SOIL SURVEY OF IOWA

CRAWFORD COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

Farm Crops and Soils Section
Soils Subsection

Soil Survey Report No. 73

March, 1935

Ames, Iowa

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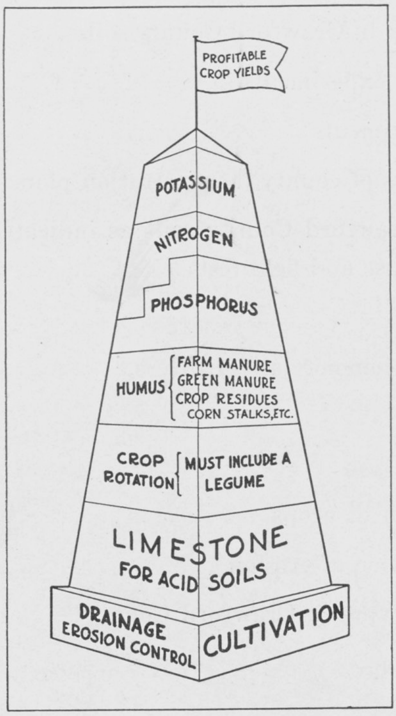
Report No. 73—CRAWFORD COUNTY SOILS

By P. E. Brown, T. H. Benton and H. R. Meldrum



IOWA AGRICULTURAL
EXPERIMENT STATION
R. E. Buchanan, Director
Ames, Iowa

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CRAWFORD COUNTY SOILS[1]

By P. E. Brown, T. H. Benton and H. R. Meldrum

Crawford County is located in western Iowa in the second tier of counties east of the Missouri River and in the middle tier between the north and south state boundaries. It lies entirely in the Missouri loess soil area and the soils of the county are, therefore, chiefly of loessial origin.

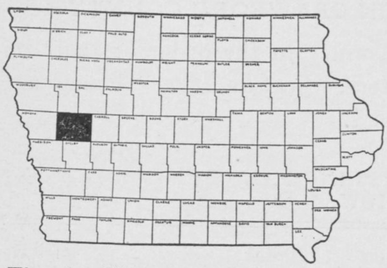

Fig. 1. Map showing location of Crawford County.

The total area of the county is 715 square miles, or 457,600 acres. Of this area, 445,330 acres, or 97.3 percent, are in farm land. The total number of farms is 2,565 and the average size of the farms is 174 acres. Owners operate 43.3 percent of the total farm land and renters the remaining 56.7 percent.

The following figures taken from the Iowa Yearbook of Agriculture for 1932 show the utilization of the farm land of the county:

Acreage in general farm crops	316,487
Acreage in farm buildings, public highways and feedlots	24,956
Acreage in pasture	114,824
Acreage in waste land not utilized for any purpose	1,621
Acreage in farm woodlots used for timber only	765
Acreage in crop land lying idle	944
Acreage in crops not otherwise listed	118

THE TYPE OF AGRICULTURE IN CRAWFORD COUNTY

The type of agriculture now practiced in Crawford County consists chiefly of a system of general farming, centered around the production of corn and the raising and feeding of hogs and cattle. Most of the corn grown is fed to livestock but some of it is sold on the markets and provides direct income on many farms. Small grains, chiefly oats, barley and wheat are grown extensively. Oats and barley are largely fed to horses, hogs and chickens on the farms. Wheat is produced only in limited amounts and is marketed. The hay crops, consisting mainly of mixed red clover and timothy and alfalfa, are fed on the farms.

Hog raising and feeding is the chief livestock industry, and the sale of hogs provides the main source of income on most farms. The feeding and raising of beef cattle is second in importance. The income from cattle often exceeds that from hogs. Some dairying is practiced and provides revenue on many farms. Occasionally sheep are raised and fed. On some farms considerable income is derived from the sale of sheep and wool. Poultry raising is practiced on most farms and the income from the sale of poultry and eggs is becoming increasingly significant. Some fruit is grown. Occasionally some of it is sold locally, but in general the production is insufficient for the local demand.

[1] See Soil Survey of Crawford County, Iowa, by T. H. Benton of the Iowa Agricultural Experiment Station and M. H. Layton of the Bureau of Chemistry and Soils. Field Operations of the Bureau. Series 1928. Project No. 237 of the Iowa Agricultural Experiment Station.

The acreage in waste land in the county is rather large, and much of it might be reclaimed and made productive if proper methods of soil treatment were followed. General recommendations for reclaiming infertile areas cannot be given as the causes for infertility are so variable. Later in this report suggestions will be offered for the treatment of areas of waste land in the various soil types. Where the conditions are abnormal, advice may be secured for the handling of soil areas, upon request to the Soils Subsection of the Iowa Agricultural Experiment Station.

THE GENERAL FARM CROPS GROWN IN CRAWFORD COUNTY

The general farm crops grown in Crawford County in the order of their importance are corn, alfalfa, oats, hay, barley, potatoes, wheat and rye. The acreage, yields and value of these crops are given in table 1.

TABLE 1. ACREAGE, YIELD AND VALUE OF PRINCIPAL CROPS GROWN IN CRAWFORD COUNTY, IOWA*

Crop	Acreage	Percentage of total farm land of county	Bushels or tons per acre	Total bushels or tons	Average price**	Total value of crops
Corn	168,737	37.89	41.7	7,036,333	$ 0.12	$844,359
Oats	79,858	17.93	30.4	2,426,218	0.10	242,621
Winter wheat	1,546	0.34	18.5	28,556	0.33	16,023
Spring wheat	1,699	0.38	11.5	19,548	0.33	6,450
Barley	12,360	2.77	20.2	249,103	0.20	49,820
Rye	298	0.06	14.4	4,293	0.24	1,030
Clover hay***	4,637	1.04	1.54	7,141	6.00	42,846
Timothy hay	5,970	1.34	1.20	7,164	4.50	32,238
Clover and timothy hay (mixed)	6,098	1.36	1.52	9,269	6.00	55,614
Wild hay	2,751	0.61	1.40	3,851	4.50	17,329
Alfalfa hay	13,474	3.02	3.11	41,904	8.00	335,232
All other tame hay	2,379	0.53	1.57	3,736	6.00	22,416
Potatoes	763	0.17	110.0	83,930	0.37	31,054
Timothy seed	130	0.02	3.3	434	0.95	412
Clover seed***	145	0.03	0.78	113	10.00	1,130
Sweet clover seed	297	0.06	2.1	631	3.00	1,893
Sweet clover****	15,345	3.44	....	....	....	....

*Iowa Yearbook of Agriculture, 1932.
**Average state farm value Dec. 1, 1932, except timothy and alfalfa hay, clover seed and sweet clover seed prices which are estimated.
***Sweet clover not included.
****All varieties for all purposes.

Corn is the most important crop both in acreage and value. In 1932 it was grown on 37.89 percent of the farm land, and average yields of 41.7 bushels per acre were obtained. In favorable seasons on the richer soils, yields are much higher, often ranging from 65 to 70 bushels per acre. Reid Yellow Dent and strains of this variety are most generally grown, but some white corn, chiefly Iowa Silvermine and Silver King, is grown too. Most of the corn is husked from the standing stalks. A part of the total acreage in corn is hogged-down, and some corn is cut for silage. Most of the corn is fed to cattle and hogs. Some is sold locally or on the market in Omaha.

Alfalfa is the second crop in value, being grown in 1932 on 3.02 percent of the total farm land with average yields of 3.11 tons per acre. Most alfalfa fields range from 5 to 30 acres in size, averaging between 15 and 20 acres. The use of lime is frequently necessary for the best growth of the alfalfa if the surface soil shows any acidity as it usually does in the eastern part of the county and sometimes in the central and western parts. The crop is usually left from 3 to 5 years, and three cuttings are generally made each season. It is a distinctly profitable crop and with proper attention to liming and inoculation, when needed, may be grown successfully in all parts of the county.

Oats are the second crop in acreage and the third in value. In 1932 they were grown on 17.93 percent of the total farm land with average yields of 30.4 bushels per acre. Under favorable conditions yields of 40 and 50 bushels per acre are frequently obtained. The chief varieties are Iowa 103, Iowa 105, Kherson, Silvermine and Green Russian. Oats are used largely as a nurse crop for sweet clover, red clover and alfalfa. Most of the crop is fed to horses and hogs and a small quantity is shipped out of the county.

Hay is the fourth crop in value. Clover and timothy is the most extensively grown hay crop. In 1932, it was produced on 1.36 percent of the total farm land, with an average yield of 1.52 tons per acre. Timothy alone was grown in 1932 on 1.34 percent of the farm land with a yield of 1.20 tons per acre. Clover alone was grown on 1.04 percent of the farm land in 1932 with an average yield of 1.54 tons per acre. All other tame hay was grown on 0.53 percent of the farm land, averaging 1.57 tons per acre in 1932. Wild hay was grown on 0.61 percent of the farm land and yielded 1.40 tons per acre on the average in 1932. The total value of the hay crop is considerable, the entire crop being fed to livestock on the farms.

Barley was raised on 2.77 percent of the farm land in 1932, and an average yield of 20.2 bushels per acre was obtained. The crop is used entirely as feed for hogs and chickens.

Potatoes are grown on practically all farms, with an average yield of 110 bushels per acre in 1932. The crop is all utilized on the farms. A few other truck and vegetable crops are produced for farm and home use. Some melons are grown commercially for sale on the local markets but not in sufficient quantities to supply the demand.

Wheat is grown in a limited way. In 1932 the winter varieties were grown on 0.34 percent of the farm land with average yields of 18.5 bushels per acre, while the spring varieties were grown on 0.38 percent of the farm land with an average yield of 11.5 bushels per acre. Turkey, Marquis and Kanred are the most favored varieties. Most of the grain is shipped to the Omaha and Sioux City markets.

Rye is grown on a limited area. Soybeans are produced on some farms. Some sudan grass is grown for summer pasture. Sorghum is raised in small quantities for sirup and feed, some millet is grown, and on many farms rape is grown for hog pasture. Some pop corn is grown in the north central and northeastern parts of the county. Sweet clover is grown extensively for pasture and green manure, and some sweet clover seed is produced.

Fruit growing is of limited importance. Apple orchards are largely restricted to small farm orchards, ranging from one-fourth to 20 acres. The fruit produced is used locally. Some cherry, plum and pear trees are found on the farms. A few grapes are raised and strawberries, raspberries and blackberries are grown on a few farms for home use.

THE LIVESTOCK INDUSTRY IN CRAWFORD COUNTY

The livestock industry includes the raising and feeding of hogs, beef cattle, dairy cattle, sheep and some horses. More hogs are raised than any other class of livestock. The common breeds are Poland China, Duroc Jersey, Chester White, Hampshire and some Tamworth. The hogs are fattened on corn, with some barley and oats. Alfalfa, sweet clover, red clover and rape furnish pasture. The hogs are usually marketed through local buyers or cooperative shipping associations. Some are sold direct to dealers, considerable numbers being hauled to Omaha and Sioux City.

The raising and feeding of beef cattle is second to hog raising in importance, but the income from beef cattle often exceeds that from hogs. From 25 to 30 head of cattle are raised on the average farm. Many cattle are shipped in for feeding and are marketed on the Omaha, Sioux City and Chicago markets. Shorthorn grades are most common with many Hereford and some Aberdeen Angus.

Dairying is practiced on some farms, usually however, in conjunction with general farming. Milking Shorthorns predominate among the dairy cattle with some Holsteins, Guernseys and Jerseys. Most of the cream is sold at the local cream-buying stations.

Sheep are raised only in limited numbers, chiefly as a sideline on farms in the rougher areas. Some farmers buy feeders on the Omaha and Sioux City markets, feed and sell the fattened animals. Corn is fed with alfalfa and clover for fattening. Sheeping-down corn is practiced on some farms. Some wool is produced and sold, providing considerable income on some farms.

Horses are raised on a few farms in order to keep up the supply of work animals. The average farm maintains from six to eight horses, most of them light draft animals and farm chunks of the Percheron breed. Some mules are raised.

Poultry raising is practiced on most of the farms. The average farm has a flock of from 125 to 200 fowls. Most of the flocks are of mixed breeds but there are some purebred ones, of the Rhode Island Red, Leghorn, Barred Plymouth Rock and other breeds. The income from the sale of poultry and poultry products is considerable on many farms. Some turkeys, geese, ducks and guineas are raised.

THE FERTILITY SITUATION IN CRAWFORD COUNTY

The yields of general farm crops in Crawford County are usually quite satisfactory, but better methods of soil treatment would undoubtedly bring about increases in many cases. The special treatment which should be practiced on any area will, of course, be determined mainly by the soil type and the general conditions. Later in this report the needs of each of the soil types will be discussed separately. There are, however, some general recommendations for the soils of the county as a whole.

The natural drainage system is adequate and there is little likelihood that artificial drainage will be needed in more than very limited areas of the uplands, if at all. In fact, the need of drainage is ordinarily confined to the narrow areas of bottomland soils. It should be emphasized, however, that in any case where the land is poorly drained, and where water stands for long periods after rains, there may be a need for tiling. Land which is too wet will not produce good crops and tiling is the first treatment needed on such areas if they are to be cultivated.

The soils of the county include types which contain some lime and are, therefore, not in need of additions, and also types which are acid in reaction and in need of lime. The only way to determine their needs is to test them. The Carrington loam, Waukesha silt loam, the Judson silt loam, and the Wabash soils are all acid in reaction and always in need of additions, if limestone has not been applied. The Knox silt loam and the Ray silt loam are well supplied with lime and do not require any additions. The Marshall silt loam is quite variable, the typical Marshall usually being acid in the surface soil, while the shallow phase is likely to be well supplied with lime. In general it is safer to test all the soils for reaction, at least before seeding to alfalfa or sweet clover, except the Knox and Ray types. The use of lime has been found to be of very large value on the soils of the county when they are acid, not only for the more sensitive legumes, but also for the general farm crops which are benefited by the increased legume residues which are left in the soil when lime is used.

The supply of organic matter in the soils is not extremely low, although the shallow phase Marshall, the Knox silt loam and the Ray silt loam are rather poor in organic matter. The other types are better in content of organic matter, but in no case is an extremely large amount present. The Wabash soils are the richest in organic matter and hence the darkest in color. Applications of farm manure are of considerable value on all the soils, and especially on those types which are the lightest in color and hence the most in need of additions. Large increases in the yields of general farm crops follow the use of farm manure, and regular additions of it are recommended. On many

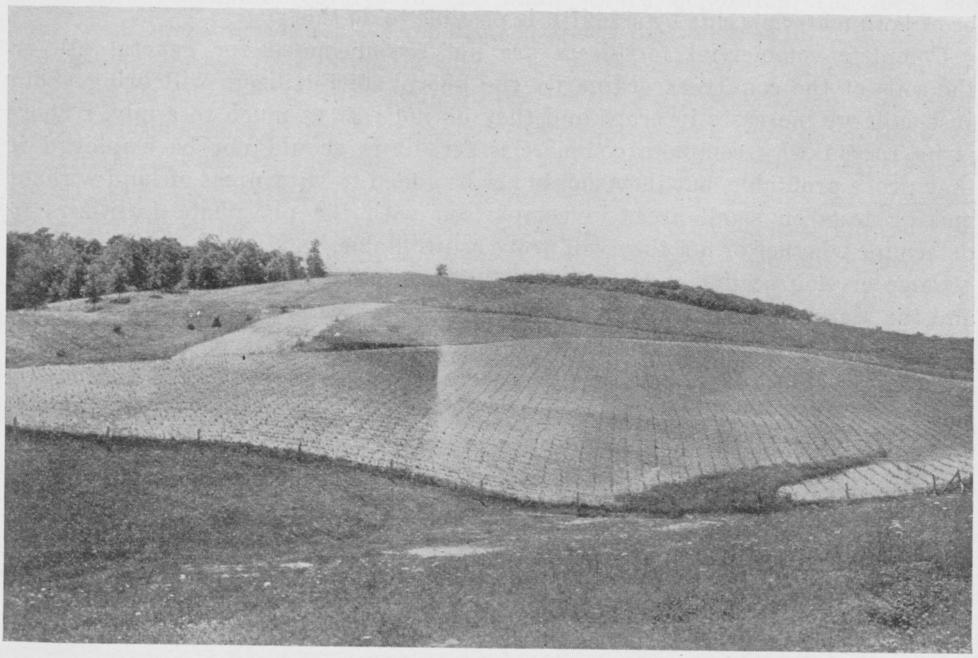

Fig. 2. An area of Marshall silt loam in Crawford County.

farms insufficient manure is produced on the farm to permit regular additions of it to all the land on the farm, and in such cases the supply of organic matter must be built up and kept up by turning under legumes as green manures. Sweet clover makes an especially desirable crop to be used as a green manure, and it may be grown successfully on the soils in this county, provided limestone is added when the soils are acid in reaction. Such crops as sweet clover when used as green manures may also add considerable amounts of nitrogen to the land, if they are well inoculated. The yields of general farm crops are increased considerably by the use of legumes as green manures.

The nitrogen content of the soils is not extremely low but additions of some form of nitrogen are necessary if the supply is to be kept up. The best way to add nitrogen to the land is by the use of well-inoculated legumes as green manures. The thorough utilization of all the farm manure produced on the farm and the turning under of all the crop residues will also aid materially in maintaining the supply of nitrogen.

The supply of phosphorus in the soils is not high, and it is evident that additions of phosphorus fertilizers will be needed in the very near future even if they are not of value at the present time. Tests in the field have indicated, however, that in many cases the addition of either rock phosphate or superphosphate will bring about increases in crop yields sufficiently large to make the application profitable. The results vary with the two phosphorus fertilizers and hence it seems desirable to test both materials under farm conditions to determine which will prove the more profitable. Superphosphate usually gives the quicker results, but rock phosphate often proves quite as efficient and even more effective when the results over the rotation are determined. Rock phosphate generally gives the largest effects the second year after the addition is made. Tests of one or the other phosphate carrier on individual farms are recommended or of both materials side by side if it is possible to do this.

Complete commercial fertilizers are not recommended for general use on the soils of the county as ordinarily the phosphate fertilizers will bring about just as large increases in crops and they do not cost as much to apply. There is no reason why complete commercial fertilizers should not be employed if they prove profitable, but they should not be added to large areas of land without making tests on small areas in comparison with the phosphate fertilizers to determine whether or not they will prove as profitable.

Some erosion occurs in Crawford County, especially on the Knox silt loam and the Marshall silt loam. In fact the shallow phase of the Marshall silt loam is the result of the extensive action of erosion on that soil type with the consequent removal of a large portion of the surface soil. The Carrington loam is also subject to some washing. In any case where erosion occurs to any extent, some method should be adopted for the prevention or control of the destructive action. Suggestions which may be put into effect on any farm for stopping the washing away of the surface soil and for the filling of gullies will be discussed later in the report. From among the methods described some one may be chosen which will fit in with practically any farm conditions and may prove very effective.

THE GEOLOGY OF CRAWFORD COUNTY

The soils of Crawford County have been formed mainly from loessial deposits, with a limited area developed from glacial material. There are bottomland areas which are covered by mixtures of the two materials, but in general they are made up of material washed down from the loess uplands. The rocks underlying the soils of the county are so deeply buried by the deposits of drift and loess that they have no influence whatever upon the soil conditions and hence they need not be considered here. The geological history of the county is of interest only in connection with the deposition of the glacial debris and the later loessial covering.

The Kansan glaciation was the earliest which covered the county, leaving behind upon its retreat a vast mass of glacial till or drift. The deposit consisted of a blue clay mixed with varying amounts of sand, gravel and boulders. The old valleys were very largely filled with the drift and the former hills and ridges were mainly leveled by the glacier. The deposit of Kansan material is quite variable in depth, ranging from a few feet in some sections to many feet in others. It has been changed from the original blue clay into a yellow or reddish-brown material, through the action of weathering agencies. The Carrington loam is the only soil type which was formed from this old Kansan till, the later covering of loess having been removed by erosion and the underlying drift exposed and made into a soil.

At some period in geologic history when climatic conditions were different from the present, there was laid down over the land a deposit of silty material known as loess. The deposition was presumably made by the wind, and it appears that the deposit was laid down from the west as the deeper areas are to the west and the deposit thins out toward the east. This loess consists of a grayish or pale buff calcareous material which was laid down evenly over the previous topographic features of the land. Since deposition, the loess has been weathered, organic matter has accumulated from the growth of plants and the soils are largely dark brown in color. There has also been much erosion and considerable amounts of the original loess have been removed, and the depth of the deposit is now extremely variable. It ranges from a few feet in thickness to more than 100 feet. In some places, as where the Carrington loam is found, the loess has been entirely removed. The Marshall silt loam and the Knox silt loam are the upland soils derived from this loess material, and most of the bottomland types are made up mainly of loessial soils washed down from the uplands. The shallow phase Marshall silt loam is formed because of the extensive erosion.

The Marshall soils are typically darker in color, containing more organic matter and being richer in fertility constituents. The Knox silt loam is light in color and low in organic matter. It generally has a high content of lime while the Marshall often has lost most of its original lime content and frequently is acid in the surface soil at least. The Knox silt loam is found on the steep slopes and in the rougher sections, while the Marshall silt loam occurs on the more gently rolling to rolling areas. The Marshall silt loam has suffered more erosion apparently than the Knox in spite of the fact that the Knox is steeper and rougher in topography but this is undoubtedly because the Marshall has been cultivated extensively while the Knox is rarely cultivated.

PHYSIOGRAPHY AND DRAINAGE

The topography of Crawford County varies from nearly level on the bottomlands along the streams to steeply rolling or rough along the stream slopes. In general the surface of the upland is characterized by rounded ridges and smooth, gentle slopes to the stream channels. More hilly and rough areas occur in the western part of the county, especially in the southwestern part. These belts of steep land are often as wide along some of the smaller streams and their short tributaries as along Boyer River, the largest stream. The roughest areas are found in Boyer and Union townships and in parts of Washington, Willow, Denison, Goodrich and East Boyer townships. Only a relatively small amount of the land in these areas, however, is too rough for cultivation. The shallow phase and the light colored phase of the Marshall silt loam and the Knox silt loam are the soils which are found in these rougher areas.

The eastern part of the county is more uniform in topography, a large proportion of it being gently rolling. Stream channels are not as deeply cut and erosion has not occurred to as great an extent as in the rougher sections of the county. Deeper surface soils are found in this section, the principal upland soil being the Marshall silt loam. Other smaller gently rolling

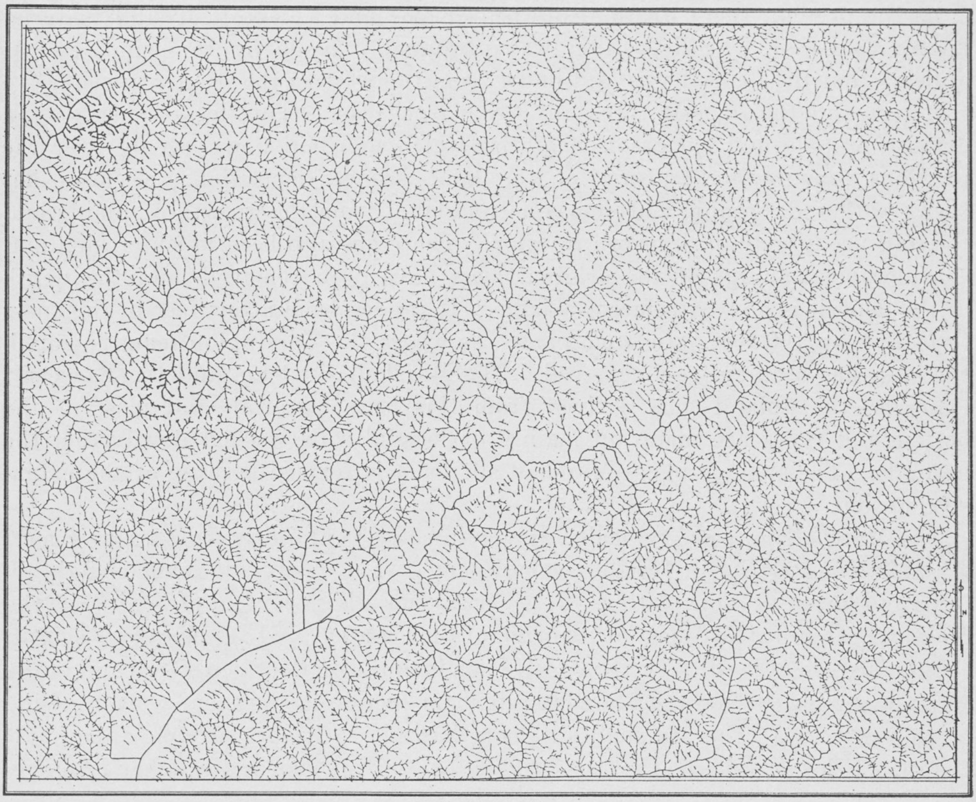

Fig. 3. Map showing natural drainage system of Crawford County.

areas occur southwest of Buckgrove, on a ridge northeast of Deloit, on the wider interstream divides in the vicinity of Charter Oak and Ricketts, and on the small divides around Schleswig in the northern part of the county.

The drainage of the county is brought about mainly by the Boyer River and its tributaries. The chief tributaries are the East Boyer River, Buffalo Creek, Otter Creek, Tucker Creek, Trinkle Creek and Beaman Creek. The Boyer River traverses the county from the northeast to the southwest. The Nishnabotna River drains the southeast part of the county while the Soldier River, Middle Soldier River, East Soldier River and Beaver Creek are the principal drainageways in the northwest section of the county. Willow Creek, Middle Willow Creek and South Willow Creek drain the southwestern part of the county, flowing in the same direction as the Boyer River.

The upland of the county has a sharp general slope toward the southwest, the streams flowing in that general direction to the Missouri River.

The bottomlands along the streams are comparatively narrow, the widest bottoms being found in the southwestern part of the county along the Boyer River. Here the valley reaches a width of more than 1½ miles. There are only small areas of second bottomlands or terraces, most of the alluvial lands being first bottomlands, and about three-fourths of them are subject to overflow. The lower course of the Boyer River as well as the channels of the Soldier and Nishnabotna rivers have been straightened which largely eliminates the damage from flood waters. Artificial drainage channels have been constructed from the larger streams for a short distance back on some of the creeks in order to prevent overflow near the junction of the streams. Considerable tiling has been done also to improve the drainage conditions on the bottomlands and prevent water standing on them after each rainfall and when any slight overflow occurs.

In general the drainage conditions in the county are satisfactory on the uplands as the streams with their tributaries and intermittent drainageways extend into practically all parts. Only on the bottoms is there any particular need for artificial drainage. The extent of the natural drainage system of the county is indicated in the accompanying drainage map.

THE SOILS OF CRAWFORD COUNTY

The soils of Crawford County are grouped into four classes according to their origin and location. These classes are drift soils, loess soils, terrace soils and swamp and bottomland soils. Drift soils are formed from deposits left by receding glaciers and consist of mixtures of sand, gravel and clay, frequently containing pebbles and boulders. Loess soils are fine, dust-like deposits laid down by the wind, presumably at a time when climatic conditions were very different from the present. Terrace soils are old bottomlands which have been raised above overflow by a decrease in the volume of the streams which deposited them or by a depression of the river channel. Swamp and bottomland soils are those occurring in low, poorly-drained areas and along streams. Many of them are subject to more or less frequent overflow. The extent and occurrence of these four groups of soils in Crawford County are shown in table 2.

TABLE 2. AREAS OF DIFFERENT GROUPS OF SOILS IN CRAWFORD COUNTY

Soil group	Acres	Percentage of total area of county
Drift soils	3,200	0.7
Loess soils	338,112	73.9
Terrace soils	8,448	1.8
Swamp and bottomland soils	107,840	23.6
Total	457,600	

Only a very limited area is covered by drift soil, 0.7 percent of the total area of the county. This soil, the Carrington loam, is found principally along the upper Boyer River and its tributaries in narrow, disconnected strips on the hill slopes. Nearly three-fourths of the county, 73.9 percent, is covered by the loess soils, the Marshall and the Knox soils. They occur over practically all of the uplands. Terrace soils occur to a limited extent, covering only 1.8 percent of the total area of the county. They are found along the principal streams of the county at the foot of the bluffs adjacent to the bottomlands. Swamp and bottomlands occur to a considerable extent in the county, covering 23.6 percent of the total area. They are found along all the major and minor streams and intermittent drainageways.

There are eight individual soil types in the county and these with the shallow phase and the light colored phase of the Marshall silt loam, and the colluvial phase of the Wabash silt loam make a total of 11 soil areas. There is 1 drift soil, 4 loess soils, 2 terrace soils and 4 swamp and bottomland soils. The various soils are distinguished on the basis of certain definite characteristics which are described in the appendix to this report. The names indicate certain group characteristics. The areas covered by the various soil types in the county are shown in table 3.

The Carrington loam, the only drift soil, covers only 0.7 percent of the county. The Marshall silt loam, together with the shallow phase and the light colored phase, covers a total of 73.7 percent of the county. The shallow phase is more extensively developed than the light colored phase, but both phases are much smaller in area than the typical soil. The Knox silt loam

TABLE 3. AREAS OF DIFFERENT SOIL TYPES IN CRAWFORD COUNTY

Soil legend on map	Soil no.	Soil type	Acres	Percentage of total area of county
		DRIFT SOILS		
Cm	1	Carrington loam	3,200	0.7
		LOESS SOILS		
Ms	9	Marshall silt loam	294,528	73.7
	213	Marshall silt loam (shallow phase)	32,512	
	257	Marshall silt loam (light-colored phase)	9,920	
Kl	11	Knox silt loam	1,152	0.2
		TERRACE SOILS		
Wt	75	Waukesha silt loam	5,248	1.1
Js	131	Judson silt loam	3,200	0.7
		SWAMP AND BOTTOMLAND SOILS		
Wh	26	Wabash silt loam	52,928	23.0
	26a	Wabash silt loam (colluvial phase)	52,352	
Wa	48	Wabash silty clay loam	2,240	0.5
Rl	195	Ray silt loam	320	0.1
		Total	457,600	....

is a minor loess type, covering only 0.2 percent of the total area of the county. The two terrace soils are rather limited in area, the Waukesha silt loam, the most extensive, covering 1.1 percent of the county, while the Judson silt loam covers 0.7 percent of the total area. On the bottomlands the Wabash silt loam with the colluvial phase, which is as extensive as the typical soil, covers 23 percent of the county. It is the second largest soil type in the area. The Wabash silty clay loam and the Ray silt loam are minor bottomland soils, the former covering 0.5 percent and the latter 0.1 percent of the total area of the county.

Fig. 4. Bottomland along the Boyer River, mostly Wabash silt loam.

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BUREAU OF CHEMISTRY AND SOILS
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SOIL MAP
CRAWFORD COUNTY
IOWA

IOWA AGRICULTURAL EXPERIMENT STATION
C. F. CURTISS, DIRECTOR
P. E. BROWN, IN CHARGE SOIL SURVEY

Thomas D. Rice, Inspector, District 3.
Soils surveyed by T. H. Benton, Iowa Agricultural Experiment Station, in charge, and M. H. Layton, U. S. Department of Agriculture.

1 ½ 0 1 2 3 4 Miles

Lith. A. Hoen & Co., Inc.

Field Operations
Bureau of Chemistry and Soils
1928

The upland soils vary somewhat in topography, the Marshall silt loam on the loessial uplands being undulating to gently rolling, while the Knox silt loam, the shallow phase and the light colored phase of the Marshall silt loam are developed on the more rolling to rougher areas. The Carrington loam is also found in the rougher sections of the uplands. The terrace and bottomland soils are all very nearly level in topography and, except for recent deposits or old channels, present no topographic features.

THE FERTILITY IN CRAWFORD COUNTY SOILS

Samples were taken for analysis from each of the soil types in the county except the light colored phase of the Marshall silt loam. This soil was not sampled because of its small total area and unimportance. The more extensively developed soils were sampled in triplicate but only one sample was taken in the case of the minor types. All samples were taken with the greatest care to insure results which would accurately represent the various types and to avoid any variations due to previous treatment of the soils or any abnormal conditions.

Samples were taken at three depths, 0 to 6⅔ inches, 6⅔ inches to 20 inches and 20 to 40 inches, representing the surface soil, the subsurface soil and the subsoil, respectively.

Analyses were made for total phosphorus, total nitrogen, total organic carbon, total inorganic carbon and limestone requirement. The official methods were used for the phosphorus, nitrogen and carbon determinations, and the Truog qualitative test was used for the limestone requirement determinations. The figures given in the tables are the averages for the results of duplicate determinations on all samples of each type, and they represent therefore, the averages of two or six determinations.

The Surface Soils

The results of the analyses of the surface soils are given in table 4. They are calculated on the basis of 2 million pounds of surface soils per acre.

TABLE 4. PLANT FOOD IN CRAWFORD COUNTY, IOWA, SOILS
Pounds per acre of 2 million pounds of surface soil (0–6⅔")

Soil no.	Soil type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
1	Carrington loam	1,373	4,000	32,887	....	2,000
	LOESS SOILS					
9	Marshall silt loam	1,373	3,840	34,332	....	4,000
213	Marshall silt loam (shallow phase)	1,791	2,800	20,405	15,618	....
11	Knox silt loam	1,684	2,760	25,773	11,723	....
	TERRACE SOILS					
75	Waukesha silt loam	1,481	3,760	30,051	....	4,000
131	Judson silt loam	1,589	3,760	34,660	....	4,000
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	1,764	3,800	40,659	....	4,000
26a	Wabash silt loam (colluvial phase)	1,387	3,920	40,250	....	....
48	Wabash silty clay loam	2,195	4,520	42,813	....	3,000
195	Ray silt loam	1,347	3,000	28,094	703	....

The phosphorus content of the different soils ranges from 1,347 pounds per acre in the Ray silt loam, a bottomland type, to 2,195 pounds per acre in the Wabash silty clay loam, also a bottomland soil. No definite relationship is evident between the various soil groups and the phosphorus content of the soils, although the loess types will average somewhat higher than the drift soils and the swamp and bottomland soils are better supplied than the upland soils, as might be expected because there has been less plant growth on these soils and hence a smaller removal of phosphorus. The variations among the individual soil types, however, are much more definite than between the various soil groups.

No definite relationship is shown between the phosphorus in the various soils and the different soil series. Usually some relation exists between the phosphorus content of soils and the characteristics which serve as the basis for the differentiation of soil series. The differences in color, topography, character of the subsoil and origin and previous history of the soil generally influence the phosphorus content. Thus types which are level to flat in topography are higher in plant food. Those which are darker in color are better supplied with the various constituents and types with heavier subsoils are richer in fertility than those with sandy or gravelly subsoils. It appears here that the Wabash soils on the bottomlands are richer than the Ray silt loam. There is little difference in the content of the Waukesha and the Judson soils on the terraces, and these types are not strikingly different. On the loessial uplands the Marshall silt loam is usually higher in phosphorus than the Knox silt loam or the shallow phase of the Marshall. It sometimes happens, however, as in the case of the soils in this county that soils high in lime content, such as the Knox and the shallow phase Marshall, show a higher content of phosphorus than other upland soils which are more productive in general. The Marshall and the Knox soils show a higher content of phosphorus than the Carrington loam as would be expected.

All the soils in the county except the Wabash silty clay loam are silt loams in texture and there is no possibility of showing any effects of texture on the phosphorus content, except in the case of the Wabash series, in which case the Wabash silty clay loam is higher in the element than the silt loam or the colluvial phase of the type. In general it has been found that fine-textured types are usually better supplied with plant food than coarse-textured soils of the same series. Thus it would ordinarily be expected that silty clay loams would be better supplied with phosphorus than silt loams, silt loams would be higher than loams and these in turn would be richer in phosphorus than sandy loams or sands.

Considering the results of the analyses as a whole, it is evident that Crawford County soils are fairly well supplied with phosphorus, but the supply is not adequate to meet the needs of crops for an indefinite period. Some provision must be made in the near future for supplying phosphorus to the various soils in the county if the supply is to be kept up and crops are not to suffer for a lack of the element. Field and greenhouse experiments on some of the soils which occur extensively in Crawford County indicate that a phosphorus fertilizer may now be used with profit in many cases.

The nitrogen content of the various soil types varies in much the same way as does the phosphorus. The amount present ranges from 2,760 pounds per acre in the Knox silt loam, a loessial upland type, to 4,520 pounds per acre in the Wabash silty clay loam, a bottomland soil. As in the case of phosphorus, no definite relationship is evident between the various soil groups and the nitrogen content of the soils. The drift soils, loess soils, terrace soils and swamp and bottomland soils contain about the same amounts on the average, although the bottomland types are somewhat better supplied than the upland types as would be expected.

The series characteristics, however, seem to have some effect upon the nitrogen content of the soils. Thus on the loessial upland the Marshall silt loam is considerably richer in nitrogen than the Knox silt loam and on the bottomlands, the Wabash silt loam is richer than the Ray silt loam. As a general rule soils which are darker in color, level in topography and have heavy subsoils, such as the Wabash types, are richer in nitrogen than the lighter colored soils which are rolling in topography or have sandy or gravelly subsoils. The Knox silt loam is lighter in color than the Marshall silt loam and it is lower in nitrogen.

Again the effects of texture on the nitrogen content is shown only in the case of the Wabash series, where the Wabash silty clay loam is higher in nitrogen than the silt loam or the colluvial phase of the silt loam. Thus it appears that insofar as the results go, they bear out the usual condition that heavy or fine-textured soils are richer in nitrogen than coarse-textured soils of the same series.

While the soils of the county are not strikingly low in nitrogen it is evident that nitrogen must be considered when the permanent fertility of the land is planned, and regular additions of fertilizing materials supplying nitrogen must be made if the content of this element is to be kept up and the best production of crops insured.

The organic carbon content of the soils of this county varies from 20,405 pounds per acre in the shallow phase of the Marshall silt loam up to 42,813 pounds per acre in the Wabash silty clay loam on the bottoms. The latter is the type which is the highest in nitrogen and the results bear out the usual condition which is that soils high in nitrogen are also usually high in organic carbon or organic matter.

There is little evidence of any relationship between the organic carbon content and the soil groups although the bottomland soils are, on the average, better supplied with organic matter, as would be expected inasmuch as they are cultivated to a much less extent if at all, and it is well known that cultivation reduces the organic matter in soils. The relation of the various soils by series to organic carbon is very much the same as in the case of nitrogen. The effects of the topography, the color of the soil and the subsoil characteristics are shown in some cases. Thus the Wabash soils are richer in organic matter than the Ray silt loam, and the Marshall silt loam is better supplied than the Knox silt loam. In general it appears that those types which are darker in color, more nearly level in topography and have heavy or fine-textured subsoils, are richer in organic matter and nitrogen than the lighter colored soils. This is due of course to two things, the greater accumulation of organic matter in such types and the lower rate of decomposition which means a slower loss of the organic matter.

Only in the Wabash series is it possible to make any observation of the effects of texture upon the content of organic carbon. The Wabash silty clay loam is higher in organic carbon than the silt loam or the colluvial phase of that type, just as in the case of nitrogen. There is no other case in which soils of the same series but with different textures are mapped and no additional illustrations are therefore available for the ordinary effects of texture. In general it seems that fine-textured soils, such as silty clay loams, may be expected to be richer in organic matter than silt loams, silt loams are generally richer than loams and the latter are better supplied than sandy loams or sands.

The soils of Crawford County are not overly well supplied with organic matter or organic carbon, except in the case of the bottomland soils, and even in these types the supply is not extremely large. The need of supplying organic matter to the upland soils is evident, therefore. It is also apparent that it will be important to add fertilizing materials containing organic matter, at regular intervals to the soils of this county, if the content of the soils is to be maintained and built up.

The Carrington loam on the drift upland and the typical Marshall silt loam on the loessial upland are acid in reaction and in need of lime. They show no content of inorganic carbon. The shallow phase Marshall silt loam and the Knox silt loam, however, contain inorganic carbon and hence are not acid in reaction and not in need of lime. The Ray silt loam on the bottomlands contains a small amount of lime, or inorganic carbon and is not acid in reaction, but the Wabash soils and the Waukesha and Judson types on the terraces are acid in reaction and in need of lime. It is very important that all the soils of the county except the Knox silt loam, the shallow phase of the Marshall and the Ray silt loam be tested for need of lime if the best yields of general farm crops are to be obtained. For legumes it is important that lime be added when needed. The amount of lime to be applied must be determined for each individual soil and tests must, therefore, be made of the soil in every field before lime is added. Even average figures such as are reported in the table do not show the exact amount of lime which is needed in every case on the same soil type.

The Surface Soils and Subsoils

Tables 5 and 6 give the results of the analyses of the subsurface soils and subsoils. They are calculated on the basis of 4 million pounds of subsurface soil and 6 million pounds of subsoil per acre.

In general the results obtained from the analyses of the surface soils may be considered to show fairly accurately the plant food content and the crop-producing power of the soils. Unless there is a very large amount of some constituent present or a deficiency, there is little effect on the fertility of the soil indicated by the analyses of the lower soil layers. The lower soil layers in Crawford County do not seem to be abnormal in amounts of plant food constituents and hence the results do not need to be considered in detail.

The general conclusions arrived at from a consideration of the results of

TABLE 5. PLANT FOOD IN CRAWFORD COUNTY, IOWA, SOILS
Pounds per acre of 4 million pounds of subsurface soil (6⅔″–20″)

Soil no.	Soil type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
1	Carrington loam	2,800	4,720	47,613	....	2,000
	LOESS SOILS					
9	Marshall silt loam	2,074	3,760	36,978		3,000
213	Marshall silt loam (shallow phase)	3,178	3,280	10,015	69,177	....
11	Knox silt loam	3,314	1,680	16,175	43,764	....
	TERRACE SOILS					
75	Waukesha silt loam	2,854	6,080	49,740	....	4,000
131	Judson silt loam	3,124	7,120	69,702	....	3,000
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	3,824	8,560	89,609		4,000
26a	Wabash silt loam (colluvial phase)	3,422	7,120	83,114	....	....
48	Wabash silty clay loam	4,848	9,680	82,846	....	3,000
195	Ray silt loam	3,258	8,240	80,228	....	2,000

the analyses of the surface soils are borne out by the data obtained on the lower soil layers. It seems evident that phosphorus will be needed on the soils of the county in the near future and the use of phosphorus fertilizers might be of large value now. The supply of organic matter and nitrogen must be built up in some of the soils of the county, and in all of them additions must be made at regular intervals if the supply is to be kept up. The use of farm manure is of particularly large value on the soils of the county in order to increase the production of available plant food. The regular addition of all crop residues and the turning under of legumes as green manures will be of value on many of the types. The soils which are acid in reaction in the surface soil should be tested for lime needs, and lime should be added as required in order to provide more nearly optimum

TABLE 6. PLANT FOOD IN CRAWFORD COUNTY, IOWA, SOILS
Pounds per acre of 6 million pounds of subsoil (20″–40″)

Soil no.	Soil type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
1	Carrington loam	4,362	4,440	39,841	....	2,000
	LOESS SOILS					
9	Marshall silt loam	3,999	3,160	18,161	....	3,000
213	Marshall silt loam (shallow phase)	4,566	2,160	36,010	72,060	....
11	Knox silt loam	4,848	1,560	19,725	5,963	....
	TERRACE SOILS					
75	Waukesha silt loam	4,242	5,640	63,157	....	4,000
131	Judson silt loam	4,362	9,660	101,771	....	2,000
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	5,010	8,640	92,527	....	5,000
26a	Wabash silt loam (colluvial phase)	5,091	12,120	95,390	....	3,000
48	Wabash silty clay loam	5,373	11,880	121.242	....	4,000
195	Ray silt loam	5,617	12,480	116,252	....	4,000

conditions for the growth of general farm crops and especially legumes. Even if there is some lime in the lower soil layers, the use of lime if the surface soil is acid, is necessary for new seedings of legumes. All the soils of the county, except the Knox silt loam, should be tested for reaction in order to determine whether or not additions of lime are need for the best legume growth.

GREENHOUSE EXPERIMENTS

Two greenhouse experiments were carried out on the soils of Crawford County in order to determine the effects of certain fertilizer treatments and to obtain some information regarding the fertilizer needs of the soils. These experiments were carried out on the Marshall silt loam and the Wabash silt loam, two of the most important soil types in the county.

The fertilizer treatments tested included manuring, liming and the use of superphosphate and muriate of potash. Manure was added at the rate of 8 tons per acre. Lime was supplied in amounts sufficient to correct the acidity of the soil. Superphosphate was added at the rate of 200 pounds per acre and muriate of potash at the rate of 50 pounds per acre. Wheat and clover were grown in the pots, the clover being seeded when the wheat had been up about 1 month.

The Results on the Marshall Silt Loam

The results obtained on the Marshall silt loam from Crawford County are given in table 7. The application of manure increased considerably the yields of

TABLE 7. GREENHOUSE EXPERIMENT, MARSHALL SILT LOAM, CRAWFORD COUNTY

Pot no.	Treatment	Weight of wheat grain in grams	Weight of clover in grams
1	Check	8.7	16.2
2	Manure	12.6	30.7
3	Manure+limestone	13.2	38.0
4	Superphosphate	11.7	43.3
5	Manure+superphosphate	12.0	56.8
6	Limestone+superphosphate	12.2	43.5
7	Manure+limestone+superphosphate	14.2	51.7
8	Manure+limestone+superphosphate+muriate of potash	13.3	64.2

both the wheat and clover, the increase showing particularly on the clover. Limestone with manure brought about an additional increase, especially on the clover. Superphosphate had a greater effect on the clover than did manure and limestone but showed a small influence on the wheat. Manure and superphosphate together had a much greater influence on the clover than did either treatment alone but showed little greater effect than superphosphate alone. Limestone and superphosphate had about the same effect as superphosphate alone. Manure, limestone and superphosphate had a greater effect than manure and limestone or superphosphate and limestone on the wheat but showed no greater effect than manure and superphosphate on the clover. It did have a greater influence than superphosphate and limestone on the clover. Manure with limestone, superphosphate and muriate of potash gave an increase

Fig. 5. Greenhouse experiment. Clover on Marshall silt loam.

in the clover over that brought about by any of the other treatments, muriate of potash evidently having a distinctly beneficial effect on that crop. There was no beneficial influence on the wheat, however, from the use of muriate of potash.

The Results on the Wabash Silt Loam

The results secured on the Wabash silt loam from Crawford County are given in table 8. The influence of manure on this soil was shown on the wheat and the clover. It particularly increased the yield of clover. Limestone with manure slightly increased both crops. Superphosphate had no effect on the wheat but brought about a very large influence on the clover, showing a much greater effect on this crop than that brought about by manure and lime. Manure and superphosphate together increased the wheat crop and had a very large effect on the clover, showing a much greater influence than either manure or superphosphate alone. Limestone and superphosphate had little effect on the wheat; it increased the clover more than did limestone alone but less than superphosphate alone. Manure, limestone and superphosphate had a slightly greater effect on the wheat than that brought about by manure and superphosphate but had less effect on the clover. Muriate of potash with manure, limestone and superphosphate showed no beneficial effects on either crop on this soil.

TABLE 8. GREENHOUSE EXPERIMENT, WABASH SILT LOAM, CRAWFORD COUNTY

Pot no.	Treatment	Weight of wheat grain in grams	Weight of clover in grams
1	Check	7.8	30.3
2	Manure	9.1	41.0
3	Manure+limestone	9.8	46.3
4	Superphosphate	7.7	63.3
5	Manure+superphosphate	10.0	87.0
6	Limestone+superphosphate	8.4	50.0
7	Manure+limestone+superphosphate	10.6	62.3
8	Manure+limestone+superphosphate+muriate of potash	8.0	59.5

FIELD EXPERIMENTS

There are no field experiments in Crawford County, but a number of tests are under way in other counties, on the same soil types as occur in this county, and the results of these tests will be reported here, as they indicate fairly accurately the results which may be obtained with the same treatments in Crawford County. Experiments on the Marshall silt loam on the Cherokee Field in Cherokee County, on the Primghar Field in O'Brien County, on the Avoca Field in Pottawattamie County, on the Red Oak Field in Montgomery County, and on the Malvern Field in Mills County, on the Carrington loam on the Scranton Field in Greene County, on the Dallas Center Field in Dallas County, on the Pilot Mound Field in Boone County, and on the Waukesha silt loam on the Clarinda Field in Page County are included.

These experiments are planned to determine the value of various soil treatments and they are laid out on land which is representative of the particular soil types. Some of the fields include 13 plots, 155 feet, 7 inches by 28 feet, or one-tenth of an acre in size and the other fields are made up of nine plots of the same size. They are permanently located by the installation of corner stakes and all precautions are taken to insure accurate results.

The fields include tests under both the livestock and grain systems of farming. In the former, manure is applied as the basic treatment, while in the latter crop residues are employed to supply organic matter. The other fertilizing materials tested include limestone, rock phosphate, superphosphate, muriate of potash and a complete commercial fertilizer. Manure is applied at the rate of 8 tons per acre once in a 4-year rotation. The crop residue treatment consists of the plowing under of the cornstalks which have been cut with a disc or stalk cutter in the spring after being winter pastured. Sometimes the second crop of clover is plowed under, but it is usually used for seed, hay or pasture and only the residues are plowed down. Limestone is applied in sufficient amounts to neutralize the acidity of the soils. Rock phosphate is added at the rate of 500 pounds per acre once in the 4-year rotation. Until 1925 this material was applied at the rate of 2,000 pounds per acre once in 4 years and from 1925 to 1932 at the rate of 1,000 pounds per acre once in 4 years. Superphosphate is applied annually at the rate of 120 pounds per acre of the 20 percent material, 3 years out of 4 in the 4-year rotation. Until 1923 this material was applied annually at the rate of 200 pounds per acre of the 16 percent material. Muriate of potash is applied at the rate of 50 pounds per acre annually. Until 1925 the old standard 2-8-2 complete commercial fertilizer was used, being applied at the rate of 300 pounds per acre annually. Until 1929 the 2-12-2 brand was employed, the application being at the rate of 200 pounds per acre annually. Since 1929 the 2-12-6 complete commercial fertilizer has been used, and it has been applied at the rate of 200 pounds per acre annually, 3 years out of 4 in the 4-year rotation.

The Cherokee Field

The results obtained on the Marshall silt loam on the Cherokee Field in Cherokee County are given in table 9. Beneficial effects from the application of manure to this soil were shown in all but one season. In many cases very large increases in crop yields were obtained. The clover and timothy in 1925 and the corn in 1923 and 1927 showed large beneficial effects from manure. Increases in the yields of oats were also pronounced in 1924 and 1929. The

TABLE 9. FIELD EXPERIMENT, MARSHALL SILT LOAM, CHEROKEE COUNTY
CHEROKEE FIELD,* SERIES I

Plot no.	Treatment	1922 corn bu. per A.	1923 corn bu. per A.	1924 oats bu. per A.	1925 clover and timothy tons per A.	1926 corn bu. per A. (1)	1927 corn bu. per A. (1)	1928 corn bu. per A. (1)	1929 oats bu. per A.	1930 clover tons per A. (2)	1931 corn bu. per A. (3)	1932 corn bu. per A. (4)	1933 barley bu. per A. (5)
1	Check	59.8	51.2	49.0	1.87	34.6	47.9	43.5	88.5	1.59	...	54.8	31.8
2	Manure	64.9	56.1	54.7	2.03	32.8	52.9	45.5	91.8	1.62	...	56.2	38.6
3	Manure+limestone	66.6	59.8	55.5	2.18	35.2	53.7	49.2	99.8	1.97	...	62.2	46.1
4	Manure+limestone+rock phosphate	69.8	60.8	60.6	2.16	37.6	54.8	49.1	103.3	1.99	...	64.7	46.5
5	Manure+limestone+superphosphate	70.8	61.3	61.6	2.37	46.2	57.9	47.2	106.7	2.24	...	64.3	52.2
6	Manure+limestone+superphosphate+muriate of potash	72.6	61.9	62.0	2.29	49.2	55.7	44.5	102.2	2.32	...	63.0	57.1
7	Manure+limestone+complete commercial fertilizer	74.2	62.8	70.3	2.38	46.0	49.7	47.3	103.3	2.21	...	62.7	51.4
8	Check	61.1	52.7	55.2	1.99	36.3	43.6	44.5	90.8	1.72	...	58.7	41.2
9	Crop residues	63.4	54.5	54.7	2.11	46.4	44.0	46.8	93.1	1.71	...	52.6	...
10	Crop residues+limestone	62.6	58.9	61.6	2.25	46.8	42.7	37.1	84.0	1.65	...	47.1	...
11	Crop residues+limestone+rock phosphate	62.6	60.3	62.7	2.19	45.8	47.7	44.3	93.1	2.04	...	47.2	...
12	Crop residues+limestone+superphosphate	60.4	64.7	66.7	2.32	44.8	46.4	44.9	90.8	2.13	...	48.5	...
13	Crop residues+limestone+superphosphate+muriate of potash	50.8	66.7	63.2	2.47	46.6	47.9	44.4	88.5	1.96	...	44.0	...
14	Crop residues+limestone+complete commercial fertilizer	50.4	66.2	68.6	2.33	44.2	49.2	44.5	96.4	2.04	...	41.5	...
15	Check	53.9	52.3	49.7	1.92	45.6	42.7	37.4	83.2	1.38	...	38.6	...

(1) Bindweed damaged plots considerably; yields are not representative and should not be used to indicate value of fertilizers.
(2) Red and alsike clover.
(3) Hot, dry weather seriously damaged corn; no harvest.
(4) Bindweed damaged plots 9 to 15.
(5) Plots 9 to 15 badly infested with bindweed. Barley poor, no results.
*The Cherokee Field, Series I, was established in the fall of 1921 on the State Hospital farm at Cherokee in Cherokee County. It is located in the NE ¼ of th SE ¼ of Section 20, T. 92 N, R. 40 W. in Cherokee Township.

application of limestone with manure brought about further increases in crop yields in all cases. Particularly large benefits were obtained from the use of limestone on the clover and timothy in 1925 and on the clover in 1930. Definite gains in the corn crops and in several cases in the oat crops were also noted.

The application of rock phosphate with manure and limestone gave appreciable increases in crop yields in almost all cases. Only in one or two instances were no gains noted. The effect was very slight on the clover and timothy in 1925 and on the clover in 1930 but considerable gains were obtained with rock phosphate on corn and oats in some seasons. Superphosphate applied with manure and limestone brought about larger increases in crop yields than did rock phosphate in practically all seasons. In some cases the differences were not very great, but in the case of the clover and timothy in 1925 and the clover in 1930, superphosphate gave large increases in crop yields, while rock phosphate had little or no effect. Muriate of potash with manure, limestone and superphosphate showed little or no effect on the crop yields. In only one or two cases were slight gains in yields noted. In most instances no beneficial effects appeared. Complete commercial fertilizer with manure and limestone gave about the same effect as superphosphate. In one or two cases slightly greater yields were obtained, and in several instances the effects were not quite as large as those brought about by superphosphate. Complete fertilizer showed a much larger effect on the oats in 1924 than superphosphate but on the corn crop in 1927 and the oats in 1929 the reverse conditions prevailed.

Crop residues had little influence on the crops grown in the various seasons although in one or two cases appreciable gains in crop yields were obtained. Limestone applied with residues showed a beneficial effect on practically all of the crops. Only in a few cases were there no increases in crop yields noted from the use of limestone.

The application of rock phosphate with crop residues and limestone increased crop yields in several seasons. In some cases considerable gains were noted, as on the corn in 1927, the oats in 1929 and the clover in 1930. In several seasons, however, rock phosphate showed little or no benefit. Superphosphate applied with the crop residues and limestone showed a larger effect than rock phosphate in several seasons. The differences, however, were not great and in two or three cases rock phosphate gave just as large crop increases as did superphosphate.

The clover and timothy in 1925, and the clover in 1930 showed a larger effect from superphosphate. Corn in 1923 and oats in 1924 were also benefited more by superphosphate. The addition of muriate of potash with manure, limestone and superphosphate showed slight beneficial effects in a few cases. The clover and timothy in 1925 was benefited by muriate of potash. The difference, however, was not great. Complete commercial fertilizer with manure and limestone showed a slightly greater effect than superphosphate in two or three cases. In general, however, the differences were not great and superphosphate brought about almost as large crop effects as did complete commercial fertilizer.

The Primghar Field

The results obtained on the Marshall silt loam on the Primghar Field in O'Brien County are given in table 10. The application of manure proved beneficial on the soil in this field in practically all seasons. Considerable increases in crop yields were noted, particularly on the corn in 1928, on the barley in 1929 and on the alfalfa in 1930 and 1932. Limestone applied with manure showed beneficial effects on most of the crops. The differences, however, were not very great except in the case of the alfalfa in 1930.

The application of rock phosphate with manure and limestone increased the crop yields in most seasons. Considerable increases were noted on the corn in 1927 and 1928, on the barley in 1929 and on the alfalfa in 1930 and 1932. Superphosphate with manure and limestone showed slightly larger effects than rock phosphate in a few cases but in some instances had no greater effect. The differences were not very pronounced in most seasons.

Muriate of potash applied with manure, limestone and superphosphate showed beneficial effects on the corn in 1927 and 1928. In general, however,

TABLE 10. FIELD EXPERIMENT, MARSHALL SILT LOAM, O'BRIEN COUNTY
PRIMGHAR FIELD,* SERIES I

Plot no.	Treatment	1924 corn bu. per A.	1925 corn bu. per A. (1)	1926 oats bu. per A. (2)	1927 corn bu. per A.	1928 corn bu. per A. (3)	1929 barley bu. per A.	1930 alfalfa tons per A. (4)	1931 alfalfa tons per A. (5)	1932 alfalfa tons per A. (5)	1933 alfalfa tons per A. (6)
1	Check	37.1	...	47.1	50.1	52.0	42.4	3.03	2.77	4.41	1.10
2	Manure	41.8	...	50.6	48.9	57.6	50.7	3.19	2.77	4.81	1.18
3	Manure+limestone	39.4	...	50.9	50.3	59.5	50.7	3.34	2.64	4.81	1.14
4	Manure+limestone+rock phosphate	40.3	...	41.4	64.0	66.4	56.0	3.50	2.59	5.21	1.16
5	Check	36.4	...	47.4	56.1	56.5	49.1	2.72	2.50	4.52	1.00
6	Manure+limestone+superphosphate	41.8	...	46.3	60.4	58.9	59.1	3.66	2.73	4.95	1.12
7	Manure+limestone+superphosphate+ muriate of potash	42.6	...	43.8	66.3	61.3	59.8	3.70	2.75	5.01	1.09
8	Manure+limestone+complete commercial fertilizer	41.6	...	52.3	61.7	60.3	56.0	3.85	2.92	5.20	1.11
9	Check	37.1	...	39.2	61.5	58.9	52.2	2.74	2.87	4.62	1.07

(1) Very poor corn because of dry season. Field hogged-down, no results taken.
(2) Bad hail storm shattered oats considerably and resulted in an uneven stand.
(3) Plots 6, 7 and 8 damaged by livestock.
(4) Total of 2 cuttings.
(5) Total of 3 cuttings.
(6) Only first cutting. Hot, dry summer resulted in alfalfa making but little growth.
*The Primghar Field, Series I, was established in the fall of 1922 on the farm of A. C. Larson at Cherokee in Cherokee County. It is located in the NE ¼ of the SE ¼ of Section 20, T. 92 N, T. 95 N, R. 40 W. in Highland Township.

very little differences were obtained in the yields of crops where the muriate of potash was applied over those obtained without it. Complete commercial fertilizer applied with manure and limestone gave very much the same results as those obtained with superphosphate. In one or two cases slightly greater increases were obtained. The differences, however, were not large enough to be significant.

The Avoca Field

The results obtained in the field experiment on the Marshall silt loam on the Avoca Field in Pottawattamie County are given in table 11. Manure on this soil benefited practically all crops. The influence on the oats may be noted particularly and also the large effects on the clover and sweet clover. The corn yields in 1926 and 1929 were very largely increased by the addition of manure. In other years the effects on the corn were much smaller. The influence of limestone was evidenced particularly on the sweet clover crop in 1924 on which a very large increase in yield resulted from the application. There was also an effect noted on oats in 1927. No beneficial effects were shown on the clover crop in 1921.

The application of rock phosphate and superphosphate along with the manure and limestone showed large beneficial effects on the crops grown in most seasons. The corn in 1919, 1922 and 1928 showed pronounced effects from the use of superphosphate and slightly less effects from rock phosphate. There was considerable influence from both phosphates on the oats in 1923 and 1930 and a large effect in 1927. The corn in 1920 and 1931 was not benefited. No effects from the phosphates were evidenced on the clover crops in 1921 and 1924. Complete commercial fertilizer had about the same effects as the phosphates on most of the crops grown. In some cases it showed a slightly larger influence, as on the sweet clover in 1924 and on the oats in 1927. In other years, as on the corn in 1928, there was less influence.

The crop residue treatment generally had a small influence. Limestone with crop residues increased the crop yields in most cases. There was no increase in the corn in 1926, 1928, 1929 or 1931. The largest effect of limestone was evidenced on the sweet clover in 1924. Considerable increases were noted, however, on the corn in 1922, on the oats in 1923 and on the corn in 1925. Rock phosphate and superphosphate increased crop yields in several cases, the effect of superphosphate being particularly evidenced in 1920 and 1923. The effects on the corn crop were not large for either of the phosphates. Complete commercial fertilizer had about the same effect as superphosphate except on the oats in 1927 where a large influence was noted, and on the clover in 1921 where it brought about a greater effect.

TABLE 11. FIELD EXPERIMENT, MARSHALL SILT LOAM, POTTAWATTAMIE COUNTY, AVOCA FIELD NO. II,* SERIES I

Plot no.	Treatment	1919 corn bu. per A. (1)	1920 oats bu. per A. (2)	1921 clover tons per A. (3)	1922 corn bu. per A. (4)	1923 oats bu. per A.	1924 sweet clover tons per A. (5)	1925 corn bu. per A. (6)	1926 corn bu. per A.	1927 oats bu. per A.	1928 corn bu. per A.	1929 corn bu. per A.	1930 oats bu. per A.	1931 corn bu. per A. (7)
1	Check	72.9	62.2	2.00	58.1	48.7	0.36	62.2	54.6	45.7	64.5	64.1	48.8	43.6
2	Manure	72.1	69.0	2.70	53.6	56.7	0.63	63.9	63.7	56.0	67.5	74.3	57.4	41.0
3	Manure+limestone	74.0	72.3	2.60	53.9	53.2	1.82	61.6	64.0	64.0	68.3	76.9	58.4	35.7
4	Manure+limestone+rock phosphate	77.8	58.8	2.70	55.5	60.0	1.52	58.1	61.3	69.8	66.4	77.7	59.4	35.3
5	Manure+limestone+superphosphate	79.3	69.0	2.50	56.5	60.0	1.68	52.3	64.8	75.0	70.9	75.6	63.0	35.7
6	Manure+limestone+complete commercial fertilizer	77.5	61.2	2.80	57.5	66.8	1.92	51.4	65.6	79.1	65.6	75.0	56.8	35.9
7	Check	71.5	56.8	2.00	44.8	47.6	0.85	39.8	61.0	50.0	64.3	66.1	49.4	40.4
8	Crop residues+superphosphate	78.9	63.9	2.00	44.8	49.8	0.90	51.0	66.4	57.1	66.7	71.9	57.9	38.9
9	Crop residues+limestone	80.7	68.1	2.10	50.0	56.7	1.92	58.7	64.5	66.7	66.4	64.0	53.4	38.7
10	Crop residues+limestone+rock phosphate	78.5	68.6	2.80	54.8	59.0	1.83	56.8	69.6	66.6	62.1	68.4	52.5	27.0
11	Crop residues+limestone+superphosphate	81.1	75.1	2.20	54.1	64.5	1.50	57.1	66.6	64.7	66.1	69.9	54.5	29.2
12	Crop residues+limestone+complete commercial fertilizer	80.4	68.6	2.90	52.0	52.1	1.44	58.4	65.8	70.0	64.8	69.4	52.3	26.5
13	Check	80.0	68.6	2.20	46.3	50.9	1.12	51.8	60.8	60.6	61.6	65.3	49.9	38.0

(1) Field slopes toward plot 13.
(2) Not limed until Oct. 1, 1920.
(3) Field pastured until June 1.
(4) Corn injured by hail in August and by rainy spring.
(5) Pastured until June 1. Superphosphate added to plot 8.
(6) Wireworms damaged stand.
(7) Hot, dry season. Fence moved, throwing field into center of a 40-acre field.
Plots discontinued in 1932 and a new series established in same field.
New series discontinued in 1933 on account of economy program.

*The Avoca Field No. II was established in the spring of 1919 on the John Sondergard farm east of Avoca in Pottawattamie County. It is located in the southeast corner of the SE ¼ of the SW ¼ of Section 2, T. 77 N, R. 39 W. in Knox Township.

The Red Oak Field

The results obtained on the Marshall silt loam on the Red Oak Field in Montgomery County are shown in table 12. Benefits from the application of

TABLE 12. FIELD EXPERIMENT, MARSHALL SILT LOAM, MONTGOMERY COUNTY, RED OAK FIELD NO. III,* SERIES I

Plot no.	Treatment	1918 winter wheat bu. per A.	1919 corn bu. per A.	1920 corn bu. per A.	1921 oats bu. per A.	1922 winter wheat bu. per A.	1923 corn bu. per A.	1924 soybeans bu. per A.	1925 winter wheat bu. per A.	1926 clover tons per A. (1)	1927 alfalfa tons per A. (2)	1928 alfalfa tons per A. (3)	1929 alfalfa tons per A. (3)	1930 alfalfa tons per A. (3)	1931 alfalfa tons per A. (4)	1932 corn bu. per A. (5)	1933 corn bu. per A. (6)
1	Check	13.6	52.0	56.0	28.2	13.2	54.5	11.2	10.4	...	1.84	3.36	4.39	3.87	...	75.7	60.0
2	Manure	34.1	57.2	61.6	36.9	15.6	57.8	12.4	11.6	...	2.20	3.70	5.58	3.92	...	79.5	63.0
3	Manure+limestone	31.8	59.2	66.0	37.8	18.6	64.7	14.2	11.3	...	3.09	3.85	5.58	4.47	...	84.3	61.4
4	Manure+limestone+rock phosphate	27.7	60.0	63.0	35.6	28.6	64.6	13.7	13.6	...	3.57	4.67	5.43	4.56	...	86.8	60.1
5	Manure+limestone+superphosphate	31.8	58.5	62.7	39.4	30.7	62.9	13.1	13.1	...	3.32	4.35	5.84	4.74	...	84.7	60.9
6	Manure+limestone+complete commercial fertilizer	29.5	56.2	64.2	36.4	25.4	61.3	14.6	10.6	...	3.75	4.18	6.09	4.11	...	85.9	60.1
7	Check	29.5	54.2	56.6	31.8	17.4	50.6	10.5	9.4	...	2.18	3.69	5.04	3.32	...	76.9	52.9
8	Crop residues	29.5	51.0	54.1	31.3	16.4	52.9	9.9	8.6	...	2.34	3.13	5.00	3.07	...	78.9	51.1
9	Crop residues+limestone	25.0	53.7	60.2	31.2	19.5	55.0	13.2	10.2	...	2.30	4.14	4.82	2.88	...	79.6	53.4
10	Crop residues+limestone+rock phosphate	18.1	57.7	59.2	35.0	23.8	55.7	12.3	13.0	...	2.54	4.21	5.34	2.75	...	82.9	49.2
11	Crop residues+limestone+superphosphate	27.2	53.7	61.6	36.9	22.3	52.7	12.1	11.6	...	2.53	4.26	5.16	2.86	...	82.0	50.9
12	Crop residues+limestone+complete commercial fertilizer	26.1	57.0	57.3	37.8	22.2	56.8	14.0	12.5	...	1.97	3.79	5.23	3.21	...	81.1	47.1
13	Check	13.6	48.2	51.4	29.0	15.2	52.0	8.9	9.9	...	1.53	3.78	4.33	2.79	...	76.0	42.6

(1) Clover stand very poor owing to dry weather. Field was plowed and seeded to alfalfa in August.
(2) Results of first and second cuttings combined. No results taken on third cutting.
(3) Three cuttings.
(4) Field pastured; no harvest.
(5) Corn listed. Difficult to harvest a uniform stand.
(6) Hot winds and dry weather affected plots 7 to 13 more than plots 1 to 6.
*The Red Oak Field No. III was established in the fall of 1917 on the farm of J. E. Taylor west of Red Oak in Montgomery County. It is located in the NW ¼ of the NE ¼ of Section 25, T. 72 N, R. 39 W. in Garfield Township.

manure to this soil are shown definitely by the data in this table. The increased yield of winter wheat in 1918 is particularly noteworthy. The corn crops were increased to a large extent in every case. Increases were also noted with the oats in 1921, the winter wheat in 1922 and 1925, the soybeans in 1924, and the alfalfa each year that it was grown. The largest beneficial effects from limestone were shown, as would be expected, on the alfalfa, but increases were also secured on the corn in 1920, 1923 and 1932, on the oats in 1921, and on the wheat in 1922. The soybeans in 1924 also showed a considerable beneficial effect from the use of limestone.

Rock phosphate or superphosphate used along with manure and limestone brought about increases in crop yields, particularly on the wheat in 1922 and 1925 and on the alfalfa. In some seasons, as in 1919 and 1920, there was very little evidence of beneficial effects from the phosphates. Superphosphate benefited the oat crop in 1921, but rock phosphate had no effect. The corn in 1923 showed no effect from the phosphates, and this was true also in 1933. The soybeans in 1924 were not benefited. Complete commercial fertilizer had about the same effect as superphosphate in practically all cases.

The crop residue treatment had little influence on the crop yields as would be expected. Limestone with residues increased the yields particularly those of the alfalfa in 1928, the soybeans in 1924, the corn in 1920 and the wheat in 1922 and 1925. Phosphate fertilizers where employed with crop residues and limestone increased crop yields in several instances, particularly the wheat in 1922 and 1925, and the alfalfa. The oats were materially benefited in 1921, and superphosphate increased the wheat yields in 1918. No large beneficial effects from the phosphates were shown on the corn either in 1920 or 1923, but rock phosphate gave an increase in 1919. Complete commercial fertilizer again brought about the same effect as that occasioned by phosphates. In one or two instances complete fertilizer gave large effects, as, for example, on the soybeans in 1924, on the corn in 1923 and on the oats in 1921, but in the other cases as with the alfalfa in 1927, and 1928 and the corn in 1920 and 1933, the effects of complete fertilizer were less than those brought about by phosphates.

The Malvern Field

The data obtained in the field experiment on the Marshall silt loam on the Malvern Field in Mills County are given in table 13. Manure increased the yields of crops grown on this soil in all seasons but two. Only in the case of the corn in 1925 and the sweet clover in 1927 was no effect of the manure indicated. The oats in 1922 and 1930, the corn in 1931 and the clover in 1923 showed the largest beneficial effects from the manure. Limestone applied with manure increased crop yields in all but two seasons. The greatest effect of limestone appeared on the sweet clover in 1927 as would be expected. There were gains in the other crops grown, however, except in the case of the corn in 1931 and 1932.

Rock phosphate applied with manure and limestone benefited the crops in a few cases, but in general it had little or no influence on the yields. Superphosphate with manure and limestone showed a beneficial effect on the crops

TABLE 13. FIELD EXPERIMENT, MARSHALL SILT LOAM, MILLS COUNTY MALVERN FIELD,* SERIES I

Plot no.	Treatment	1922 oats bu. per A.	1923 clover tons per A.	1924 corn bu. per A.	1925 corn bu. per A. (1)	1926 oats bu. per A.	1927 sweet clover tons per A.	1928 corn bu. per A.	1929 corn bu. per A.	1930 oats bu. per A.	1931 corn bu. per A. (2)	1932 corn bu. per A. (3)	1933 alfalfa tons per A. (4)
1	Check	41.1	0.73	39.5	35.9	38.7	0.64	70.3	87.4	50.5	48.2	42.6	...
2	Manure	52.7	0.91	46.3	34.7	41.4	0.53	72.5	88.6	63.2	58.1	45.7	...
3	Manure+limestone	54.4	0.93	48.1	37.3	43.0	1.67	80.4	89.2	64.1	54.0	41.2	...
4	Manure+limestone+rock phosphate	48.4	0.93	50.6	37.1	43.0	1.54	71.7	82.2	68.6	37.9	43.5	...
5	Check	31.3	0.78	47.2	36.6	34.0	0.46	72.8	86.3	52.3	38.9	43.0	...
6	Manure+limestone+superphosphate	52.5	1.24	50.7	35.8	46.6	1.59	72.5	88.0	65.5	56.2	45.2	...
7	Manure+limestone+superphosphate+muriate of potash	47.3	1.13	48.8	38.0	41.4	1.77	75.3	91.3	65.9	53.6	46.3	...
8	Manure+limestone+complete commercial fertilizer	51.4	1.56	53.1	29.1	44.1	2.14	81.2	87.4	76.6	53.6	42.1	...
9	Check	42.9	1.05	47.4	35.1	33.8	0.42	71.4	82.5	53.4	55.1	44.7	...

(1) Poor stand on plot 8 as compared with other plots.
(2) Drouth and hot winds damaged corn.
(3) Dry weather damaged corn. Corn listed. Difficult to harvest a uniform stand.
(4) Alfalfa seeded in June but owing to hot, dry weather, reseeding was necessary in August.
*The Malvern Field was established in the fall of 1921 on the farm of H. F. Clark, northwest of Malvern in Mills County. It is located in the NE ¼ of the SE ¼ of Section 18, T. 72 N, R. 41 W. in Silver Creek Township.

in most seasons. In one or two cases there was no influence and in no instance was there any very large effect from the phosphate. Muriate of potash applied with manure, limestone and superphosphate showed a beneficial effect on the sweet clover in 1927, but in most other seasons it had no influence, or only a very slight effect. Complete commercial fertilizer with manure and limestone had a somewhat greater effect than superphosphate on the clover in 1923, the sweet clover in 1927, the corn in 1928 and the oats in 1930. In the other seasons it had about the same influence as superphosphate.

The Scranton Field

The results obtained on the Scranton Field in Greene County on the Carrington loam are shown in table 14. The application of manure increased the crop yields in most seasons, the largest beneficial effects appearing on the corn in 1927 and 1928 and on the oats in 1923 and 1926. Limestone increased all crops. The largest influence appeared on the clover and timothy in 1933.

Rock phosphate with manure and limestone increased the crop yields in practically all seasons, but in most cases the gains were not large. The corn in 1925, the oats in 1926 and the clover and timothy in 1933 showed the greatest effects. Superphosphate with manure and limestone brought about larger effects than rock phosphate in the case of the oats in 1923, 1929 and 1932, and the corn in 1924 and 1925. In the other seasons rock phosphate gave slightly larger effects. Muriate of potash with superphosphate, manure and limestone showed small increases in most seasons. The differences were not large, however, in any case. Complete commercial fertilizer with manure and limestone brought about larger effects than superphosphate on the corn in 1924, 1927 and 1928 and on the oats in 1923 and 1932 but had less effect on the corn in

TABLE 14. FIELD EXPERIMENT, CARRINGTON LOAM, GREENE COUNTY SCRANTON FIELD,* SERIES I

Plot no.	Treatment	1923 oats bu. per A.	1924 corn bu. per A. (1)	1925 corn bu. per A.	1926 oats bu. per A. (2)	1927 corn bu. per A.	1928 corn bu. per A.	1929 oats bu. per A.	1930 corn bu. per A. (3)	1931 corn bu. per A. (3)	1932 oats bu. per A.	1933 clover and timothy tons per A.
1	Check	59.0	38.0	50.8	35.4	41.5	59.8	52.3	33.8	47.8	39.1	1.67
2	Manure	63.5	42.8	54.1	35.7	46.7	64.5	71.5	32.7	46.6	49.3	1.63
3	Manure+limestone	63.5	46.2	60.4	35.7	53.4	69.3	74.9	37.2	49.1	51.1	1.87
4	Manure+limestone+rock phosphate	63.5	44.3	63.1	39.5	54.1	70.9	74.9	38.7	53.4	48.8	2.11
5	Check	55.5	36.3	50.2	34.0	44.6	58.1	64.6	34.2	45.1	38.6	1.56
6	Manure+limestone+superphosphate	72.5	48.4	66.7	...	50.2	67.7	85.1	35.5	52.5	53.9	2.01
7	Manure+limestone+superphosphate +muriate of potash	74.8	50.8	62.2	39.2	50.9	68.8	87.3	33.5	48.5	54.4	2.03
8	Manure+limestone+complete commercial fertilizer	82.7	51.6	59.9	39.7	52.0	68.5	85.1	33.7	49.2	56.2	2.17
9	Check	61.2	33.1	51.6	33.2	48.1	57.6	66.1	33.0	41.8	38.0	1.56

(1) Cattle and hogs were turned into the field a few days before the plots were harvested, which affected the yields.
(2) Plot 6 sample lost.
(3) Damage from hot winds and dry weather.
*The Scranton Field, Series I, was established in the fall of 1922 on the E. J. Holden farm near Scranton in Greene County. It is located in the NE ¼ of the NE ¼ of Section 14, T. 83 N, R. 32 W. in Scranton Township.

1925, 1930 and 1931. The clover and timothy in 1933 was benefited more by complete fertilizer. Usually the differences between the effects of superphosphate and complete commercial fertilizer were not great.

The Dallas Center Field

The results obtained in the field experiments on the Carrington loam on the Dallas Center Field in Dallas County are given in table 15. The addition of farm manure to this soil brought about increases in crop yields in practically all seasons. The effects were especially noted on the sweet clover in 1928 and the red clover in 1932. Gains which were quite definite were also found in the corn and small grain crops. The application of limestone along with manure increased the crop growth in practically all cases. The beneficial effects of limestone were especially noted on the red clover in 1932 and on the corn in 1925, 1926, 1929 and 1933. There was no effect on the sweet clover in 1928.

Rock phosphate with manure and limestone increased the crops in all but two seasons, the greatest effects appearing on the oats in 1927, the sweet clover in 1928 and the red clover in 1932. No effects were found on the corn in 1930 nor in 1933, and in some of the other years the influence of rock phosphate was slight. Superphosphate with manure and limestone had a greater effect than rock phosphate in most seasons, notably on the wheat in 1923, the sweet clover in 1928, the corn in 1929, 1930 and 1933, and the oats in 1931. In the case of the corn in 1926, the oats in 1927 and the red clover in 1932, the rock proved a little more effective than superphosphate. In most seasons, however, the differences were not very large. Muriate of potash with manure, limestone and superphosphate showed little or no effects on the crops grown. Only the corn in 1933 was definitely benefited by the use of this material. Complete commercial fertilizer with manure and limestone had about the same effects as superphosphate in most cases, showing a larger influence on the sweet clover in 1928 but in most other seasons it had a slightly smaller effect than superphosphate.

TABLE 15. FIELD EXPERIMENT, CARRINGTON LOAM, DALLAS COUNTY DALLAS CENTER FIELD,* SERIES I (1)

Plot no.	Treatment	1923 winter wheat bu. per A.	1924 clover tons per A. (2)	1925 corn bu. per A.	1926 corn bu. per A.	1927 oats bu. per A.	1928 sweet clover tons per A. (3)	1929 corn bu. per A.	1930 corn bu. per A. (4)	1931 oats bu. per A.	1932 red clover tons per A. (5)	1933 corn bu. per A.
1	Check	24.8	...	50.3	69.9	52.6	1.81	72.6	35.7	63.9	1.18	64.6
2	Manure	25.9	...	51.2	73.0	51.7	2.00	77.7	40.7	66.6	1.67	70.3
3	Manure+limestone	29.6	...	54.1	78.9	50.2	1.97	81.1	42.5	66.6	2.12	76.5
4	Manure+limestone+rock phosphate	30.9	...	58.8	79.2	68.2	2.29	81.4	40.3	68.6	2.27	73.9
5	Check	21.8	...	51.9	76.0	53.4	1.78	71.7	38.4	62.6	1.21	65.1
6	Manure+limestone+superphosphate	33.8	...	58.8	76.8	64.3	2.42	84.6	41.1	71.5	2.07	76.5
7	Manure+limestone+superphosphate +muriate of potash	34.5	...	59.6	78.9	62.4	2.17	83.1	44.4	73.7	2.09	82.9
8	Manure+limestone+complete commercial fertilizer	30.4	...	59.5	73.6	64.4	2.69	83.7	43.7	70.4	1.96	76.7
9	Check	20.6	...	53.3	65.3	46.3	1.65	76.6	43.2	60.6	0.91	65.2

(1) Corn cut early in 1922 to seed winter wheat; no results.
(2) Field was pastured; no results.
(3) Total of two cuttings.
(4) Hot, dry season.
(5) Large amount of weeds in plot 3.
*The Dallas Center Field, Series I, was established in the fall of 1921 on the H. C. Mortimer farm, west of Dallas Center in Dallas County. It is located in the SE ¼ of the SE ¼ of Section 32, T. 80 N, R. 27 W. in Sugar Grove Township.

The Pilot Mound Field

The results obtained in the experiment on the Carrington loam on the Pilot Mound Field in Boone County are given in table 16. Manure increased the crop yields on this soil in most cases. The largest increases were obtained on the oats in 1924 and the sweet clover in 1929. Some of the corn crops also were increased. In 1928, 1930, 1931 and 1933 no increases were obtained with manure. Limestone with manure increased the crop yields in practically all seasons. No beneficial effect appeared on the clover in 1929 which was somewhat surprising. Probably the yield on Plot 2 in that season was abnormal, and there was really some benefit from limestone. The largest effects appeared on the oats in 1922 and 1924 and on the corn in 1931.

Rock phosphate with manure and limestone increased the crops in all but two seasons. The increase was very definite in the case of the oats in 1924 and the sweet clover in 1929. The corn in 1926 and in 1931 was not increased but in all other seasons small gains were noted. Superphosphate with manure and limestone showed a greater effect than rock phosphate in several seasons. The oats in 1922, 1928 and 1933, and the corn in 1926, 1927 and 1931 showed more benefits from superphosphate. Rock phosphate had larger effects than superphosphate on the corn in 1923 and 1932, on the oats in 1924

TABLE 16. FIELD EXPERIMENT, CARRINGTON LOAM, BOONE COUNTY PILOT MOUND FIELD,* SERIES I

Plot no.	Treatment	1922 oats bu. per A.	1923 corn bu. per A.	1924 oats bu. per A.	1925 sweet clover tons per A. (1)	1926 corn bu. per A.	1927 corn bu. per A.	1928 oats bu. per A. (2)	1929 sweet clover tons per A. (3)	1930 corn bu. per A. (4)	1931 corn bu. per A. (4)	1932 corn bu. per A.	1933 oats bu. per A.
1	Check	33.4	59.9	43.5	...	52.8	48.3	77.1	1.27	44.7	42.7	58.9	31.2
2	Manure	37.8	64.4	50.8	...	59.7	51.9	74.9	1.74	44.2	42.6	60.8	31.2
3	Manure+limestone	44.8	60.4	58.1	...	60.8	53.9	72.6	1.46	48.9	51.7	60.3	32.9
4	Manure+limestone+rock phosphate	45.1	64.4	68.2	...	53.8	54.6	74.9	1.68	49.6	45.0	60.8	37.9
5	Check	35.4	56.0	46.8	...	45.8	41.8	61.3	1.26	42.7	44.6	56.6	25.6
6	Manure+limestone+superphosphate	50.0	61.8	57.0	...	55.4	66.9	77.1	1.33	50.1	50.0	56.5	45.4
7	Manure+limestone+superphosphate+muriate of potash	59.4	68.5	66.8	...	58.6	65.2	74.9	2.09	46.6	40.9	58.2	37.9
8	Manure+limestone+complete commercial fertilizer	71.7	59.9	66.1	...	50.6	63.5	77.1	1.57	39.7	36.0	63.2	49.9
9	Check	36.3	59.8	46.8	...	49.1	54.1	58.9	1.11	50.8	40.2	61.9	35.2

(1) Field was pastured; no results taken.
(2) Unable to account for high yield on plot 1.
(3) Plots damaged by late fall and early spring pasturing.
(4) Hot, dry season.
*The Pilot Mound Field, Series I, was established in the fall of 1921 on the farm of D. E. Sackerson, near Pilot Mound in Boone County. It is located in the NW ¼ of the SW ¼ of Section 21, T. 85 N, R. 27 W.

and on the sweet clover in 1929. The largest difference in favor of superphosphate appeared on the corn in 1927.

Muriate of potash with manure, limestone and superphosphate had beneficial effects on the crops grown in a number of cases. The largest increase appeared on the sweet clover in 1929, but there were also definite increases on the oats in 1922 and 1924 and on the corn in 1923 and 1926. Complete commercial fertilizer with manure and limestone brought about larger increases than superphosphate in two or three cases. The oats in 1922, 1924 and 1933, the sweet clover in 1929 and the corn in 1932 showed larger effects from complete commercial fertilizer than from superphosphate. In other seasons, however, smaller benefits appeared.

The Clarinda Field

The results obtained on the Waukesha silt loam on the Clarinda Field, Series I, in Page County are given in table 17. Manure definitely increased yields of most crops on this field, especially the clover in 1927, the timothy and clover in 1930, and the corn in 1922, 1923 and 1927. Limestone applied with manure benefited practically all the crops grown. The clover in 1917, 1925, and the timothy and clover in 1930 were benefited materially, as were the oats and corn in some seasons. A large increase was obtained in the oats in 1916, 1920, 1924, and particularly in 1928.

Rock phosphate or superphosphate with manure and limestone proved of considerable value to most of the crops grown. The influence was particularly great on the clover in 1917 and on the corn in 1919 and 1923. In some seasons, however, only small increases or none at all were obtained. Complete commercial fertilizer had a greater effiect than superphosphate in several

TABLE 17. FIELD EXPERIMENT, WAUKESHA SILT LOAM, PAGE COUNTY, CLARINDA FIELD,* SERIES I

Plot no.	Treatment	1915 corn bu. per A.	1916 oats bu. per A.	1917 clover tons per A.	1918 corn bu. per A. (1)	1919 corn bu. per A.	1920 oats bu. per A.	1921 soybeans bu. per A.	1922 corn bu. per A.	1923 corn bu. per A.	1924 oats bu. per A.	1925 clover tons per A.	1926 corn bu. per A.	1927 corn bu. per A. (2)	1928 oats bu. per A. (3)	1929 winter wheat bu. per A. (4)	1930 timothy and clover tons per A.	1931 corn bu. per A. (5)	1932 corn bu. per A. (6)	1933 corn bu. per A.
1	Check	51.2	61.1	1.19	...	55.1	51.0	23.5	79.4	65.9	55.6	1.45	41.0	45.6	61.2	29.0	2.20	16.5	60.4	46.1
2	Manure	49.9	54.4	1.36	...	58.7	52.3	25.3	87.4	73.7	53.4	1.48	42.6	53.7	52.3	29.0	2.71	20.3	63.0	56.9
3	Manure+limestone	50.6	63.3	1.56	...	62.6	61.8	25.2	89.6	73.6	61.3	1.53	42.5	55.1	74.9	36.3	3.08	19.6	64.4	56.4
4	Manure+limestone+rock phosphate	48.2	50.0	2.89	...	69.3	63.6	24.2	87.9	82.1	53.7	1.41	44.4	53.2	77.1	40.8	2.83	12.8	63.7	58.4
5	Manure+limestone+superphosphate	54.8	52.2	3.40	...	70.9	60.4	24.3	88.3	78.0	56.7	1.31	44.0	53.9	72.6	39.9	3.09	12.9	65.7	61.8
6	Manure+limestone+complete commercial fertilizer	49.7	50.0	2.55	...	59.7	73.5	23.3	90.8	76.7	66.0	1.41	42.6	53.9	84.0	38.1	3.10	12.8	64.1	61.9
7	Check	48.0	47.7	1.36	...	56.3	41.8	24.0	82.4	64.6	46.5	1.50	40.9	31.5	61.2	22.6	2.64	40.3	...	...
8	Crop residues	45.2	41.1	1.53	...	56.5	55.7	23.0	71.8	53.8	61.4	1.74	41.4	46.4	63.5	29.0	2.61	45.0	...	...
9	Crop residues+limestone	51.4	43.3	2.21	...	58.2	58.7	25.8	81.2	48.6	49.0	1.81	43.7	52.3	65.9	31.5	2.33	35.6	...	...
10	Crop residues+limestone+rock phosphate	51.6	47.7	2.71	...	66.7	61.1	25.8	85.2	54.5	52.7	1.65	42.9	57.2	70.4	32.2	2.40	28.1	...	...
11	Crop residues+limestone+superphosphate	53.4	54.4	2.89	...	69.8	60.4	24.8	87.5	57.2	54.1	1.71	42.5	54.7	68.1	33.3	2.75	16.2	...	...
12	Crop residues+limestone+complete commercial fertilizer	50.3	47.7	2.72	...	65.3	62.4	24.8	90.6	70.1	58.8	1.50	41.6	50.9	77.1	37.6	2.42	10.9	...	...
13	Check	50.5	47.7	1.36	...	57.2	42.5	22.5	88.7	71.8	43.9	1.49	41.3	45.5	72.6	29.0	1.91	...	...	...

(1) Hot winds seriously damaged the corn crop.
(2) Poor drainage on plots 7, 8, 12 and 13.
(3) Spring freezes damaged the oats, especially on plot 2.
(4) Plots 7, 8 and 13 were damaged by low wet area.
(5) Hot, dry season; plots 7, 8 and 9 were on low ground with more moisture. Plot 13 cut by mistake.
(6) Plots 7 to 13 were discontinued owing to poor drainage and soil conditions.
*The Clarinda Field, Series I, was established in the fall of 1914 on the State Hospital Farm at Clarinda in Page County. It is located in the NE ¼ of the SW ¼ of Section 20, T. 69 N, R. 36 W. in Nodaway Township.

cases, particularly on the oats in 1920, 1924 and 1928. Generally superphosphate was just as effective or even more so than complete commercial fertilizer.

Crop residues showed little effects on the various crops, except on the oats in 1920 and 1924 and on the corn in 1927. Limestone in addition to residues proved of value on practically all of the crops. Very large increases were noted on the clover in 1917, on the corn in 1922 and in 1927. Rock phosphate or superphosphate with crop residues and limestone increased the crop yields in many cases. A large beneficial effect was noted from both materials on the clover in 1917, on the oats in 1916, 1924 and 1928, and on the corn in 1919, 1922, 1923, and 1927. In most cases superphosphate showed up much better than rock phosphate, particularly on the oats in 1916, on the clover in 1917, on the corn in 1923 and on the timothy and clover in 1930. In other cases the effects of the two materials were very similar.

The results obtained on the Waukesha silt loam on the Clarinda Field, Series II, in Page County are shown in table 18. The beneficial effect of manure was evident in practically all seasons, and very large increases were obtained on the corn crops of 1920, 1923 and 1927. The oats showed a large increase in 1925. In one or two cases no increases were obtained with the use of manure, undoubtedly because of some abnormal condition. The addition of limestone with manure gave increases in practically all seasons. A large effect was noted on the clover in 1926, on the oats in 1917 and 1921, and small gains were shown on practically all of the corn crops.

Rock phosphate or superphosphate usually increased crop yields, particularly the clover in 1918 and 1926, the oats in 1917, and the corn in 1919, 1923 and 1928. In several instances superphosphate proved superior to rock phosphate, as with the oats in 1917, but in other cases rock phosphate gave slightly greater effects than those brought about by superphosphate. The clover in 1918 and in 1926 was increased more by rock phosphate. Complete commercial fertilizer brought about crop increases similar to those occasioned by the use of the phosphates. There did not seem to be any pronounced superiority for complete commercial fertilizer.

Crop residues increased crop yields to a limited extent in several seasons. Limestone with residues greatly increased the corn in 1919, 1924 and 1927, the oats in 1917 and the timothy and clover in 1930.

Rock phosphate or superphosphate with crop residues and limestone increased crop yields in most seasons. The largest benefits were shown on the oats in 1917, although gains were also noted in 1921 and 1925. The corn showed pronounced benefits in 1919 and 1928, but in general the gains were not large. There was very little difference in the effects of the two phosphates, although in one or two cases superphospate seemed to have slightly greater effects than rock. Complete commercial fertilizer gave crop yields which in most cases, were very similar to or slightly lower than those brought about by superphosphate. There is no evidence to show any particular superiority of complete commercial fertilizer on this soil.

TABLE 18. FIELD EXPERIMENT, WAUKESHA SILT LOAM, PAGE COUNTY, CLARINDA FIELD,* SERIES II

Plot no.	Treatment	1916 corn bu. per A.	1917 oats bu. per A.	1918 clover tons per A. (1)	1919 corn bu. per A.	1920 corn bu. per A. (2)	1921 oats bu. per A.	1922 Hubam clover tons per A. (3)	1923 corn bu. per A.	1924 corn bu. per A.	1925 oats bu. per A.	1926 clover tons per A. (4)	1927 corn bu. per A. (5)	1928 corn bu. per A. (6)	1929 winter wheat bu. per A. (7)	1930 timothy and clover tons per A.	1931 (8)
1	Check	73.1	83.0	1.80	52.2	54.3	49.2	...	70.0	31.2	35.2	1.87	40.9	62.8	26.6	2.26	...
2	Manure	77.1	83.0	1.40	56.0	64.4	32.6	...	79.3	41.8	46.6	0.86	60.1	62.3	30.3	2.28	...
3	Manure+limestone	78.2	88.0	1.20	57.3	65.0	60.8	...	82.4	44.7	48.5	1.28	63.9	59.8	33.3	2.18	...
4	Manure+limestone+rock phosphate	74.9	91.1	1.80	60.9	65.9	45.8	...	87.4	39.4	47.2	1.64	60.3	67.7	38.7	2.26	...
5	Manure+limestone+superphosphate	75.9	103.6	1.50	64.5	60.9	40.2	...	86.6	40.0	48.8	1.00	62.0	61.3	38.7	1.91	...
6	Manure+limestone+complete commercial fertilizer	80.2	98.0	1.70	61.5	62.2	52.0	...	83.1	28.1	53.7	0.95	50.3	63.6	36.3	2.08	...
7	Check	76.7	74.8	2.30	55.0	54.8	43.4	...	79.2	24.4	37.9	1.51	42.1	56.6	26.6	1.75	...
8	Crop residues	78.9	73.0	2.00	54.0	58.8	45.6	...	73.8	24.1	39.7	1.55	49.7	58.1	32.2	1.64	...
9	Crop residues+limestone	77.5	77.8	1.80	65.7	60.0	44.8	...	69.6	31.7	39.6	1.34	61.2	61.3	35.1	1.95	...
10	Crop residues+limestone+rock phosphate	75.8	101.0	1.70	72.7	62.1	53.9	...	70.2	26.2	40.1	1.50	62.8	64.9	35.1	1.99	...
11	Crop residues+limestone+superphosphate	76.6	100.3	1.70	72.8	61.1	52.4	...	63.6	26.6	45.2	1.33	57.1	69.9	36.3	2.13	...
12	Crop residues+limestone+complete commercial fertilizer	74.4	91.6	1.40	70.8	42.7	54.1	...	69.6	25.4	46.1	1.38	37.6	57.8	29.0	1.70	...
13	Check	74.6	68.1	1.30	58.6	44.8	48.4	...	62.8	20.6	36.3	1.12	33.1	50.2	24.2	1.54	...

(1) Plots varied in amount of growth owing to moisture conditions.
(2) Poor drainage on plots 12 and 13.
(3) Stand failed because of dry weather.
(4) Uneven stand because of large amount of weeds on some plots.
(5) Poor stand on plots 1, 7, 8, 12 and 13 because of poor drainage.
(6) Unable to harvest uniform stand because the corn was listed.
(7) Plots 1, 7, 8, 12 and 13 damaged by low wet areas.
(8) Field discontinued in 1931.

*The Clarinda Field, Series II, was established in the fall of 1914 on the State Hospital farm at Clarinda in Page County. It was located in the NE ¼ of the SW ¼ of Section 20, T. 69 N, R. 36 W in Nodaday Township. This series was discontinued in 1931 owing to lack of uniformity of soil and drainage conditions.

Some Results of County Demonstration Plots*

In 1930 tests were carried out on five farms with alfalfa, the soils being treated with manure at the rate of 8 tons per acre, with limestone at the rate of two tons per acre, sufficient to neutralize the acidity of the soil and with 45 percent superphosphate at the rate of 100 pounds per acre. Summarizing the results it appeared that the lime and phosphate gave a 26 percent increase over the checks. Lime alone gave a 3 percent increase. Manure gave 8.8 percent increase over the checks. With the manure the value of the increase was $1.89 per acre and with the limestone and superphosphate, the value of the increase was $5.95 per acre. These results are calculated on the basis of a cost of $4.00 per acre for the limestone and $3.50 per acre for the phosphate; the alfalfa hay was figured at $12.00 per ton.

Summarizing the results obtained in 1931, the value of the alfalfa hay, two cuttings, was increased $7.10 per acre by the treatment with limestone and phosphate. With limestone alone, the value of the treatment was $4.28 per acre over the checks. With manure alone, the value was $4.42 per acre over the checks. Averaging the 2 years' results, it is calculated that limestone and phosphate returned 170 percent above the cost of the fertilizers, limestone alone returned 120 percent above the cost, and manure alone gave a return of $9.00 per acre. In other tests reports are made of a 19-bushel increase, and a 10-bushel increase in corn with phosphate treatment, a 30 percent increase in alfalfa, and a 10 percent increase in winter wheat.

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* These results were obtained and reported by P. A. Johnson, county agent for Crawford County.

THE NEEDS OF CRAWFORD COUNTY SOILS AS INDICATED BY LABORATORY, GREENHOUSE AND FIELD TESTS

The results obtained in the laboratory, greenhouse and field tests on the soils of this county indicate the general needs of the soils. Even though the field experiments reported here have been carried out in other counties, they have been conducted on the same soils as those occurring in Crawford County and hence the results may be considered to show fairly accurately the effects which may be expected from the same treatments on the soils of this county.

All the recommendations given here are based not only upon such experimental results as are available, but also upon the general experience of farmers. The suggestions for soil treatments which are offered are only such as may be put into effect on any farm without special difficulty and which have been shown to be of practical use when carried out under actual farm conditions.

MANURING

The supply of organic matter in the soils of Crawford County is neither low nor extremely high. It is apparent from a study of the analyses of the soils of the county that the addition of fertilizing materials supplying organic matter would be very desirable at the present time to build up the content of this important constituent. The regular addition of such materials would of course be necessary in order to maintain the supply. On the lighter colored soils, the use of organic matter is particularly necessary at the present time.

The application of farm manure is of particularly large value now. It may be depended upon to bring about large increases in crop yields, and it builds up the supply of organic matter in the soils and hence increases their natural fertility. On those soils which are especially lacking in organic matter, subject to erosion, light in color, and poor in physical condition, the use of farm manure is most desirable. Large applications will prove of the greatest value. The experiments referred to earlier in this report have shown the large effects of normal amounts of farm manure on the Marshall silt loam, the most extensively developed soil type in the county. The use of farm manure was also shown to be of large value on the Carrington loam, on the Waukesha silt loam and the Wabash silt loam, a bottomland soil. Undoubtedly many other types occurring in the county would respond just as definitely and perhaps more so, to the addition of manure. Unquestionably the Knox silt loam and the shallow and the light colored phases of the Marshall silt loam, for example, would be benefited materially by the liberal application of farm manure. Lighter colored soils may be expected to show the greatest effects from manurial applications. But on heavier, darker colored and apparently richer soils, the addition of farm manure will often bring about large beneficial effects.

The proper application to the land of all the crop residues will aid materially in maintaining the supply of organic matter in soils. Valuable organic matter is added in such materials and they should never be burned nor otherwise destroyed. On the livestock farm the residues may be applied with the farm manure, as is usually the case, having been employed largely for feed or bedding. On the grain farm the residues may be stored and allowed to decompose at least partially before being applied in order that they may exert the best effects.

On many farms, the supply of farm manure is quite inadequate to permit of regular applications to all the land on the farm and in many cases some land receives only very small amounts of manure. In such cases the use of legumes as green manures is very necessary to increase and keep up the content of organic matter. Legumes not only supply readily decomposable organic matter, but they also add considerable nitrogen to the land, provided they are well-inoculated, as they should be and hence they have a double value on the soil. The practice of green manuring is very desirable on many of the farms in Crawford County in order to supplement the use of farm manure and increase the supply of organic matter in the soils and hence improve their fertility or crop-producing power. Green manuring must never be followed blindly nor carelessly, however, as it may prove undesirable if the green material is turned under in the soil and does not decompose sufficiently rapidly. Lack of moisture may prevent the green manure from having any beneficial effect.

THE USE OF COMMERCIAL FERTILIZERS

The analyses of the soils of Crawford County have shown that the supply of phosphorus is low, and it is apparent that additions of phosphorus fertilizers will be needed on these soils in the near future even if they are not of value now, if crop yields are to be most satisfactory. The results of the greenhouse and field experiments which have been described earlier in this report and the experiences of many farmers indicate that the use of a phosphate may prove of large value on the soils of this county now. Large beneficial effects have been noted from the use of rock phosphate or superphosphate on the Marshall silt loam, the Carrington loam, the Waukesha silt loam and the Wabash silt loam in the experiments discussed. Undoubtedly the other soil types in the county would show just as large a response to those materials and perhaps even a larger effect. In fact in the case of the poorer soils such as the Knox silt loam, the light colored phase and the shallow phase of the Marshall silt loam, the benefits from the use of phosphates would certainly be larger than on the better soils, such as were used in the experiments.

Either rock phosphate or superphosphate may be employed to supply phosphorus to the soil. Rock phosphate is less expensive, but it must be applied in larger amounts, usually at the rate of 1,000 pounds per acre once in a 4-year rotation. The phosphorus in this fertilizer is not in an available form and must be changed before it can be taken up by plants. Often rock phosphate exerts its largest effects the second year after it is applied. Superphosphate, on the other hand, contains the element phosphorus in a form available for plant use, and while it costs more it is applied in smaller amounts, usually at the rate of 120 pounds of the 20 percent material annually or 3 years out of 4 in the 4-year rotation. It gives quicker results than the rock phosphate. The choice between the two phosphorus carriers depends upon the conditions and no general recommendations can be made. In the experiments which have been described, superphosphate sometimes gave better results, but in other cases rock phosphate brought about just as large effects. For quick results the superphosphate is undoubtedly preferable but rock phosphate may often be quite as profitable for use in individual cases. Farmers in this county may test the value of these two phosphorus fertilizers on their own soils and thus determine which will bring about the greatest effect upon the crops grown. This is the only exact way to learn which of these two phosphates will prove the more profitable, as the results obtained will vary with different conditions. It does seem, however, that one or the other of the phosphates will prove of value on the soils of this county for general farm crops.

The nitrogen supply of the soils of the county is not high, and it is certain that applications of some fertilizing material supplying nitrogen must be made regularly to these soils if the supply is to be kept up. It seems probable that in some cases now, the use of such materials might prove of value, especially on those soils which are lighter in color and hence lower in nitrogen content. In all cases, however, nitrogen must not be overlooked when planning for permanent fertility as the supply must be replenished regularly or the amount present will soon become inadequate for the best crop growth.

When all of the manure produced on the farm is applied to the land, it aids materially in maintaining the supply of nitrogen in the soils. By the proper preservation and application of farm manure a large part of the nitrogen removed from the soil by crop growth is returned to the land. The utilization of all crop residues also aids in keeping up the content of nitrogen in the soil. But these materials do no more than aid in maintaining the nitrogen in the soils, they do not increase the supply and usually they are not adequate to return all the nitrogen removed by crops grown and in the drainage water. There is a constant loss of nitrogen from most farms even when the manure and the residues are thoroughly utilized.

The turning under of legume crops as green manures is undoubtedly the cheapest and best means of increasing the nitrogen supply of the soil. When legumes are inoculated, as they should be for the best growth and most value, they take a large part of their nitrogen from the atmosphere and hence when they are plowed under they increase the nitrogen content of the land correspondingly. The proper use of legumes as green manures will permit of the maintenance of the nitrogen in the soil, and by the turning down of large, well-inoculated crops, the nitrogen supply may be increased considerably. Commercial nitrogenous fertilizers cannot be recommended for general use in Crawford County at present, as leguminous green manuring along with the use of farm manure and crop residues will permit of the proper addition of nitrogen and the maintenance of a necessary amount for crop growth. There is no objection to the use of such commercial fertilizers if tests prove them to be of value. But they should not be employed on large areas until they have been tested on a small scale and their value proven. In some cases, and especially for certain crops they may prove profitable for use.

The analyses of the soils of the county do not indicate that there is any likelihood of a deficiency of potassium for the production of farm crops. The use of commercial potassium fertilizers, therefore, cannot be recommended.

If available potassium is produced sufficiently rapidly to meet the needs of growing crops, there should be no need for any addition. When the soils are kept in proper condition physically and chemically there is little danger of an inadequate production of available potassium. If potassium fertilizers are used, they should be tested on small areas, before an application is made to any considerable area. In this way a definite idea may be obtained of the value or profit from their use.

Complete commercial fertilizers may prove of value on some of the soils of this county at the present time. In general, however, it appears that superphosphate will probably bring about just as large effects on crops and will, therefore, prove more profitable as it does not cost as much. Complete fertilizers must bring about much larger increases in crops if they are to prove desirable, or as economical as superphosphate. The soils of the county are generally well supplied with potassium, and nitrogen may be more cheaply provided by the use of legumes as green manures, hence it would not seem necessary to use a complete fertilizer supplying these two elements along with phosphorus, when a phosphate alone will do just as well. There is no possible objection to the use of a complete commercial fertilizer if the application proves profitable. The thing to do, therefore, is to test the particular complete brand on a small area in comparison with superphosphate and thus determine which may be used with the greater profit. Farmers who are interested may make simple tests of this sort and determine for their particular conditions which fertilizer they should employ.

LIMING

The soils in Crawford County are all acid in reaction in the surface soil, except the shallow phase Marshall silt loam and the Knox silt loam on the upland and the Ray silt loam on the bottoms. The typical Marshall silt loam, the most extensively developed type in the county, is acid in reaction throughout the three-foot section. The Carrington loam on the drift upland, the Waukesha silt loam and the Judson silt loam on the terraces and the Wabash types on the bottoms are all acid in reaction throughout the soil section and hence they are in need of lime for the best growth of general farm crops and especially legumes.

Liming acid soils is essential for the proper growth of all farm crops. Legumes, especially alfalfa and sweet clover, may make little or no growth on acid soils. Yields are greater of all legumes when liming is practiced, and while corn and small grain crops do not usually show large effects from the use of lime, sometimes there are large increases. The greater growth of legumes in the rotation provides for greater residues in the soil and hence the grain crops of the rotation are benefited indirectly as well as directly by the liming. Even if the acidity of the soil is not high, the use of lime is desirable for legumes, and lime in the subsoil will not obviate the desirability of the use of lime on the surface soil when legumes are newly seeded.

The experiments which have been discussed earlier in this report have shown that limestone will increase the crop yields on the Marshall silt loam, the Carrington loam, the Waukesha silt loam and the Wabash silt loam, all soils which are acid in reaction and in need of lime. The effects would be quite as great on other acid soils in the county. On all these acid types in the county, therefore, it is important that farmers test the soil and determine the need for lime before seeding to legumes. They may test their own soils, but it will usually be more satisfactory if they will send a small sample of soil to the Soils Subsection of the Iowa Agricultural Experiment Station where it will be tested free of charge and recommendations made regarding treatment. One application of limestone is not sufficient to keep soils supplied indefinitely, and it is necessary to test soils once in the rotation, preceding the legume crop in order that the lime may be applied as needed. Further information on the use of lime on acid soils, losses by leaching and other points regarding liming are given in Extension Service Bulletin 105 of the Iowa Agricultural Extension Service.

DRAINAGE

The natural drainage system of the county is quite adequate as has already been pointed out and indicated in the drainage map. The various streams with their tributaries and intermittent drainageways extend into practically all parts of the upland. There may be a few cases where drainage is not entirely satisfactory on the uplands of Marshall silt loam, but in general drainage is good. On the bottomlands, some of the Wabash soils are not adequately drained, and they must be drained artificially if they are to be cropped. These soils must also be protected from overflow if they are to be used satisfactorily for crop production.

The installation of tile in land which is poorly drained is very desirable. Tiling may seem somewhat expensive, but the increased crop growth will pay for the cost. No fertilizing treatments and in fact, no other soil treatments will prove of any use if the land is too wet and in need of drainage. Drainage and protection from overflow are the first treatments needed on the bottomland soils.

THE ROTATION OF CROPS

The growing of any one crop continuously on the land very quickly reduces the fertility of the soil and lowers crop yields. Even when it is necessary to grow crops of lower money or market value in order to provide for a proper rotation of crops, the total income from the land will be larger than from growing one crop continuously.

While no rotation experiments have been conducted in Crawford County, suggestions may be offered regarding rotations which will prove of value. A number of excellent rotations are available and may serve as a basis for the development of a satisfactory rotation for almost any condition. Modifications of any of the rotations recommended may be made and, in fact, almost any rotation may be used, provided it contains a legume crop and the money crop of the region. The following are good rotations which have been found to be of value in Iowa at the present time:

1. Six-Year Rotation

First year—Corn.
Second year—Corn.
Third year—Wheat or oats (with clover or clover and grass.)
Fourth year—Clover or clover and grass.
Fifth year—Wheat (with clover or grass and clover.)
Sixth year—Clover or clover and grass. (This rotation may be reduced to a 5-year rotation by cutting out the second or sixth years and to a 4-year rotation by omitting the fifth and sixth years.)

2. Four or Five-Year Rotation

First year—Corn.
Second year—Corn.
Third year—Wheat or oats (with clover or with clover and timothy.)
Fourth year—Clover. (If timothy was seeded with the clover the preceding year, the rotation may be extended to 5 years. The last crop will consist principally of timothy.)

3. Four-Year Rotation with Alfalfa

First year—Corn.
Second year—Corn.
Third year—Clover.
Fourth year—Wheat.
Fifth year—Alfalfa. (The crop may remain on the land for 5 years. This field should then be used for the 4-year rotation outlined above and the alfalfa shifted to one of the fields which previously was in the 4-year rotation.)

4. Four-Year Rotations

First year—Wheat (with clover.)
Second year—Corn.
Third year—Oats (with clover.)
Fourth year—Clover.

First year—Corn.
Second year—Wheat or oats (with clover.)
Third year—Clover.
Fourth year—Wheat (with clover.)

First year—Wheat (with clover.)
Second year—Clover.
Third year—Corn.
Fourth year—Oats (with clover.)

5. Three-Year Rotations

First year—Corn.
Second year—Oats or wheat (with clover seeded in the grain.)
Third year—Clover (In grain farming only the grain and clover seed should be sold; most of the crop residues such as corn stover should be plowed under. The clover may be clipped and left on the land to be returned to the soil and only the seed taken from the second crop.)

First year—Corn.
Second year—Oats or wheat (with clover.)
Third year—Clover.

First year—Wheat (with clover.)
Second year—Corn.
Third year—Cowpeas or soybeans.

THE PREVENTION OF EROSION

Erosion is the carrying away of soil by the free movement of water over the surface of the land. If all the rain falling on the ground were absorbed, erosion could not occur, hence it is evident that the amount and distribution of rainfall, the character of the soil, the topography or the "lay of the land" and the cropping of the soil are the factors which determine the occurrence of this injurious action.

The two types of erosion are sheet washing and gullying. The former may occur over a rather large area, and the surface soil may be removed to such an extent that the subsoil is exposed and crop growth prevented. Gullying is more striking in appearance but less harmful and it is usually more easily controlled. If, however, a rapidly growing gully is allowed to develop unchecked, an entire field may soon be made useless for farming purposes.

Erosion occurs to some extent in Crawford County, its effect being particularly noted on the Marshall silt loam. In fact the development of the shallow phase and the light colored phase of that soil is due to erosion or the washing away of the surface soil. The Carrington loam has also been eroded to a considerable extent. The Knox silt loam is somewhat affected too. It is evident that there are many cases in the county where some means of prevention or control of the destructive action of erosion should be adopted.

The means which may be employed to control or prevent erosion in Iowa may be considered under five headings, as applicable to "dead furrows" to small gullies, to large gullies, to bottomlands and to hillside erosion.

Erosion Due to Dead Furrows

Dead furrows or back furrows, when running with the slope or at a considerable angle with it frequently result in the formation of gullies.

"Plowing In"—It is quite customary to "plow in" the small gullies that result from dead furrows, and in level areas this process may be effective. In the more rolling areas, however, it is best to supplement the "plowing in" with a series of "staked in" dams or earth dams.

"Staking In"—The method of "staking in" is better than plowing in as it requires less work and there is less danger of washing out. The process consists of driving in several stakes across the gully and up the entire hillside at intervals of from 15 to 50 yards, according to the slope. The stakes in each series should be placed 3 or 4 inches apart. It is then usually advisable to weave some brush about the stakes, allowing the tops of the brush to point upstream. Additional brush may also be placed above the stakes, with the tops pointing upstream, permitting the water to filter through, but holding the fine soil.

Earth Dams—Earth dams consist of mounds of soil placed at intervals along the slope. There are some objections to the use of earth dams, but they are often effective in preventing erosion in dead furrows.

Small Gullies

Gullies result from the enlargement of surface drainageways, and they may occur in cultivated land, on steep hillisdes in grass or other vegetation, in the bottomlands, or at any place where water runs over the surface of the land. Small gullies may be filled in a number of ways, but it is not practicable to fill them by dumping soil into them; that takes much work and is not lasting.

Checking Overfalls—The formation of gullies or ditches is practically always the result of overfalls. An easy method of checking the overfalls is to put in an obstruction of straw and brush and stake down with a post. One or more posts should be set firmly in the ground in the bottom of the gully. Brush is intertwined between the posts, straw is well tramped down behind them and the straw and brush are held in place by cross pieces nailed to the posts.

"Staking In"—The simplest method of controlling small or moderate sized gullies and the one that gives the most general satisfaction is the staking in operation recommended for the control of dead furrow gullies.

The Straw Dam—A simple method of preventing erosion in small gullies is to fill them with straw. This may be done at threshing time with some saving of time and labor. The straw is usually piled near the lower part of the gully but if the gully is rather long or branching, it should be placed near the middle or below the junction of the branches, or more than one dam should be used.

The Earth Dam—The use of an earth dam or mound of earth across a gully may be a satisfactory method of controlling erosion under some conditions. In general it may be said that when not provided with a suitable outlet under the dam for surplus water, the earth dam cannot be recommended. When such an outlet is provided the dam is called a "Christopher" or "Dickey" dam.

The "Christopher" or "Dickey" Dam—This modification of the earth dam consists merely in laying a line of tile down the gully and beneath the dam. An elbow or a "T" called the surface inlet, usually extends 2 or 3 feet above the bottom of the gully. A large sized tile should be used to provide for flood waters and the dam should be provided with a cement or board spillway or runoff to prevent any cutting back by the water flowing from the tile. The earth dam should be made somewhat higher and wider than the gully and higher in the center than at the sides to reduce the danger of washing. It is advisable to grow some crop upon the earth dam, such as sorghum, or even oats or rye, and later seed it to grass.

The Adams Dam—This dam is practically the same as the Christopher or Dickey dam. In fact the principle of construction is identical. In some sections the name "Adams dam" has been applied and hence it is mentioned separately.

The Stone or Rubble Dam—Where stones abound they are frequently used in constructing dams for the control of erosion.

The Rubbish Dam—The use of rubbish in controlling erosion is a method sometimes followed and a great variety of materials may be employed. The results are, in the main rather unsatisfactory and it is an unsightly method.

The Woven Wire Dam—The use of woven wire, especially in connection with brush or rubbish, has sometimes proven satisfactory for the prevention of erosion in small gullies.

Sod Strips—The use of narrow strips of sod along natural surface drainageways may often prevent these channels from washing into gullies, as the sod serves to hold the soil in place. Bluegrass is the best crop to use for the sod, but timothy, redtop, clover or alfalfa may serve satisfactorily and for quick results sorghum may be employed if it is planted thickly.

The Concrete Dam—One of the more effective means of controlling erosion is by the concrete dam, provided the Dickey system is used in connection with it. They are, however, rather expensive. Owing to their high cost and the difficulty involved in obtaining a correct design and construction, such dams cannot be considered as adapted to general use on the farm.

Drainage—The ready removal of excess water may be accomplished by a system of tile drains properly installed. This removal of water to a depth of the tile increases the water absorbing power of the soil and thus decreases the tendency toward erosion.

Large Gullies

Large gullies or ravines may in general be controlled by the same methods as for small gullies. The Dickey dam is the only method that can be recommended for controlling and filling large gullies and it seems to be giving very satisfactory results at the present time.

Bottomlands

Erosion frequently occurs in bottomlands, especially where they are crossed by small streams and the land may be very badly cut up and rendered almost entirely valueless for farming purposes.

Straightening and Tiling—The straightening of the larger streams in bottomland areas may be accomplished by any community and while the cost is considerable, large areas of land may thus be reclaimed.

Trees—Erosion is sometimes controlled by rows of trees such as willows which extend up the drainage channels. While the method has some good features it is not generally desirable.

Hillside Erosion

Hillside erosion may be controlled by certain methods of soil treatment which are of value not only in preventing the injurious washing of soils but also aid materially in obtaining satisfactory crop growth.

Use of Organic Matter—Organic matter or humus is the most effective means of increasing the absorbing power of the soil and hence it proves very effective in preventing erosion. Farm manure may be used for this purpose or green manures may be employed if farm manure is not available in sufficient amounts. Crop residues such as straw and cornstalks may also be turned under to increase the organic matter content.

Growing Crops—The growing of crops such as alfalfa, that remain on the land continuously for a period of 2 or more years is often advisable on steep hillsides. Alsike clover, sweet clover, timothy and redtop are also desirable for use in such locations.

Contour Discing—Discing around a hill instead of up and down the slope or at an angle to it is frequently effective in preventing erosion. This practice is called "contour discing" and has proved satisfactory in many cases in Iowa.

Terracing—The use of terraces to control erosion has been found very effective in some parts of Iowa. The terrace is a broad ridge with a shallow ditch on the upper side. It runs around the hill and serves to prevent large amounts of water from running straight down hill at high speed. Terraces are usually spaced from 50 to 100 feet apart and have a grade or fall of 6 inches or less per 100 feet as they go around the hill. Surface water is caught and led slowly away in the terrace channel, thus permitting the soil to absorb large amounts of the moisture which normally would be lost by run-off. Land with more than a 12 to 15 percent slope cannot be satisfactorily terraced and should be left in pasture.

Sod Strips—The use of narrow strips of sod is very desirable for preventing gully erosion. The sod protects the field from the flow of water during rains and prevents the washing away of the surface soil. The practice of "strip cropping" is gradually gaining in favor and is undoubtedly a method of controlling sheet erosion which will be largely used in some areas in the future.

Deep Plowing—Deep plowing increases the absorptive power of the soil and hence decreases erosion. It is especially advantageous for some soils if it is done in the fall, as the soil is then put into condition to absorb and hold the largest possible amount of the late fall and early spring rains.

INDIVIDUAL SOIL TYPES IN CRAWFORD COUNTY *

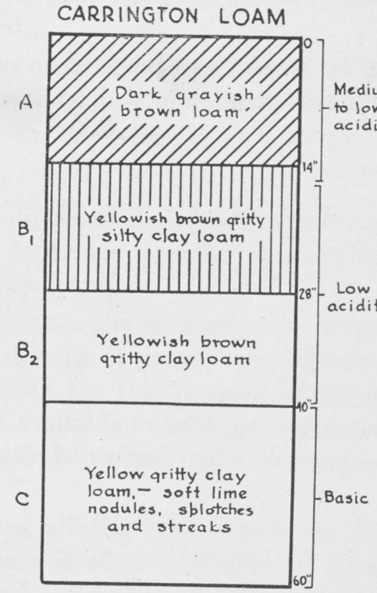
There are 8 soil types in Crawford County and these with the shallow phase Marshall silt loam, the light colored phase of that type, and the colluvial phase of the Wabash silt loam, make a total of 11 separate soil areas. They are divided into four groups, drift soils, loess soils, terrace soils and swamp and bottomland soils.

DRIFT SOILS

Carrington Loam (1) (Cm)

The only drift soil in the county is the Carrington loam. It is of very limited occurrence, covering only 0.7 percent of the total area of the county. It is found principally along the Boyer River. There are also areas along the East Boyer River and some of the other larger streams and their tributaries. There are no large individual areas of the type, the soil occurring in narrow strips along the streams where erosion has removed the original loess covering and exposed the earlier drift deposit.

The surface of the Carrington loam is a loose friable dark grayish-brown silt loam or loam to a depth of 6 inches. Between 6 and 14 inches there is a dark grayish-brown loam which is slightly lighter in color than the top soil. Below 14 inches and extending to a depth of 28 inches there is an abrupt change to a brown or yellowish-brown gritty sticky silty clay loam which is coarsely granular. Between 28 and 40 inches the material is a yellowish-brown gritty clay loam, containing a high percentage of sand and gravel. In places in the lower subsoil, there are lime nodules and concretions and the soil probably should have been called Clarion loam rather than Carrington, inasmuch as this lime occurrence is characteristic of Clarion soils.



There are many variations in the soil in this type. In typical areas silt loam from the higher-lying Marshall silt loam areas has washed down and intermixed with the drift to form Carrington loam. These areas occur at the upper part of the drift slopes and in narrow strips. Coarse sand, gravel and small boulders are scattered throughout the drift, producing small areas of Carrington sandy loam which because of their small areas were included with the Carrington loam as mapped. The largest development of the sandy loam is in Sections 1 and 2, Stockholm Township. Gravel and sand pits occur in many places but principally along the Boyer and East Boyer rivers, 1 mile southeast of Denison and between Denison and Deloit. Lighter colored drift soil is also included with the type, because of its small area. Areas of this

* The descriptions of individual soil types given in the Bureau of Soils report have been closely followed in this section of the report.

lighter material are found 1 mile east and southeast of Denison along the East Boyer River and they extend a short distance up some of the shorter tributaries. A small area of Lindley sandy loam consisting of only a few acres, occurs in Section 33, Milford Township, and is included with this soil. The soil in this area is calcareous in only a few places principally where the drift has been deeply eroded to the underlying calcareous drift material below. Many areas of drift material ranging from 10 to 50 feet wide could not be shown separately on the map and were included with the Marshall silt loam, shallow phase.

The Carrington loam is of little agricultural importance because of its small extent in the county. About 50 percent of the land is farmed, most of the remainder being in pasture. A few small areas support a scattered growth of trees. Most of the type should undoubtedly remain in pasture as it is too rough or steep to be satisfactorily cropped. Where it is not too rough to cultivate, general farm crops may be grown. The yields are very much the same as on the Marshall silt loam, where the best Carrington loam is found. In the lighter colored and sandier areas, the yields are much lower.

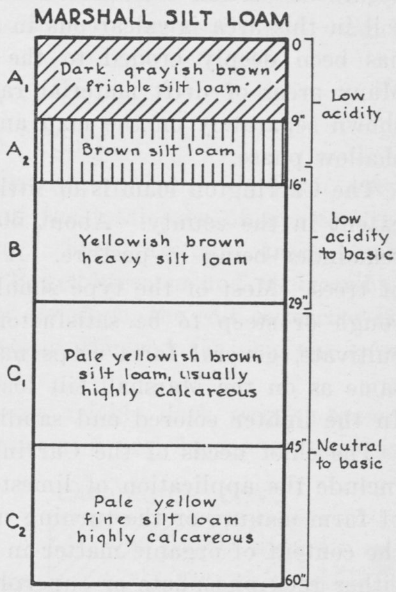
The chief needs of the Carrington loam, if it is to be profitably cultivated include the application of limestone to correct the acidity of the soil, the use of farm manure or the turning under of legumes as green manures to increase the content of organic matter in the soil and the use of a phosphate fertilizer, either rock phosphate or superphosphate. The use of manure has been found to bring about large crop increases, and this fertilizing material should be applied regularly and in large amounts to this soil to improve its fertility or crop producing power. The tests reported earlier have shown the large value from manure on this soil. The use of legumes as green manures will be of value, to supplement the farm manure, in building up and maintaining the supply of organic matter in the soil. They will also add nitrogen and will thus have large value as a nitrogenous fertilizer. The liming of the soil is necessary for the best crop growth especially of legumes. The addition of phosphorus will be needed in many cases on the type, and the testing of rock phosphate and superphosphate under individual farm conditions is very desirable. One or the other of these materials will undoubtedly prove of value.

LOESS SOILS

There are two loess types in the county, the Marshall silt loam and the Knox silt loam, and these with the shallow phase and the light colored phase of the Marshall make four soil areas. Together they cover 73.9 percent of the total area.

Marshall Silt Loam (9) (Ms)

The typical Marshall silt loam is the most extensively developed of the loess soils and by far the largest individual soil type in the county. It covers 64.5 percent of the total area. It is found throughout the uplands of the county in extensive individual areas, being cut by the terrace and bottomland areas along the streams and by the small narrow areas of the Knox silt loam and the Carrington loam in the rougher areas. The surface soil of the Marshall silt loam is a dark grayish-brown friable silt loam extending to a depth of about 8 inches. When moist the soil is a very dark grayish-brown to almost black. The lower part of the surface layer, below a depth of 4 inches, is slightly heavier than the upper part. The surface layer averages about 8 inches on the uplands, but on the less rolling areas, it is often 11 inches or more in depth. At the base of the slopes the top soil is always thicker, ranging from 15 to 20 inches while higher up on the slope, it may be rather thin. From 8 to 16 inches, the subsurface layer is a brown silt loam, or more often a dark grayish-brown in appearance. Below this layer and extending to a depth of 21 inches, the soil is heavier in texture, being a yellowish-brown heavy silt loam, with some faint stains of organic matter. This layer is more compact than the layer above and the soil is somewhat granular. From 21 to 29 inches the soil is a yellow or yellowish-brown heavy silt loam, faintly granular, the color of the soil being uniform and solid. Below this layer there is a yellowish-brown or light-yellow silt loam, lighter in color than the layer above and containing a few faint iron stains and gray mottlings. This layer extends to a depth of 45 inches where there is a sharp change to a very light gray or pale yellow silt loam which is powderlike and smooth. The color is uniform except for a few small rust-brown iron concretions. This layer is the unweathered parent material from which the soil has been formed and it is high in lime, containing many lime concretions.



There are many variations in the soil in different areas. The depth of the surface soil is exceedingly variable and the depth to the underlying lime material is also variable. In places this gray, finely powdered limy silt material occurs within 10 inches of the surface. In other areas it lies at a depth of 10 feet. There is no relation between the depth of the lime and the topography of the soil. On one side of a gentle slope the lime may occur at a depth of 15 to 30 inches while only a few feet away on the opposite slope, the lime may not appear even at a depth of 10 feet. This is strikingly illustrated in the 10-foot road cut in Section 31 of East Boyer Township, on the graveled road from Denison to Manilla. In several other areas there are variations in the depth of the surface soil, a deeper darker-colored, more acid topsoil occurring than is typical. Most of these areas occur in the less rolling country along the east side of the county, particularly north and east of Vail, on the gently rolling divides around Schleswig, Ricketts and Charter Oak, and on the uplands northeast of Deloit. Another rolling area of this character is found 3 miles south of Buckgrove, near and along the county line. These areas of a deeper surface soil could not be separated into a phase of the type because of variability of the soil at the same topographic position. In the northeastern part of the county, the depth of the lime is generally greater than in other parts.

In topography the Marshall silt loam is rolling, ranging from gently rolling to sharply rolling in different sections. The more rolling areas with steeper relief are largely in the southwestern part of the county. The shallow phase and the light colored phase of the soil are found in this section of the county, where erosion has been more active. In places the surface soil has been entirely washed away and the light brown calcareous subsoil is exposed. These spots and narrow strips are low in organic matter and very high in lime, often showing a content of 20 to 30 percent. Drainage of the type is well established. Streams and their tributaries, with intermittent drainage-ways, extend into all parts of the uplands of Marshall silt loam and bring about thorough natural drainage. Only in small level areas is there ever any indication of lack of drainage.

Practically all of the Marshall silt loam is under cultivation or in pasture. Tree growth is limited to a few thinly wooded slopes and hillsides and planted windbreaks of cottonwood, elm, maple and evergreens. Corn, oats and hay are the most important crops. Corn yields about 40 bushels per acre on the average, while on the better farms, the yields are frequently 60 to 70 bushels per acre. Oats are the second crop in importance, yielding on the average 30 bushels per acre, with yields of 60 bushels common under the better farm conditions and in favorable seasons. The hay crop consists mainly of mixed timothy and clover with some clover alone and some timothy alone. The hay crop averages 2 tons per acre. These hay crops are grown mainly in the northeastern part of the county on the gently rolling uplands. Alfalfa is extensively grown. Three cuttings usually are obtained with a yield of 3 tons per acre, when the soil is limed and the crop is properly seeded and handled. Sweet clover is grown extensively in the western and southwestern

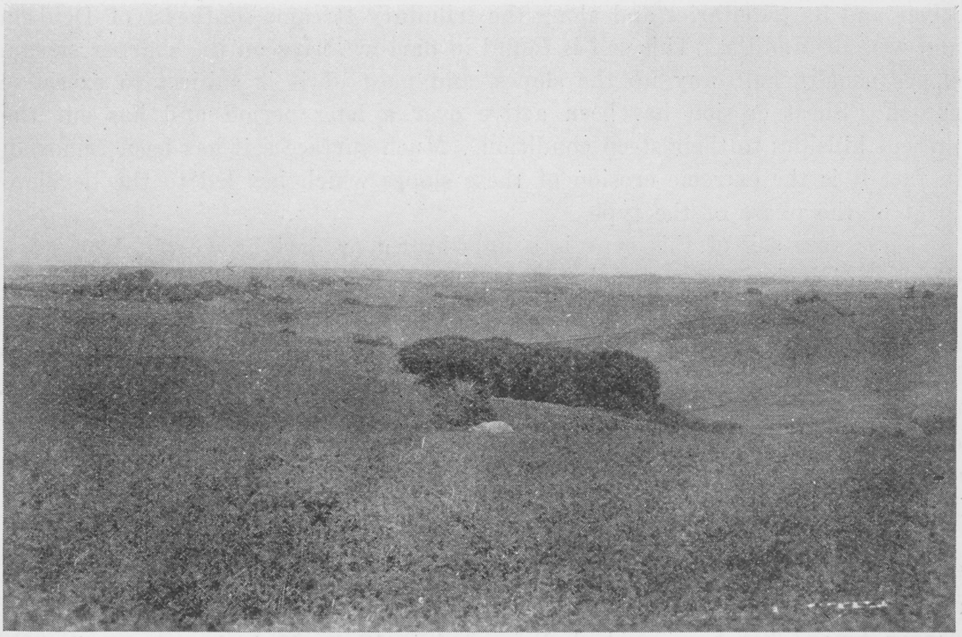


Fig. 6. Sweet clover in foreground. Corn can only be grown 1 year on these steeper slopes which must then be seeded down usually with oats.

part of the county and is utilized mainly for pasture and green manure. Liming is necessary for this crop as well as for the alfalfa. Very few soybeans are grown. Winter wheat and spring wheat are of little importance. The yields average about 23 bushels per acre of the winter varieties and 15 bushels per acre of the spring wheat. Some barley is grown, yielding about 27 bushels per acre. Fruit production is mostly in small farm orchards, containing a few trees each. Very little truck is grown, hardly sufficient to supply the local demands. Small gardens are maintained on nearly all farms.

The yields of general farm crops are usually satisfactory, but the yields often are much lower than they should be and increases are possible if soil conditions are improved by proper methods of soil management. The addition of fertilizing materials supplying organic matter is particularly necessary on this soil, and the liberal use of farm manure brings about large and profitable increases in crops. The turning under of legumes as green manures will also prove of large value on this soil in order to build up and maintain the supply of organic matter. The soil is acid in reaction at the surface and often to considerable depths; the addition of limestone before growing legumes especially sweet clover and alfalfa, is very necessary. The application of a phosphate fertilizer will often bring about large gains in crops, and tests of rock phosphate and superphosphate under individual farm conditions are desirable. The experiments which have been discussed earlier in this report have shown the large value of farm manure, limestone and a phosphate fertilizer.

Marshall Silt Loam (shallow phase) (213)

The shallow phase of the Marshall silt loam is much smaller in extent than the typical Marshall, covering 7.1 percent of the total area of the county. It occurs principally in the western half of the county, but extends up the Boyer River and its tributaries and along the tributary streams southeast of Denison and west of Manilla. This soil is found in narrow strips on the sharper stream slopes usually half way up the slopes, and most of it is subject to excessive run-off. Sheet erosion has been active over a long period and has cut the present hillsides to their steep condition. Much surface soil has been removed, in fact it is the extreme erosion of these slopes which has led to the development of the phase of the type.

The surface soil of this type is a light-brown or dark-brown silt loam to a depth of 4 inches. Between 4 and 14 inches there is a light-yellowish-brown silt loam. Below this and continuing to a depth of 48 inches or more the soil is a light-yellow floury silt loam. The surface soil is often calcareous and the lower soil layers are almost always high in lime. In places no lime concretions occur in the subsoil, but over the surface large lime nodules are found, decreasing downward until they disappear at 12 inches. The lime in the subsoil is often finely divided and undistinguishable from the silt particles. Nodules of lime may occur anywhere throughout the soil section.

This phase of the Marshall silt loam is variable and the color is nowhere uniform. There are many light colored spots showing the exposed subsoil, and there are darker colored areas at the bottoms of the slopes where the darker topsoil has been washed down and is 12 to 20 inches deep. In the rougher areas in the western and southwestern parts of the county and along the deeper cut streams, the slopes are very light colored. When dry they appear uniformly grayish-brown but when wet they are a darker grayish-brown. These lighter slopes occur in Union, Boyer and Willow Townships. They could not be shown on the map because of their small extent. Small pockets from 20 to 50 feet across, and narrow strips from 5 to 15 feet wide and from 100 to several hundred feet long are exposed on many of the slopes, the drift in these areas ranging in color from dark grayish-brown, or buff to yellow and from neutral to calcareous in reaction to acid. Most of the areas of drift included are found in the southwestern and western parts of the county. In Sections 4, 5 and 6 of Jackson Township, the shallow phase as mapped more nearly corresponds to the light-colored phase as mapped in the western part of Crawford County, but is slightly darker. It joins with the phase mapped in Sac County.

Most of the land in the shallow phase of the Marshall silt loam is in cultivation. Forest trees once covered many of the hillsides, but most of the trees have been removed. There are a few scattered trees along the Boyer and East Boyer Rivers, on the bottoms and along some of the other streams, but most of the natural tree growth of the county is found on the shallow phase of the Marshall silt loam. The trees consist mainly of oak, ash, maple, elm, cottonwood and other hardwoods.

The same crops are grown as on the typical Marshall. Corn yields about 40 bushels per acre. Oats yield 25 to 40 bushels per acre. Hay yields from 1½ to 2 tons per acre and alfalfa and sweet clover about the same as on the typical Marshall when grown on the better areas. On the poorer, thinner areas, the yields are much lower.

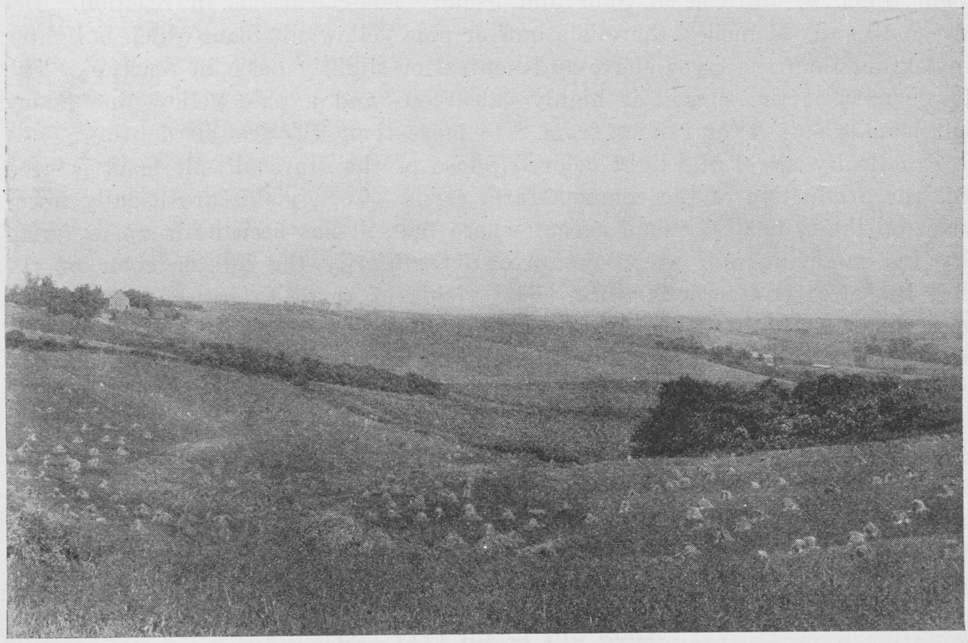


Fig. 7. Sheet erosion on slopes has removed the original dark colored surface soil and left a lighter colored loess on upper slopes with narrow bands of drift 50 to 100 feet wide at the bottom of the slope.

The soil is subject to erosion and gullies are easily formed. One heavy rain may make a gully from 2 to 5 feet deep, if no measures are taken to prevent the action. Some of the land in this type should certainly be left in pasture and should not be cultivated. It may be cultivated if it is not too steep but precautions should be taken to plow at right angles to the slope, to practice contour farming, to strip crop, or to seed down to legumes frequently to build up the organic matter content of the soil which will reduce the danger of erosion. By proper cropping and handling of the land and the use of liberal amounts of organic matter, the areas of the type which are not too thin and steep may be successfully cultivated. The use of lime may be necessary for the best growth of legumes when the soil is acid, and the use of a phosphate fertilizer may often help. Tests are desirable. But the use of farm manure and legumes as green manures is of major importance.

Marshall Silt Loam (light colored phase) (257)

The light colored phase of the Marshall silt loam is quite limited in area, covering 2.1 percent of the total area of the county. It occurs chiefly on the narrower interstream divides and stream slopes in the western part of the county and northwest of Dow City. A large area is on the high upland ridges, deeply cut by drainageways, 1½ miles northeast of Denison. Smaller areas, on narrow, rounded, eroded ridge tops, occur in the south central part of the county where the streams have cut to a depth of 100 or more feet into the original upland plain.

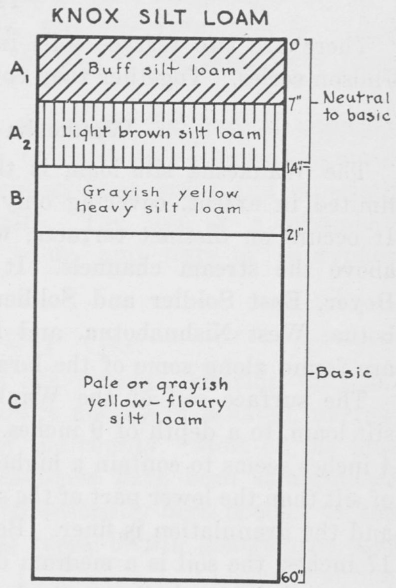
The surface soil of this phase is a grayish-brown silt loam to a depth of 7 inches. In places material from the originally darker surface layer is left in the surface soil. From 7 to 15 inches the soil is a heavy light brown silt loam which is uniform in color and usually non-calcareous in reaction. Between 15 and 24 inches, there is a buff or pale yellow silt loam which is lighter in texture than the layer above and neutral or slightly basic in reaction. The lower part of the subsoil is highly calcareous and a pale yellow fine floury silt loam. This layer ranges from 2 to more than 3½ feet in depth.

Practically all of the light colored phase of the Marshall silt loam is used for the production of the common farm crops. Corn yields are usually lower than on the typical Marshall except where the soil has been built up in fertility by manuring and green manuring. Ordinarily the lighter color of the soil indicates its lower fertility. The yields of small grains and hay crops are almost as high as on the typical Marshall. Sweet clover and alfalfa do well on the soil but are reported to be rather susceptible to winter-killing. Special care in preparing for these crops is necessary.

The chief need of this soil is organic matter. The liberal application of farm manure or the turning under of legumes as green manures is desirable, in order to build up the supply of organic matter. Lime may sometimes be needed for the growing of legumes such as sweet clover or alfalfa, but usually the type is well supplied with lime. The application of a phosphate fertilizer will often prove of value, and tests of superphosphate are recommended.

Knox Silt Loam (11) (Kl)

The Knox silt loam is a minor type in the county, covering only 0.2 percent of the total area. It occurs mostly along the west county line in Willow and



Boyer Townships and in Paradise Township. Areas of the soil occurring as small narrow ridges, too small to show on the map, are included with the Marshall silt loam. There are only a few small areas of the type.

The surface soil of the Knox silt loam is a dark-brown silt loam to a depth of 7 inches. Between 7 and 14 inches the material is a light brown or buff heavy silt loam, with some organic matter markings from the surface layer above. The soil in this layer is firm but not compact. In general there is little difference in the soil in these two surface layers except for the lighter color of the topsoil which is a buff or light brown, and the slightly lighter textured surface layer. Below 14 inches and to a depth of 21 inches the soil is a grayish-yellow, uniform in color, and very mealy and smooth. Between 21 and 34 inches, the color of the soil is the same as above, except that there are some faint gray mottlings. Below 34 inches the soil is lighter in color, being pale yellow or grayish-yellow, flour-like in texture and high in lime. Often the layer above is high in carbonates and it is generally at least neutral in reaction, but the surface layers are normally leached of all carbonates. The lower part of the subsoil from 34 inches to varying depths is high in lime, white or gray in color, soft and structureless, and mottled with yellow and rust-brown iron stains. In places the lime nodules and concretions appear on the surface of the soil, especially where the soil is eroded and thin. The depth of the soil to the subsoil is variable, ranging from 2 to more than 5 feet from the surface to the underlying high-lime subsoil, but in most places the calcareous subsoil occurs at a depth ranging from 24 to 30 inches.

The land in Knox silt loam is all in cultivation mostly to corn, oats and sweet clover. Yields are somewhat smaller than on the typical Marshall silt loam. Small grains, potatoes, vegetables, grapes and bush and tree fruits are well suited to this soil and do very well. They are not extensively grown, however. Drainage ranges from good to excessive on the steeper slopes, and erosion is common and brings about considerable injury. The soil is generally rolling to steeply rolling in topography, and it must be farmed with care.

The chief need of the Knox silt loam, if it is to be successfully cultivated, is for the addition of organic matter. The liberal application of farm manure is very desirable and the turning under of legumes as green manures is necessary to supplement the use of farm manure and build up the content of organic matter. The use of a phosphate fertilizer may be of value also, and tests of superphosphate are recommended. The land should be handled so as to reduce the danger of erosion to a minimum. Some of the land with steep topography should undoubtedly be left in pasture.

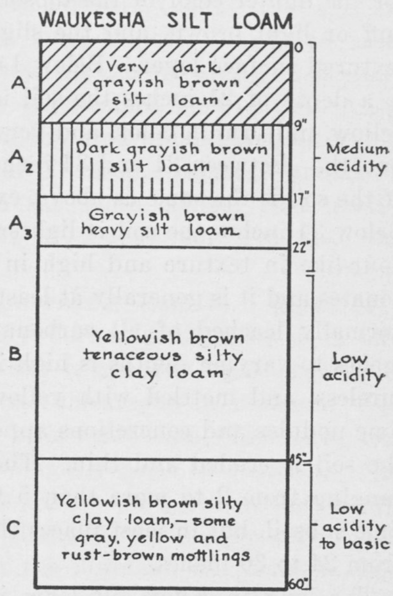
TERRACE SOILS

There are two terrace soils in the county, classified in the Waukesha and Judson series. Together they cover 1.8 percent of the total area of the county.

Waukesha Silt Loam (75) (Wt)

The Waukesha silt loam is the larger of the two terrace types, but it is limited in extent, covering only 1.1 percent of the total area of the county. It occurs on distinct terraces, well above overflow, lying from 10 to 40 feet above the stream channels. It is developed mainly along the Boyer, East Boyer, East Soldier and Soldier rivers. Areas also occur along the Nishnabotna, West Nishnabotna, and Middle Soldier rivers, and a few small areas are found along some of the larger tributary streams.

The surface soil of the Waukesha silt loam is a very dark grayish-brown silt loam, to a depth of 9 inches. The upper 4 inches seems to contain a higher percentage of silt than the lower part of the surface layer, and the granulation is finer. Between 9 and 17 inches, the soil is a medium dark grayish-brown silt loam, similar to the layer above except that the color is lighter. From 17 to 22 inches there is a layer of grayish-brown heavy silt loam, heavier than the layer above and colored by dark streaks of organic matter coming down from above. This layer has a larger amount of clay in it than the layer above. The lower part of the subsoil, from 22 to 45 inches is a yellowish-brown, tenacious silty clay loam, which is very heavy, sticky and plastic. In places at depths of 5 to 6 feet there are layers of sandier material. Beds of sand and gravel occur in the subsoil occasionally.



In sections 15 and 16 of Denison Township, a few small areas have sandy surface soils and subsoils. They are included with the Waukesha silt loam, although they are entirely different in character, because they represent such a small total acreage. There is an area containing some sand and gravel on a terrace, 3½ miles northeast of Denison along the East Boyer River. Other areas in which some fine sand is mixed with the soil are found on the high terraces along the Boyer River southwest of Dow City. With these exceptions, however, the soil as mapped, is typical Waukesha silt loam.

In topography the Waukesha silt loam is nearly flat to gently sloping toward the streams. The streams flowing out from the uplands cut the terrace areas. The natural drainage of the type is good. Only in small depressions is there any lack of rapid and adequate drainage.

All the land in the Waukesha silt loam is now under cultivation and general farm crops are grown. At one time a few trees occurred on these terraces, but they have all been cut. The yields of corn range from 40 to 70 bushels per acre, oats from 30 to 60 bushels, and hay from 1½ to 2 tons per acre. Alfalfa would grow very well on the soil if the land were limed and the crop properly handled.

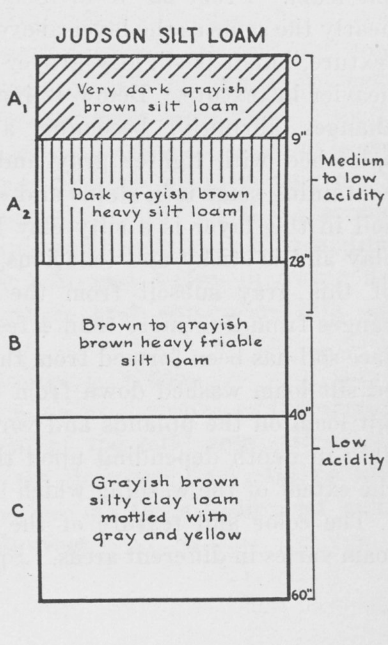
The Waukesha silt loam will be benefited materially by normal additions of farm manure and by the turning under of legumes as green manures. The soil needs lime for the best growth of general farm crops and especially for legumes such as sweet clover and alfalfa. The use of a phosphate fertilizer would also undoubtedly prove of value, and tests of superphosphate and rock phosphate are urged.

Judson Silt Loam (131) (Js)

The Judson silt loam is a minor type in the county, covering only 0.7 percent of the total area of the county. It occurs mainly in isolated, narrow, disconnected strips along the larger streams of the county. Most of the land lies well above overflow. Since the stream channels have been straightened there has been little flooding even in times of exceptionally high floods. A few areas may still be under water after torrential rains, but in general the land is not subject to overflow now.

The surface soil of the Judson silt loam is a very dark grayish-brown friable silt loam to a depth of 9 inches. It is underlaid by a dark grayish-brown heavy silt loam, which extends to a depth of 37 inches, where it changes to a dark gray friable silt loam, slightly lighter in color than the layer above and a little heavier in texture. In a few small depressed areas the surface soil is slightly heavier in texture and the subsoil is grayer with some deeper gray mottlings.

This soil has been formed by carrying down the darker colored silt loam soil from the uplands by sheet erosion and by the streams flowing through the uplands. It consists therefore of colluvial material made up of dark colored silt loam from the adjacent uplands, and occurs on the outer edges of the bottomlands. The topography is level to flat with a slight slope toward the bottomlands. The soil boundaries between this soil and the bottomland types are often placed quite arbitrarily as there is a gradual merging of the soils from the foot of the hill slope where the Judson silt loam begins to the bottomland type along the stream.



The Judson silt loam is all under cultivation, and general farm crops are grown. The yields are usually satisfactory. The yield of corn and small grains is about the same as on the best areas of the Marshall silt loam. Hay crops also do well. Practically none of the soil is used for pasture. The needs of the type include the application of farm manure in order to maintain the supply of organic matter. The use of farm manure proves of value in increasing the yields of farm crops. The turning under of legumes as green manures would also help in order to supplement the use of farm manure. The soil is acid in reaction and the application of limestone is necessary for the best growth of crops and particularly for legumes such as sweet clover and alfalfa. The use of a phosphate fertilizer would also undoubtedly prove of value, and tests of superphosphate and rock phosphate are recommended.

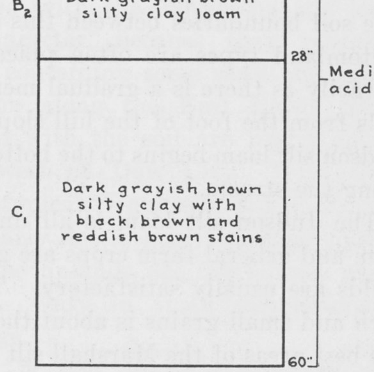
SWAMP AND BOTTOMLAND SOILS

Three swamp and bottomland soil types occur in the county, and these with the colluvial phase of the Wabash silt loam make four soil areas. They are classified in the Wabash and Ray series. Together they cover 23.6 percent of the total area.

Wabash Silt Loam (26) (Wh)

The Wabash silt loam is the largest of the bottomland soils and the second largest type in the county. Together with the colluvial phase, this soil covers 23 percent of the total area. It is extensively developed along all the streams of the county. The largest areas are found along the Boyer, East Boyer, East Soldier, Middle Soldier and Soldier rivers and some of their larger tributaries. The bottomlands normally occur in narrow, ribbonlike strips along the tributary streams extending well back toward the heads of the streams, and they range from 150 feet to as much as 1½ miles in width.

The surface soil of the Wabash silt loam is a very dark grayish-brown friable silt loam to a depth of 12 inches. Between 12 and 22 inches the soil is a very dark brown to almost black heavy silt loam. From 22 to 42 inches the soil is nearly the same as the layer above in color and texture, but it is slightly grayer in color and heavier in texture. Below 42 inches the color changes abruptly, becoming a dull gray, splotched with lighter gray and yellow and containing some iron stains and streaks. The soil in this layer is a silty clay loam to silty clay and is sticky and tenacious. The depth of this gray subsoil from the surface soil ranges from 2 to more than 4 feet. The surface soil has been formed from the dark colored silt loam washed down from the Marshall silt loam on the uplands and varies considerably in depth depending upon the slope and the extent of the washing which has occurred.



The color and texture of the Wabash silt loam varies in different areas. Spots of sandy and light colored soils occur principally along the Boyer River, but they could not be shown on the map because of their small extent and irregularity. Along the East Soldier River much of the soil is intensely black and heavy being almost a silty clay loam. Other areas of heavier soil were also included with the type because of their small extent. In many places along the Soldier River the soil is more nearly dark chocolate-brown when dry, but the difference in color was not sufficient to warrant separating the areas from the typical Wabash. The surface texture of the soil along the Soldier River is also extremely variable, and the soil included many heavy spots, high in clay, where the texture is almost a silty clay loam. Many small patches of dark grayish-brown or black silty clay loam occur along the smaller tributary streams, in areas from one-eighth of an acre to more than an acre in size. They could not be shown separately on the map.

Most of the typical Wabash silt loam is subject to overflow only at times of abnormally high floods. The channel of the Boyer River has been straightened for some distance back, from the southwest corner of the county and new channels have been made to some extent along the Soldier, Nishnabotna and Middle Soldier rivers and for short distances along some of the larger tributary streams where they join the main streams. Over 13,000 acres are included in this drainage project, affecting much of the Wabash silt loam and Wabash silty clay loam in the county. The small narrow strips along some of the smaller streams are subject to overflow occasionally, but the damage is usually not serious. Pastures are maintained along these narrower bottomlands and they provide good bluegrass and native grass pasturage. A few trees are found along the banks of these streams.

General farm crops grown include corn which yields from 45 to 80 bushels per acre, wheat and oats which give good yields but are apt to lodge in wet seasons, and alfalfa which yields from 3 to 3½ tons per acre. Other hay crops are grown and give good yields. Some wild hay is cut on the lower more poorly drained areas. This soil is chiefly in need of better drainage in some areas, where adequate drainage has not yet been provided. Then it will respond to small applications of farm manure, especially after being newly cultivated following drainage. Large amounts of manure should not be employed. The growing of legumes will prove of value on this soil, but liming is necessary as the soil is acid, and legumes will not do well until lime is added. The use of a phosphate fertilizer will also prove of value for general farm crops and tests of rock phosphate and superphosphate are recommended.

Wabash Silt Loam (colluvial phase) (26a)

The colluvial phase of the Wabash silt loam is about the same as the typical Wabash silt loam in area, covering 11.5 percent of the total area. It occurs in all parts of the county, at the sources of the drainage lines and extends toward the streams for short distances. There are no large individual areas of the type, but it is found in numerous small areas.

The surface soil of the colluvial phase of the Wabash silt loam is a very dark brown friable silt loam, consisting of material washed down from the adjacent uplands. The depth of the surface soil is variable, ranging from 10 inches to 4 feet, but it averages between 15 and 20 inches. In many places with slight depressions, the soil is almost a silty clay loam in texture but these areas were too small to show separately on the map. The subsoil between 18 and 28 inches is a dark brown silty clay with a gray cast, and the lower part of the subsoil changes to a grayish-brown or dull gray silty clay containing some mottlings of yellow and some rust-brown iron stains.

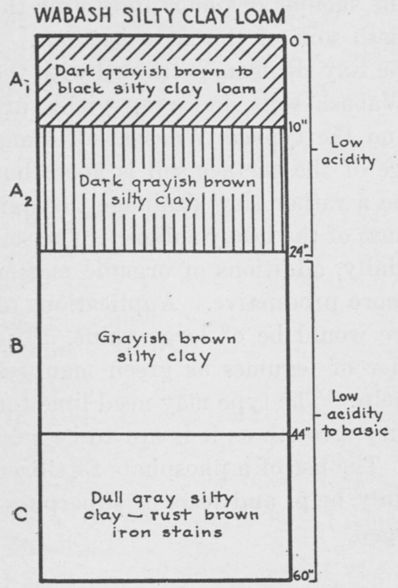
Most of the land in this type is rather flat with a gentle slope toward the stream channel and a sharper slope downstream. Drainage is good in most cases, although water stands for some time in some of the depressed areas, and tiling is needed when these areas are cropped. The greater part of this soil is left in native grasses, especially on the narrower strips extending up the hill slopes. The remainder of the type is farmed with the Marshall silt loam on the adjacent uplands, and general farm crops are grown. The yields of crops are much the same as on the Marshall, although on the better drained areas the yields of corn may be somewhat higher, while the small grains are more apt to lodge.

The needs of this soil when it is cultivated, are first of all, for adequate drainage unless this has been provided. It will respond to small applications of farm manure, especially when newly drained. The manure stimulates the production of available plant food in the soil. The growing of legumes is desirable on the land. The application of lime is necessary as the soil is acid. It is especially needed for legumes. The application of a phosphate would undoubtedly help, and tests of superphosphate and rock phosphate are suggested.

Wabash Silty Clay Loam (48) (Wa)

The Wabash silty clay loam is of minor importance in the county, covering only 0.5 percent of the total area. It occurs mainly along the Boyer River, extending from below Deloit to the county line. Some areas lie along the East Boyer River on the bottomlands, and there are some areas on the bottoms along some of the smaller streams. In some cases the areas along the smaller streams are too small to separate, and they are included with the Wabash silt loam.

The surface soil of the Wabash silty clay loam is a dark grayish-brown or black silty clay loam to a depth of 10 inches. It is underlaid by a dark grayish-brown or black clay loam or silty clay which is sticky and plastic. Between 24 and 44 inches the soil is a dark grayish-brown or grayish-brown silty clay containing a few iron stains. The lower part of the subsoil has a grayish cast and is slightly lighter in texture than the upper subsoil layer. In many places the lower subsoil is dull gray in color and a heavy silty clay in texture, with mottlings of lighter gray and brown at a depth of about 30 inches. In places, usually at a depth of 15 to 20 inches, there are thin layers of a lighter colored, lighter textured material mostly silt. The texture of the surface



soil of the type in the various areas varies from heavy silt loam to heavy silty clay loam, owing to the association of the type with the Wabash silt loam areas.

The Wabash silty clay loam is level in topography, and most of the land lies from 10 to 12 feet above the stream channel. The natural drainage is poor, but artificial drainage channels along the larger streams and open laterals carrying the water from the upland drainage courses have greatly improved the drainage conditions of the type. Occasionally crops are damaged on the type, because of the slow removal of water after rains.

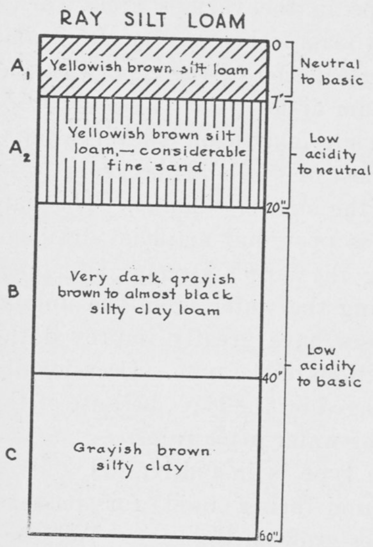
Most of the type is in cultivation, only a small proportion being used for pasture. Few or no trees grow on the type. Wild hay is cut from some of the more poorly drained areas with average yields of 2 tons per acre. Corn is the main crop grown and yields from 40 to 50 bushels per acre. Small grains are grown to a limited extent as these crops are apt to lodge in wet seasons. Alfalfa does very well when grown on well-drained areas after the soil is limed, but it is not grown at all extensively.

The Wabash silty clay loam is chiefly in need of drainage. It must be handled carefully when plowed and cultivated to prevent clodding and baking. It is acid in reaction and must be limed, especially for sweet clover and alfalfa. It will be benefited by a small application of farm manure, but large amounts of this material should not be employed. Small amounts will stimulate the production of available plant food, especially on newly drained areas. The use of a phosphate fertilizer would also prove of value, and tests of superphosphate and rock phosphate are advised.

Ray Silt Loam (195) (R1)

The Ray silt loam is a minor type in the county, covering only 0.1 percent of the total area. It occurs in a few small areas ranging in size from 5 to 30 acres, along the lower course of the Boyer River. There is also a small area 3½ miles northeast of Denison along the East Boyer River.

The surface soil of the Ray silt loam is a grayish-brown or yellowish-brown smooth silt loam to a depth of 7 inches. From 15 to 22 inches, the soil is a grayish-brown silt loam containing some fine sand washed in from the adjacent drift uplands. The lower subsoil is a very dark grayish-brown or almost black silty clay loam or heavy silt loam. The light colored surface and subsurface layers vary widely in texture, ranging from a buff fine powdery silt loam to almost a silty clay loam. The soil has been formed by the wash from the hill slopes carried down into the bottomlands by the tributary streams and deposited in layers in the lower spots and depressions



and along the smaller drainage lines over the darker Wabash soils of the main bottoms.

Most of the Ray silt loam is farmed with the adjoining Wabash soils, but crop yields are lower than on the typical Wabash silt loam. The drainage of the surface soil is good, but there may be a rather slow drainage through the soil because of the heavy subsoil. The soil needs, especially, additions of organic matter to make it more productive. Applications of farm manure would be of large value. The turning under of legumes as green manures would also help. The type may need lime for the best legume growth as it is apt to be acid in reaction. The use of a phosphate fertilizer would certainly help, and tests of superphosphate are urged.

APPENDIX

THE SOIL SURVEY OF IOWA

What soils need to make them highly productive and to keep them so, and how their needs may be supplied, are problems which are met constantly on the farm today.

To enable every farmer to solve these problems for his local conditions, a complete survey and study of the soils of the state has been undertaken, the results of which will be published in a series of county reports. This work includes a detailed survey of the soils of each county, following which all the soil types, streams, roads, railroads, etc., are accurately located on a soil map. This portion of the work is being carried on in cooperation with the Bureau of Soils of the United States Department of Agriculture.

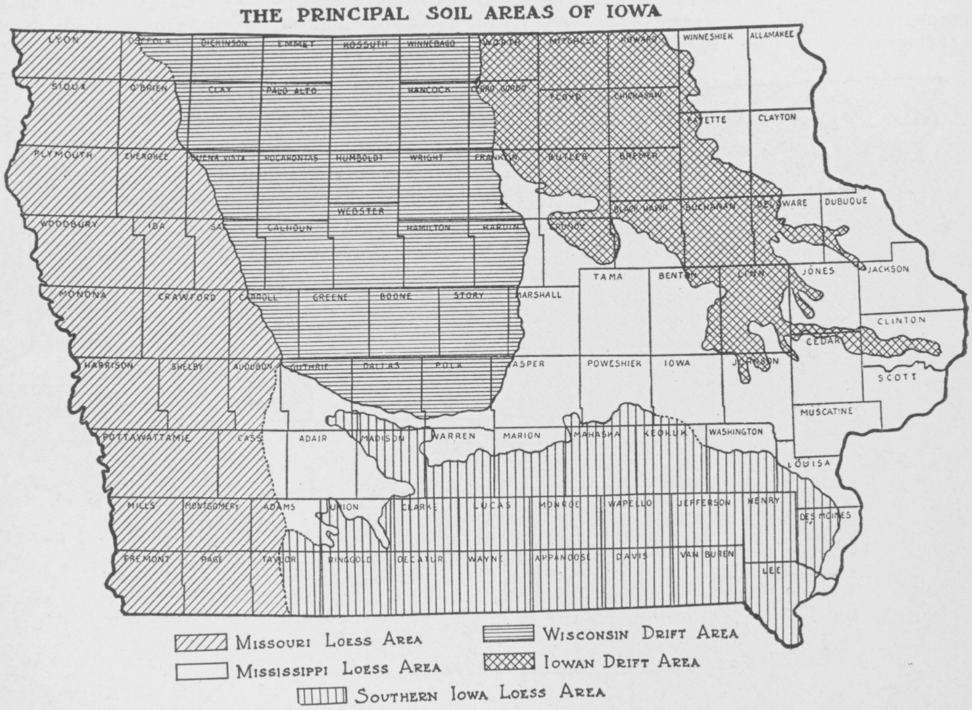
Samples of soils are taken and examined mechanically and chemically to determine their character and composition and to learn their needs. Pot experiments with these samples are conducted in the green house to ascertain the value of the use of manure, fertilizers, lime and other materials on the various soils. These pot tests are followed in many cases by field experiments to check the results secured in the greenhouse. The meagerness of the funds available for such work has limited the extent of these field studies, and tests have not been possible in each county surveyed. Fairly complete results have been secured, however, on the main types in the large soil areas.

Following the survey, systems of soil management which should be adopted in the various counties and on the different soils are worked out, old methods of treatment are emphasized as necessary or their discontinuance advised, and new methods of proved value are suggested.

SOIL AREAS IN IOWA

There are five large soil areas in Iowa, the Wisconsin drift, the Iowan drift, the Missouri loess, the Mississippi loess and the Southern Iowa loess. These five divisions of the soils of the state are based on the geological force which brought about the formation of the various soil areas.

THE PRINCIPAL SOIL AREAS OF IOWA



Map showing the principal soil areas in Iowa.

With the exception of the northeastern part of the state, the whole surface of Iowa was in ages past overrun by great continental ice sheets. These great masses of ice moved slowly over the land, crushing and grinding the rocks beneath and carrying along with them the material which they accumulated in their progress. Five ice sheets invaded Iowa at different geological eras, coming from different directions and carrying, therefore, different rock material with them.

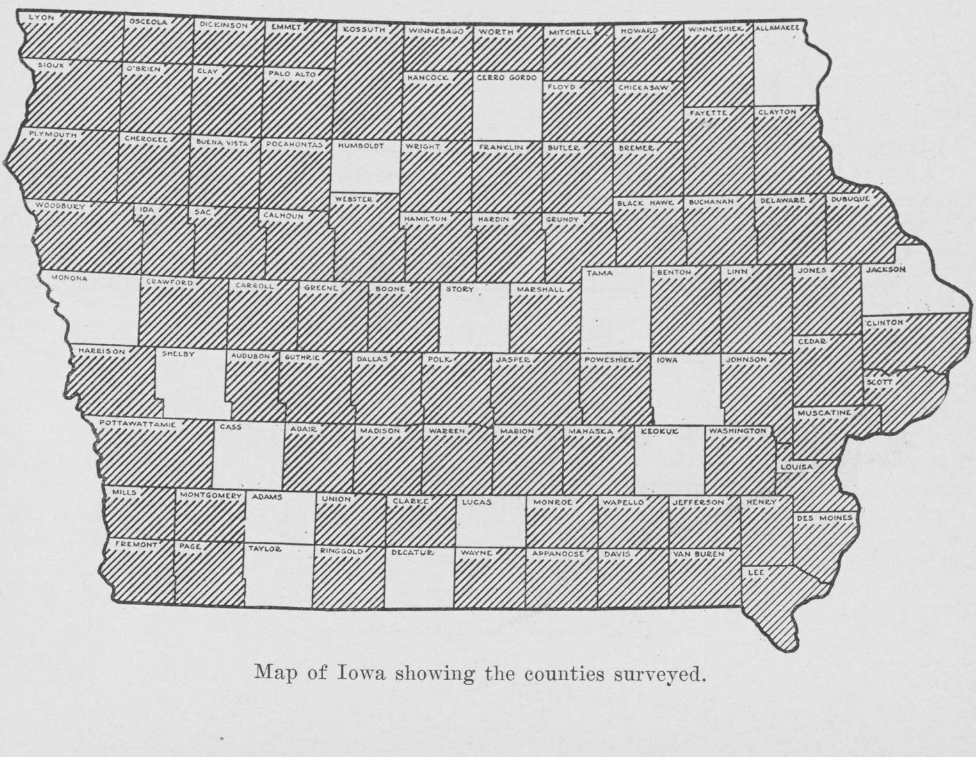
The deposit, or sheet of earth debris left after the ice of such glaciers melts, is called "glacial till" or "drift" and is easily distinguished by the fact that it is usually a rather stiff clay, containing pebbles of all sorts as well as large boulders of "nigger heads." Two of these drift areas occur in Iowa today, the Wisconsin drift and the Iowan drift, covering the north central part of the state. The soils of these two drift areas are entirely different in chemical composition, due primarily to the different ages of the two ice invasions. The Iowan drift was laid down at a much earlier period and is somewhat poorer in plant food than the Wisconsin drift soil, having undergone considerable leaching in the time which has elapsed since its formation.

The drift deposits in the remainder of the state have been covered by so-called loess soils, vast accumulations of dust-like materials which settled out of the air during a period of geological time when climatic conditions were very different from the present. These loess soils are very porous in spite of the fine texture, and they rarely contain large pebbles or stones. They present a strong contrast to the drift soils, which are somewhat heavy in texture and filled with pebbles and stones. The three loess areas in the state, the Missouri, the Mississippi and the Southern Iowa, are distinguished by differences in texture and appearance, and they vary considerably in value for farming purposes. In some sections the loess is very deep, while in other places the underlying leached till or drift is very close to the surface. The fertility of these soils and their needs are greatly influenced, therefore, by their depth.

It will be seen that the soils of the state may be roughly divided into two classes, drift soils and loess soils, and that further division may then be made into various drift and loess soils because of differences in period of formation, characteristics and general composition. More accurate information demands, however, that further divisions be made. The different drift and loess soils contain large numbers of soil types which vary among themselves, and each of these should receive special attention.

THE SOIL SURVEY BY COUNTIES

It is apparent that a general survey of the soils of the state can give only a very general idea of soil conditions. Soils vary so widely in character and composition, depending on many other factors than their source, that definite knowledge concerning their needs can be secured only by thorough and complete study of them in place in small areas. Climatic conditions, topography, depth and character of soil, chemical and mechanical composition and all other factors affecting crop production must be considered.



Map of Iowa showing the counties surveyed.

This is what is accomplished by the soil survey of the state by counties, and hence the needs of individual soils and proper systems of management may be worked out in much greater detail and be much more complete than would be possible by merely considering the large areas separated on the basis of their geological origin. In other words, while the unit in any general survey is the geological history of the soil area, in the soil survey by counties or any other small area, the unit is the soil type.

GENERAL SOIL CHACTERISTICS

Soil types possess more or less definite characteristics which may be determined largely in the field, although some laboratory study is necessary for final disposition. Usually the line of separation between adjoining soil types is distinct and it is a simple matter to locate the type boundaries. In some cases, however, there is a gradation from one type to another and then the boundaries may be fixed only with great difficulty. The error introduced into soil survey work from this source is very small and need cause little concern.

The factors which must be taken into account in establishing soil types have been well enumerated by the Illinois Experiment Station in its Soil Report No. 1. They are:

1. The geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial or cumulose.
2. The topography or lay of the land.
3. The structure or depth and character of the surface, subsurface and subsoil.
4. The physical and mechanical composition of different strata composing the soil, as the percentages of gravel, sand, silt, clay and organic matter which they contain.
5. The texture or porosity, granulation, friability, plasticity, etc.
6. The color of the strata.
7. The natural drainage.
8. The agricultural value based upon its natural productiveness.
9. Native vegetation.
10. The ultimate chemical composition and reaction.

The common soil constituents may be given as follows:†

Organic Matter	All partially destroyed or decomposed vegetable and animal matter.
Inorganic Matter	Stones—over 32 mm.* Gravel—32—2.0 mm. Very coarse sand—2.0—1.0 mm. Coarse sand—1.0—0.5 mm. Medium sand—05.—0.25 mm. Fine sand—0.25—0.10 mm. Very fine sand—0.10—0.05 mm. Silt—0.05—0.00 mm.

SOILS GROUPED BY TYPES

The general groups of soils by types are indicated thus by the Bureau of Soils.

Peats—Consisting of 35 percent or more of organic matter, sometimes mixed with more or less sand or soil.

Peaty Loams—15 to 35 percent organic matter mixed with much sand and silt and a little clay.

Mucks—25 to 35 percent of partly decomposed organic matter mixed with much clay and some silt.

Clays—Soils with more than 30 percent clay, usually mixed with much silt; always more than 50 percent silt and clay.

Silty Clay Loams—20 to 30 percent clay and more than 50 percent silt.

Clay Loams—20 to 30 percent clay and less than 50 percent silt and some sand.

Silt Loams—20 percent clay and more than 50 percent silt mixed with some sand.

Loams—Less than 20 percent clay and less than 50 percent silt and from 30 to 50 percent sand.

Sandy Clays—20 percent silt and small amounts of clay up to 30 percent.

Fine Sandy Loams—More than 50 percent fine sand and very fine sand mixed with less than 25 percent very coarse sand, coarse sand and medium sand, much silt and a little clay; silt and clay 20 to 50 percent.

Sandy Loams—More than 25 percent very coarse, coarse and medium sand; silt and clay 20 to 50 percent.

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* 25mm. equals 1 in. † Bureau of Soils Handbook.

Very Fine Sand—More than 50 percent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Fine Sand—More than 50 percent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent fine sand, less than 20 percent silt and clay.

Coarse Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent of other grades, less than 20 percent silt and clay.

Gravelly Loams—25 to 50 percent very coarse sand and much sand and some silt.

Gravels—More than 50 percent very coarse sand.

Stony Loams—A large number of stones over 1 inch in diameter.

METHODS USED IN THE SOIL SURVEY

It may be of some interest to state briefly the methods which are followed in the field in surveying the soils.

As has been indicated, the completed map is intended to show the accurate location and boundaries, not only of all soil types, but also of the streams, roads, railroads, etc.

The first step, therefore, is the choice of an accurate base map, and any official map of the county may be chosen for this purpose. Such maps are always checked to correspond correctly with the land survey. The location of every stream, road and railroad on the map is likewise carefully verified and corrections are frequently necessary. When an accurate base map is not available the field party must first prepare one.

The section is the unit area by which each county is surveyed and mapped. The distances in the roads are determined by an odometer attached to the vehicle, and in the field by pacing, which is done with accuracy. The directions of the streams, roads, railroads, etc., are determined by the use of the compass and the plane table. The character of the soil types is ascertained in the section by the use of the auger, an instrument for sampling both the surface soil and the subsoil. The boundaries of each type are then ascertained accurately in the section and indicated on the map. Many samplings are frequently necessary, and individual sections may contain several soil types and require much time for mapping. In other cases, the entire section may contain only one soil type, which fact is readily ascertained, and in that case mapping may proceed rapidly.

When one section is completed, the party passes to the next section and the location of all soil types, streams, etc., in that section is then checked with their location in the adjoining area just mapped. Careful attention is paid to the topographic features of the area, or the "lay of the land," for the character of the soils is found to correspond very closely to the conditions under which they occcur.

The field party is composed of two men, and all observations, measurements and soil type boundaries are compared and checked by each man.

The determinations of soil types are verified also by inspections and by consultation with those in charge of the work at the Bureau of Soils and at the Iowa Agricultural Experiment Station. When the entire county is completed, all section maps or field sheets are assembled and any variations or questionable boundaries are verified by further observations of the particular area.

The completed map, therefore, shows as accurately as possible all soils and soil boundaries, and it constitutes also an exact map of the county.