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SOIL SURVEY OF SHAWNEE COUNTY, KANSAS.

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The Soil Survey of Shawnee county was made by the Kansas State Agricultural College in cooperation with the Bureau of Soils, U. S. Department of Agriculture. The field work was done by R. I. Throckmorton of the Department of Agronomy and W. C. Byers of the Bureau of Soils. The samples for chemical analysis were taken and the analyses made by C. O. Swansan and C. E. Millar of the Department of Chemistry. The report was written by L. E. Call and R. I. Throckmorton of the Department of Agronomy and C. O. Swanson of the Department of Chemistry. The mechanical analyses of the soil types were made by the Bureau of Soils, U. S. Department of Agriculture.

W. M. JARDINE, *Director*.

CONTENTS.

SOIL SURVEY OF SHAWNEE COUNTY.

Shawnee county, Kansas, is situated in the northeastern part of the state. It has an area of approximately five hundred and fifty-eight square miles, or three hundred and fifty-seven thousand one hundred twenty acres. The Kansas river crosses the county from west to east.

Topographically, Shawnee county is a high plateau, frequently cut by valleys of varying size. There has been no disturbance of the originally horizontally deposited rocks, thus the surface features are the direct result of erosion, which has acted in proportion to the relative hardness of the sandstones, shales and limestones that underlie the county. The numerous and extensive shale horizons are characterized by level to undulating topography, which gives way to a more rolling country where the underlying limestone has been exposed. Along the streams are long, gentle slopes in which it is frequently difficult to determine the extent of the overflowed land. The streams are fringed by steep slopes which give rise to a belt of rough country. Abundant outcrops of thin beds of limestone accentuate the roughness.

There is a total range of elevation of over three hundred and fifty feet. The lowest point, where the Kansas river leaves the county, is about eight hundred feet, and the highest, in the southwestern corner, is over one thousand one hundred and fifty feet above sea level. The broad plateau strip which enters the county at its southwestern boundary and extends in an easterly direction, forms the highest land in the county. East of Mission township, the high rolling prairie gives way to a flat, level plain dissected by few streams. In Monmouth township, on the eastern boundary of the county, the elevation is fully as high as that in the western part, with deep valleys and numerous outcrops of limestone along the streams.

North of the Kansas river the topography is slightly modified by the presence of a thin layer of glacial till, although in general the topography is that of a residual rather than a glacial country. Here the elevation is slightly less than south of the river, and in only a few instances does it exceed one thousand one hundred feet.

The valleys, taken as a whole, are broad, with gentle slopes. In the east-central part of the county, where limestone predominates, the streams form narrow cone-like valleys, whose steep rugged sides add picturesqueness to the landscape and break the otherwise monotonous uniformity of the topography.

DRAINAGE.

The greater part of the drainage of the county flows into the Kansas river. The northern part of the county is drained mainly by the following tributaries of the Kansas: Bourbon Cross, Big Soldier, Walnut, Little Soldier, and Muddy creeks. Midday, Indian, and Little Muddy are creeks of minor importance, rising within the county.

South of the river the larger part of the drainage is carried by Mission, Shunganunga and Wakarusa creeks and their tributaries. Deer, Whetstone and Tecumseh creeks are of minor importance and drain the east central part of the county.

CLIMATE.

The precipitation in Shawnee county is relatively light from October to March, inclusive, and is heaviest during the crop-growing season, from April through the summer, including September. There is sometimes a deficiency of rainfall during the latter part of July and August, and corn at such times may suffer unless special care is taken to conserve the moisture.

SOILS.

The soils of Shawnee county may be divided into two broad groups, viz., upland and bottom-land soils. The upland soils may be subdivided into glacial and residual soils. The glacial soils are found principally north of the Kansas river, the residual soils south of the river, and the alluvial soils in the river and creek bottoms.

The glacial soils, where typically developed, are easily recognized by their uniform reddish-brown color throughout the soil section, by the presence of sharp quartz sand in the subsoil, and the absence of shale or limestone fragments in the soil and subsoil. During the glacial period the ice extended approximately as far south as the Kansas river, with a few lobes extending south of this boundary. Small local areas of glacial soil are found within two miles of the southern boundary of the county, on the north bank of Wakarusa creek.

NORMAL MONTHLY SEASONAL, AND ANNUAL TEMPERATURE AND PRECIPITATION AT TOPEKA.

Month.	Temperature.			Precipitation.			
	Mean.	Absolute maximum.	Absolute minimum.	Mean.	Total amount for the driest year.	Total amount for the wettest year.	Snow, average depth.
	Degree F.	*Degree F.*	*Degree F.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
December	31.1	74	—10	0.84	0.63	0.91	3.60
January	25.6	71	—23	1.21	.63	.44	4.20
February	30.0	78	—25	1.50	1.03	1.14	6.10
Winter	28.9			3.55	2.29	2.49	13.90
March	40.9	93	—1	2.15	2.30	1.27	3.00
April	53.7	97	20	2.53	2.13	3.08	.80
May	65.0	94	28	5.09	1.00	8.63	.10
Spring	53.2			9.77	5.43	12.98	3.90
June	73.5	101	36	4.78	2.07	4.91	0.00
July	77.6	107	50	4.79	2.56	3.74	.00
August	76.0	105	40	4.57	7.67	12.69	.00
Summer	75.7			14.14	12.30	21.34	0.00
September	68.3	104	33	3.33	1.31	2.74	T.
October	56.3	92	22	2.01	.33	3.50	0.10
November	41.7	83	—5	1.27	2.83	1.09	1.30
Fall	55.4			6.61	4.47	7.33	1.40
Year	53.3	91.5	—25	34.07	24.49	44.14	19.20

Average date of last killing frost in spring, April 9: of first in the fall, October 15.

The glacial soils of Shawnee county are derived from the Kansan till, which consists of rocks and crushed fragments transported by glacial action from territories farther north. Originally the Kansan till was deposited as a layer of varying thickness upon the underlying shale and limestone, but by the process of erosion it has been greatly modified, so that now the till often appears only on the tops of the hills. In such cases the underlyng limestone and shale is exposed on the slopes, and becomes the main source of soil-forming material. Where the till was deposited in a thicker layer, and where the agencies of erosion have been less active, the topography is undulating to gently rolling and the soil is uniformly of glacial origin. The latter case is particularly noticeable on the gentle rise from the river bottom on the north. Where the change of topography is more abrupt, forming a bluff, the underlying limestone and shale are exposed, and the soils are of residual origin.

In many instances the till is quite thin along the northern boundary of the county, with many rock outcrops, and in some spots the material is entirely lacking. Along the southern boundary, which is approximately the Kansas river valley, the soil derived from the glacial material is quite deep, and in several places, where cuts have been made for roads, a section of ten feet or more has been exposed without any appearance or indication of the underlying rock. It is noted that the glacial soils bordering the alluvial soils of the bottoms are much more sandy than those encountered farther into the uplands. This would indicate some reworking of the soil or soil-forming material since its deposition as till, similar to the sorting action in the case of residual soils.

The Kansan till has given rise to the Shelby series of soils, two types of which were found, viz., loam and stony loam. The separation of these is based upon the quantity of fragmental rocks which they contain.

The soils of the unglaciated portion of the upland are of residual origin, *i. e.,* derived from the immediately underlying rocks. The rocks of this region belong to the Pennsylvania division of the Carboniferous, and consist of interbedded shale, sandstone and limestone.

Shale, the predominating rock, may vary from argillaceous to arenaceous in different beds, or even in the same stratum, in color from light yellow to black, and in hardness from soft and micaceous to almost a slate. The beds of limestone and sandstone are comparatively thin and uniform. The strata lie nearly horizontal, with only a slight dip to the northwest. Faulting and folding are nowhere in evidence. Were the present surface level, it is evident that the soils would be practically the same all over the unglaciated portion of the country, but this condition has been altered by the effects of erosion, with the result that different strata of rocks have been exposed to the process of weathering and soil formation at different levels, giving rise to varying soil conditions.

The residual soils of the area are separated according to their origin. Shale has entered more largely into the formation of the soil than either sandstone or limestone, and has given rise to two series of soils—Summit and Oswego.

The sandstone gives rise to the Boone fine sandy loam, which is of minor importance. The limestone gives rise to the Crawford silty clay loam.

The bottom-land soils, or those of alluvial origin, are related in respect to their origin and the manner of their formation, and are placed in the Osage series.

Along the larger creeks are broad areas locally known as "second bottom" land. There is ample reason to believe that these areas are not alluvial in origin, but residual, and therefore were mapped as Oswego silty clay loam.

The following table gives the name and extent of each soil mapped in the area:

Soil.	Acres.	Per cent.
Shelby loam	54,748	16.40
Light phase	1,854	
Shelby stony loam	832	.20
Summit silty clay loam	113,472	33.70
Stony phase	1,856	
Heavy phase	1,152	
Oswego silt loam	41,984	12.10
Oswego silty clay loam	22,400	6.50
Crawford silty clay loam	7,936	2.30
Boone fine sandy loam	2,368	.70
Osage silty clay loam	22,400	6.50
Osage silt loam	15,104	10.90
Colluvial phase	22,464	
Osage very fine sandy loam	36,544	10.60
Osage very fine sand	4,096	1.20
Total	345,600	

SHELBY SERIES

The two phases of the Shelby loam and the Shelby stony loam comprise the entire glacial section of the county. While the larger part of this series lies north of the Kansas river, in Soldier, Menoken, Silver Lake and Rossville townships, small extensions are found south of the river.

The prevailing topography of the Shelby series is gently rolling. Few level areas occur, and on the steeper slopes the glacial material has been washed away.

The Shelby series is derived from the weathering of the Kansas till. The stone and gravel in the Kansas till is composed almost wholly of quartz, granite, and conglomerate mixed with varying quantities of sandstone and chert. It was originally deposited over the entire northern part of the county, but erosion has removed it in many places, exposing the underlying rock. In this case only the tops of hills and divides between streams are of glacial origin, the steeper slopes being composed of limestone and shale and their derivative soils. The limestone outcrop in such cases usually forms the boundary between the glacial and residual soils.

The drainage of the type is usually good, though small areas on the lower slopes become waterlogged during the wet seasons. The prevailing topography is such as to insure good drainage, though the subsoil is rather heavy to permit the free downward percolation of moisture. This latter condition is somewhat improved by the presence of rounded gravel, which makes the mass more porous. The lower elevations, receiving the seepage water from the higher adjacent areas, are less perfectly drained and lack aeration. There is no doubt that tile drainage would greatly benefit such areas. During the dry season the subsoil becomes hard and baked, and unless thoroughly cultivated, cracks to a considerable depth. This cracking may be largely prevented by maintaining a soil mulch.

THE SHELBY LOAM.

The Shelby loam is characterized by a dark chocolate-brown to reddish-brown loam or silt loam containing varying quantities of sharp quartz sand to a depth of ten inches. Below this the soil grades into a reddish-brown to reddish-yellow stiff clay loam, which becomes lighter in color with depth. From twenty-four inches downward the clay content increases rapidly, and at thirty-six inches the subsoil is a reddish-yellow clay to heavy clay loam. In a few local areas the lower subsoil is composed of clay, gravel, and sand in such combination as to form excellent road material. Deposits of this nature occur along the northern border of the county, in those areas of Shelby loam lying one mile north of Pauline, and also in the ridge of this soil which lies southwest of Topeka and one and one-half miles west of the Burlingame road.

THE SHELBY LOAM, LIGHT PHASE.

The Shelby loam, light phase, consists of a fine sandy loam of dark reddish-brown to dark chocolate-brown color and loose, open structure, resting at an average depth of ten inches on a fine sandy loam or fine sandy clay loam of reddish-yellow color. The subsoil is compact to a depth of about twenty-four inches, where it usually becomes more friable, the sand content being greater. At lower depths the subsoil is lighter in color and at thirty-six inches it is usually a reddish-yellow. Numerous well-rounded quartz gravel are found in both soil and subsoil.

This soil occurs in small areas along the bluff north of the Kansas river bottom. The largest body is that directly north of Silver Lake.

THE SHELBY STONY LOAM.

The Shelby stony loam consists of a chocolate-brown silt loam to a depth of eight inches, containing varying quantities of glacial stones ranging in size from coarse gravel to large boulders. With the exception of the content of quartz, gravel, and boulders, the subsoil is much like that of the Shelby loam.

The Shelby stony loam occurs in small isolated areas. The more important bodies are: that area lying two miles southeast of Tevis and that lying two miles north of Dover. The subsoil of this type is well adapted to road building.

SUMMIT SERIES.

The Summit series consists of Summit silty clay loam, Summit silty clay loam, heavy phase, and Summit silty clay loam, stony phase.

This series is the largest in the county, and one of the most important. It is found in all parts of the county, its greatest extent being in the southern sections.

The topography is rolling to hilly, this type occupying ridges and gentle slopes which form the sides of valleys. Occasional flat areas occur on the tops of hills and between ridges, though these are of small extent and constitute but a small part of the type. Limestone outcrops occur frequently, and as far as possible have been shown on the map by symbols. Flat limestone fragments are scattered over the surface in the vicinity of the outcrops, and especially on the stony phase. The rolling topography insures good drainage, though the character of the subsoil is such that water does not penetrate as quickly as might be desired. Elevation within the series will not vary more than one hundred and fifty feet, most of the land lying above the one-thousand-foot contour line.

The Summit series is of residual origin, being derived from the weathering of the shale which underlies the county. Occurring both above and below the shale are thin strata of limestone which frequently outcrop on steeper slopes. Immediately over this outcrop and where the limestone lies near the surface, the soil is more or less influenced by the admixture of limestone material. The presence of occasional chert fragments and limestone concretions in the subsoil give evidence of the influence of limestone.

When plowed, the soil is loose, friable and easily tilled. Where the topography is at all steep, the soil washes badly and gullies are formed. With a little expense and labor, water could be diverted from these channels and erosion would be less severe.

THE SUMMIT SILTY CLAY LOAM.

The Summit silty clay loam to a depth of eight to fourteen inches consists of a dark brown, drab or light gray, medium heavy friable silty clay loam, becoming lighter in color and heavier in texture at depths below ten inches, underlain by a brown, granular silty clay or clay loam, which becomes lighter in color with depth and finally grades into a yellow or light brown clay loam. Occasional mottlings of drab, yellow, or yellowish brown are found in the deeper subsoil. The surface soil has a decided tendency to granulate or break up into small particles, with the result that it does not pack, bake, crack, or run together.

THE SUMMIT SILTY CLAY LOAM, HEAVY PHASE.

The Summit silty clay loam, heavy phase, consists of a dark brown to almost black heavy loam or silty clay loam, resting at an averabe depth of ten inches on a dark brown clay loam subsoil, which at about twenty-four inches grades into a pale yellowish-brown to yellow sticky clay loam or clay.

The only body of this phase of the type of any importance lies west of Topeka, in Mission township, although areas too small to map exist in other parts of the county.

THE SUMMIT SILTY CLAY LOAM, STONY PHASE.

The Summit silty clay loam, stony phase, includes those areas of upland soil of residual formation whose steep topography and stony nature render them unsuited for cultivation. Outcrops of limestone rock are frequent. Some areas occur on the tops of hills, and here the surface is less steep, but the bed rock is usually encountered at about twelve inches below the surface. This phase is found in almost every part of the county, though no large areas occur. Almost all of the type is devoted to pasture.

The following table gives the results of mechanical analysis of samples of the soil and subsoil of the typical Summit silty clay loam:

MECHANICAL ANALYSIS OF SUMMIT SILTY CLAY LOAM.

No.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
380,929..	Soil..........	3.4	3.3	1.5	2.7	5.9	54.9	28.3
380,930..	Subsoil.......	.9	1.9	.9	2.0	3.8	45.2	45.2

OSWEGO SERIES.

The Oswego series consists of the Oswego silt loam and Oswego silty clay loam.

This series is locally known as "gumbo" or "hard pan" land, because of the presence of a stiff subsurface layer. The silt loam occupies level to undulating areas on the level tops of hills, and is developed most extensively on the divides between streams. The silty clay loam, which is erroneously called "second bottom" land, lies in strips of varying width between the bottom and the more rolling upland. The topography is almost level, with only a gentle slope toward the stream.

The soils of the Oswego series are of residual origin, being derived from the different strata of soft black argillaceous shale that occurs both immediately above and below the limestone. The shale is so perfectly weathered that no trace of it can be seen in the soil, though in several places it was seen in banks where it had been protected from the processes of weathering by a ledge of limestone.

The level topography is no doubt caused by the horizontal stratum of limestone that underlies the Oswego soils at varying depths, Outcrops of thin-bedded limestone can almost always be seen in cuts both above and below the bed of shale, and no doubt this overlying stratum has some influence on the topography and soils.

The series as a whole is poorly drained. The level surface does not permit of the free flow of surface water, nor does the heavy subsoil permit of a free downward movement of moisture. However, the topography and location of the soil are such as to make artificial drainage practicable and easy.

Tile drainage would not only be beneficial in removing the excess water, but also in aerating the soil and thereby improving its structure. While the results would not be immediate, perfect aeration would eventually break down the close structure of the soil and make it loose and friable. Some areas of alkali occur, but they are of small extent and of purely local importance. Thorough drainage is the most effective means of removing the alkali salts. Small "gumbo" spots also occur. These may be treated with heavy applications of lime, which flocculates the particles and changes the structure of the soil.

THE OSWEGO SILT LOAM.

The Oswego silt loam consists of six to twelve inches of a dark gray, dark brown, or black loose silt loam, of ashy feel, underlain by a stiff, impervious, tenacious silty clay or silty clay loam, uniformly black or very dark in color. This is in turn underlain at an average depth of twenty-six inches by a loose silt loam or silty clay loam, varying in color from light drab to light brown, or mottled drab and brown. Small iron and lime concretions in the subsoil are largely responsible for the mottled condition that sometimes occurs. The lines of demarcation between surface, subsurface, and subsoil are well established, the changes being abrupt.

THE OSWEGO SILTY CLAY LOAM.

The Oswego silty clay loam consists of a black, loose, silty clay loam, with an average depth of twelve inches, overlying a stiff, plastic, impervious, black silty clay which extends to an average depth of twenty-six inches. Below thirty-six inches the subsoil is much like that of the silt loam.

The following table gives the results of mechanical analysis of samples of the soil, subsoil and lower subsoil of the Oswego silty clay loam:

MECHANICAL ANALYSIS OF OSWEGO SILTY CLAY LOAM.

No.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
380,903..	Soil..........	0.1	0.3	0.5	1.1	3.5	62.6	32.0
380,904..	Subsoil.......	.0	.3	.5	1.5	3.5	64.1	29.8
380,905..	Lower subsoil.	.0	.4	.6	0	1.7	63.4	32.8

CRAWFORD SERIES.

CRAWFORD SILTY CLAY LOAM.

The Crawford silty clay loam is a limestone soil. Most of the type is developed at a lower lever than the Summit silty clay loam, though some areas occur at a greater elevation. The range in elevation is from one thousand to eleven hundred feet above sea level. The topography is rolling, the types occupyjng gentle slopes and narrow ridges.

The area of the Crawford silty clay loam is small, owing to the fact that the shales which overlie the limestone have played a more important part in the formation of the soil than the limestone, with the result that the purely limestone residual soil is not widely developed. Occasional areas of Crawford silty clay loam cap the tops of hills. These are usually rough with limestone fragments scattered over the surface and the limestone rock lying close to the surface.

The largest area of Crawford silty clay loam is in Tecumseh township, though a large tract also occurs in Auburn township.

The type is usually well drained, though the subsoil is rather too heavy for the free percolation of water. When wet the soil is sticky and plastic, but when exposed to the action of air and frost it breaks down into a crumbly mellow seed bed.

The Crawford silty clay loam consists of from eight to ten inches of dark brownish-gray to dark brown heavy silty clay loam, which at twelve to fifteen inches grades into a red clay loam. At about twenty-four inches the clay content increases. and at lower depths the subsoil is a red, plastic and sticky clay. Except for the red color of the subsoil, the type very much resembles the Summit silty clay loam, being granular in structure and rather mellow, which makes it easily tilled. Flat limestone blocks are scattered over the surface, and smaller fragments of limestone and chert are disseminated through the soil section. The parent limestone rock is frequently struck in borings at depths of twenty-four to thirty-six inches.

The following table gives the results of mechanical analysis of samples of the soil and subsoil of Crawford silty clay loam:

MECHANICAL ANALYSIS OF CRAWFORD SILTY CLAY LOAM.

No.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
380,915..	Soil..........	0.0	0.2	0.4	1.3	3.9	67.6	26.5
380,916..	Subsoil.......	.0	.3	.5	.7	4.0	49.2	45.5

BOONE SERIES.

BOONE FINE SANDY LOAM.

The Boone fine sandy loam is derived from a fine-grained micaceous, red or reddish-brown sandstone, which occurs interbedded with limestone and shale. In Dover township the rock overlies the limestone and shale, capping the ridge that forms the highest land in the county.

The largest area of this type occurs in Dover township, with small areas in other parts of the county.

The topography is rolling. Erosion is very marked, because of the loose, fluffy structure of the type, and gullies of considerable depth dissect the area, giving a topography of well-rounded hills and knobs of slightly greater elevation than the adjacent valleys.

Drainage is well established, and in places where the county rock is near the surface is even excessive. The topography insures good surface drainage, and the loose nature of the soil and subsoil allow rapid downward movement of the water. Where the rock lies near the surface crops suffer from drought. The loose sandy nature of the soil makes it practicable to cultivate over a wide range of moisture content.

The Boone fine sandy loam, to a depth of six to twelve inches and averaging about ten inches, consists of a dark, slightly reddish-brown to chocolate-brown loose fine sandy loam, underlain by a reddish-brown to reddish-yellow fine sandy loam of slightly heavier texture. Both soil and subsoil are loose and friable, with a rather floury feel, due to the presence of large quantities of mica. In places the bed rock is encountered in borings at about fifteen inches and is seldom more than four feet from the surface.

The following table gives the results of mechanical analysis of the soil and subsoil of this type:

MECHANICAL ANALYSIS OF BOONE FINE SANDY LOAM.

No.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
380,927..	Soil..........	0.1	0.2	0.8	37.1	13.4	26.2	22.0
380,928..	Subsoil.......	.5	.7	1.1	43.2	11.7	22.0	20.7

OSAGE SERIES.

The Osage series, which consists of the Osage silty clay loam, Osage silt loam, Osage silt loam colluvial phase, Osage very fine sandy loam, and Osage very fine sand, comprises all the bottom-land soils along the Kansas river, the creeks, and the smaller streams of the county.

The topography of this series is gently sloping to level. The bottom-land soils north of the Kansas river are derived largely from reworked glacial material, while those south of the river are derived from the deposition of the soil carried down from surrounding residual upland soils.

THE OSAGE SILTY CLAY LOAM

The Osage silty clay loam occupies the lowest position in the Kansas river bottoms, and is well developed along some of the larger streams coming from the north. Cross creek and Big Soldier creek bottoms are made up of soils of this type. In the Kansas bottoms the type follows the local drainage channels and is best developed at the outer edge of the bottoms near the upland. Although its position is lower than the other bottom types, the difference in elevation is not marked by terraces, but the slope is almost an imperceptible one. For this reason there is a zone of gradation from the Osage silty clay loam to the Osage very fine sandy loam.

The Osage silty clay loam is subject to frequent overflows from the creeks along which it is developed, but only in extreme instances is it overflowed by the Kansas river. Drainage is necessary, and on most of this type some system of drainage is in use. Tile drains are recommended above all others, as they not only carry away the surplus water, but are advantageous in improving the structure of the soil and subsoil.

The Osage silty clay loam to an average depth of eight inches consists of a heavy black silty clay loam, underlain by a heavier, more compact, plastic silty clay loam or silty clay, usually of uniform black color, though occasionally at about twenty-eight inches the subsoil changes to a dark drab color.

The following table gives the results of mechanical analysis of samples of the soil and subsoil of the Osage silty clay loam:

MECHANICAL ANALYSIS OF OSAGE SILTY CLAY LOAM.

No.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
380,925..	Soil..........	.0	0.2	0.2	0.8	5.8	61.4	31.5
380,926..	Subsoil.......	.0	.3	.4	.7	3.2	70.3	25.0

THE OSAGE SILT LOAM

The Osage silt loam occupies the first bottoms along the larger creeks south of the Kansas river and some of the smaller ones north of the river. Although subject to frequent overflow, the porous nature of the soil and subsoil permit of rapid drying out, and the soil is soon ready for cultivation. Where the bottom is broad the Osage silt loam is usually bordered by the Oswego silty clay loam, which rises a few feet above the general level of the bottoms. The drainage, for a bottom soil, is good, though some areas occur that are deficient in this respect.

This type consists of ten inches of a dark brown or somewhat grayish-brown loose silt loam, containing a large quantity of very fine sand, resting on a subsoil of slightly lighter color and more compact structure, which becomes heavier in texture with depth. At thirty-six inches this grades into a light brown heavy loam, compact when first exposed, but breaking down into a mealy, crumbly loam when worked between the fingers. The subsoil also contains varying quantities of very fine sand.

The colluvial phase of the Osage silt loam occupies a position next to the local drainage channels, and is found in all parts of the country. Where the stream bottoms are overflowed the type gives way to one of alluvial soils. It consists of a dark brown to black loam to about fourteen inches in depth. The subsoil is more compact and lighter in color than the surface soil. The line of demarcation between surface soil and subsoil is very indistinct.

The following table gives the results of mechanical analysis of samples of the soil and subsoil of the typical Osage silt loam:

MECHANICAL ANALYSIS OF OSAGE SILT LOAM.

No.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
380,908..	Soil..........	0.0	0.1	0.4	8.1	16.5	51.9	23.0
380,909..	Subsoil......	.0	.0	.2	4.9	15.8	51.7	27.2

OSAGE VERY FINE SANDY LOAM.

Osage very fine sandy loam occupies the highest elevation in the Kansas bottom. The topography is level to slightly undulating, Small hummocks and mounds sometimes occur, on which the soil is more sandy. The drainage is good, though not excessive.

The type consists of a loose, very fine sandy loam of brownish-gray to grayish-brown color and an average depth of twelve inches, resting upon a more compact and somewhat heavier very fine sandy loam of brownish-drab color, becoming lighter in color with depth. A variation occurs in areas adjacent to the river and creeks, where there is a dark or almost black stratum in the subsoil. This layer usually appears at a depth of about twelve inches.

OSAGE VERY FINE SAND.

Osage very fine sand has a hummocky topography, caused by the action of wind. It occupies a position adjacent to the river at about the same elevation as the Osage very fine sandy loam. The drainage of the type is good, and in places even excessive.

The Osage very fine sand consists of twenty inches of loose, incoherent, light brown, light gray or yellowish very fine sand, underlain by a loose very fine sand, or light very fine sandy loam. The color of the surface soil varies with the organic content.

CHEMICAL ANALYSIS OF SOIL TYPES OF SHAWNEE COUNTY.

The complete report of the chemical analysis of the soil types in Shawnee county is given in the table in the appendix. This table gives the location where each sample was taken, the type as given in the soil survey, and the percentage of each element determined in the different types. In the following table the pounds per acre in the surface soil are given. This is calculated from the average percentages in the table in the appendix.

CHEMICAL ANALYSIS OF SOILS FROM SHAWNEE COUNTY.

Results are given as pounds per acre in two million pounds surface soil (0-7 inches).

Type as given in soil survey.	Nitrogen.	Phosphorus.	Potassium.	Calcium.	Organic carbon.
Osage silt loam	3,360	1,060	37,000	8,800	43,200
Osage silty clay loam	4,020	1,220	41,200	16,200	49,400
Osage very fine sandy loam	2,660	880	39,200	15,000	31,600
Osage very fine sand	820	440	41,200	18,600	5,200
Shelby loam	2,780	540	30,000	8,200	33,400
Shelby loam, sandy phase	3,900	780	34,800	10,800	49,400
Crawford silty clay loam	5,100	840	31,400	7,800	54,600
Oswego silty loam	4,240	580	29,200	10,600	55,400
Oswego silty clay loam	3,540	1,140	35,000	9,600	38,000
Summit silty clay loam	5,500	800	32,000	10,800	67,600
Boone fine sandy loam	2,760	780	22,000	7,600	29,600

THE NITROGEN CONTENT.

The nitrogen content of the soil types in Shawnee county average 0.175 per cent for the surface soil, 0.123 per cent for the subsurface, and 0.085 per cent for the subsoil. Calculated to pounds per acre for the various depths, this gives 3500 pounds for the surface seven inches, 4920 pounds for the subsurface thirteen inches, and 5100 pounds for the twenty inches of the subsoil. As nitrogen is useful to plants only when converted into soluble forms by bacterial action, and as bacterial activity is mostly confined to the surface soil, the nitrogen in the top layer is of most importance. The organic matter in the surface soil has resulted from more recent accumulations of plant residues, while that in the lower strata consists mostly of that part of the plant residues which have been most resistant to decay. As plants decay the nitrogen in the portion least resistant to disintegration is first converted into the soluble form. The more resistant portions tend to accumulate in the soil, and these contain the bulk of the soil nitrogen. Thus, that which is more available is found near the surface and the less available in the subsoil.

While the nitrogen content is apparently high in most of these soils, crop production will suffer first for want of nitrogen. All the samples for the Summit silty clay loam were taken in native pastures or in native meadows. The one Sample of the Crawford silt loam was also taken in a native pasture. These two types average the highest in nitrogen content. The cultivated soils of the Shelby loams average the lowest in nitrogen of all the upland types. One sample of this type, No. 1133 (see Appendix), was taken in a native pasture, and here fhe nitrogen was one-third higher than in the cultivated soil. That the nitrogen is not necessarily lower when the land has been cultivated may be seen from sample Nos. 1136 and 1146, representing the Oswego silt loam. The latter was taken in a native meadow while the former was taken in a cultivated field of a well-managed farm. The Boone fine sandy loam is low in nitrogen. This sample was taken in a native pasture. The difference between the nitrogen content of the samples taken in the cultivated soils as compared with the uncultivated is very noticeable. Depletion of nitrogen is rapid under cultivation, if no care is taken to supply organic matter containing nitrogen.

With the exception of the Shelby loam and the Boone fine sandy loam, the bottom soils average lower in nitrogen than the uplands. All the samples of the bottom soils were taken from cultivated fields. The nitrogen content varies inversely with the sandiness of the soil. Osage very fine sand contains only 820 pounds of nitrogen per acre, while the Osage silty clay loam contains 4020 pounds, or nearly five times as much. The Osage very fine sandy loam contains less nitrogen in the surface soil than the poor upland Shelby loam. The first represents one of the most fertile soils in the county, while the second represents a poor soil. This difference in fertility is due mainly to the physical texture. The openness of the sandy soil affords a much larger feeding ground for the roots, and also a greater amount of bacterial activity which converts nitrogen into soluble forms. A supply of organic matter furnishing nitrogen is the important need of the Osage very fine sandy loam.

THE PHOSPHORUS CONTENT.

As a class, the upland soils are poor in phosphorus, the Shelby loam averaging 540 pounds for the surface soil, followed by the Oswego silt loam, which averages 580 pounds. The phosphorus content in the surface soil of the Summit silty clay loam averages 800 pounds per acre. The phosphorus coutent of this soil decreases in the subsoil. The average per cent for the surface soil is 0.040; for the subsurface 0.030; and for the subsoil 0.021. This variation is either due to the fact that large amounts of phosphorus are stored in the organic matter or the phosphorus has been brought from the lower strata by deep-rooted plants, and then when these were burned by the prairie fires the phosphorus was left near the surface. As this land is usually hilly, erosion becomes serious because the removal of the surface soil exposes the subsoil, which is so much poorer in phosphorus. Usually the subsoils are as well stocked with phosphorus as the surface soil, but this type forms a notable exception. The Boone fine sandy loam and the Crawford silty clay loam average as high in phosphorus content as the Summit silty clay loam. Both show a slight decrease in phosphorus in the lower strata. The Osage silty clay loam has the highest phosphorus content of any type in the county, followed by the Osage silty clay loam.

With the exception of the unimportant Osage very fine sand, all the bottom types are higher in phosphorus content than the upland types. In the upland types the nitrogen content averages higher than the bottom soils. In the cultivation of soils nitrogen is used up relatively faster than the phosphorus. In the heavier upland soils which have not been cultivated the ratio of phosphorus to nitrogen is about one to six, while in the cultivated soils, both upland and lowland, especially soils of sandy texture, the ratio is much narrower. Nitrogen is lost from the soil faster than measured by crop removal, while phosphorus is not so lost. The loss of phosphorus from the soil is insignificant.

The importance of a large supply of plant food in the soil can be seen from the following considerations. From a study of crop requirements in relation to soil composition it is estimated that under favorable conditions about 1 per cent of the total phosphorus present in the surface soil will become available for plant use during the growing season. That means 10.6 pounds available phosphorus when the soil contains 1060 pounds total, and 5.4 pounds available when the soil contains 540 pounds total per acre. Forty bushels of wheat require 12.8 pounds of phosphorus. If only 10.6 pounds will become available during the growing season, 33.1 bushels is the maximum crop possible. That occasionally larger crops may be produced is true. But that larger crops than these will not be the average on this kind of land is a fact well known. In fact the average will be less. On the poorer land, where 5.4 pounds become available during the growing season, 16.9 bushels will be the maximum crop. Rotation of crops and seasonable variations will largely influence the yield, but the average production will be limited by the amount of the essential elements which become available for the use of plants during the growing season, and the element which occurs in the smallest amount, as measured by the crop requirements, is the limiting element in crop production.

THE POTASSIUM CONTENT.

All these soils are high in potassium content. As a class the bottom soil contains more of this element than the uplands. The Boone fine sandy loam has the lowest potassium content, 22,000 pounds in the surface soil, while the Osage silty clay loam and the Osage very fine sand have the highest, 41,200 pounds, in the surface soil. This is a very large amount of potassium, as measured by crop requirements, in comparison with the phosphorus or the nitrogen. The 39,200 pounds of potassium in the Osage very fine sandy loam is the amount used by four thousand one hundred twenty-five 50-bushel crops of corn, grain only, or one thousand one hundred four crops, stalks and grain. The 880 pounds of phosphorus in the same soil is the amount used by seventy-seven 50-bushel crops of corn, grain and stalks, or one hundred four crops, grain only. The 2660 pounds of nitrogen in this soil is the amount used by thirty-five 50-bushel crops of corn, grain and stalks, or fifty-three crops, grain only. As measured by the requirements for the grain crop, the stock of potassium in the Osage very fine sandy loam is forty times as great as that of phosphorus, and seventy-seven times as great as the supply of nitrogen; as measured by the requirements of the total crop, the potassium supply is fourteen times as great as that of phosphorus, and thirty-one times as great as that of nitrogen. The problem of potassium in all the soils is that of liberation. The amount present is so large that the amount removed in the grain will not seriously deplete the stock on hand. The physical changes in the soil will, in such long periods of time, more than counterbalance that removed in grain crops. Potassium, in comparison with nitrogen, accumulates to a much larger extent in the leaves and stalks, such substances as are seldom removed from the farm.

Pottassium will be liberated for the use of the crop by the same agencies as liberate phosphorus and make soluble nitrogen, namely, good drainage and cultivation, and a supply of fresh decaying organic matter. If these conditions are fulfilled, potassium will last indefinitely in most Kansas soils where only the grain is removed from the land.

THE CALCIUM CONTENT.

Calcium is highest in the bottom soils as compared with the upland soils. This seems paradoxical, from the fact that calcium leaches more readily from the soil than does potassium. Soils formed from limestone are not necessarily rich in lime. Soils formed from limestone are made up 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 ones, soils are well stocked with lime. From this the conclusion follows that lime leaches out of the soil faster than the other elements under consideration. The Crawford silty clay loam formed from limestone is poorer in lime than these bottom soils which are not formed from limestone. When these alluvial soils were formed the lime was leached from the uplands and deposited together with the soil matter in suspension. This is shown by the very high lime content of the Osage very fine sand, which has a higher calcium content than any other type in the county. The Osage silty clay loam has the next highest lime content. These soils are subject to floods.

The upland soils as a class are much lower in lime than the bottom soils. This is due to the leaching of calcium. Crawford silty clay loam is formed from limestone, yet its lime content is one of the lowest. In a limestone-formed soil, the lime increases in the subsurface and subsoil. The lime content of the Crawford silty clay loam is more than two and a half times as great in the subsoil as in the surface soil, while in the Boone fine sandy loam there is no such increase. The Summit silty clay loam formed from limestone and shale also shows a large increase in the subsoil. This leaching may make it necessary in time to add lime to soils even though they are formed from limestone.

THE CARBON CONTENT.

In the table in the appendix, the carbon is given as organic and inorganic. The first represents that present in plant residues, while the second is that found in such substances as limestone. The presence of inorganic carbon indicates undecomposed carbonates such as limestone. Some of these soils do not contain any inorganic carbon, while others contain only traces; in a few the per cent is very small. When it is remembered that several of these soils have been formed from limestone, the great solvent action of the soil water on this substance is emphasized. The presence of inorganic carbon in the soil is an assurance of the presence of carbonates or such conditions as prevent acidity. While this is true, the absence of inorganic carbon does not necessarily mean an acid soil.

The organic carbon is an index to the amount of organic matter in the soil. The organic carbon is estimated to represent one-half the organic matter or such substances as have been derived from plant and animal life.

A study of the table in the appendix will show that the samples taken from native pastures or native meadows are the richest in carbon. The samples from Summit silty clay loam average 67,600 pounds of carbon in the surface soil. On the assumption that straw contains fifteen per cent of moisture and that the dry substance is forty-five per cent carbon, 1000 pounds of carbon represents as much organic matter as would be present in 1¼ tons of wheat straw; or the organic matter in Summit silty clay loam represents as much organic matter as would be made by the application of eighty-four tons of wheat straw on an acre. This large amount of organic matter has accumulated during the many years' growth of prairie grass, which has decayed on the land.

The amount of carbon present in these soils is closely related to the physical texture. The sandy soils contain less carbon than the silty soils, and these in turn less than the silty clay soils. The openness of the texture tends to the rapid decay of organic matter.

MAINTAINING SOIL FERTILITY.

The maintenance of soil fertility is one of the most vital problems concerning farmers of Shawnee county to-day. A step of utmost importance in the maintenance of the fertility of the soil is the adoption of some system of crop rotation in which a leguminous crop, such as alfalfa, cowpeas, clover, or sweet clover, is grown at definite periods on each of the cultivated fields of the farm. At the present time over 75 per cent of the Oswego silt loam and Oswego silty clay loam, two of the richest upland soils of the county, are in corn each season. Some of these fields have been cropped to corn continuously for over thirty years. The same is true of some of the soils of the Osage series. Under such treatment it is not surprising that the acre yield of corn in the county has declined. A rotation of crops should be practiced on these soil types, and in the rotation some leguminous crop should be systematically grown to supply nitrogen. The chemical analyses of these soils show that nitrogen is the limiting element of plant food, and must be supplied if maximum crops are to be grown.

COWPEAS IN ROTATION.

The cowpea is a good leguminous crop to grow for the purpose of supplying nitrogen to the soil. This crop may be planted in the summer after harvesting a crop of wheat or oats, and in seasons of ordinary rainfall will produce an abundant growth by fall. The best practice is to plow the crop under before frost, leave the ground rough over winter, and plant the field the next season to corn or kafir.

ALFALFA.

Alfalfa is a good crop to grow in rotation with other crops for the purpose of adding nitrogen to the soil. Like the cowpea, alfalfa is a leguminous crop, and therefore has the ability, due to bacteria growing with it, to utilize as food the nitrogen of the atmosphere. Some of the nitrogen taken by alfalfa bacteria from the atmosphere, and utilized by alfalfa for growth, may in turn be used by other crops that succeed alfalfa in the rotation, providing the alfalfa grown is fed to live stock and the plant food in the manure returned to the soil. Alfalfa will not add a large amount of nitrogen to the soil when the crop is cut for hay and sold from the farm. It must not be forgotten that alfalfa uses in its growth not only the nitrogen secured from the air, but, like other crops, uses as well nitrogen secured from the soil. When the alfalfa hay is cut and sold from the farm nearly all the nitrogen secured from the air is sold with the hay, and that left in the alfalfa roots will not much more than offset the nitrogen secured from the soil. It becomes necessary, therefore, to feed the alfalfa raised on the farm, and return the manure to the land, if any large gain in nitrogen is to be obtained by growing alfalfa.

ALFALFA REMOVES MINERAL PLANT FOOD.

Alfalfa uses in its growth mineral plant food, which it can secure only from the soil. It removes from the soil very rapidly both phosphorus and potassium. Selling alfalfa hay is one of the fastest methods of exhausting these plant food elements. By feeding alfalfa hay and carefully using the manure more than three-fourths of the mineral plant food can be saved. It is evident, therefore, that if alfalfa is grown for the improvement of the soil it must be fed to live stock on the farm, and when so used will add organic matter and nitrogen.

DIFFICULTY IN STARTING ALFALFA ON THE UPLAND.

Considerable difficulty has been experienced in starting alfalfa on some of the upland soil types in Shawnee county. This is especially true on the soils of the Oswego and Shelby series. Many failures on the Oswego series have resulted from poor drainage. Many acres of both the Oswego silt loam and the Oswego silty clay loam must be tile underdrained before they will grow alfalfa successfully. On the soil of the Shelby series poor drainage is seldom the cause of failure. On this soil type, failure often results from a lack of available plant food, from a poorly prepared seed bed, from an acid soil, and from a lack of inoculation. In starting alfalfa for the first time, upon the upland, the best seed bed possible should be prepared. One of the best methods is to follow wheat or oats with alfalfa, and prepare the seed bed by plowing just deep enough to cover the stubble well as soon as the crop has been removed. The ground should be worked thoroughly and at frequent intervals with a disk and harrow until the middle or the last of August, when the alfalfa should be sown. An application of ten to twelve tons of manure should be applied the preceding fall or winter. This will furnish the necessary plant food to start the alfalfa well. Where the soil is sour or acid an application of two tons of ground lime rock should be made six months or a year before seeding. It is always safe to inoculate with alfalfa bacteria. This may be done by using commercial cultures or by applying soil taken from an old alfalfa field. The soil should be applied at the rate of three to four hundred pounds per acre and harrowed in immediately It should be applied but a short time before seeding.

SUPPLYING ORGANIC MATTER.

The problem of maintaining the supply of organic matter in the soil of Shawnee county is a most serious one. Organic matter is constantly decaying in a cultivated soil, and, unless applied in some form, soon becomes so deficient that low crop yields result. Organic matter enables the soil to hold water, keeps the soil in good tilth, and in decaying makes available the unavailable plant food of the soil. The depletion of organic matter may cause decreased crop production, not because the essential plant food elements have been exhausted, but because the fresh organic matter, which is the most potent force in releasing plant food from the soil, has been depleted to such an extent that plant food is no longer made available.

BARNYARD MANURE.

Barnyard manure is one of the best forms in which to supply organic matter. As large a quantity as possible should be produced on every farm, and the manure produced should be carefully saved and applied to the soil. Fresh manure furnishes the largest amount of organic matter. Therefore, whenever possible, manure should be applied in a fresh condition. If manure is stored, it decays rapidly, and organic matter as well as plant food is lost. One of the greatest wastes of plant food on the average farm results from leaching and fermentation of manure. This waste goes on in every barnyard. Half the manurial value of manure is lost when it is allowed to lie in the barnyard from spring until late summer. It is, therefore, the best policy, whenever conditions permit, to apply manure to the field as fast as made. The feed lots should be cleaned out in the early spring and never left for the manure to be leached by the rains of spring and summer. Manure can be applied with the best results to crops like alfalfa, corn or kafir. It should be applied in small quantities and evenly spread over a large area. Twenty tons of manure will have greater value upon two acres than upon one. Manure can also be used with profit as a top dressing upon wheat providing it is distributed evenly. When used on wheat it should be applied in the fall or early winter, where it will serve as a protection to the wheat during a severe freeze and as a mulch to prevent evaporation during the following spring and summer.

Organic matter is supplied by any kind of plant material. Cornstalks and straw are useful for the purpose of supplying organic matter. When they can not be utilized for feed or made into manure, they should be worked into the soil. Such material should never be burned, for when burned the organic matter is destroyed.

Upon many farms it is impossible to maintain the supply of organic matter by means of barnyard manure, and even the return of all straw and cornstalks to the soil is not sufficient to replace the organic matter as rapidly as destroyed. On such farms it will be necessary to grow crops for the purpose of plowing under as green manure. Cowpeas, clover, rye, soy beans, sweet clover, and sorghum crops may be used for this purpose. Rye and sorghum crops are inferior to the others beause they are nonleguminous and do not add nitrogen. They can, however, often be used to advantage and will supply a large amount of rapidly decaying organic matter when plowed under green.

COMMERCIAL FERTILIZERS.

Commercial fertilizers have not been commonly used in the past in Shawnee county, but as the soil becomes less fertile greater interest is taken in their use. Commercial fertilizers are manufactured and sold for the purpose of supplying one or more of the three essential elements of plant food, nitrogen, phosphorus, and potassium. The fertilizers commonly sold on the market are known as "complete fertilizers" and supply all three of these elements. It is possible, however, to purchase fertilizers supplying but a single element.

NITROGEN.

A forty-bushel crop of wheat removes from the soil in the grain alone about 57 pounds of nitrogen. Nitrogen costs on the market when purchased in the form of commercial fertilizer about 19 cents per pound. At this price, the 57 pounds of nitrogen removed from the soil in a forty-bushel crop of wheat would be worth $10.83. It would, therefore, cost over one-fourth the value of the wheat crop to supply by means of commercial fertilizer, the nitrogen removed in the grain. It would be impracticable at present market prices to attempt to supply the nitrogen removed by wheat in this way. It would not only be impracticable, but it would be foolish when in the air above the soil there are millions of pounds of nitrogen which may be obtained by means of leguminous crops. In order that the wheat crop may receive the benefit of the nitrogen thus secured, leguminous crops must be grown in rotation with wheat or manure obtained from feeding leguminous crops must be applied to the ground upon which wheat is grown. With such a cheap and practical means of securing nitrogen from the air, it is only the unthinking farmer that would purchase nitrogen in any large quantity in the form of commercial fertilizer.

POTASSIUM.

A forty-bushel crop of wheat removes from the soil about ten and a half pounds of potassium. The chemical analysis of the soil of Shawnee county shows that the potassium content of the first seven inches varies from twenty-two thousand to forty-one thousand pounds per acre. With this large supply of potassium in the soil and the small amount actually removed by grain crops, it is doubtful if it will ever become necessary to supply potassium by means of commercial fertilizers. The problem in potassium fertilization is not to supply larger quantities of this plant food, but to liberate and make available the supply that is now in the soil in an unavailable condition. This may be done by practicing good methods of cultivation and keeping the soil well supplied with organic matter.

PHOSPHORUS.

Phosphorus occurs in the soil of Shawnee county in very limited amounts, as was shown by the chemical analysis of these soils. There is no cheap source of supply of this element, as is the case with nitrogen. Neither can it be liberated from the soil in sufficient quantities to grow crops indefinitely, as appears to be true of potassium. Where good methods of cultivation are practiced and crop rotations are followed, phosphorus will be the first element of plant food that it will be necessary to supply. It may be obtained in such commercial fertilizers as bone meal, acid phosphate, or raw rock phosphate. Phosphorus can be obtained the cheapest in the form of raw rock phosphate, but when used in this form must be applied with barnyard manure or plowed under with a green manure crop. Acid phosphate and bone meal may prove profitable on either wheat or alfalfa, but it is doubtful if they will give paying returns when used upon corn.

Where commercial fertilizers are not known to be profitable, as in Shawnee county, they should not be used extensively. They should be used first on an acre or two of wheat or alfalfa, and, if found profitable on a small area, used later more extensively. Commercial fertilizers should not be expected to replace barnyard manure or green manuring crops, but should be used only where necessary to supplement these materials.

APPENDIX.

THREE METHODS OF CHEMICAL ANALYSIS OF SOILS.

The chemical analysis of a soil gives an inventory of the plant food present under the conditions of analysis. The methods employed in the chemical analysis of soils may be divided into three classes: (1) solution by water or weak acids; (2) solution by strong acids; (3) solution by strong acids after fusion. The first method gives the amount of plant food of immediate use to the plant at the time the analysis is made. This analysis furnishes an index to the immediate productive uses of the soil. It is very valuable in investigating systems of cropping and methods of handling the soil; but it has no value in a soil survey when it is desired to know the duration of the crop-producing power of the soil. Soil water always contains carbon dioxide where organic matter is present; in a state of decay other acids are also present. Consequently the soil water has the properties of a weak acid, and the strength is influenced by the amount of decaying organic matter present, and also by the physical condition of the soil, which to a large extent controls the rate of decay of organic matter.

SOLUTION BY STRONG ACIDS.

The method of solution by strong acids has been followed by soil analysts more than any other method. It was thought that hydrochloric acid of the strength which remains constant during boiling would dissolve all the plant food which was possible for a plant ever to obtain. It was found that an acid of such strength would dissolve more plant food than a stronger or a weaker acid. For this reason the results were taken as a measure of the duration of crop production. 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 on soil analysis in reports or books are on this basis. The weakness of this method is that the results are in a measure relative. They represent the amount of plant food soluble at the time the analysis was made. The amount is subject to slow change. The acid-insoluble silicates, which contain the greater amount of the potassium and a small amount of the phosphorus, are continually acted on by the weathering agencies. The decay of organic matter, the freezing and thawing of every winter, the growth of crops and the cultivation of the soil slowly change these insoluble compounds into such as are soluble, first in strong acids and finally in weak acids.

SOLUTION BY STRONG ACIDS AFTER FUSION.

The solution by strong acids after fusion gives the total amount of elements present. Only those elements are determined which are likely to be present in such small amounts as to be inadequate for profitable crop production or those which notably influence crop production. At any one time only a small amount of this total is present in such form as to be soluble in weak acids and consequently of immediate use to the crop. But the greater the total amount present, the larger amount will be made soluble, provided the agencies which produce soluble plant food are equally active. Thus of two soils having similar physical properties and the same content of decaying organic matter, the one which has the larger amount of total plant food will be the more fertile. There is no exception to this general rule.

NUMBER OF SOIL SAMPLES TAKEN.

Soil types which are predominant in the county were usually sampled in several places. Predominant types present several phases of variations, and where possible these were sampled. It is impossible to sample all the different shades of the type. Only those which are most pronounced are included. The types which occupy a relatively small area are usually sampled in only one place. 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.

LOCATION OF SOIL SAMPLES.

The place where a sample is taken is located by a method of United States land survey, ten acres being the smallest limit. In selecting the place to sample, a careful study is made of the type in regard to its formation and relation to other types. Unless the sample represents the type, the analysis is of comparatively little value; but if carefully taken a few samples represent large areas and the results are applicable to all farms where the type occurs.

METHOD OF TAKING AND NUMBERING THE SOIL SAMPLES.

A soil sample for chemical analysis usually consists of three portions: soil, subsurface, and subsoil. The first is taken to a depth of 7 inches, or more exactly, 6 2/3 inches, the second from 7 to 20 inches, and the third from 20 to 40 inches. The first represents the soil as deep as plowing is usually practiced; the second depth represents the subsurface feeding ground of most plants, and the third depth the lower feeding ground. Ordinarily soil to the depth of 6 2/3 inches weighs about 2,000,000 pounds per acre, the subsurface about 4,000,000 pounds, and the subsoil 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 percentage of the constituent by two, four, or six, with due regard to the decimal point. Thus, a percentage of one-tenth of any one constituent means 2000 pounds per acre for the surface soil, 4000 pounds for the subsurface, and 6000 pounds for the subsoil. With a little practice it is possible to read the pounds per acre from the table of the percentage of composition.

For taking the top soil a tube made of galvanized iron 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 on account of recent cultivation. For taking the subsurface and the subsoil a 1½-inch auger is a good tool. At least five borings are made for each sample, and the soil from each depth mixed into one portion. 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 1134.1, 1134.2, and 1134.3 mean the soil, subsurface, and subsoil from sample 1134. Occasionally, by reason of peculiar local conditions, only one or two portions are taken. In some places the subsurface and subsoil are so full of small stones that boring is impossible.

The following table gives the analyses of all the soil types sampled in Shawnee county. It shows the location at which the sample was taken; the type of soil and stratum sampled; fhe sample number; and the percentage of plant-food elements, nitrogen, phosphorus, potassium, calcium, and organic and inorganic carbon.

ANALYSIS OF SOILS FROM SHAWNEE COUNTY.

Location by land survey.	Type as given in soil survey.	Stratum sampled, inches.	Sample No.	Percentage of plant food elements.					
				Nitrogen.	Phosphorus.	Potassium.	Calcium.	Organic carbon.	Inorganic carbon.
N. W. 10 of N. W. ¼, Sec. 16, T. 12 S., R. 14 E.	Osage silt loam (Cultivated)	Soil 0-7	1142.1	0.168	0.053	1.85	0.44	2.16	Trace.
		Subsurface 7-20	1142.2	.161	.044	1.79	.51	1.82	None.
		Subsoil 20-40	1142.3	.116	.044	1.81	.75	1.10	Trace.
S. W. 10 of S. W. 40 of N. W. ¼, Sec. 8, T. 11, R. 15 E.	Osage silty clay loam (Cultivated)	Soil 0-7	1132.1	0.207	0.066	2.07	0.92	2.50	Trace.
		Subsurface 7-20	1132.2	.161	.060	2.15	.82	1.90	Trace.
		Subsoil 20-40	1132.3	.118	.043	2.23	.86	1.46	Trace.
S. E. 10 of S. E. 40 of S. W. ¼, Sec. 27, T. 10, R. 13 E.	Osage silty clay loam (Cultivated)	Soil 0-7	1140.1	.194	.055	2.05	.70	2.44	Trace.
		Subsurface 7-20	1140.2	.146	.041	2.04	.70	1.95	Trace.
		Subsoil 20-40	1140.3	.070	.023	1.98	.70	1.11	None.
	Average	Soil	....	0.201	0.061	2.06	0.81	2.47	....
		Subsurface	....	.540	.051	2.10	.76	1.93	....
		Subsoil	....	.030	.033	2.11	.78	1.29	....
S. E. 10 of N. W. 40 of S. E. ¼, Sec. 14, T. 11, R. 15 E.	Osage very fine sandy loam (Cultivated)	Soil 0-7	1131.1	0.127	0.043	1.95	0.81	1.55	Trace.
		Subsurface 7-20	1131.2	.083	.034	1.99	.73	.83	Trace.
		Subsoil 20-40	1131.3	.055	.019	2.07	.84	.90	None.
N. W. 10 of N. W. 40 of N. E. ¼, Sec. 11, T. 11, R. 13 E.	Osage very fine sandy loam (Cultivated)	Soil 0-7	1137.1	.139	.045	1.96	.69	1.61	0.013
		Subsurface 7-20	1137.2	.089	.043	2.00	.69	.94	.022
		Subsoil 20-40	1137.3	.062	.038	2.06	.79	.66	Trace.
	Average	Soil	....	0.133	0.044	1.96	0.75	1.58	....
		Subsurface	....	.086	.039	2.00	.71	.89	....
		Subsoil	....	.059	.029	2.07	.82	.78	....
S. E. 10 of S. E. 40 of S. W. ¼, Sec. 23, T. 11, R. 16 E.	Osage very fine sand (Cultivated)	Soil 1-12	1130.1	0.041	0.022	2.06	0.93	0.26	0.067
		Subsurface 12-40	1130.2	.033	.043	2.04	.99	.22	.107
S. W. 10 of S. E. 40 of S. W. ¼, Sec. 19, T. 10, R. 16 E.	Shelby loam (Cultivated)	Soil 0-7	1134.1	0.138	0.026	1.07	0.50	1.64	Trace.
		Subsurface 7-20	1134.2	.097	.015	1.13	.75	1.08	None.
		Subsoil 20-30	1134.3	.058	.022	1.15	.77	.50	0.470
N. W. 10 of S. W. 40 of N. W. ¼, Sec. 19, T. 10, R. 16 E.	Shelby loam (Native pasture)	Soil 0-7	1138.1	.132	.028	2.05	.33	1.69	Trace.
		Subsurface 7-20	1138.2	.094	.030	2.11	.30	1.22	.010
		Subsoil 20-40	1138.3	.060	.021	2.18	.27	.71	Trace.
N. W. 10 of N. W. 40 of N. E. ¼, Sec. 26, T. 10, R. 13 E.	Shelby loam (Cultivated)	Soil 0-7	1139.1	.147	.027	1.39	.040	1.69	Trace.
		Subsurface 7-20	1139.2	.113	.025	1.38	.42	1.34	Trace.
		Subsoil 20-50	1139.3	.047	.015	1.42	.51	.67	0.025
	Average	Soil	....	0.139	0.027	1.50	0.41	1.67	....
		Subsurface	....	.101	.023	1.54	.49	1.21	....
		Subsoil	....	.055	.019	1.58	.52	.63	....

N. E. 10 of N. W. 40 of N. W. ¼, Sec. 7, T. 11, R. 15 E.	Shelby loam, sandy phase (Native pasture)	Soil.....0–7	1133.1	0.195	0.039	1.74	0.54	2.47	Trace.
		Subsurface.....7–20	1133.2	.139	.032	1.66	.44	1.66	Trace.
		Subsoil.....20–40	1133.3	.086	.036	1.73	.75	1.16	Trace.
N. E. 10 of S. E. 40 of N. E. ¼, Sec. 15, T. 12, R. 16 E.	Crawford silty clay loam (Native pasture)	Soil.....0–7	1135.1	0.255	0.042	1.57	0.39	2.73	0.010
		Subsurface.....7–20	1135.2	.179	.031	1.49	.49	1.85	Trace.
		Subsoil.....20–30	1135.3	.093	.036	1.60	.93	.70	.167
N. E. 10 of N. W. 40 of N. E. ¼, Sec. 32, T. 12, R. 16. E.	Oswego silt loam (Cultivated)	Soil.....0–7	1136.1	0.218	0.035	1.47	0.57	2.85	0.014
		Subsurface.....7–20	1136.2	.146	.027	1.44	.56	1.69	Trace.
		Subsoil.....20–40	1136.3	.076	.039	1.69	.81	.83	.201
N. W. 10 of S. W. 40 of N. W. ¼, Sec. 28, T. 12, R. 17 E.	Oswego silt loam (Native meadow)	Soil.....0–7	1146.1	.207	.023	1.44	.48	2.68	Trace.
		Subsurface.....7–20	1146.2	.138	.018	1.47	.60	1.67	Trace.
		Subsoil.....20–40	1146.3	.090	.033	1.56	.58	.89	0.020
N. 20 of S. E. 40 of N. W. ¼, Sec. 27, T. 13, R. 16 E.	Oswego silty clay loam (Cultivated)	Soil.....0–7	1145.1	.177	.057	1.75	.48	1.90	Trace.
		Subsurface.....7–20	1145.2	.115	.038	1.85	.52	1.48	Trace.
		Subsoil.....20–40	1145.3	.072	.037	1.87	.50	1.15	Trace.
	Average	Soil	....	0.212	0.029	1.46	0.53	2.77	....
		Subsurface	....	.142	.023	1.46	.58	1.68	....
		Subsoil	....	.083	.036	1.63	.70	.86	....
S. W. 10 of S. W. 40 of N. W. ¼, Sec. 19, T. 12, R. 15 E.	Summit silty clay loam (Native meadow)	Soil.....0–7	1141.1	0.300	0.033	1.66	0.56	3.71	0.017
		Subsurface.....7–20	1141.2	.184	.019	1.70	.60	2.59	Trace.
		Subsoil.....20–40	1141.3	.107	.022	1.80	1.75	1.05	.477
N. W. 10 of N. W. 40 of N. E. ¼, Sec. 24, T. 13, R. 15 E.	Summit silty clay loam (Native meadow)	Soil.....0–7	1144.1	.302	.052	1.71	.67	3.62	Trace.
		Subsurface.....7–20	1144.2	.162	.045	1.90	1.15	1.71	.023
		Subsoil.....20–40	1144.3	.090	.025	2.13	.47	.82	Trace.
N. E. 10 of N. E. 40 of N. W. ¼, Sec. 21, T. 12, R. 17 E.	Summit silty clay loam (Native meadow)	Soil.....0–7	1147.1	.222	.035	1.42	.38	2.80	Trace.
		Subsurface.....7–20	1147.2	.139	.027	1.34	.62	1.57	Trace.
		Subsoil.....20–40	1147.3	.061	.015	1.18	.51	.67	Trace.
	Average	Soil	....	0.275	0.040	1.60	0.54	3.38	....
		Subsurface	....	.162	.030	1.65	.79	1.96	....
		Subsoil	....	.086	.021	1.70	.91	.85	....
N. W. 40 of S. W. ¼, Sec. 29, T. 12, R. 14 E.	Boone fine sandy loam (Native pasture)	Soil.....0–7	1143.1	0.138	0.039	1.10	0.38	1.48	Trace.
		Subsurface.....7–18	1143.2	.085	.030	1.16	.42	.69	0.013

Shawnee

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