.8	.03

DURATION OF CROP PRODUCTION IN RUSSELL COUNTY.

AVERAGE CROP PRODUCTION FOR 40 YEARS.

The average crop production for forty years in Russsell county is given in Table XI. The forty years divided into ten-year periods show a decrease in the average of the three crops, In the last ten-year average as compared with the first ten-year average, corn shows a decrease of over seven bushels, wheat nearly four, and oats over six bushels. On the basis of the average for the first ten years this amounts to about one-fourth. That is, the crops have decreased one-fourth in yearly average. The fourth ten-year average is better than the third ten-year average. This is no doubt due to climatic conditions. The decreased crop-producing power of the land is unmistakable. To offset more unfavorable years in some ten-year periods there has been an advance in cultural methods resulting in moisture conservation. Seed varieties which are better adapted to dry-weather conditions have also been introduced. But for these factors the decreased crop production would be greater.

THE AVERAGE AMOUNT OF PLANT FOOD IN THE SURFACE SOIL AND ITS RELATION TO CROP PRODUCTION.

The average amount of plant food in the surface seven inches of all the types of the county are: nitrogen 4170 pounds, phosphorus 1060 pounds, potassium 36,800 pounds, calcium 38,600 pounds and organic carbon 49,150 pounds. The amount of plant food removed yearly by the average crops of the last twenty years are given in Table XII. The percentage removed by these average crops is calculated on the basis of the total amount present. Corn removes 0.62 per cent of the nitrogen, 0.38 per cent of the phosphorus, and 0.03 per cent of the potassium. Oats removes 0.39 per cent of the nitrogen, 0.26 per cent of the phosphorus, and 0.03 per cent of the potassium. From these figures it follows that corn is able to utilize the largest amount of plant food and that for all these crops the nitrogen is used in the largest percentage amounts. That means that nitrogen will first be the limiting factor of crop production, which condition may exist already in many soils. With continuous wheat farming, as is true of most of these soils, the nitrogen assumes the greatest importance. Depletion of organic matter which follows continuous wheat cropping will bring about such conditions in the soil that the phosphorus will not be liberated in quantities sufficient for the needs of crops. In comparison with both Brown and Allen counties the percentages of plant food removed are less than in these two counties. This is due to lack of moisture. If Russell county had a larger rainfall with the present chemical composition of the soil there would be a larger crop production. But the depletion of organic matter and nitrogen decreases the water-holding capacity of the soil and consequently its ability to withstand drought is decreased. This condition also makes the mineral elements less available and the plants can not withstand adverse climatic conditions so well. Any system of farming which will increase the organic matter under such conditions that it will decay and become incorporated with the soil will help soils of Russell county.

THE GARDEN CITY AREA.

IN FINNEY AND GRAY COUNTIES.

The Garden City area comprises portions of Finney and Gray counties, the greater portion being in the former county. In this area the Bureau of Soils has mapped nine types of soil, named as follows: Marshall silt loam, Laurel loam, Laurel sandy loam, Finney sandy loam, Colorado adobe, Dune sand, Colorado sand, rough stony land, and Finney clay. Of these the four last named were not under cultivation and probably never will be. They have, however, an interest, and therefore all the types were sampled. The complete results of the chemical analyses are found in Table XXIX in the appendix, and the results calculated to pounds per acre in the seven inches of surface soil are found in Table XIII.

TABLE XIII.—ANALYSIS OF SOILS FROM FINNEY COUNTY.

TYPE AS GIVEN IN SOIL SURVEY.	*Pounds per acre in two million pounds of surface* soil, (0-7 in.)				
	Nitrogen.	Phosphorus.	Potassium.	Calcium.	Organic carbon.
Marshall silt loam	2,480	1,340	45,200	23,400	23,200
Sandy phase	2,060	1,220	48,400	21,600	18,800
Laurel loam	3,360	1,380	49,600	23,800	30,400
Laurel sandy loam	1,800	1,200	48,400	19,400	16,400
Finney sandy loam	1,480	760	46,400	52,600	12,800
Colorado adobe	2,000	1,360	50,200	16,200	19,400
Dune sand	340	720	55,800	1,200	2,200
Colorado sand	540	700	49,200	9,000	4,800
Rough stony land	1,580	1,340	47,200	57,200	12,800
Finney clay	2,160	1,300	44,800	16,200	17,600
Average	2,197	1,210	48,033	26,167	20,167

DESCRIPTION OF SOIL TYPES.

MARSHALL SILT LOAM.*

(Brown silt loam.)

The Marshall silt loam is the most extensive of the upland arable type. The type is very uniform, both in topography, physical texture and chemical composition. The soil is a dark chocolate brown silty loam. The subsurface is very much like the surface, except that it has a lighter color. The subsoil is a light gray or a grayish yellow. When dry it has a mealy texture. Unless the surface has been specially prepared, so as to take up and retain water, or in seasons of more than average rainfall, this subsoil is continually dry. It has not undergone leaching. The soil is apparently formed from windblown deposits. Its fine texture makes it retentive of moisture, but not receptive unless the surface is specially prepared by cultivation. It is well adapted for the growth of wheat, but suffers more from dry weather than the more sandy types, which naturally take water more easily and give it more readily to plants.

This type was sampled in four places, and the results are found in Table XXIX in the appendix. The most remarkable difference between this soil and soils farther east is the increase of calcium in the subsurface and subsoil. That this calcium is largely in the form of carbonate is shown by the large amounts of inorganic carbon present. Table XIII shows that the surface seven inches contain per acre: nitrogen 2480 pounds, phosphorus 1340 pounds, potassium 45,200 pounds, calcium 23,400 pounds, and carbon 23,250 pounds. In contrast with the soils farther east it is low in nitrogen and organic carbon, but comparatively high in all the other elements. This soil, with sufficient rainfall, is best adapted for wheat or kafir, but the ordinary rainfall is too uncertain to insure profitable crops of wheat except in years of abnormal precipitation, or where irrigation is practiced. From the chemical standpoint the problem is to keep up the supply of nitrogen and organic matter. The mineral plant food is amply sufficient for several generations.

The sandy phase of the Marshall silt loam is very much like the main type, except, being sandier, it takes up more water

* Called Richfield silt loam in later survey.

which falls as rain, and as a consequence suffers less from drought. The chemical composition is very similar to that of the main type.

FINNEY SANDY LOAM.

(Upland sandy soil.)

The largest area of the Finney sandy loam is found about five miles east of Garden City. There is also a smaller area of this type northwest of Garden City. The soil is a medium to fine sandy loam underlaid with silt loam. This combination is valuable in a semiarid climate. The surface is of such a nature that it takes up the water as it falls as rain, and the subsoil has such a texture that it stores it for the crops. At the time the samples were taken most of the soil types in this county were thoroughly dry, except where irrigated, but this sandy loam had considerable moisture, and crops were growing on this land when other types composed of silt loam or clays were bare only a few rods away.

The chemical analysis shows that this soil contains in the first seven inches of one acre: nitrogen 1480 pounds, phosphorus 760 pounds, potassium 46,400 pounds, calcium 52,600 pounds, and organic carbon 12,800 pounds. It has the lowest nitrogen and organic carbon content of any of the arable types; but the more open texture allows a larger feeding ground for the roots, and consequently its crop-producing power is as great as those types which have more plant food but a closer texture.

This soil seems to be well adapted to the growth of corn or sorghum. In contrast with the silt loam it is able to grow crops without irrigation in seasons when none are grown on such soils as the Marshall silt loam.

LAUREL SANDY LOAM.

(First- and second-bottom soil.)

The Laurel sandy loam is both a first- and second-bottom soil, and is the principal type in regard to extent in the bottom lands of the Arkansas river. It lies on both sides of the river and parallel to it. It is gently undulating, but not enough so to prevent irrigation, and a large portion of the type is irrigated.

Like most alluvial soils, it is very variable in texture. The soil is composed of varying amounts of sand and gravel mixed with a variable percentage of clay and silt. This assortment of materials changes frequently, consequently the same field presents several shades of texture, some coarser and some finer. The subsoil is much coarser, as a rule, than the soil and subsurface. A bed of sand and gravel is generally found at 18 to 36 inches. This reduces the moisture-holding capacity of the soil, and on the second-bottom phase crops are not assured except where irrigation is practiced. The first-bottom phase is generally used at present for permanent pasture. The water table is so near the surface that grasses are supplied with water from below. It seems to be too near the surface for the successful growth of alfalfa. On the second-bottom phase, where irrigation is practiced, are found some alfalfa fields. The alfalfa is largely grown for seed.

The chemical analysis of this soil shows that it contains in the first seven inches of each acre: nitrogen 1800 pounds, phosphorus 1200 pounds, potassium 48,400 pounds, calcium 19,400 pounds, and organic carbon 16,400 pounds. Like the Finney sandy loam, it is low in nitrogen and organic carbon, but it is higher than the latter in phosphorus.

LAUREL LOAM.

(Dark brown loam, mostly second bottom.)

The Laurel loam is a second-bottom soil, and is the best in the Arkansas valley. The largest areas are found east and west of Garden City. The soil is a heavy, dark brown loam, becoming lighter with depth. Like all alluvial soils, it varies greatly in texture according to the presence of larger or smaller amounts of sand and gravel mixed with the silt and clay. The water table is sufficiently near the surface to be reached by deep-rooted plants; such as alfalfa. In the field where this sample was taken alfalfa makes a successful growth without irrigation. Trees also grow without irrigation on this soil. Beds of sand and gravel underlie this soil about 3 to 6 feet. Some of this soil occupies the first bottom, and here it is shallower, the beds of sand and gravel being found nearer the surface. Here, also, the water table is too near for the successful growth of alfalfa.

The chemical analysis of this soil shows that it contains in the first seven inches of each acre: nitrogen 3360 pounds, phosphorus 1380 pounds, potassium 49,600 pounds, calcium 23,800 pounds, and organic carbon 30,400 pounds. In nitrogen, phosphorus and organic carbon it is richer than any of the other types found in the county. This, and the physical texture, together with the favorable situation for water supply, accounts for its being the best soil in the valley. It is well adapted for all kinds of crops when water is available. Principal crops grown are alfalfa and sugar beets.

COLORADO ADOBE.

The least extensive type in the area is the Colorado adobe. It occupies old river bottoms and is modified by the addition of materials from the hillsides and wind-blown deposits. These wind-blown deposits give to the surface 3 to 5 inches the appearance of a sandy loam. From about 5 to 18 inches it consists of silt and clay, the texture being more nearly a clay loam. It is very hard, and when crushed breaks into cubes. It is rather impervious to water. With heavy rains and poor surface drainage the water stands, forming buffalo wallows. The adobe stratum at about 18 inches becomes lighter, until at from 4 to 8 feet a bed of sand and gravel is reached. The yearly deposits of slight amounts of sand by wind tend to make the surface soil of lighter texture as the years go on.

The chemical analysis shows that this soil contains per acre in the first seven inches: nitrogen 2000 pounds, phosphorus 1360 pounds, potassium 50,200 pounds, calcium 16,200 pounds, and organic carbon 19,400 pounds. As a soil it is well stocked with plant food. Where sufficient water is available it is well adapted to the growth of sorghum, wheat, and alfalfa. Sugar beets are also grown under irrigation.

DUNE SAND.
(Sand hills.)

The dune sand is the most extensive and probably the least valuable of any of the types in this area. The sand is of a yellowish color, composed mostly of quartz and feldspar, and varies from a few feet to about 60 feet in depth. The greater portion of this dune sand lies south of the river. The dune sand is now generally covered with vegetation, and as the organic matter in the sand increases the moisture-holding capacity becomes better. This in turn will produce more growth. It is extremely unwise to disturb this covering of vegetable matter by attempts at cultivation as that will start the drifting of the sand, and it will take a long time for enough vegetable matter to accumulate to stop the drifting.

This land is used mostly for pasture, being covered with sage brush, bunch grass, blue stem, and Redfield grasses. It warms up easily in the spring, and, having a good water-receiving and a fair water-holding capacity, furnishes moderately good pasture for a semiarid country. Pasturing too many cattle will soon start the sand drifting.

The chemical analysis shows that this land contains in each acre seven inches surface soil: nitrogen 340 pounds, phosphorus 720 pounds, potassium 55,800 pounds, calcium 1200 pounds, organic carbon 2200 pounds. Of all the types it is poorest in nitrogen and organic matter and richest in potassium. The phosphorus content is equivalent to that of some excellent wheat-producing soils farther east. The high potassium content is due to the presence of feldspathic material from which part of the sand was formed. The calcium content is remarkably low.

If trees could be grown in the low places between the dunes this would check the tendency to drift, and the soil would continue to grow better with the accumulation of vegetable matter.

COLORADO SAND.

(More level than the sand hills.)

The Colorado sand is very similar to dune sand, except that the areas it occupies lie lower and more level. The topography is gently rolling or undulating. It is composed of the same material as the dune sand. Where it is situated so that irrigation can be practiced good crops are possible. At present it is used for pasture land.

The chemical analysis gives the following results calculated for one acre seven inches deep: nitrogen 540 pounds, phosphorus 700 pounds, potassium 49,200 pounds, calcium 9000 pounds, and organic carbon 4800 pounds. The similarities between this and the dune sand are very apparent, the chief difference being in the content of nitrogen and organic matter. This is no doubt due to a longer period in which the organic matter has accumulated because of less drifting.

FINNEY CLAY.

(Buffalo wallows.)

This is a dark tenacious clay soil occupying saucer-like depressions in the area covered with Marshall silt loam. These depressions on the prairie receive the surface water from the surrounding slopes. The subsoil is so hard and impervious that the water stands till it evaporates. At the depth of about twenty inches, where the samples were taken, the soil was hard and dry, although water was standing on the surface a few feet away and the surface soil was water-soaked where the hole was bored for the sample.

This soil has at present no agricultural value, and where found in arable soil, in small patches known as buffalo wallows, it is a positive hindrance to cultivation.

The chemical analysis shows that the soil is well stocked with plant food, but being of such a poor physical texture, it is not available to cultivated plants. The following results are calculated for one acre, seven inches deep: nitrogen, 2160 pounds; phosphorus, 1300 pounds; potassium, 44,800 pounds; calcium, 16,200 pounds; and organic carbon, 17,600 pounds.

ROUGH STONY LAND

This soil consists of sand, gravel, pebbles, mixed with clay, silt and limestone. It occupies the bluffs north of the river. It is used as range land, and has no value for any other purpose.

The chemical analysis gave the following results, calculated for each acre seven inches deep: nitrogen 1580 pounds, phosphorus 1340 pounds, potassium 47,200 pounds, calcium 57,200 pounds, and organic carbon 12,800 pounds. In a region of adequate rainfall these bluffs would be valuable land for pasture or as timber land.

DURATION OF CROP PRODUCTION IN FINNEY COUNTY.

The average crop production for Finney county in the last twenty-six years, 1885-1911, is given in Table XIV. Corn and wheat show a decrease. As the water supply is the most important factor in this county, these results do not mean as much as they do in other counties where the rainfall is more abundant. But the low content of nitrogen and organic matter is a serious problem. In Table XV it is shown that for all crops nitrogen is used in the largest amount relative to the stock present in the soil. The decrease of organic matter lessens the water-holding capacity of the soil. The present problem is to maintain the supply of organic matter and the nitrogen.

TABLE XIV.—CROP PRODUCTION IN BUSHELS PER ACRE IN FINNEY COUNTY FOR 26 YEARS, 1885-1911.

	Years.	Corn.	Wheat.	Oats.
Six-year average	1885-1891	24.67	17.50	4.70
Ten-year average	1892-1901	12.00	5.00	16.60
Ten-year average	1902-1911	16.20	8.70	18.30
Twenty-year average	1892-1911	14.10	6.85	17.45
Sixteen-year average	1885-1901	18.34	11.25	22.39
Twenty-six year average	1885-1911	17.62	10.40	21.02

TABLE XV.—AVERAGE AMOUNTS OF NITROGEN, PHOSPHORUS AND POTASSIUM REQUIRED YEARLY BY THE CORN, WHEAT AND OATS CROPS FOR THE 20 YEARS, 1892-1911, CALCULATED IN POUNDS AND IN PERCENTAGES OF THE AVERAGE QUANTITIES PRESENT IN IMPORTANT TYPES OF THE SOILS OF THE COUNTY.

	Corn.		Wheat.		Oats.	
	Pounds.	Per cent.	Pounds.	Per cent.	Pounds.	Per cent.
Nitrogen	21.2	0.96	13.2	0.59	16.9	0.77
Phosphorus	3.2	.27	2.2	.18	2.8	.23
Potassium	10.0	.02	7.9	.02	11.9	.02

SOILS OF RILEY COUNTY.

The Bureau of Soils has classified the soils in Riley county into eight types. Of these, five were sampled for chemical analysis. The rough stony land, the Laurel fine sandy loam and the Laurel fine sand were not sampled. The reason for this was that these types were so uneven that it would be almost impossible to obtain a fair sample, and also, the problem of fertility is only secondary with these types. The rough stony land is valuable only for pasture. The mineral fertility of this soil is kept up by the lowering of the land surface. Soil never remains long enough on these hills to become worn out before it is removed to lower levels. In fact, it is this continual erosion which prevents the accumulation of soil of sufficient depth for the cultivation of farm crops. On the flat hilltop and in the small valleys patches of soil are found. These are similar to the Oswego silt loam and the Marshall silt loam to be described later.

The Laurel fine sandy loam occurs near the rivers. It is recent alluvial soil. It is very uneven. Some is like the silt soil called Laurel silt loam, and some is more sandy, bordering on Laurel fine sand. The latter is also a recent formation, the texture depending to a large extent on the velocity of the current at the time of formation. The types sampled were: Oswego silt loam, Marshall silt loam, Wabash silt loam, Laurel silt loam, Wabash clay loam. The complete analyses of these soils are found in Table XXX, in the appendix.

TABLE XVI.—ANALYSIS OF SOILS FROM RILEY COUNTY.

TYPE AS GIVEN IN SOIL SURVEY.	Pounds per acre in two million pounds of surface soil, (0-7 in.)				
	Nitrogen.	Phosphorus.	Potassium.	Calcium.	Organic carbon.
Oswego silt loam	4,340	1,060	36,400	13,600	52,000
Marshall silt loam	4,100	1,020	41,000	13,400	40,400
Wabash silt loam	3,760	1,100	42,400	15,400	42,200
Laurel silt loam	5,040	1,140	39,000	41,400	55,000
Wabash clay loam	4,800	1,560	43,200	8,800	72,400
Average	4,408	1,176	40,400	18,520	52,400

DESCRIPTION OF SOIL TYPES.

OSWEGO SILT LOAM.

(Grayish to brown silt loam.)

The Oswego silt loam of Riley county is not like the brown silt loam of Brown county, nor is it like the gray silt loam of Allen county, also called Oswego silt loam. It is like the latter in its origin. The Oswego silt loam of Allen county is derived from shale. This is also true of the soil known by the same name in Riley county, but the influence of limestone is more pronounced. In Allen county the shale layer is deeper; consequently only traces or very small percentages of carbonates were found in the subsoil, while in Riley county the percentage of limestone in the subsoil is much greater.

This soil is a heavy silt loam. The color varies from gray to a dark brown, The color varies largely with the depth. On level uplands, where erosion has been very slight and the limestone layer is deeper down, the soil has a dark gray color. In more hilly sections which have been eroded more and the limestone comes nearer the surface the color is more of a dark brown, shading to a brick red in the subsoil. In low places which have received accumulations from the hillsides the soil is much deeper and is almost black when wet. The soil also varies greatly in depth, as can be inferred from the above. As a whole the soil is uniform and free from stones, except where too much erosion has occurred. The subsoil of the Oswego silt loam in Riley county is much more open than that of the type known by the same name in Allen county, although it is sufficiently close to cause poor drainage in flat areas. On slopes and hillsides are found patches known as "gumbo." These seem to be the result of the removal of the surface soil, with its accumulation of organic matter, through the action of water and wind. The soil now consists of what was formerly the subsurface and subsoil. Weathering and application of large quantities of organic matter will improve these patches of "gumbo."

The Oswego silt loam is the most extensive type in the county, covering nearly half of the area. It is the main upland type, where it covers section after section, and it is also found in small patches in the rough stony land. This latter type has been formed by the erosion of the upland. On the hilltops in the rough stony lands which are sufficiently level to prevent soil removal keeping pace with soil formation are found small patches of this Oswego silt loam. This soil as a whole, except where nearly level, suffers much from erosion, and this is one of the difficulties the farmer has to contend with continually wherever the land has any considerable slope.

The largest area of this soil is found in the western and northern parts of the county. It is well adapted to the growth of wheat, corn, alfalfa, and almost any crop grown in this latitude. The appearance of the country where this soil is found denotes more than average prosperity. Corn is the principal crop.

The chemical analysis of this soil calculated to pounds for one acre seven inches deep is as follows: nitrogen 4340 pounds, phosphorus 1060 pounds, potassium 36,400 pounds, calcium 13,600 pounds, and organic carbon 52,000 pounds. This compares well with the upland brown soil in Brown county, and is higher in nitrogen. This favorable showing is due partly to the fact that several samples were taken on native meadows where the nitrogen and organic matter had not been depleted. Sample 1023 (Table XXX in the appendix), a long-cultivated soil, has 3700 pounds of nitrogen per acre in the surface soil, while No. 1024, a native meadow alongside the former, has

4980 pounds in the surface soil. The mineral elements do not show such differences between cultivated and uncultivated types.

The fertility of this type, as well as other types in Riley county, can easily be maintained, as most of the corn and alfalfa is fed on the farms, provided the farm manures are properly husbanded. But that is one of the difficulties. The feed yard is too often located on a stony hillside just above a draw or a small creek. Here the manure is allowed to accumulate, and what is not leached out and washed away is allowed to burn up by fermentation in the summer time. While this is not true of all farmers it is the practice of too many for the future agricultural prosperity of the county. With proper husbanding of manures, commercial fertilizers will not be needed for a long time on this land. Large amounts of live stock will always be fed, as the close proximity of the rough stony land makes this class of farming profitable.

THE MARSHALL SILT LOAM.

(Brown silt loam, glacial and loessal.)

Next to the Oswego silt loam, the most valuable upland type in the county is the Marshall silt loam. It is different from the soil in Brown county known by the same name, both in formation and situation. On highest upland is found the Oswego silt loam. Where this has been extensively eroded occurs the rough stony land, and below the hills where the land flattens out is found the soil called the Marshall silt loam. It is formed partly from materials out of the surrounding hills and partly from glacial drift. This composite origin makes it one of the best all-purpose soils in the county. The soil is a brown to dark brown silt loam. The subsoil is a reddish brown to yellow silt loam. This soil is easily cultivated and has an excellent tilth. The natural drainage is good, but the soil is subject to erosion and is easily and quickly washed away if proper remedies are not used.

This soil is well adapted for all farm crops. It grows alfalfa particularly well, being surpassed in this respect only by bottom soils. As it is adjacent to large tracts of permanent pasture land the keeping of live stock on farms where this soil occurs is assured.

The chemical analysis of this soil calculated to the depth of seven inches for one acre gives the following result: nitrogen 4100 pounds, phosphorus 1020 pounds, potassium 41,008 pounds, calcium 13,400 pounds, and organic carbon 40,400 pounds. In plant-food content it compares very favorably with the Oswego silt loam. The greater portion of the farm owned by the Agricultural College is composed of this soil. Many more analyses have been made of this type than are found in this bulletin, but these results will be reported elsewhere.

With proper attention to the care of farm manures, rotation of crops, and supply of organic matter the fertility of this soil will be maintained. With the increased price of land and consequent desired intensive farming commercial fertilizers may be profitable in the future.

THE WABASH SILT LOAM.

(Alluvial, mostly second bottom.)

The Wabash silt loam is the most extensive of the bottom soils in Riley county. Along the smaller streams it is known as first bottom, and along the rivers as second bottom. The soil is a heavy, dark brown silt loam from one to two feet deep. The subsoil is rather heavy, compact and of a lighter color than the surface. It also contains more silt and clay. The natural drainage of this soil is fairly good, and the elevation is such that it is seldom flooded. This soil is formed from water deposits, and like all alluvial soils it varies greatly in texture, according to the presence or absence of more or less sand.

The chemical analysis of this soil shows that in each acre the first seven inches contain: nitrogen 3760 pounds, phosphorus 1100 pounds, potassium 42,400 pounds, calcium 15,400 pounds, and organic carbon 42,200 pounds. The comparatively low nitrogen content is due to the fact that the fields where the two samples were taken had been in continuous cultivation to corn and wheat for about 40 years. The stock of mineral plant food compares well with the other types.

This soil is well adapted to the growth of corn, wheat and alfalfa. But the continuous growing of grain without any application of farm manures is seriously depleting the stock of nitrogen and organic matter. This class of soil is at present in no need of commercial fertilizers if the stock of nitrogen is kept up by the use of farm manures and legumes.

LAUREL SILT LOAM.

(Alluvial, first bottom.)

The Laurel silt loam is more variable in texture than either the Wabash silt loam or the Wabash clay loam. The typical soil is a brown or gray silt loam, and about a foot deep. The subsoil is a gray silt loam. The variation is due to the larger or smaller amounts of sand mixed with the soil. In the same field may be found light sandy soil and a rather heavy silt soil with all the grades between. This soil occurs mainly along the Kansas and Blue rivers, and is the main soil type next to these rivers where it occupies the first bottom. Very little of this soil occurs along the creeks. The sand content increases as the river channel is approached, and where the channel is receding it merges into the Laurel fine sandy loam, and this in turn into the Laurel fine sand. The relation between the Wa. bash silt loam and the Laurel silt loam may be stated thus: The Wabash occurs mainly in the creeks, where it is the first-bottom soil. The small areas which occur along the two rivers occupy the second bottom. The Laurel occurs nearer the rivers and occupies the first bottom. It is of more recent formation. It is a more valuable soil. The largest areas occur on the receding side of the channel.

The chemical analysis of this soil gives the following figures calculated to one acre seven inches deep: nitrogen 5040 pounds, phosphorus 1140 pounds, potassium 39,000 pounds, calcium 41,400 pounds, and organic carbon 55,000 pounds. The sample was taken in a field that was recently put under cultivation. This partially accounts for the good showing. But on the whole it is a soil well stocked with plant food, and is well adapted to corn, wheat, and alfalfa, and fruits of all kinds. It is a good truck soil, and is so used near towns. It is not often flooded. It is naturally well drained and easy to cultivate.

WABASH SILT CLAY.

(Gumbo.)

The Wabash silt clay is locally known as "gumbo." It is found on the second-bottom or bench land having the same elevation as the Wabash silt loam. It is not an extensive type. The surface few inches is a dark brown silt loam. The subsoil is a black or very dark brown waxy, tenacious clay. The surface has undoubtedly been modified by wind-blown material.

It generally lies flat and has poor natural drainage, and is difficult to cultivate.

The chemical analysis shows that the soil is well stocked with plant food. The following results are calculated for one acre seven inches deep: nitrogen 4800 pounds, phosphorus 1560 pounds, potassium 43,200 pounds, calcium 8800 pounds, and organic carbon 72,400 pounds. It is lower in calcium than any of the other types, but this is true only of the surface soil. The subsurface and subsoil are well stocked with lime, as shown by the table in the appendix, but as the supply in the surface soil is very low, it may be profitable to apply ground limestone to this soil at the rate of two tons per acre. This ought to give the soil a better texture and make it easier to cultivate.

It is well adapted, where drained, to the growth of alfalfa. It also produces good crops of corn and wheat.

TABLE XVII.—CROP PRODUCTION IN BUSHELS PER ACRE IN RILEY COUNTY FOR 40 YEARS, 1872-1911.

	Years.	Corn.	Wheat.	Oats.
Ten-year average	1872-1881	34.22	14.44	33.44
Ten-year average	1882-1891	33.40	18.10	38.20
Ten-year average	1892-1901	21.10	14.40	23.90
Ten-year average	1902-1911	29.70	17.90	28.10
Twenty-year average	1872-1891	33.81	16.27	35.82
Twenty-year average	1892-1911	25.40	16.15	26.00
Thirty-year average	1872-1901	29.57	15.65	31.85
Forty-year average	1872-1911	29.61	16.21	30.91

TABLE XVIII.—AVERAGE AMOUNTS OF NITROGEN, PHOSPHORUS AND POTASSIUM REQUIRED YEARLY BY THE CORN, WHEAT AND OATS CROPS FOR THE 20 YEARS, 1892-1911, CALCULATED IN POUNDS AND IN PERCENTAGES OF THE AVERAGE QUANTITIES PRESENT IN IMPORTANT TYPES OF THE SOILS OF THE COUNTY.

	Corn.		Wheat.		Oats.	
	Pounds.	Per cent.	Pounds.	Per cent.	Pounds.	Per cent.
Nitrogen	38.1	0.86	31.0	0.70	25.2	0.57
Phosphorus	5.8	.49	5.2	.44	4.2	.35
Potassium	18.0	.04	18.7	.05	17.7	.04

DURATION OF CROP PRODUCTION IN RILEY COUNTY.

A calculation giving the number of average crops which will use up all the nitrogen, phosphorus and potassium in the first seven inches of soil will show that crop production in relation to the supply of nitrogen and phosphorus is very limited. Nitrogen is the most limited element, followed closely by phosphorus. Potassium is so plentiful that where grain only is removed the insensible lowering of the land surface will supply the element indefinitely. The stock of phosphorus is also maintained the same way to some extent. If all the roughage were fed on the farm, particularly alfalfa, and the manure carefully husbanded and returned to the soil, the duration of the phosphorus could also be prolonged.

AVERAGE CROP PRODUCTION IN RILEY COUNTY FOR FORTY YEARS, 1872-1911.

These data are found in Table XVII. The first three decades show a decrease and the last decade shows an increase. This is no doubt a case where better seed and improved machinery and cultural methods have more than offset the lessened crop-producing power of the land due to decrease in fertility. This is the only one of the counties covered by this report which shows this increase in crop production for all the three crops in the last decade.

In Table XVIII are given the pounds of the different elements used for the average of the three crops for the last twenty years, and also the percentage of this amount calculated with reference to the total. Nitrogen is used in the largest percentage, but as the percentage is much less than one, it is evident that much larger crops could be grown than at present.

THE WICHITA AREA.

PART OF SEDGWICK AND BUTLER COUNTIES.

The Wichita area is made up of the southeast portion of Sedgwick county and the southwest portion of Butler county. In this area nine types of soil were mapped by the Bureau of Soils. All these were sampled for chemical analysis. Tables XXXI and XXXII gives the complete report.

TABLE XIX.—ANALYSIS OF SOILS FROM SEDGWICK COUNTY.

TYPE AS GIVEN IN SOIL SURVEY.	Pounds per acre in two million pounds of surface soil (0-7 in.)				
	Nitrogen.	Phosphorus.	Potassium.	Calcium.	Organic carbon.
Sedgwick clay loam	3,720	1,100	39,800	11,000	50,200
Sedgwick loam	3,620	800	44,200	7,800	39,400
Sedgwick black clay loam	2,720	620	38,400	9,600	31,140
Sedgwick sandy loam	1,980	600	46,400	12,600	20,540
Derby loam	3,040	1,000	42,200	11,000	33,800
Arkansas loam	3,820	1,020	45,000	10,600	40,800
Miami sand	3,620	800	44,200	7,800	39,400
Miami fine sand	1,320	760	52,800	15,000	14,160
Average	2,980	838	44,125	10,675	33,680

TABLE XX.—ANALYSIS OF SOILS FROM BUTLER COUNTY.

TYPE AS GIVEN IN SOIL SURVEY.	Pounds per acre in two million pounds of surface soil (0-7 in.)				
	Nitrogen.	Phosphorus.	Potassium.	Calcium.	Organic carbon.
Sedgwick clay loam	3,600	520	31,800	9,800	43,800
Clarksville stony loam	3,340	500	31,400	9,200	42,800
Average	3,470	510	31,600	9,500	43,300

DESCRIPTION OF SOIL TYPES.

SEDGWICK CLAY LOAM.

(Dark brown clay loam.

The most extensive of the types is the Sedgwick clay loam. The largest stretch occurs east of Wichita. Here it covers the country for miles and miles, except in small patches where broken by other types. It occupies a rolling prairie and covers elevations and depressions alike. Most of it has good natural drainage, the exception being on flat elevations. The soil to about nine inches is a chocolate-brown or a dark-brown silt loam. The texture is even and uniform, and appears more clayey than silty. The subsoil is a heavy brown clay loam. At lower depths it becomes lighter in color. In the eastern part of the area, near the Walnut river, this soil type is generally more brown. Here it also appears to be thinner and is not so well stocked with plant food.

This soil is derived from limestone and shales. It is well adapted for corn and wheat. Alfalfa is grown in some places, but the subsoil is rather heavy for this crop. The appearance of the country denotes average prosperity. The heavy nature of the soil renders it somewhat difficult to till when too wet or too dry; but at optimum moisture content it is easily reduced to a loose, friable condition well suited for crops.

The chemical analysis shows that this soil, average of two samples from Sedgwick county, contains in one acre seven inches deep: nitrogen 3720 pounds, phosphorus 1100 pounds, potassium 39,800 pounds, calcium 11,000 pounds, and organic carbon 50,200 pounds. The average of the three samples from Butler county gave: nitrogen 3600 pounds, phosphorus 520 pounds, potassium 31,800 pounds, calcium 9800 pounds, and organic carbon 43,800 pounds. The phosphorus content of the soil in Butler county is remarkably low for a fertile soil. It will not be long before it will be necessary to supply this element. It ought to be added now in the form of rock phosphate together with large amounts of organic matter from legumes and farm manures. As this soil is heavy the roots have a more limited feeding area than in more sandy soil. This makes the application of organic matter all the more necessary. The calcium content is low in the surface soil, but increases as the subsoil is approached. It may be that some of this land would be benefited by the application of ground limestone. A trial would not be expensive, and might be very profitable.

CLARKSVILLE STONY LOAM.

(Rough limestone soil.)

The Clarksville stony loam is an unimportant type as regards extent. It occurs in small patches in the Sedgwick clay loam area, most of it in Butler county. The soil is a yellowish to brown silty loam, rather loose in texture. It contains a large amount of limestone and chert fragments. This type occupies high ridges and hillsides along streams and ravines. The soil is usually too thin and stony to have much agricultural value. It is used mostly for pasture land.

The chemical analysis shows that this soil contains in one acre seven inches deep: nitrogen 3340 pounds, phosphorus 500 pounds, potassium 31,400 pounds, calcium 9200 pounds, and organic carbon 42,800 pounds. It is well stocked with all the elements of plant food except phosphorus. In this respect it is like the Sedgwick clay loam, with which it occurs. The calcium content increases in the subsurface and subsoil.

SEDGWICK LOAM.
(Brown loam.)

The Sedgwick loam is a reddish brown loam down to about ten inches. This type contains more sand than the Derby loam, and is more friable, and easy to till. It has a very desirable texture. Just enough sand and yet sufficiently compact and silty to insure water-retaining capacity. The subsoil is reddish brown, and somewhat tough. This type is found largely northwest of Wichita and in smaller areas southwest of Wichita. It lies quite level, but owing to the open nature of the soil little artificial drainage is needed. It is well adapted to the growth of wheat, corn, and general farm crops. It is a strong soil but easy to handle. Alfalfa is grown to some extent, but for some reason it is difficult to obtain a stand.

The chemical analysis, calculated to one acre seven inches deep, shows that this soil contains: nitrogen 3620 pounds, phosphorus 800 pounds, potassium 44,200 pounds, calcium 7800 pounds, and organic carbon 39,400 pounds. It is well stocked with all elements except calcium and phosphorus. This statement seems to be true of all types south and west of the Arkansas river. It is not as low on phosphorus as the Sedgwick clay loam in Butler county, but is lower in calcium. This low calcium content is probably the cause of the failure of readily securing a stand of alfalfa. The table in the appendix shows that calcium is present only in traces as carbonate in soil, subsurface and subsoil. This suggests very strongly that the application of lime in the form of ground limestone would be very beneficial to the growth of alfalfa. The low phosphorus content is also one of the conditions which give trouble to the alfalfa grower.

SEDGWICK BLACK CLAY LOAM.

The Sedgwick black clay loam is a rather unimportant type. It occurs only in small patches, mostly southwest of Wichita. The soil to about twelve inches is a fine-grained black silty loam. The subsoil is a heavy, tough, bluish gray to drab clay. This type occurs in flat, basin-like depressions, and in most places needs drainage. The surface is somewhat modified by wind-blown materials, and contains some sand in the surface few inches. Where drained it is well adapted to wheat and corn. Most of it is now left in native meadow or pasture.

The chemical analysis shows that this soil contains in one acre seven inches deep: nitrogen 2720 pounds, phosphorus 620 pounds, potassium 38,400 pounds, calcium 9600 pounds, and organic carbon 31,140 pounds. For an upland clay soil it is low in nitrogen and phosphorus. The low content of calcium indicates that ground limestone would be profitable on this land. For best results it also needs organic matter containing nitrogen, and also phosphorus.

SEDGWICK SANDY LOAM.

The Sedgwick sandy loam is very much like the Sedgwick loam in texture, the main difference being the larger content of sand, which is a medium to fine, reddish brown in color. The soil is friable and easy to cultivate. It is derived from the same materials as the Sedgwick loam, and in general adaptability to crops is very much the same.

The chemical analysis shows that this soil contains in one acre seven inches deep; nitrogen 1980 pounds, phosphorus 600 pounds, potassium 46,400 pounds, calcium 12,600 pounds, and organic carbon 20,540 pounds. On the whole it is much lower in plant food than the Sedgwick loam, to which it is most similar. The reported failures to obtain a stand of alfalfa on this soil are no doubt due to the low content of phosphorus and nitrogen. The young plants need available nitrogen until such time as they have developed power to take it from the air. With such a low per cent of phosphorus present in the soil the amount in available forms is insufficient for the needs of the young plants. Alfalfa needs phosphorus in relatively larger amounts than corn or wheat. The content of organic matter is also low. To replenish the nitrogen and organic matter of this soil it would no doubt be best to plow under a crop of cowpeas. If to this was added 200 pounds per acre of bone meal, alfalfa would make successful growth. To increase the permanent stock of phosphorus, rock phosphate would be the cheapest form to use, but for the immediate effect some quickly available form should be used at first.

DERBY LOAM.
(Brown silty loam.)

The great area of the Derby loam is found south of Wichita, on the east side of the Arkansas river. It is an upland type. The soil to about ten inches is a yellowish brown to reddish brown silty loam containing a small proportion of fine sand. The soil grades almost imperceptibly into the subsoil. This latter is somewhat heavier and more compact.

This soil has good drainage. It is easier to cultivate than the Sedgwick clay loam. It is less likely to bake or form clods. On the whole it is a much more desirable soil for general farming purposes. It is well adapted for the growth of corn and wheat. Alfalfa is grown to some extent and apparently is yielding well. There is no reason on account of the texture and composition of this soil why alfalfa should not be a successful crop.

The chemical composition of this soil shows that it contains in one acre of soil seven inches deep: nitrogen 3040 pounds, phosphorus 1000 pounds, potassium 42,200 pounds, calcium 11,000 pounds, and organic carbon 33,800 pounds. On the whole it is as well stocked with plant food as the Sedgwick clay loam in Sedgwick county, and because it has a more open texture the plant food is more available. This results in greater crop-producing power. In mineral plant food it compares well with the best soils covered by this report.

THE ARKANSAS LOAM.
(Bottom soil loam.)

The Arkansas loam is a bottom soil, and like all such soils it has a variable texture. It is a very dark brown loam; some would call it black. In places it is modified by wind-blown materials from the sand dunes; in low places it is more waxy and heavy. Some of it lies sufficiently high to be well drained; other portions need artificial drainage before successful crops can be grown. The subsoil is grayish brown. It is a mixture composed of clay, silt and some very fine sand. At about three feet, layers of sand are found alternating with clay and silt. In some places fragments of limestone as well as other stones are found. It is a typical bottom soil and the most valuable for general farming in the valley of the Arkansas. It is well adapted to corn and alfalfa. Wheat does not do as well as on the upland. While its largest area is found in the valley of the Arkansas it is found along all the more important streams. The chemical analysis shows that this soil contains in one acre seven inches deep: nitrogen 3920 pounds, phosphorus 1020 pounds, potassium 45,000 pounds, calcium 10,600 pounds, and organic carbon 40,800 pounds. It is well stocked with all of the different elements of plant food. This together with a desirable physical texture makes a very fertile soil. With proper attention to the renewal of organic matter and nitrogen this soil will be in no need of commercial fertilizers for some time. In some places it may be that the addition of ground limestone would be profitable.

MIAMI SAND.

(Bottom sandy loam.)

The Miami sand is a loose yellowish brown sand, medium to coarse in texture. Like all bottom soils it is variable, the variation being due to the amount and fineness of the sand, In some places the subsoil contains considerable silt. This adds greatly to the value of the soil. This soil is wholly derived from transported material a large portion of which has come from Colorado. Pebbles of granite are often found.

This soil is well adapted to the growth of corn, alfalfa, and fruit. It is also an excellent truck soil.

The chemical analysis, calculated to one acre seven inches deep, gives the following results : nitrogen 3620 pounds, phosphorus 800 pounds, potassium 44,200 pounds, calcium 7800 pounds, and organic carbon 39,400 pounds. For a sandy soil it is remarkably well stocked with plant food.

MIAMI FINE SAND.

(Bottom, fine sandy land.)

The Miami fine sand is very much like the Miami sand, one difference being in the fineness of the sand grains. It is the soil type which borders immediately on the river channel. It is also a variable type. Some of it is more loamy and in other places the sand is coarser. The main difference between this type and the Miami sand is in the nature of the subsoil. In the latter is found fine silt-like materials, which are absent in the Miami fine sand. The subsoil of the latter is almost pure yellow sand. It is an excellent truck and fruit soil. Some corn is grown, but it is best adapted for fruit and trucking.

TABLE XXI.—CROP PRODUCTION IN BUSHELS PER ACRE IN SEDGWICK COUNTY FOR 40 YEARS, 1872-1911.

	Years.	Corn.	Wheat.	Oats.
Ten-year average	1872-1881	33.22	16.00	31.33
Ten-year average	1882-1891	30.77	17.70	37.20
Ten-year average	1892-1901	17.60	12.70	22.30
Ten-year average	1902-1911	22.75	12.30	26.67
Twenty-year average	1872-1891	32.00	16.85	34.27
Twenty-year average	1892-1911	20.18	12.50	24.49
Thirty-year average	1872-1901	27.20	15.47	30.28
Forty-year average	1872-1911	26.09	14.68	29.38

TABLE XXII.—AVERAGE AMOUNTS OF NITROGEN, PHOSPHORUS AND POTASSIUM REQUIRED YEARLY BY THE CORN, WHEAT AND OATS CROPS FOR THE 20 YEARS, 1892-1911, CALCULATED IN POUNDS AND IN PERCENTAGES OF THE AVERAGE QUANTITIES PRESENT IN IMPORTANT TYPES OF THE SOILS OF THE COUNTY.

	Corn.		Wheat.		Oats.	
	Pounds.	Per cent.	Pounds.	Per cent.	Pounds.	Per cent.
Nitrogen	29.87	1.36	11.94	0.54	23.75	1.08
Phosphorus	4.64	.63	2.00	.27	3.92	.53
Potassium	14.33	.03	7.25	.02	16.65	.04

TABLE XXIII.—CROP PRODUCTION IN BUSHELS PER ACRE IN BUTLER COUNTY FOR 40 YEARS, 1872-1911.

	Years.	Corn.	Wheat.	Oats.
Ten-year average	1872-1881	35.08	14.11	32.22
Ten-year average	1882-1891	29.19	17.10	36.60
Ten-year average	1892-1901	19.80	12.87	21.15
Ten-year average	1902-1911	22.10	13.43	23.60
Twenty-year average	1872-1891	32.14	15.61	34.41
Twenty-year average	1892-1911	20.95	13.15	22.38
Thirty-year average	1872-1901	28.02	14.69	29.99
Forty-year average	1872-1911	26.54	14.38	28.39

The chemical analysis calculated to one acre seven inches deep gives the following results: nitrogen 1320 pounds, phosphorus 760 pounds, potassium 52,800 pounds, calcium 15,000 pounds, and organic carbon 14,160 pounds. The nitrogen content is lower than in any of the other soils of the area, and it will be necessary to supply organic matter containing this element if profitable crop production is to be maintained. The other elements are fairly abundant for a sandy soil.

DURATION OF CROP PRODUCTION IN THE WICHITA AREA.

Table XXI shows that during the forty-year period, 1872-1911, there was a decrease in the average production of corn and oats for the three decades, but a slight increase for these two crops in the last decade. Wheat shows a decrease of over 20 per cent in the first three decades, and no increase the last decade. The average amount of plant food for the types sampled in Sedgwick county calculated to one acre seven inches deep is as follows: nitrogen 2980 pounds, phosphorus 838 pounds, potassium 44,125 pounds, calcium 10,675 pounds, and organic carbon 33,680 pounds. Table XXIII shows the number of pounds of nitrogen, phosphorus, and potassium used yearly by the average crop of corn, wheat, and oats for the last 20 years, and also the percentages of the amount present in the important types. Of the three elements nitrogen is removed in the largest amounts, both absolutely and relatively. It is the limiting element of crop-producing power in most of these soils. Next to nitrogen is phosphorus. This, however, is the only element which needs to be purchased, aside from lime for limited areas. The nitrogen can be supplied by the growth of legumes, but these must be either plowed under or fed and the manure carefully preserved and applied. Selling alfalfa from the lands will deplete the low stock of phosphorus more rapidly than selling any other crop. If an abundance of organic matter containing nitrogen is supplied, the cheapest form of phosphorus is ground rock phosphate, and a system of farming must be adopted which takes into account the facts here presented if these lands are to retain that crop-producing power which will maintain those who work the land.

TABLE XXIV.—ANALYSIS OF SOILS FROM DONIPHAN COUNTY.

TYPE AS GIVEN IN SOIL SURVEY	Pounds per acre in two million pounds of surface soil (0-7 in.)				
	Nitrogen.	Phosphorus.	Potassium.	Calcium.	Organic carbon.
Brown fine sandy loam (1056 and 1057)	3,840	1,200	40,800	10,600	42,600
Dark brown silt loam (1058 and 1059)	3,520	1,240	36,000	10,400	38,800
Brown silt loam (1060 and 1062)	2,060	1,280	34,600	10,800	21,800
Average	3,140	1,240	37,133	10,600	34,400

MISCELLANEOUS ANALYSES.

DONIPHAN COUNTY.

Six samples were taken in this county, representing three types of soil, which from their appearance and texture are named as follows: brown fine sandy loam, dark brown silt loam, brown silt loam. (Complete report is given in Table XXXIII.) The soil in Doniphan county is mostly derived from loess deposits. The greater portion of the county is quite rolling, but the soil is uniformly good. The southwestern portion of the county is more level, similar to the adjacent portion of Brown county. Here the soil is like the Marshall silt loam described under Brown county.

The main difference between these types is in amount and distribution of sand. All the soils have a brown color. The subsurface is a chocolate to red, and the subsoil is a deeper red which in places shades to a yellow, in other places it is a brick red. The soil classed as brown silt loam is the soil used for fruit raising. Sample No. 1060 was taken on one of these fruit farms, and 1062 on a very similar soil which was used for corn. The corn soil contains the more chemical plant food. The other two types were used for general farming. They are well adapted to corn, wheat and oats. As a class of soils they are much earlier than the more level lying soils in the adjacent counties. While only a small portion of the county is devoted to fruit raising, there is no reason why greater sections of it will not do as well as those that have been tried. To ascertain the chemical nature of the deep subsoil, sample 1061 was taken about 8 feet deep in a cut in the road. With the exception of nitrogen this subsoil is as well stocked with plant food as the surface soil. This subsoil has an open texture affording good natural drainage and easy penetration for the roots. It is no doubt due to this character of the subsoil that successful tree growth takes place.

These soils as a class are remarkably rich in phosphorus. In potassium and calcium they average well. The soils used for fruit farming are low in nitrogen and organic carbon. The problem of all these soils seems to be the renewal and conservation of the nitrogen and organic matter. If this is done, the insensible lowering of the land surface will keep up a needed supply of the phosphorus and potassium.

TABLE XXV.—ANALYSIS OF SOILS FROM HARPER COUNTY.

TYPE AS GIVEN IN SOIL SURVEY.	Pounds per acre in two million pounds surface soil (0-7 in.)				
	Nitrogen.	Phosphorus.	Potassium.	Calcium.	Organic carbon.
Brown loam (1072 and 1076)	1,820	700	36,000	7,400	16,200
Brown fine sandy loam (1073)	1,500	640	43,000	10,200	10,600
Brown sandy loam (1074)	1,940	760	39,800	4,600	18,000
Coarse sandy loam (1075)	2,100	740	41,000	7,400	20,200
Alluvial loam (1077)	1,620	820	39,200	4,400	14,000
Gray silt loam (1078)	2,460	720	34,200	7,800	27,600
Average	1,907	720	38,867	6,967	17,767

HARPER COUNTY.

In this county seven samples of soil were taken, classified as given in Table XXV, and also in Table XXXIV of the appendix.

SAMPLES 1072 and 1076, classed as brown loam, represent the best wheat soil of the county. The surface is a chocolate brown on a dark red subsoil. The subsoil is remarkable for its open and loose texture. The subsoil at three feet depth is more loose and open than many surface soils in good tilth. Some of this land is said to have grown nine successive crops of wheat without being plowed. There is no tendency whatever to form clods or a compact surface. It is one of the easiest of soils to till, the physical structure being most ideal. The chemical analysis of this soil shows it to be low in plant food as compared with other soils of the state, particularly in regard to nitrogen and organic matter, yet this soil is a good yielder. This is due to the extensive feeding ground allowed the roots by the loose, open nature of the subsoil. Were the roots confined to the plant food furnished by the surface soil, as in more compact types, the duration of crop-producing power in this soil would be short.

SAMPLE 1073 represents the brown sandy soil of the western part of the county. The surface is a brown to red. A great deal of this soil is underlaid by a silt subsoil. This is a very good complement to the more sandy surface. This soil has the reputation of withstanding dry weather conditions better than the heavier brown soil represented by Nos. 1072 and 1076. This sandy soil is well adapted for the growth of corn. The open nature of the surface soil enables it to take in the rain water and give it up more easily to crops than the heavier soil. The chemical analysis shows that this soil contains less nitrogen, phosphorus and organic carbon than any of the other types sampled in the county. That it is as productive as it is is due to the open, loose physical texture and the silty subsoil, which enables it both to store water and to give it to growing crops.

SAMPLE 1074. This soil, called a brown sandy loam, contains less sand than 1073; the subsoil is somewhat heavier. It is a good soil, withstands dry conditions well, and is a fair yielder. It contains on the surface numerous pebbles of granitic origin, Where these have come from is not known,

SAMPLE 1075. This soil is a dark brown underlaid with a coarse sandy silt. Where the subsoil is exposed in cuts in the road, and washing takes place, the roads become very sandy. The soil is fine and works easily. The subsurface is a brown, and the subsoil shades to a more red. The subsoil is open and porous, affording good drainage. The chemical analysis shows that this soil is the richest in plant food of any in the county. It lies flat, and it is almost exclusively devoted to wheat culture.

SAMPLE 1077. This represents the best alluvial soil in the county. The top soil is a dark brown, darker than any of the previous types. The subsoil is more of a brick-red color. The loose, open nature of the subsoil is as pronounced as in 1076. This soil shows a wonderful capacity for fruit production, due no doubt to the nature of the subsoil. The extent of this type is limited. The chemical analysis shows that this soil is low in nitrogen, phosphorus and organic carbon. This is partly due to the fact that the field where the sample was taken had grown wheat continuously for thirty years, and was still producing good crops. The soil is also well adapted for corn and alfalfa.

SAMPLE 1078. This represents the heavy gray silt loam of the eastern part of the county. It is locally known as "gumbo." The surface soil is a gray, of fairly loose texture; the subsurface and subsoil are darker and of a very compact structure, This soil is best adapted for wheat culture. Alfalfa does fairly well. It is not suited for corn. The chemical analysis shows that this soil contains more nitrogen and organic carbon than any of the other soils in the county, but as compared with soils in northeastern Kansas it is low in plant food.

EXPLANATION OF TABLES OF CHEMICAL ANALYSIS.

"The Location by Land Survey" gives the geographical position of the place where each sample was taken. The "Type as Given in Soil Survey" refers to the descriptive terms of the soil types used in the survey made by the Bureau of Soils. These terms are used in this report in describing these soils. The "Stratum Sampled" refers to the depth in inches of the soil sampled. The approximate weight of soil per acre represented by these strata are, respectively, 2,000,000, 4,000,000 and 6,000,000 pounds for the soil, subsurface, and subsoil. To convert percentages of plant food constituents into pounds per acre for the stratum it is only necessary to multiply these percentages by 20, 40 or 60 where there are three decimal places, and 200,400 or 600 where there are two decimal places. Thus, one-tenth of one per cent of any constituent is equal to 2000 pounds for the surface, 4000 pounds for the subsurface, and 6000 pounds for the subsoil; and one hundredth of one per cent is equal to 200, 400 and 600 pounds for the respective strata.

The elements nitrogen, phosphorus, calcium and carbon are determined in total. This does not mean the amount available or soluble in certain kinds of acids. It simply means all that there is in the soil of that element. It should also be understood that these are percentages of the element, and not of compounds of that element as is the case with many tables of chemical analysis of soils. Phosphorus is often given as percentages of phosphorus pentoxide, or so-called phosphoric acid. The element phosphorus constitutes approximately three-sevenths of the weight of this compound. Therefore, percentages of phosphorus in these tables would indicate more than twice the agricultural value of equal percentages stated in the terms of phosphorus pentoxide.

What has been said of phosphorus is true also of potassium and calcium. The percentages of potassium in these tables have approximately five-sixths the numerical value they would have if the percentages were in terms of potassium oxide or potash, and the percentages of calcium are very nearly five-sevenths the value they would be if the percentages were expressed as lime or calcium oxide.

Carbon is given as organic and inorganic. The organic carbon is the carbon in the organic or vegetable matter of the soil. The inorganic carbon is the carbon connected with the mineral portion of the soil in the form of carbonates. The vegetable or organic matter is what gives life to the soil. The percentage of organic matter in the soil is about twice that of the organic carbon. Inorganic carbon is such as is found in limestone or other carbonates. The presence of inorganic carbon denotes absence of soil acidity, but the absence of inorganic carbon does not necessarily denote acidity.

CHEMICAL ANALYSES.

TABLES GIVING COMPLETE REPORT ON CHEMICAL ANALYSES OF SOILS FROM ALLEN, BROWN, RUSSELL, FINNEY, RILEY, SEDGWICK, BUTLER, DONIPHAN AND HARPER COUNTIES.

TABLE XXVI.—ANALYSIS OF SOILS FROM ALLEN COUNTY. PERCENTAGES OF ELEMENTS IN THE MOISTURE-FREE SOIL.

Location by land survey.	Type as given in soil survey.	Stratum sampled, inches.	Sample No.	Nitrogen.	Phosphorus.	Potassium.	Calcium.	Organic carbon.	Inorganic carbon.
S. E. 10 of S. W. 40 of S. W. ¼,	Oswego silt loam	Soil............0-7	1007.1	0.216	0.056	1.44	0.45	2.48	Trace.
Sec. 32, T. 24, R. 18 E..............	(Gray silt loam mostly from shale)...............	Subsurface.....7-20	1007.2	.125	.048	1.64	.66	1.38	Trace.
		Subsoil.......20-40	1007.3	.078	.047	1.61	.39	.79	Trace.
S. W. 10 of S. W. 40 of S. E. ¼,	Oswego silt loam	Soil............0-7	1009.1	.200	.052	1.46	.51	2.19	Trace.
Sec. 24, T. 24, R. 18 E..............	(Gray silt loam mostly from shale)...............	Subsurface.....7-20	1009.2	.116	.053	1.40	.53	1.19	Trace.
		Subsoil.......20-40	1009.3	.074	.041	1.21	.51	.68	0.015
N. E. 10 of N. E. 40 of S. E. ¼,	Oswego silt loam	Soil............0-7	1010.1	.189	.042	1.46	.36	2.07	Trace.
Sec. 12, T. 24, R. 19 E..............	(Gray silt loam mostly from shale)...............	Subsurface.....7-20	1010.2	.124	.040	1.40	.53	1.52	Trace.
		Subsoil.......20-40	1010.3	.079	.032	1.46	.42	.66	Trace.
N. E. 10 of N. E. 40 of N. W. ¼,	Oswego silt loam	Soil............0-7	1012.1	.156	.044	1.25	.38	1.74	Trace.
Sec. 27, T. 25, R. 19 E..............	(Gray silt loam mostly from shale)...............	Subsurface.....7-20	1012.2	.094	.033	1.27	.46	.96	.016
		Subsoil.......20-40	1012.3	.032	.033	1.36	.64	.39	.018
S. W. 10 of N. W. 40 of N. W. ¼,	Oswego silt loam	Soil............0-7	1013.1	.304	.061	1.54	.65	3.69	Trace.
Sec. 8, T. 26, R. 20 E...............	(Gray silt loam mostly from shale)...............	Subsurface.....7-20	1013.2	.122	.051	1.55	.65	1.40	.010
		Subsoil.......20-40	1013.3	.071	.037	1.80	.76	.70	.015
S. W. 10 of S. E. 40 of S. W. ¼,	Oswego silt loam	Soil............0-7	1092.1	.254	.034	.92	1.67	2.89	Trace.
Sec. 22, T. 24, R. 20 E...............	(Gray silt loam mostly from shale)...............	Subsurface.....7-20	1092.2	.125	.029	1.55	.85	1.22	.189
		Subsoil.......20-40	1092.3	.064	.037	1.22	2.26	.49	1.691
S. E. 10 of N. E. 40 of S. E. ¼,	Oswego silt loam	Soil............0-7	1095.1	*	....	....	....	....	....
Sec. 14, T. 26, R. 20 E..............	(Gray silt loam mostly from shale)...............	Subsurface.....7-20	1095.2	.110	.037	1.12	.43	1.17	Trace.
		Subsoil.......20-40	1095.3	.065	.032	1.08	.47	.50	Trace.
		Soil...............	....	0.220	0.048	1.35	0.67	2.51	....
	Average....................................	Subsurface.........	....	.118	.042	1.41	.59	1.26	....
		Subsoil............	....	.066	.037	1.42	.48	1.05	....
N. E. 10 of N. E. 40 of N. W. ¼,	Oswego fine sandy loam	Soil............0-7	1093.1	0.188	0.021	0.96	0.25	2.09	None.
Sec. 4, T. 25, R. 21 E...............	(Sandy loam from sandstone)....................	Subsurface.....7-20	1093.2	.102	.029	.95	.28	1.10	None.
		Subsoil.......20-36	1093.3	.073	.013	.90	.28	.59	None.
S. E. 10 of S. W. 40 of S. E. ¼,	Oswego fine sandy loam	Soil............0-7	1094.1	.122	.030	.66	.22	1.16	None.
Sec. 1, T. 26, R. 20 E...............	(Sandy loam from sandstone)....................	Subsurface.....7-20	1094.2	.064	.031	.63	.22	.55	None.
		Subsoil.......20-36	1094.3	.042	.031	.95	.17	.32	None.
		Soil...............	....	0.155	0.026	0.81	0.24	1.63	....
	Average....................................	Subsurface.........	....	.083	.030	.79	.25	.83	....
		Subsoil............	....	.058	.022	.93	.23	.46	....

S. E. 10 of S. W. 40 of S. W. ¼, Sec. 19, T. 23, R. 19 E.	Sedgwick clay loam (Black or dark brown clay loam formed from limestone)	Soil 0–7	1008.1	0.220	0.046	1.68	0.58	2.50	Trace.
		Subsurface 7–20	1008.2	.159	.048	1.67	.56	1.75	0.015
		Subsoil 20–30	1008.3	.110	.030	1.73	1.65	1.03	.407
N. E. 10 of N. E. 40 of N. W. ¼, Sec. 14, T. 25, R. 19 E.	Sedgwick clay loam (Black or dark brown clay loam formed from limestone)	Soil 0–7	1011.1	.227	.065	1.49	.49	2.64	.014
		Subsurface 7–20	1011.2	.162	.042	1.49	.40	1.78	.014
		Subsoil 20–40	1011.3	.102	.037	1.19	.54	.93	.015
S. E. 10 of N. E. 40 of N. E. ¼, Sec. 14, T. 26, R. 18 E.	Sedgwick clay loam (Black or dark brown clay loam formed from limestone)	Soil 0–7	1089.1	.232	.028	1.46	.43	2.60	None.
		Subsurface 7–20	1089.2	.147	.027	1.46	.46	1.53	Trace.
		Subsoil 20–40	1089.3	.084	.024	1.30	.62	.79	Trace.
S. E. 10 of S. E. 40 of S. E. ¼, Sec. 29, T. 25, R. 21 E.	Sedgwick clay loam (Black or dark brown clay loam formed from limestone)	Soil 0–7	1096.1	.204	.039	1.79	.38	2.14	Trace.
		Subsurface 7–20	1096.2	.152	.043	1.77	.46	1.20	Trace.
		Subsoil 20–40	1096.3	.109	.031	1.62	.32	.74	None.
S. E. 10 of S. E. 40 of S. E. ¼, Sec. 29, T. 25, R. 21 E.	Sedgwick clay loam (Black or dark brown clay loam formed from limestone)	Soil 0–7	1097.1	.202	.035	1.56	.41	2.10	Trace.
	Average	Soil		0.217	0.043	1.60	0.47	2.40	
		Subsurface		.155	.040	1.60	.47	1.57	
		Subsoil		.101	.031	1.46	.78	.88	
S. W. 10 of S. E. 40 of S. E. ¼, Sec. 31, T. 25, R. 18 E.	Neosho silt loam (Ash gray silt loam, second bottom)	Soil 0–7	1086.1	0.166	0.026	1.32	0.39	1.58	Trace.
		Subsurface 7–20	1086.2	.107	.025	1.29	.39	.91	Trace.
		Subsoil 20–40	1086.3	.062	.015	1.34	.37	.51	Trace.
S. W. 10 of N. W. 40 of N. E. ¼, Sec. 5, T. 26, R. 18 E.	Yazoo loam (First bottom soil)	Soil 0–7	1087.1	0.154	0.035	1.85	0.51	1.55	None.
		Subsurface 7–20	1087.2	.119	.030	1.87	.54	1.34	None.
		Subsoil 20–40	1087.3	.077	.025	1.80	.43	.72	None.
S. E. 10 of N. E. 40 of N. W. ¼, Sec. 18, T. 24, R. 18 E.	Yazoo loam (First bottom soil)	Soil 0–7	1091.1	.193	.049	1.80	.54	2.11	None.
		Subsurface 7–20	1091.2	.100	.044	1.99	.36	.91	None.
		Subsoil 20–40	1091.3	.102	.045	1.99	.60	1.06	None.
	Average	Soil		0.173	0.042	1.83	0.53	1.83	
		Subsurface		.110	.037	1.93	.45	1.13	
		Subsoil		.090	.035	1.90	.52	.89	
N. W. 10 of N. W. 40 of S. W. ¼, Sec. 8, T. 26, R. 18 E.	Yazoo clay (First bottom soil)	Soil 0–7	1088.1	0.269	0.059	1.77	0.44	2.69	None.
		Subsurface 7–20	1088.2	.142	.046	1.85	.55	1.37	None.
		Subsoil 20–40	1088.3	.109	.027	1.85	.59	1.04	Trace.
N. E. 10 of N. E. 40 of N. E. ¼, Sec. 29, T. 24, R. 18 E.	Sharkey clay (First bottom soil)	Soil 0–7	1090.1	0.267	0.058	1.80	0.68	2.79	None.
		Subsurface 7–20	1090.2	.105	.045	1.76	.66	1.14	None.
		Subsoil 20–40	1090.3	.070	.032	1.57	.75	.77	Trace.

* Sample lots.

TABLE XXVII.—ANALYSIS OF SOILS FROM BROWN COUNTY. PERCENTAGES OF ELEMENTS IN THE MOISTURE-FREE SOIL.

Location by land survey.	Type as given in soil survey.	Stratum sampled, inches.	Sample No.	Nitrogen.	Phosphorus.	Potassium.	Calcium.	Organic carbon.	Inorganic carbon.
S. E. 10 of S. W. 40 of S. E. ¼, Sec. 21, T. 4, R. 18 E.	Marshall silt loam (Brown silt loam, glacial and loessal)	Soil 0-7	1030.1	0.214	0.057	1.79	0.46	2.74	None.
		Subsurface 7-20	1030.2	.151	.063	1.81	.50	1.75	None.
		Subsoil 20-40	1030.3	.071	.059	1.82	.54	.64	None.
S. E. 10 of S. W. 40 of S. E. ¼, Sec. 4, T. 2, R. 16 E.	Marshall silt loam (Brown silt loam, glacial and loessal)	Soil 0-7	1048.1	.228	.062	1.63	.54	2.70	None.
		Subsurface 7-20	1048.2	.154	.053	1.40	.62	1.72	None.
		Subsoil 20-40	1048.3	.072	.066	1.73	.66	.64	None.
S. E. 10 of S. E. 40 of N. E. ¼, Sec. 33, T. 1, R. 17 E.	Marshall silt loam (Brown silt loam, glacial and loessal)	Soil 0-7	1049.1	.193	.062	2.12	.48	2.26	Trace.
		Subsurface 7-20	1049.2	.161	.050	2.08	.50	1.69	Trace.
		Subsoil 20-40	1049.3	.091	.047	2.12	.47	.85	None.
N. E. 10 of N. E. 40 of N. E. ¼, Sec. 2, T. 3, R. 15 E.	Marshall silt loam (Brown silt loam, glacial and loessal)	Soil 0-7	1050.1	.232	.049	2.07	.68	2.77	Trace.
		Subsurface 7-20	1050.2	.176	.046	2.23	.78	2.19	None.
		Subsoil 20-40	1050.3	.078	.049	2.18	.80	.64	Trace.
N. W. 10 of N. W. 40 of N. W. ¼, Sec. 7, T. 4, R. 16 E.	Marshall silt loam (Brown silt loam, glacial and loessal)	Soil 0-7	1052.1	.274	.062	1.88	.59	3.48	Trace.
		Subsurface 7-20	1052.2	.168	.042	1.93	.68	2.02	Trace.
		Subsoil 20-40	1052.3	.085	.047	1.92	.70	.82	Trace.
N. E. 10 of N. E. 40 of N. E. ¼, Sec. 17, T. 4, R. 17 E.	Marshall silt loam (Brown silt loam, glacial and loessal)	Soil 0-7	1053.1	.228	.048	2.00	.63	2.79	Trace.
		Subsurface 7-20	1053.2	.170	.052	1.92	.78	1.94	Trace.
		Subsoil 20-40	1053.3	.087	.054	1.85	.78	.76	Trace.
S. W. 10 of S. E. 40 of S. E. ¼, Sec. 30, T. 2, R. 18 E.	Marshall silt loam (Brown silt loam, glacial and loessal)	Soil 0-7	1055.1	.181	.064	2.09	.57	2.17	Trace.
		Subsurface 7-20	1055.2	.163	.059	1.86	.53	1.79	None.
		Subsoil 20-40	1055.3	.087	.063	2.02	.59	.89	0.016
	Average	Soil		0.221	0.053	1.94	0.56	2.70	
		Subsurface		.163	.052	1.89	.63	1.87	
		Subsoil		.082	.055	1.95	.65	.75	
S. W. 10 of S. W. 40 of N. W. ¼, Sec. 6, T. 4, R. 16 E.	Marshall gravelly loam (Mostly glacial)	Soil 0-7	1051.1	0.247	0.037	1.34	0.60	2.79	Trace.
		Subsurface 7-20	1051.2	.140	.037	1.34	.55	1.45	Trace.
		Subsoil 20-40	1051.3	.070	.039	1.35	.55	.73	Trace.
S. E. 10 of S. E. 40 of S. E. ¼, Sec. 3, T. 2, R. 16 E.	Yazoo silt loam (Bottom soil)	Soil 0-7	1047.1	0.158	0.078	1.77	0.84	3.95	0.042
		Subsurface 7-20	1047.2	.160	.064	2.06	.83	2.07	None.
		Subsoil 20-40	1047.3	.079	.077	1.86	1.35	1.03	.622
S. E. 10 of S. W. 40 of N. W. ¼, Sec. 1, T. 3, R. 17 E.	Yazoo silt loam (Bottom soil)	Soil 0-7	1054.1	.187	.051	1.91	.56	2.40	Trace
		Subsurface 7-20	1054.2	.130	.054	1.93	.65	1.65	Trace.
		Subsoil 20-40	1054.3	.081	.050	1.97	.65	1.00	Trace.
	Average	Soil		0.173	0.065	1.84	0.70	3.18	
		Subsurface		.145	.059	2.00	.74	1.86	
		Subsoil		.080	.064	1.92	1.00	1.02	

TABLE XXVIII.—ANALYSIS OF SOILS FROM RUSSELL COUNTY. PERCENTAGES OF ELEMENTS IN THE MOISTURE-FREE SOIL.

Location by land survey.	Type as given in soil survey.	Stratum sampled, inches.	Sample No.	Nitrogen.	Phosphorus.	Potassium.	Calcium.	Organic carbon.	Inorganic carbon.
N. W. 10 of S. E. 40 of S. E. ¼, Sec. 16, T. 14, R. 14 W.	Sedgwick clay loam (Dark brown or black clay loam from shale and limestone)	Soil 0–7	1036.1	0.148	0.063	1.89	0.80	1.61	None.
		Subsurface 7–20	1036.2	.091	.056	1.95	.83	.82	None.
		Subsoil 20–40	1036.3	.056	.056	2.05	.82	.49	0.296
N. E. 10 of N. E. 40 of S. E. ¼, Sec. 15, T. 14, R. 14 W.	Sedgwick clay loam (Dark brown or black clay loam from shale and limestone)	Soil 0–7	1037.0	.213	.051	2.10	.76	2.46	Trace.
S. E. 10 of S. W. 40 of S. E. ¼, Sec. 15, T. 13, R. 14 W.	Sedgwick clay loam (Dark brown or black clay loam from shale and limestone)	Soil 0–7	1039.1	.182	.066	2.12	.86	2.03	.164
		Subsurface 7–20	1039.2	.110	.051	1.96	.92	1.13	.053
		Subsoil 20–40	1039.3	.062	.050	1.86	2.03	.49	1.201
S. W. 10 of S. W. 40 of N. W. ¼, Sec. 31, T. 13, R. 12 W.	Sedgwick clay loam (Dark brown or black clay loam from shale and limestone)	Soil 0–7	1041.1	.217	.064	2.15	1.20	2.40	.089
		Subsurface 7–20	1041.2	.124	.069	2.20	1.02	1.60	.200
		Subsoil 20–40	1041.3	.063	.062	1.63	5.32	.86	5.179
N. E. 10 of N. E. 40 of N. E. ¼, Sec. 7, T. 14, R. 14 W.	Sedgwick clay loam (Dark brown or black clay loam from shale and limestone)	Soil 0–7	1042.1	.192	.038	2.18	.75	2.29	Trace.
		Subsurface 7–20	1042.2	1.008	.048	2.25	.80	1.33	Trace.
		Subsoil 20–40	1042.3	.051	.042	2.23	1.85	.67	1.062
S. W. 10 of S. E. 40 of S. W. ¼, Sec. 8, T. 15, R. 14 W.	Sedgwick clay loam (Dark brown or black clay loam from shale and limestone)	Soil 0–7	1044.1	.167	.025	1.80	.65	2.03	Trace.
		Subsurface 7–20	1044.2	.105	.054	2.20	.96	1.30	.084
		Subsoil 20–40	1044.3	.057	.062	2.22	1.45	.87	.609
	Average	Soil	....	0.187	0.051	2.04	0.84	2.14	....
		Subsurface	....	.106	.056	2.11	.91	1.24	....
		Subsoil	....	.058	.054	2.00	2.29	.68	....
S. W. 10 of N. E. 40 of N. W. ¼, Sec. 2, T. 15, R. 14 W.	Sedgwick sandy loam (Sandy loam from sandstone)	Soil 0–7	1038.1	0.141	0.048	1.80	0.74	1.61	None.
		Subsurface 7–20	1038.2	.094	.057	2.03	.76	1.07	Trace.
		Subsoil 20–40	1038.3	.061	.063	1.91	.72	.63	Trace.
S. E. 10 of N. E. 40 of S. W. ¼, Sec. 5, T. 15, R. 14 W.	Benton loam (Eroded and hilly land)	Soil 0–7	1043.1	0.237	0.053	1.62	5.03	2.90	4.501
		Subsurface 7–20	1043.2	.145	.059	1.32	8.60	1.70	9.125
		Subsoil 20–40	1043.3	.073	.063	1.30	8.05	1.28	12.352
S. W. 10 of S. W. 40 of N. W. ¼, Sec. 21, T. 13, R. 13 W.	Waldo loam (Brown silt loam, mostly bottom soil)	Soil 0–7	1040.1	0.269	0.060	1.90	1.11	3.18	Trace.
		Subsurface 7–20	1040.2	.134	.055	1.87	1.11	1.46	Trace.
		Subsoil 20–40	1040.3	.072	.055	2.14	1.99	.76	1.380

TABLE XXIX.—ANALYSIS OF SOILS FROM FINNEY COUNTY. PERCENTAGES OF ELEMENTS IN THE MOISTURE-FREE SOIL.

Location by land survey.	Type as given in soil survey.	Stratum sampled, inches.	Sample No.	Nitrogen.	Phosphorus.	Potassium.	Calcium.	Organic carbon.	Inorganic carbon.
S. W. 10 of S. E. 40 of S. E. ¼, Sec. 3, T. 24, R. 32 W. (Station Farm)	Marshall silt loam (Brown silt loam, loessal)	Soil 0-7	1111.1	0.104	0.064	2.31	0.82	1.02	Trace.
		Subsurface 7-20	1111.2	.080	.063	2.34	1.62	.76	0.334
		Subsoil 20-40	1111.3	.060	.072	2.02	4.34	.38	1.193
S. E. 10 of N. E. 40 of S. E. ¼, Sec. 3, T. 24, R. 32 W. (Station Farm)	Marshall silt loam (Brown silt loam, loessal)	Soil 0-7	1112.1	.126	.069	2.28	1.88	1.13	.295
		Subsurface 7-20	1112.2	.086	.074	2.19	3.42	1.12	.602
		Subsoil 20-40	1112.3	.045	.066	2.22	3.98	.32	.979
N. E. 10 of N. E. 40 of N. E. ¼, Sec. 3, T. 24, R. 32 W. (Station Farm)	Marshall silt loam (Brown silt loam, loessal)	Soil 0-7	1115.1	.128	.058	2.21	.76	1.31	Trace.
		Subsurface 7-20	1115.2	.084	.062	2.28	1.18	.64	.347
		Subsoil 20-40	1115.3	.048	.069	2.20	3.44	.21	.886
N. W. 10 of N. W. 40 of N. W. ¼, Sec. 33, T. 23, R. 33 W.	Marshall silt loam (Brown silt loam, loessal)	Soil 0-7	1124.1	.139	.075	2.25	1.22	1.18	.110
		Subsurface 7-20	1124.2	.101	.075	2.04	3.42	.69	.764
		Subsoil 20-40	1124.3	.044	.074	2.05	3.53	.29	1.112
	Average	Soil	....	0.124	0.067	2.26	1.17	1.16	....
		Subsurface	....	.088	.069	2.21	2.41	.80	....
		Subsoil	....	.049	.070	2.12	3.82	.30	....
N. W. 10 of N. E. 40 of N. W. ¼, Sec. 13, T. 22, R. 32 W.	Marshall silt loam (Sandy phase)	Soil 0-7	1125.1	0.103	0.061	2.42	1.08	0.94	0.133
		Subsurface 7-20	1125.2	.072	.045	2.41	1.08	.66	.016
		Subsoil 20-40	1125.3	.040	.056	2.45	1.81	.31	.253
N. W. 10 of N. W. 40 of S. W. ¼, Sec. 16, T. 24, R. 22 W.	Laurel loam (Dark brown, mostly second bottom soil)	Soil 0-7	1110.1	0.168	0.069	2.48	1.19	1.52	0.960
		Subsurface 7-20	1110.2	.098	.060	2.34	1.78	.89	.282
		Subsoil 20-40	1110.3	.053	.010	2.04	4.55	.39	1.123
S. W. 10 of S. W. 40 of S. W. ¼, Sec. 4, T. 24, R. 33 W.	Laurel sandy loam (First and second bottom soil)	Soil 0-8	1116.1	0.084	0.056	2.49	0.93	0.84	0.186
S. E. 10 of S. E. 40 of S. E. ¼, Sec. 6, T. 24, R. 33 W.	Laurel sandy loam (First and second bottom soil)	Soil 0-7	1118.1	.096	.064	2.34	1.01	.80	.092
		Subsurface 7-20	1118.2	.069	.060	2.35	1.02	.63	.138
		Subsoil 20-36	1118.3	.048	.060	2.24	3.59	.31	.898
	Average	Soil	....	0.090	0.060	2.42	0.97	0.82	....

S. E. 10 of N. W. 40 of S. E. ¼, Sec. 3, T. 24, R. 32 W. (Station Farm)	Finney sandy loam (Upland sandy soil)	Soil 0–7	1113.1	0.076	0.047	2.34	0.78	0.81	Trace.
		Subsurface 7–20	1113.2	.062	.042	2.31	.59	.45	Trace.
		Subsoil 20–40	1113.3	.039	.022	2.31	1.00	.18	0.206
N. W. 10 of N. W. 40 of N. E. ¼, Sec. 24, T. 24, R. 32 W.	Finney sandy loam (Upland sandy soil)	Soil 0–7	1120.1	.071	.029	2.30	4.47	.46	Trace.
		Subsurface 7–20	1120.2	.080	.017	2.30	.41	.40	.041
		Subsoil 20–40	1120.3	.062	.033	2.12	1.23	.48	6.450
	Average	Soil	....	0.074	0.038	2.32	2.63	0.64	....
		Subsurface	....	.071	.030	2.31	.50	.43	....
		Subsoil	....	.051	.028	2.22	1.12	.33	....
S. W. 10 of S. E. 40 of N. W. ¼, Sec. 30, T. 24, R. 32 W.	Dune sand (Sand hills)	Soil 0–8	1119.1	0.017	0.036	2.79	0.60	0.11	Trace.
S. E. 10 of S. W. 40 of S. W. ¼, Sec. 24, T. 25, R. 31 W.	Colorado sand (More level than the sand hills)	Soil 0–10	1122.1	0.027	0.035	2.46	0.45	0.24	None.
Sec. 11, T. 23, R. 31 W.	Rough stony land	Soil 0–12	1123.1	0.079	0.067	2.36	2.86	0.64	0.703
S. W. 10 of N. W. 40 of S. E. ¼, Sec. 3, T. 24, R. 32 W. (Station Farm)	Colorado adobe	Soil 0–7	1114.1	0.087	0.076	2.48	0.82	0.89	Trace.
		Subsurface 7–20	1114.2	.038	.067	2.45	2.27	.24	.496
		Subsoil 20–40	1114.3	.031	.056	2.26	2.29	.07	.649
N. E. 10 of N. E. 40 of N. W. ¼. Sec. 5, T. 24, R. 33 W.	Colorado adobe	Soil 0–7	1117.1	.112	.060	2.54	.80	1.04	.022
		Subsurface 7–20	1117.2	.059	.067	2.24	1.74	.56	.418
		Subsoil 20–40	1117.3	.042	.080	2.20	2.31	.31	.582
	Average	Soil	....	0.100	0.068	2.51	0.81	0.97	....
		Subsurface	....	.049	.067	2.35	2.01	.40	....
		Subsoil	....	.037	.068	2.23	2.30	.19	....
N. W. 10 of N. W. 40 of N. W. ¼, Sec. 21, T. 24, R. 31 W.	Finney clay (Buffalo wallows)	Soil 0–7	1121.1	0.108	0.065	2.24	0.81	0.88	Trace.
		Subsurface 7–20	1121.2	.057	.052	2.24	.47	.44	Trace.
		Subsoil 20–36	1121.3	.038	.067	2.27	.98	.28	0.029

TABLE XXX.—ANALYSIS OF SOILS FROM RILEY COUNTY. PERCENTAGES OF ELEMENTS IN THE MOISTURE-FREE SOIL.

Location by land survey.	Type as given in soil survey.	Stratum sampled, inches.	Sample No.	Nitrogen.	Phosphorus.	Potassium.	Calcium.	Organic carbon.	Inorganic carbon.
N. E. 10 of S. W. 40 of N. E. ¼, Sec. 2, T. 10, R. 5 E.	Oswego silt loam (Gray silt loam from limestone and shale)	Soil ... 0-7	1023.1	0.185	0.057	2.03	0.68	2.14	Trace.
		Subsurface ... 7-20	1023.2	.137	.051	1.83	.74	1.44	Trace.
		Subsoil ... 20-40	1023.3	.079	.051	2.05	.81	.85	Trace.
S. W. 10 of N. E. 40 of N. W. ¼, Sec. 35, T. 9, R. 5 E.	Oswego silt loam (Gray silt loam from limestone and shale)	Soil ... 0-7	1024.1	.249	.045	1.75	.66	3.06	Trace.
		Subsurface ... 7-20	1024.2	.130	.052	1.62	.68	1.34	None.
		Subsoil ... 20-40	1024.3	.069	.069	2.00	1.01	.61	0.351
N. W. 10 of S. E. 40 of S. E. ¼, Sec. 14, T. 8, R. 4 E.	Oswego silt loam (Gray silt loam from limestone and shale)	Soil ... 0-7	1025.1	.190	.049	1.71	.69	2.20	None.
		Subsurface ... 7-20	1025.2	.128	.048	1.80	.72	1.31	Trace.
		Subsoil ... 20-40	1025.3	.077	.042	1.89	.76	.57	.437
S. W. 10 of S. W. 40 of S. W. ¼, Sec. 14, T. 6, R. 6 E.	Oswego silt loam (Gray silt loam from limestone and shale)	Soil ... 0-7	1026.1	.254	.067	1.92	.77	3.14	None.
		Subsurface ... 7-20	1026.2	.168	.055	1.94	.80	1.98	None.
		Subsoil ... 20-40	1026.3	.081	.060	1.95	.80	.15	.042
N. W. 10 of S. E. 40 of S. E. ¼, Sec. 16, T. 6, R. 5 E.	Oswego silt loam (Gray silt loam from limestone and shale)	Soil ... 0-7	1027.1	.168	.053	1.83	.57	2.09	None.
		Subsurface ... 7-20	1027.2	.119	.048	2.00	.76	1.06	None.
		Subsoil ... 20-40	1027.3	.027	.041	1.88	.96	.67	.335
N. E. 10 of N. E. 40 of N. W. ¼, Sec. 3, T. 8, R. 5 E.	Oswego silt loam (Gray silt loam from limestone and shale)	Soil ... 0-7	1028.1	.253	.044	1.67	.70	2.98	Trace.
		Subsurface ... 7-20	1028.2	.130	.045	1.83	.61	1.39	None.
		Subsoil ... 20-40	1028.3	.068	.044	2.00	.63	.55	.269
	Average	Soil	...	0.217	0.053	1.82	0.68	2.60	...
		Subsurface	...	.135	.050	1.84	.72	1.42	...
		Subsoil	...	.104	.043	1.96	.83	.57	...
S. W. 10 of S. E. 40 of N. W. ¼, Sec. 1, T. 11, R. 6 E.	Marshall silt loam (Brown silt loam, glacial and loessal)	Soil ... 0-7	1084.1	0.205	0.051	2.05	0.67	2.02	None.
		Subsurface ... 7-20	1084.2	.120	.028	2.07	.62	1.06	None.
		Subsoil ... 20-40	1084.3	.070	.023	1.99	.64	.43	None.

N. W. 10 of S. E. 40 of S. W. ¼, Sec. 3, T. 7, R. 6 E.	Wabash silt loam (Alluvial, mostly second bottom)	Soil	0–7	1029.1	0.223	0.060	1.96	0.79	2.75	None.
		Subsurface	7–20	1029.2	.152	.058	2.09	.55	1.56	None.
		Subsoil	20–40	1029.3	.071	.048	2.06	.55	.63	None.
S. E. 10 of S. W. 40 of N. W. ¼, Sec. 19, T. 10, R. 8 E.	Wabash silt loam (Alluvial, mostly second bottom)	Soil	0–7	1082.1	0.153	0.050	2.08	0.74	1.46	None.
		Subsurface	7–20	1082.2	.117	.054	2.16	.71	1.02	None.
		Subsoil	20–40	1082.3	.074	.134	2.11	.86	.65	None.
	Average	Soil			0.188	0.055	2.12	0.77	2.11	
		Subsurface			.135	.056	2.13	.63	1.29	
		Subsoil			.073	.091	2.09	.71	.64	
S. E. 10 of N. E. 40 of S. E. ¼, Sec. 8, T. 11, R. 7 E.	Laurel silt loam. (Alluvial, first bottom)	Soil	0–7	1085.1	0.252	0.057	1.95	2.07	2.75	0.341
		Subsurface	7–20	1085.2	.137	.061	2.01	2.10	1.37	1.214
		Subsoil	20–40	1085.3	.064	.054	1.94	1.84	.59	1.204
N. E. 10 of N. E. 40 of N. E. ¼, Sec. 27, T. 10, R. 8 E.	Wabash silt clay (Locally known as "Gumbo")	Soil	0–7	1083.1	0.340	0.078	2.16	0.44	3.62	4.462
		Subsurface	7–20	1083.2	.188	.066	1.99	5.63	1.91	5.990
		Subsoil	20–40	1083.3	.082	.047	1.95	6.06	.62	6.571

Table XXXI.—ANALYSIS OF SOILS FROM SEGWICK COUNTY. PERCENTAGES OF ELEMENTS IN THE MOISTURE-FREE SOIL.

Location by land survey.	Type as given in soil survey.	Stratum sampled, inches.	Sample No.	Nitrogen.	Phosphorus.	Potassium.	Calcium.	Organic carbon.	Inorganic carbon.
N. W. 10 of N. W. 40 of S. W. ¼, Sec. 11, T. 27, R. 2 E.	Sedgwick clay loam (Dark brown clay loam)	Soil............0–7	1014.1	0.075	0.054	1.85	0.55	2.69	Trace.
		Subsurface.....7–20	1014.2	.099	.041	2.26	.53	1.27	Trace.
		Subsoil.......20–40	1014.3	.069	.035	2.03	.35	.76	0.046
N. W. 10 of N. W. 40 of N. W. ¼, Sec. 10, T. 28, R. 2 E.	Sedgwick clay loam (Dark brown clay loam)	Soil............0–7	1015.1	.188	.055	2.12	.55	2.33	.047
		Subsurface.....7–20	1015.2	.118	.051	2.43	.72	1.29	1.122
		Subsoil.......20–40	1015.3	.059	.053	2.35	7.39	2.88	1.004
	Average	Soil............	....	0.132	0.055	1.99	0.55	2.51	....
		Subsurface.........	....	.109	.046	2.35	.63	1.28	....
		Subsoil............	....	.064	.044	2.19	3.87	1.82	....
N. W. 10 of N. W. 40 of N. W. ¼, Sec. 31, T. 27, R. 1 W.	Sedgwick black clay loam	Soil............0–7	1187.1	0.136	0.031	1.92	0.48	1.56	Trace.
		Subsurface.....7–20	1187.2	.107	.034	1.83	.56	1.17	Trace.
		Subsoil.......20–40	1187.3	.069	.047	1.93	1.00	.55	0.108
N. W. 10 of N. W. 40 of N. W. ¼, Sec. 7, T. 27, R. 1 W.	Sedgwick loam (Brown loam)	Soil...........0–8	1018.1	0.181	0.040	2.21	0.39	1.97	Trace.
		Subsurface.....8–20	1018.2	.140	.047	2.18	.50	1.39	Trace.
		Subsoil.......20–40	1018.3	.064	.048	2.12	.59	.74	Trace.
S. W. 10 of N. W. 40 of N. W. ¼, Sec. 9, T. 27, R. 1 W.	Sedgwick sandy loam	Soil............0–7	1188.1	0.099	0.030	2.32	0.63	1.03	Trace.
		Subsurface.....7–20	1188.2	.094	.029	2.28	.47	.89	Trace.
		Subsoil.......20–40	1188.3	.069	.029	2.19	.37	.60	Trace.
S. W. 10 of S. W. 40 of S. E. ¼, Sec. 25, T. 28, R. 1 E.	Derby loam (Brown loam)	Soil............0–7	1016.1	0.152	0.050	2.11	0.55	1.69	Trace.
		Subsurface.....7–20	1016.2	.110	.047	2.08	.53	1.05	Trace.
		Subsoil.......20–40	1016.3	.060	.032	2.08	.64	.50	0.166
N. W. 10 of N. E. 40 of N. E. ¼, Sec. 3, T. 28, R. 1 E.	Arkansas loam (Bottom soil)	Soil............0–7	1017.1	0.191	0.051	2.25	0.53	2.04	Trace.
		Subsurface.....7–20	1017.2	.137	.062	2.31	.52	1.37	Trace.
		Subsoil.......20–40	1017.3	.062	.042	2.24	.55	5.56	Trace.
N. W. 10 of N. W. 40 of N. W. ¼, Sec. 7, T. 27, R. 1 W.	Miami sand (Bottom soil)	Soil...........0–18	1019.1	0.041	0.040	2.60	0.52	0.52	0.044
		Subsoil.......18–38	1019.2	.057	.051	2.19	.75	.60	.259
S. W. 10 of S. W. 40 of N. W. ¼, Sec. 7, T. 27, E. 1 E.	Miami fine sand (Bottom soil)	Soil............0–7	1189.1	0.066	0.038	2.64	0.75	0.71	Trace.
		Subsurface.....7–20	1189.2	.055	.038	2.43	.90	.52	0.031
		Subsoil.......20–40	1189.3	.028	.040	2.61	.80	.25	.059

TABLE XXXII.—ANALYSIS OF SOILS FROM BUTLER COUNTY. PERCENTAGES OF ELEMENTS IN THE MOISTURE-FREE SOIL.

Location by land survey.	Type as given in soil survey.	Stratum sampled, inches.	Sample No.	Nitrogen.	Phosphorus.	Potassium.	Calcium.	Organic carbon.	Inorganic carbon.
N. E. 10 of N. E. 40 of S. E. ¼, Sec. 20, T. 28, R. 3 E.	Sedgwick clay loam (Dark brown clay loam)	Soil............0-7	1127.1	0.214	0.026	1.68	0.51	2.66	0.011
		Subsurface.....7-20	1127.2	.114	.025	1.73	.51	1.37	Trace.
		Subsoil.......20-40	1127.3	.083	.025	1.67	1.61	.86	.349
S. E. 10 of S. W. 40 of S. W. ¼, Sec. 24, T. 28, R. 3 E.	Sedgwick clay loam (Dark brown clay loam)	Soil............0-7	1128.1	.140	.028	1.57	.45	1.67	Trace.
		Subsurface.....7-20	1128.2	.111	.029	1.60	.52	1.13	.019
		Subsoil.......20-30	1128.3	.062	.025	1.58	....	.59	.165
S. E. 10 of N. E. 40 of N. E. ¼, Sec. 25, T. 27, R. 3 E.	Sedgwick clay loam (Dark brown clay loam)	Soil............0-7	1129.1	.186	.024	1.53	.52	2.24	Trace.
		Subsurface.....7-20	1129.2	.122	.020	....	.57	1.39	Trace.
		Subsoil.......20-40	1129.3	.078	.025	1.51	.95	.78	.136
	Average	Soil...............	....	0.180	0.026	1.59	0.49	2.19	....
		Subsurface.........	....	.116	.025	1.66	.53	1.30	....
		Subsoil............	....	.074	.025	1.59	.85	.74	....
N. W. 10 of N. W. 40 of N. W. ¼, Sec. 11, T. 28, R. 3 E.	Clarksville stony loam (Rough limestone soil)	Soil............0-7	1126.1	0.167	0.025	1.57	0.46	2.14	Trace.
		Subsurface.....7-20	1126.2	.130	.026	1.57	.69	1.46	0.086
		Subsoil.......20-30	1126.3	.087	.026	1.59	1.38	.78	.349

TABLE XXXIII.—ANALYSIS OF SOILS FROM DONIPHAN COUNTY. PERCENTAGES OF ELEMENTS IN THE MOISTURE-FREE SOIL.

Location by land survey.	Type as given in soil survey.	Stratum sampled, inches.	Sample No.	Nitrogen.	Phosphorus.	Potassium.	Calcium.	Organic carbon.	Inorganic carbon.
S. E. 10 of S. E. 40 of S. W. ¼, Sec. 14, T. 4, R. 20 E.	Brown fine sandy loam	Soil 0-7	1056.1	0.192	0.056	1.84	0.50	2.08	None.
		Subsurface 7-20	1056.2	.166	.055	1.80	.53	1.75	Trace.
		Subsoil 20-40	1056.3	.102	.062	1.94	.52	1.29	Trace.
S. W. 10 of N. W. 40 of N. W. ¼, Sec. 6, T. 4, R. 20 E.	Brown fine sandy loam	Soil 0-7	1057.1	.192	.064	2.23	.55	2.17	Trace.
		Subsurface 7-20	1057.2	.164	.055	2.28	.52	1.81	Trace.
		Subsoil 20-40	1057.3	.107	.063	2.04	.50	1.44	0.035
	Average	Soil	....	0.192	0.060	2.04	0.53	2.13	....
		Subsurface	....	.165	.055	2.04	.53	1.78	....
		Subsoil	....	.105	.063	1.99	.51	1.37	....
S. W. 10 of S. W. 40 of S. W. ¼, Sec. 35, T. 2, R. 19 E.	Dark brown silt loam	Soil 0-7	1058.1	0.163	0.056	1.78	0.48	1.77	Trace.
		Subsurface 7-20	1058.2	.097	.049	1.79	.52	.93	Trace.
		Subsoil 20-40	1058.3	.062	.053	1.82	.57	.61	Trace.
N. W. 10 of N. W. 40 of S. E. ¼, Sec. 9, T. 3, R. 20 E.	Dark brown silt loam	Soil 0-7	1059.1	.189	.067	1.82	.56	2.10	Trace.
		Subsurface 7-20	1059.2	.127	.049	2.19	.54	1.27	Trace.
		Subsoil 20-40	1059.3	.075	.054	2.01	.50	.64	Trace.
	Average	Soil	....	0.176	0.062	1.80	0.52	1.94	Trace.
		Subsurface	....	.112	.049	1.99	.53	1.10	Trace.
		Subsoil	....	.069	.054	1.92	.54	.63	....
N. E. 10 of S. W. 40 of S. W. ¼, Sec. 28, T. 3, R. 22 E.	Brown silt loam	Soil 0-7	1060.1	0.084	0.056	1.59	0.50	0.89	Trace.
		Subsurface 7-20	1060.2	.048	.067	1.96	.50	.44	Trace.
		Subsoil 20-40	1060.3	.033	.080	1.88	.77	.32	Trace.
N. W. 10 of S. E. 40 of S. E. ¼, Sec. 25, T. 3, R. 21 E.	Brown silt loam	Soil 0-7	1062.1	.121	.071	1.87	.58	1.26	0.064
		Subsurface 7-20	1062.2	.081	.068	2.23	.51	.87	Trace.
		Subsoil 20-40	1062.3	.055	.071	2.01	.63	.58	.037
	Average	Soil	....	0.103	0.064	1.73	0.54	1.09	....
		Subsurface	....	.065	.068	2.11	.51	.66	....
		Subsoil	....	.043	.076	1.95	.70	.45	....
N. E. 10 of N. E. 40 of S. W. ¼, Sec. 29, T. 3, R. 22 E.	Silt subsoil	Subsoil	1061.0	0.025	0.070	2.11	0.65	0.32	None.

TABLE XXXIV.—ANALYSIS OF SOILS FROM HARPER COUNTY. PERCENTAGES OF ELEMENTS IN THE MOISTURE-FREE SOIL.

Location by land survey.	Type as given in soil survey.	Stratum sampled, inches.	Sample No.	Nitrogen.	Phosphorus.	Potassium.	Calcium.	Organic carbon.	Inorganic carbon.
Center of N. W. ¼, Sec. 24, T. 34, R. 7 W.	Brown loam	Soil.....0-7	1072.1	0.093	0.034	1.68	0.31	0.84	None.
		Subsurface.....7-20	1072.2	.078	.040	1.60	.34	.62	Trace.
		Subsoil.....20-40	1072.3	.051	.040	1.58	.50	.29	0.288
S. E. 10 of S. E. 40, of S. E. ¼, Sec. 11, T. 34, R. 8 W.	Brown loam	Soil.....0-7	1076.1	.089	.036	1.91	.42	.78	None.
		Subsurface.....7-20	1076.2	.082	.042	1.89	.41	.75	None.
		Subsoil.....20-40	1076.3	.061	.038	1.94	.48	.52	None.
	Average	Soil	......	0.091	0.035	1.80	0.37	0.81	......
		Subsurface	......	.080	.041	1.75	.38	.69	......
		Subsoil	......	.056	.039	1.76	.49	.41	......
N. E. 10 of S. W. 40 of S. E. ¼, Sec. 13, T. 33, R. 9 W.	Brown fine sandy loam	Soil.....0-7	1073.1	0.075	0.032	2.15	0.51	0.53	Trace.
		Subsurface.....7-20	1073.2	.042	.035	2.10	.54	.21	0.204
		Subsoil.....20-40	1073.3	.035	.080	2.12	.51	.21	.420
N. W. 10 of N. W. 40 of S. W. ¼, Sec. 17, T. 32, R. 7 W.	Brown sandy loam	Soil.....0-7	1074.1	0.097	0.038	1.99	0.23	0.90	None.
		Subsurface.....7-20	1074.2	.073	.044	3.00	.54	.63	Trace.
		Subsoil.....20-40	1074.3	.040	.034	1.97	.54	.30	None.
N. W. 10 of N. W. 40 of S. E. ¼, Sec. 27, T. 32, R. 7 W.	Coarse sandy loam	Soil.....0-7	1075.1	0.105	0.037	2.05	0.39	1.01	Trace.
		Subsurface.....7-20	1075.2	.088	.031	2.02	.31	.82	Trace.
		Subsoil.....20-40	1075.3	.053	.035	2.03	.38	.46	Trace.
N. E. 10 of S. W. 40 of S. E. ¼, Sec. 12, T. 34, R. 6 W.	Alluvial loam	Soil.....0-7	1077.1	0.081	0.041	1.96	0.22	0.70	Trace.
		Subsurface.....7-20	1077.2	.065	.044	1.94	.32	.60	Trace.
		Subsoil.....20-40	1077.3	.044	.038	1.89	.49	.39	Trace.
S. W. 10 of S. W. 40 of S. E. ¼, Sec. 23, T. 33, R. 5 W.	Gray silt loam	Soil.....0-7	1078.1	0.123	0.036	1.71	0.39	1.38	Trace.
		Subsurface.....7-20	1078.2	.087	.035	1.86	.53	.78	Trace.
		Subsoil.....20-40	1078.3	.061	.036	1.33	.98	.58	0.506