Series 1933, No. 34 Issued August 1940

# Soil Survey



# Audubon County Iowa

By
T. H. BENTON
Iowa Agricultural Experiment Station, in Charge
and
W. J. GEIB
United States Department of Agriculture

UNITED STATES DEPARTMENT OF AGRICULTURE
BUREAU OE PLANT INDUSTRY
In cooperation with the
Iowa Agricultural Experiment Station



y the SUPERINTENDENT OF DOCUMENTS, WASHINGTON, D. C. Price 3C cents

This soil survey is a contribution from

BUREAU OF PLANT INDUSTRY

E. C. AUCHTER, *Chief*

DIVISION OF SOIL SURVEY

CHARLES E. KELLOGG, *Principal Soil Scientist, in Charge*

IOWA AGRICULTURAL EXPERIMENT STATION

R. E. BUCHANAN, *Director*
P. E. BROWN, *in Charge Soil Survey*

Series 1933, No. 34 Issued August 1940

# SOIL SURVEY OF AUDUBON COUNTY, IOWA

By T. H. BENTON, Iowa Agricultural Experiment Station, in Charge, and W. J. GEIB, Soil Survey Division,[1] Bureau of Chemistry and Soils, United States Department of Agriculture

Area inspected by T. D. RICE, Inspector, District 3

United States Department of Agriculture, in cooperation with the Iowa Agricultural Experiment Station

CONTENTS

| | Page | | Page |
|---|---|---|---|
| County surveyed | 1 | Soils and crops—Continued | |
| Climate | 4 | Lindley loam | 22 |
| Agricultural history and statistics | 6 | Waukesha silt loam | 23 |
| Soil-survey methods and definitions | 10 | Judson silt loam | 24 |
| Soils and crops | 11 | Judson-Wabash silt loams | 24 |
| Marshall silt loam | 13 | Wabash silt loam | 25 |
| Tama silt loam | 15 | Land uses and agricultural methods | 26 |
| Tama silt loam, light-colored phase | 17 | Productivity ratings | 33 |
| Shelby silt loam | 18 | Morphology and genesis of soils | 36 |
| Shelby loam | 19 | Summary | 39 |
| Lindley silt loam | 21 | Map. | |

## COUNTY SURVEYED

Audubon County is in the west-central part of Iowa (fig. 1). It lies in the fourth tier of counties north of the Missouri State line, is the third county east of the Missouri River, and is about 70 miles west of Des Moines, the State capital. The eastern boundary of the county lies very near the divide between the drainage basins of the Mississippi and Missouri Rivers. The total area of the county, which includes 12 townships, is 443 square miles, or 283,520 acres.

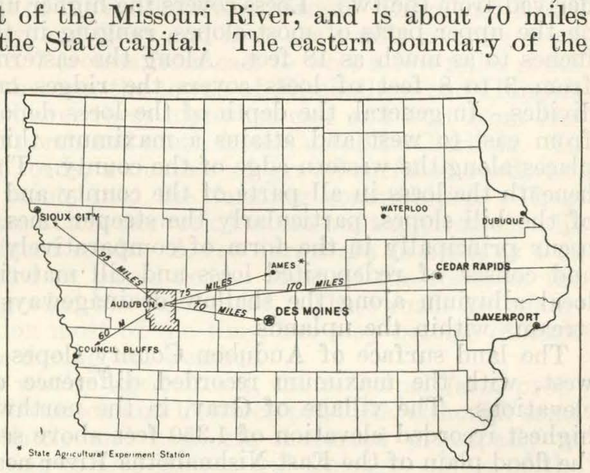



FIGURE 1.—Sketch map showing location of Audubon County, Iowa.

The county is part of a rolling to gently rolling plain, originally rather smooth, which has been moderately dissected by streams. Two rather distinct topographic divisions are represented, the gently rolling to rolling uplands and the flat comparatively narrow valleys of the streams. The relief ranges from undulating to sharply rolling, but most of the upland is charac-

[1] The Soil Survey Division was transferred to the Bureau of Plant Industry on July 1, 1939.

terized by a moderately rolling surface with rounded hills or ridge tops and long smooth slopes. Local relief of the land surface is greatest in the northeastern and west-central parts. The total area occupied by the rolling uplands far exceeds that of the stream valleys.

The master streams and their tributaries have penetrated every part of the uplands to form a dendritic drainage system. The largest stream within the county is the East Nishnabotna River, which enters near the middle of the northern boundary and flows in a general southerly direction, leaving the county 6 miles east of the southwestern corner. Its principal tributaries are Davids Creek, which enters the river near Exira, and Troublesome Creek, which crosses the southern boundary of the county and joins the river in Cass County. East Branch of the West Nishnabotna River drains the northwestern part of the county, including all of Lincoln Township, most of Douglas Township, and parts of Cameron and Leroy Townships. The Brushy Fork of the Raccoon River crosses the extreme northeastern corner of the county and with its tributaries drains about 18 square miles in Viola Township. Almost all of Audubon County lies within the drainage basin of the Missouri River, and by far the greatest part of it is drained by the East Nishnabotna River. Drainage waters from the eastern half of Viola Township in the northeastern corner of the county find their way to the Mississippi, by way of the Raccoon and Des Moines Rivers.

Soil parent materials within the county may be grouped in three classes: (1) Loess, which is probably Peorian; (2) glacial till, referred to the Kansan age; and (3) alluvial materials that were derived from the two. Loess covers the higher uplands and is present on the upper parts of most slopes, ranging in thickness from a few inches to as much as 18 feet. Along the eastern edge of the county from 3 to 8 feet of loess covers the ridges on the broad upland divides. In general, the depth of the loess deposit increases slightly from east to west and attains a maximum thickness of 18 feet in places along the western edge of the county. The Kansan till occurs beneath the loess in all parts of the county and is exposed on many of the hill slopes, particularly the steeper ones. Alluvial materials occur principally in the form of comparatively narrow flood plains and consist of redeposited loess and till materials. There is much local alluvium along the shallow drainageways of the intermittent streams within the uplands.

The land surface of Audubon County slopes gently to the southwest, with the maximum recorded difference of 141 feet between elevations. The village of Gray, in the northwestern part, has the highest recorded elevation of 1,350 feet above sea level; Brayton, on the flood plain of the East Nishnabotna River near the southern edge, has an elevation of 1,209 feet; Audubon, 1,299 feet; and Exira, 1,227 feet.[2] Nearly all of the county lies between elevations of 1,220 and 1,350 feet above sea level.

The first settlement in the territory now included in Audubon County was established in 1851, in the southeastern part near the Cass-Audubon boundary. The county was organized in the same year, and a survey of the townships was started. The first county

---

[2] GANNETT, HENRY. A DICTIONARY OF ALTITUDES IN THE UNITED STATES. U. S. Geol. Survey Bul. 274, ed. 4, 1072 pp. 1906.

seat was established at a town named Dayton, in the southern part of the county, in 1855. In 1866 the county seat was moved to a locality that is now the town of Exira, and later, in 1879, it was moved to Audubon, where it is now located.

The population of the county, as reported by the United States census in 1930, was 12,264, all classed as rural, of which 8,043 were classed as farm population and 4,221 as nonfarm. People of Danish and German extraction were most numerous, followed by those of Swedish, Irish, and Scotch descent. Danes settled the southwestern part of the county and have since spread to other parts. People of German descent located chiefly in the southeastern and northwestern parts. Audubon, the county seat, is the largest town, with a population of 2,255, followed by Exira, which has 937 inhabitants. Kimballton, in the southwestern part of the county, has 378 inhabitants. Other towns and trading centers with a population of less than 250 are Gray, Brayton, Viola Center, Fiscus, Ross, and Hamlin. In 1935 the total number of people living on farms was 7,977.

Railway transportation is furnished by branch lines of two railways that extend into the county. Branches of the Chicago, Rock Island & Pacific Railway and the Chicago & North Western Railway reach Audubon, the former extending north from Atlantic, the latter south from Carroll. Railway shipping points on these two lines include Audubon, Brayton, Exira, Gray, Hamlin, and Ross.

Paved highways cross the county from north to south and from east to west. United States Highway No. 71 runs straight south to Audubon, then parallels the railway to the southern boundary to a point about 5 miles east of the southwestern corner. Exira and Brayton are on this highway, and Gray and Ross are a mile or more from it. State Highway No. 7 crosses from east to west a few miles south of Audubon, passing through the towns of Kimballton and Hamlin. Bus service is provided over these highways east and west from Des Moines to Omaha, and north and south from Carroll to Clarinda. In addition to the paved roads, a number of gravel-surfaced roads extend from shipping points into the farming communities. These roads do not as yet form a close network, but most of the farms now lie within 3 miles of surfaced roads. A few farms are as much as 4 or 5 miles from a graveled or paved road. Most of the roads in the farming districts are graded but unsurfaced. These roads are maintained in good condition most of the time, but may become difficult to travel or impassable during wet weather.

Audubon County is wholly agricultural, the principal farm products sold consisting of livestock and livestock products, although some grain is marketed. Cattle and hogs are marketed principally at Omaha, with a few going to Des Moines and Chicago. Most of the livestock shipped to Omaha and Des Moines are hauled by truck. A large creamery at Exira manufactures butter and operates an extensive cream route over the county, collecting cream at many of the farms. Elevators at Audubon, Exira, Brayton, Gray, and Ross receive grain from the local communities, and a canning factory at Audubon provides a local market for sweet corn.

Telephone lines and rural mail routes reach every part of the county, and power lines furnish electricity to a number of farms. Rural schools are located at about 2-mile intervals and are accessible to all farm homes, and graded schools and high schools are in many of the towns and villages. Churches are located in most of the towns, and a few have been built in the rural communities.

Drilled or dug wells serve as a source of water for most of the farms, and good water can be obtained over the entire county. On the higher uplands drilled wells, ranging from 100 to 200 feet in depth, supply water for household purposes and for livestock. Most of the dug wells are from 10 to 30 feet deep and are either at the heads of drainageways or in the lowlands along the stream courses. There are a few springs at the bases of slopes bordering the bottom lands, which supply water for livestock. Windmills are used to furnish power to pump water from wells on many farms, especially where drilled wells furnish the water. A few farms have water piped to the house and barns from partly buried concrete tanks on hilltops near the farm home. On such farms, water usually is pumped to the tanks by means of power supplied by windmills.

According to the 1935 United States census report, the average value of farm land in the county was $79.70 an acre. A few very well improved farms in especially good locations sold for as much as $150 an acre in 1935 and 1936.

## CLIMATE

The climate of Audubon County is continental, with characteristically cold winters and warm summers. Rain falls chiefly during the growing season when the temperatures are highest, although appreciable quantities of precipitation fall during the cooler months.

The mean annual temperature is 47.4° F., but the range between winter and summer temperatures is rather wide. The mean temperature for the summer months of June, July, and August is 71.2° and for the winter months 21.1°. The recorded minimum and maximum temperatures are −35° in February and 105° in both July and August. The average frost-free season covers a period of 154 days, the average date of the last killing frost being May 3 and that of the first October 4. The latest recorded killing frost occurred on May 26 and the earliest on September 12. Field work ordinarily begins before the last killing frost in spring and continues for some time after the first killing frost in the fall. The grazing season, averaging about 180 days, ordinarily is longer than the frost-free period.

The average annual precipitation, as recorded at Audubon, is 30.87 inches, slightly more than one-half of which falls during the growing season. The precipitation during summer may be in the form of gentle rains or in short heavy showers associated with thunderstorms. The gentle long-continued rains ordinarily cover rather large areas, whereas the thundershowers are local, usually occurring after abnormal heat. The more gentle rains, associated with gray overcast skies, are more beneficial to the crops. At times, hail accompanies the thundershowers and damages crops over areas a mile or two wide and several miles long.

Spring rains occasionally delay planting but seldom long enough to prevent maturing of the corn before the first killing frosts occur.

Similarly, fall rains may interfere with corn picking, but the weather in October and November usually allows the drying and early harvesting of the corn crop.

Periods of drought during the growing season generally are short, but in some years they are long enough to cause severe damage to crops and pastures. Damage to crops and pastures is most severe on the slopes and hilltops, which are exposed to hot winds from the southwest. Yields of corn and small grains in such places may be reduced to very low figures by hot dry spells accompanied by high winds.

The prevailing winds are westerly, from the southwest in summer and from the northwest in winter. Situated as it is, in the area of the midlatitude cyclones, however, Audubon County experiences winds from all directions. Ordinarily, the hot dry winds in summer are from the southwest. In winter, occasional strong winds from the north or northwest cause severe snowstorms or blizzards. These storms are not common, but occasionally they cause traffic to be suspended on rural and main highways for a day or two.

Table 1, compiled from the records of the United States Weather Bureau station at Audubon, located near the geographical center of the county, gives the normal monthly, seasonal, and annual temperature and precipitation. These data may be considered fairly representative for the county as a whole.

TABLE 1.—*Normal monthly, seasonal, and annual temperature and precipitation near Audubon, Audubon County, Iowa*

[Elevation, 1,297 feet]

| Month | Temperature | | | Precipitation | | | |
|---|---|---|---|---|---|---|---|
| | Mean | Absolute maximum | Absolute minimum | Mean | Total amount for the driest year (1930) | Total amount for the wettest year (1909) | Snow, average depth |
| | °F. | °F. | °F. | *Inches* | *Inches* | *Inches* | *Inches* |
| December | 23.2 | 60 | −26 | 0.94 | 0.39 | 1.56 | 6.0 |
| January | 18.1 | 60 | −34 | .91 | .97 | 3.17 | 7.3 |
| February | 21.9 | 68 | −35 | 1.13 | .43 | 2.08 | 7.9 |
| Winter | 21.1 | 68 | −35 | 2.98 | 1.79 | 6.81 | 21.2 |
| March | 34.0 | 89 | −12 | 1.42 | .77 | 1.65 | 5.2 |
| April | 48.0 | 90 | 11 | 2.60 | 1.55 | 2.72 | 1.5 |
| May | 59.4 | 94 | 20 | 3.83 | 2.87 | 4.03 | .3 |
| Spring | 47.1 | 94 | −12 | 7.85 | 5.19 | 8.40 | 7.0 |
| June | 68.6 | 99 | 35 | 4.59 | 4.16 | 6.58 | .0 |
| July | 73.4 | 105 | 40 | 3.52 | .65 | 7.33 | .0 |
| August | 71.5 | 105 | 35 | 3.84 | 2.27 | .41 | .0 |
| Summer | 71.2 | 105 | 35 | 11.95 | 7.08 | 14.32 | .0 |
| September | 64.0 | 96 | 22 | 4.22 | .87 | 5.32 | .0 |
| October | 50.9 | 88 | 8 | 2.27 | 1.28 | 2.38 | .6 |
| November | 35.2 | 75 | −8 | 1.60 | 2.44 | 8.57 | 2.4 |
| Fall | 50.0 | 96 | −8 | 8.09 | 4.59 | 16.27 | 3.0 |
| Year | 47.4 | 105 | −35 | 30.87 | 18.65 | 45.80 | 31.2 |

## AGRICULTURAL HISTORY AND STATISTICS

Agriculture has been the principal occupation of the people of Audubon County since the first settlement in 1851. The first settlers brought with them cattle and horses, and the livestock obtained excellent grazing on the tall native grasses of the prairies. Strips of woodland, along the East Nishnabotna River and some of the larger creeks in the southwestern corner of the county, furnished fuel and lumber for the building of homes. Settlers came in rather slowly at first, the population being only 454 in 1860 and 1,212 in 1870. After the building of the branch line of the Chicago, Rock Island & Pacific Railway from Atlantic to Audubon in 1878, people began to come in more rapidly, the greatest influx taking place between 1880 and 1885.

Wheat, was, perhaps, the main cash crop of the early settlers, but it was soon superseded by corn. The total acreage in corn reached its peak in 1899 and has fluctuated slightly since that time. Acreages of the principal crops, as reported by the Federal census, for the years 1879 to 1934, inclusive, are shown in table 2.

TABLE 2.—*Acreage of the principal crops in Audubon County, Iowa, in stated years*

| Crop | 1879 | 1889 | 1899 | 1909 | 1919 | 1929 | 1934 |
|---|---|---|---|---|---|---|---|
| Corn: | *Acres* | *Acres* | *Acres* | *Acres* | *Acres* | *Acres* | *Acres* |
| Harvested for grain | 36, 985 | 88, 361 | 96, 995 | 93, 626 | 85, 029 | 91, 883 | 43, 599 |
| For silage, fodder, or hogged off | ------- | ------- | ------- | ------- | ------- | 5, 777 | 37, 936 |
| Oats: | | | | | | | |
| Threshed | 2, 871 | 37, 371 | 43, 055 | 34, 781 | 40, 160 | 50, 333 | 42, 821 |
| Cut and fed unthreshed | ------- | ------- | ------- | ------- | ------- | 479 | 1, 009 |
| Wheat | 20, 406 | 3, 251 | 26, 468 | 5, 798 | 12, 239 | 580 | 1, 309 |
| Rye | 104 | 586 | 125 | 36 | 127 | 197 | 271 |
| Barley | 584 | 7, 591 | 4, 025 | 9, 580 | 6, 117 | 4, 053 | 3, 681 |
| All hay | 6, 258 | 24, 187 | 30, 128 | 39, 318 | 23, 622 | 31, 738 | 24, 151 |
| Alfalfa | ------- | ------- | 20 | 71 | 1, 345 | 5, 415 | 10, 791 |
| Timothy and clover mixed | ------- | ------- | ------- | 34, 301 | 16, 649 | 14, 336 | 6, 987 |
| Clover alone | ------- | ------- | 3, 618 | 684 | 1, 137 | 10, 927 | 472 |
| Other tame hay | ------- | ------- | 19, 479 | 934 | 2, 815 | 466 | [1] 5, 901 |
| Wild grasses | ------- | ------- | 7, 011 | 3, 328 | 1, 676 | 594 | ------- |

[1] Includes wild grasses.

As can be seen in table 2, total acreages planted to cultivated crops have fluctuated but have not changed materially since 1890. Corn was the principal crop in 1879 and had reached an acreage approximating the present one by 1889. Oats had also reached the approximate present acreage by 1889. The total area sown to wheat has shown a tendency to decline since the earliest census, except for temporary increases in 1899 and 1919 during the Spanish-American and World War periods. In general, the proportionate acreages of the different crops have changed but little since the late eighties, when practically all of the land in the county had been settled and been taken up for farms.

Most of the farms are devoted to the raising and feeding of livestock. Corn, oats, and the hay crops are used as feeds, and only small quantities of the three crops are sold for cash. The number and value of livestock and poultry, and the value of dairy products, during census years, are given in table 3.

TABLE 3.—*Number and value of domestic animals, poultry and poultry products produced, and dairy products sold in Audubon County, Iowa, in stated years*

| Livestock | 1900 | | 1910 | | 1920 | | 1930 | | 1935 [1] |
|---|---|---|---|---|---|---|---|---|---|
| | *Number* | *Value* | *Number* | *Value* | *Number* | *Value* | *Number* | *Value* | *Number* |
| All cattle | 51,164 | | 45,099 | $1,141,905 | 42,526 | $2,372,518 | 43,165 | $2,544,031 | 46,255 |
| Swine | 99,494 | | 78,787 | 779,471 | 78,070 | 1,643,384 | 94,237 | 1,332,100 | 49,006 |
| Sheep | 2,961 | $2,595,773 | 7,573 | 41,027 | 5,409 | 66,923 | 11,699 | 94,088 | 10,893 |
| Horses | 11,922 | | 13,972 | 1,655,048 | 12,731 | 1,236,630 | 9,791 | 804,530 | 7,997 |
| Mules | 687 | | 474 | 67,963 | 607 | 77,164 | 831 | 77,677 | 690 |
| All poultry | 150,811 | 50,852 | 195,545 | 100,296 | 240,659 | 228,499 | [2] 282,889 | 231,969 | 248,989 |
| Animals sold and slaughtered [3] | | 1,139,302 | | 1,993,439 | | | | | |
| Dairy products sold [3] | | 176,005 | | 285,267 | | 247,288 | | 654,146 | |
| Poultry and eggs produced [3] | | [4] 77,232 | | 249,996 | | 590,490 | | 865,054 | |

[1] Value not reported.
[2] Chickens only.
[3] Figures for calendar year preceding each respective census.
[4] Poultry only; eggs not reported.

The total number of cattle has shown but little change during the last 50 years. Among the beef cattle raised, Herefords and Shorthorns greatly predominate, but small numbers of Aberdeen Angus are raised. In addition to the beef cattle raised on the farms, a number of feeders, weighing from 450 to 500 pounds each, are shipped in each year, put on pasture, then fattened and sold in the fall.

The sale of dairy products has become an important source of income, bringing in a maximum of $654,146 in 1929. Dairy products are marketed chiefly in the form of cream, which is sold locally. The average farm dairy herd consists of eight or nine cows, few of which are purebred animals but most of them good grades. Very few farms have herds composed entirely of purebred cattle, although purebred sires are used on many farms. Holstein-Friesian is the most popular breed of dairy cattle, followed rather closely by Milking Shorthorns, and there is also a small number of Guernseys. Only a very few farms are devoted exclusively to dairying, and these are near or immediately adjoining one of the towns.

The value of poultry and eggs in 1919 and 1929, respectively, according to the 1920 and 1930 Federal censuses, slightly exceeded that of dairy products sold, having reached $865,054 in 1929. Most of the poultry and poultry products marketed are sold locally. In general, the farm flocks include fowls of a mixture of breeds, although there is an increasing tendency to keep flocks consisting of only one breed. The most popular breeds of chickens are White Leghorn, Rhode Island Red, and Barred Plymouth Rock. In addition to chickens, a few other kinds of poultry are kept on farms, but their total numbers are relatively small.

Hogs are raised on nearly every farm, most farmers keeping 7 or 8 brood sows and raising from 30 to 40 pigs each year. Many farmers raise from 80 to 100 head, and a few as many as 200. Spotted Poland China and Chester White are the most popular breeds, followed by Hampshire and Duroc-Jersey. The total number of hogs on farms decreased sharply between 1930 and 1935, primarily because of the drought and consequent shortage of feed crops in 1934. According to the Iowa Yearbook of Agriculture for 1937, the number of hogs had not reached the 1930 level.

number of farms were sold at much lower figures. Relative prices depend upon a number of factors, such as the character o: soil, improvements, distance from market, and lay of the land.

Farm buildings on the whole are fairly good and generall clude a house, barn, corncrib, and a number of smaller build The barn, corncrib, and outbuildings are adequate for the ho of livestock and the storing of grain, except in years of unus large corn crops. In such years, surplus corn, which cann placed in permanent cribs, is stored in the open in slat or wire Practically all of the buildings are of wood construction and g ally are kept in a fair state of repair. On the better farms, buil are well painted and well maintained, but in the more rolling farm buildings are somewhat run-down.

Farm machinery includes such equipment as plows, disks, planters, cultivators, harrows, mowers, tractors, and corn pi Each farm ordinarily is equipped with such implements as p corn planters, cultivators, harrows, and wagons. Many farm have tractors, and the number of mechanical corn pickers h creased rapidly during the last few years. A number of the th ing outfits and mechanical corn pickers are owned cooperative several farmers or by a group of men.

Most of the farm work is performed by the farmer and his f but additional help was employed on 866 farms, or 47.5 perc the total number, in 1929, at a cost of $254,448, or $293.82 a fa porting. Prevailing wages for single men range from $25 t a month, plus meals and lodging when the men are employed l season. Married men receive about $45 a month, plus house, g space, and usually a cow. Laborers hired by the day during or harvesttime generally are paid from $2 to $3, plus meals and ing. Men who pick corn in the fall ordinarily receive from cents a bushel.

Considerable quantities of feed are purchased, in addition corn, oats, and hay grown on the farm. In 1929, 70.2 percent farms reported an expenditure of $508,601 for feed, or an aver $397.34 a farm reporting. The feeds purchased are used to s ment those grown locally.

Commercial fertilizers are used to only a very small extent cording to the 1930 Federal census, only $5,984 was spent fo lizer in 1929 on 78 farms, or an average of $76.72 a farm rep The fertilizer purchased was principally phosphate, which w for commercially grown sweet corn and on a few fields for le In addition to the phosphate, several carloads of lime are ship annually, most of which is used on Tama silt loam and ass soils in the eastern half of the county.

During recent years, with the organization of associations i township, much greater interest has been shown in soil impro Better practices for the maintenance of soil fertility and the of soil erosion are being demonstrated under Federal supervi three selected farms within the county. Methods of cultivatio as contour farming, strip cropping, and terracing, are demon on these farms. In addition, eight demonstrations on the use o analysis phosphate fertilizers are in progress on selected far ated on the predominant soil types.

Little forest now remains in the county. The largest areas are along the streams in the southeastern quarter. The remaining trees are chiefly oak, elm, hickory, cottonwood, and willow, with a few each of wild crab apple, cherry, and plum. Few of these trees are fit for lumber, but they can be used for cordwood or for fence posts. According to the 1930 Federal census, forest products either sold or used on farms in 1929, consisting primarily of cordwood and posts, were valued at $21,671. The census of 1935 reported an income of only $200 from the sale of all forest products in 1934.

Trees have been planted on many of the farms and now comprise groves and windbreaks scattered over the entire county. The groves around the farmsteads include principally elms, boxelders, a few cottonwoods, and maples, with an occasional fir, cedar, pine, and spruce. Most of them are located on the north and northwest sides of the buildings so as to protect the buildings from the prevailing winter winds. Many of the older groves were set out 50 or 60 years ago and are now being replaced, as the severe droughts of 1934 and 1936 killed many of the older trees, especially the maples.

## SOIL-SURVEY METHODS AND DEFINITIONS

Soil surveying consists of the examination, classification, and mapping of soils in the field.

The soils are examined systematically in many locations; test pits are dug; borings are made; and exposures, such as those in road or railroad cuts, are studied. Each excavation exposes a series of distinct soil layers or horizons called, collectively, the soil profile. Each horizon of the soil, as well as the parent material beneath the soil, is studied in detail; and the color, structure, porosity, consistence, texture, and content of organic matter, roots, gravel, and stone are noted. The reaction of the soil [3] and its content of lime and salts are determined by simple tests.[4] The drainage, both internal and external, and external features, such as the lay of the land, are considered, and the interrelationships of soils and vegetation are studied carefully.

The soils are classified according to their characteristics, both internal and external, special emphasis being given to those features influencing the adaptation of the land for the growing of crops, grasses, and trees. On the basis of these characteristics, soils are grouped into mapping units, the three principal ones of which are series, type, and phase. At times, two or more soil types or phases may form such an intricate pattern that the individual soils cannot be indicated on the map and must be shown as a complex.

The most important of these groups is the series, which includes soils having genetic horizons similar in their important characteristics and arrangement in the soil profile and having been developed from a particular type of parent material. Thus, the series includes soils in which the profiles are essentially similar in the character and arrangement of the horizons, as determined by observations of color, structure, and other internal characteristics, and which have the same

[3] The reaction of the soil is its degree of acidity or alkalinity expressed mathematically as the pH value. A pH value of 7 indicates precise neutrality, higher values indicate alkalinity, and lower values indicate acidity.

[4] The total content of readily soluble salts is determined by the use of the electrolytic bridge. Phenolphthalein solution is used to detect a strong alkaline reaction.

natural drainage conditions and range in relief. The texture of the upper part of the soil, including that commonly plowed, may vary appreciably within a series. The soil series are given names of places or geographic features near which they were first found; thus, Marshall and Shelby are names of important soil series occurring in Audubon County.

Within a soil series there are one or more soil types, differentiated according to the texture of the upper part of the soil. The class name of the soil texture, such as sand, sandy loam, loam, silt loam, silty clay loam, and clay is added to the series name to give the complete name of the soil type. For example, Shelby silt loam and Shelby loam are two soil types within a single series. Except for the different textures of the surface layers, the two types have essentially the same internal and external characteristics. The soil type is the principal unit of mapping and, because of its specific character, is usually the soil unit to which agronomic data are definitely related.

A phase is recognized for the separation of soils within a type, which differ in some minor characteristic that has an important practical significance. Differences in relief, stoniness, and the degree of accelerated erosion frequently are shown as phases. For example, within the normal range of relief for a soil type, there may be parts that are adapted to the use of machinery and the growth of cultivated crops and other parts that are not, even though there may be no important differences with respect to the growth of native plants. In such an instance, the more sloping parts of the soil type may be segregated on the map as a sloping phase. Similarly, soils having differences in stoniness may be mapped as phases even though these differences are not reflected in the character of the growth of native plants.

The soil surveyor makes a map of the county or area, showing the location of each of the soil series, types, phases, and complexes in relation to roads, houses, streams, lakes, section and township lines, and other local natural and cultural features of the landscape.

## SOILS AND CROPS

The soils of Audubon County have developed under vegetation consisting principally of prairie grasses, and most of them are characterized by dark-colored surface soils, which grade slowly into the soil parent material beneath. The different soil types have developed from essentially three related kinds of parent material, namely, loess, glacial till, and alluvial materials derived from them. The soils are, with few exceptions, highly fertile and very productive for corn and the associated crops.

Two of the soil types, Marshall silt loam and Tama silt loam, cover more than 50 percent of the area of the county. Both have developed under grass vegetation on loess materials and are similar in many of their important characteristics. Both have dark-colored surface soils, which have resulted from the accumulation, under prairie grasses, of large quantities of organic matter. Both tend to be friable and readily penetrable by roots throughout their profiles. The principal difference between these two soil types is the occurrence, in general, of calcium carbonate in the lower layers of the Marshall soil and the absence of calcium carbonate in any part of Tama silt loam. Marshall silt loam occurs largely in the western half of the county and occupies gently rolling to strongly rolling relief, and a few small areas are too rough or too steep to be cultivated with ordinary machinery. Tama silt loam occupies the eastern half of the county and is commonly less rolling than the Marshall soil.

In addition to the Tama and Marshall soils, other well-drained Prairie soils within the county are Shelby loam, Shelby silt loam, Waukesha silt loam, and Judson silt loam. The Shelby soils are developed upon glacial till, whereas the Waukesha soil is on terraces and the Judson on alluvial fans. The Shelby soils have dark-colored upper layers, not quite so thick as the corresponding layers of Marshall silt loam or Tama silt loam, and the soils are somewhat less productive. The members of the Waukesha and Judson series are well drained, high in organic matter, and very productive. The Wabash and Wabash-Judson soils are similar in many of their characteristics to the Judson and Waukesha soils, but the former occur in the flood plains of the larger streams and the latter in upland drainageways. Both soils are slightly less well drained than are the Judson and Waukesha soils. The soils of both series have very thick dark-colored surface layers and are highly productive wherever natural drainage is adequate.

The Lindley soils have light-colored surface layers and are associated with the members of the Shelby series. They have been formed from the same glacial till as the Shelby soils, but, either through the influence of forest cover or of accelerated erosion and removal of the upper layers, the surface soil has become light in color. The Lindley soils, where they are cultivated, require careful management, in order to improve and maintain their productivity.

The agriculture of the county is centered around the raising and fattening of cattle and hogs, and the crops grown are used primarily as feed for livestock. Corn is the principal crop, followed by oats and hay, which are used as supplementary feed. The growing of these various crops allows the use of well-balanced rotations, but many of the farmers, particularly during the last few years, have not been able to do this and have simply grown corn and oats in alternate years. The growing of legumes more often in the rotation would be advisable, as it would help to maintain the fertility of the soils. Such legumes as red clover, sweetclover, or alfalfa can be grown on many of the soils without the use of lime, but the application of lime is essential on the Tama and associated soils in the eastern part of the county before alfalfa can be grown. The growing of more legumes will also aid in the control of erosion on the more rolling land. Particular farming practices, which apply to individual soil types, will be treated as each type of soil is discussed.

The soils of the county are described in the following pages, and the agricultural importance of each is discussed; their location and distribution are shown on the accompanying soil map; and their acreage and proportionate extent are given in table 5.

TABLE 5.—*Acreage and proportionate extent of the soils mapped in Audubon County, Iowa*

| Soil type | Acres | Per-cent | Soil type | Acres | Per-cent |
|---|---|---|---|---|---|
| Marshall silt loam | 101, 568 | 35.8 | Lindley loam | 1, 728 | 0.6 |
| Tama silt loam | 46, 080 | 16.2 | Waukesha silt loam | 1, 536 | .5 |
| Tama silt loam, light-colored phase | 19, 392 | 6.8 | Judson silt loam | 896 | .3 |
| Shelby silt loam | 22, 016 | 7.8 | Judson-Wabash silt loams | 28, 480 | 10.0 |
| Shelby loam | 3, 392 | 1.2 | Wabash silt loam | 40, 768 | 14.6 |
| Lindley silt loam | 17, 664 | 6.2 | Total | 283, 520 | |

**Marshall silt loam.**—Marshall silt loam is the predominant soil type, occurring chiefly in the western half and occupying an area of 158.7 square miles. This soil developed under tall-grass prairie vegetation, and remnants of the original grasses and flowers were observed in the few small virgin areas remaining. A few slopes are now covered with a scattered growth of trees of comparatively recent origin.

The Marshall soils have been formed from deposits of Peorian loess which overlie Kansan till in most places. The depth of the loess ranges from a few inches on the shoulders of the steeper slopes to as much as 18 feet in areas where dissection by streams and normal erosion have not been active. Where the covering of loess is thin, the soil that has developed differs from the normal Marshall soil and is mapped as Shelby silt loam. Ordinarily, the depth to glacial till in areas mapped as Marshall silt loam is greater than the length of a 36-inch soil auger, although a number of patches, too small to be shown on a small-scale map, have less than 36 inches of loess over the till. The transition from Marshall silt loam to Shelby silt loam is gradual in most places, and the boundary separating the two soils on the map is necessarily somewhat arbitrary. Boundaries must also be more or less arbitrary where Tama silt loam and Shelby silt loam lie adjacent to each other.

Where the relief ranges from undulating to gently rolling, the profile of Marshall silt loam, to a depth of 15 inches, consists of dark grayish-brown friable silt loam, which is almost black when wet. This grades through a transitional layer of brown or dark-brown silt loam, more or less uniformly stained with organic matter, into a lighter colored silty clay loam below a depth ranging from 18 to 22 inches. The silty clay loam layer is uniformly yellowish brown in the upper part but contains some dull-orange or rust-brown mottlings in the lower part. At or near a depth of 40 inches the soil material changes to pale-yellow or grayish-yellow silt loam, which in many places contains calcium carbonate or lime nodules. The depth to lime over the entire area mapped as Marshall silt loam is variable. In places visible effervescence with hydrochloric acid does not occur at a depth of 6 to 8 feet, whereas lime is present in some places from 6 to 12 inches below the surface. As a rule, calcium carbonate is present in the profile of Marshall silt loam within a depth of 5 feet.

Some variations in the profile have been observed in Marshall silt loam. The surface horizon, or dark-colored layer, differs considerably in thickness, ranging from only a few inches on the steeper hill slopes to as much as 15 or 16 inches on the undulating interstream divides. On the steeper areas the dark-colored layer apparently never was so thick as it is on the undulating areas or gentle slopes. Furthermore, part of the surface layer has been removed by accelerated erosion following cultivation of the steeper areas. At the foot of some slopes there is an accumulation of dark-colored silt loam material, which has been washed from the slopes above. These fanlike deposits merge gradually with the bottom land in many places, and where they are definite they are mapped in the Judson series. The change from the Marshall soil on the slopes above to the Judson soil on the local alluvial fans or terraces, which extend out into the bottom land, is very gradual, however, and in some places the deeper soil is included with the Marshall soil in mapping. Areas of Marshall silt loam on the steeper slopes are somewhat less productive than the gently undulating areas, which, in turn, are not so productive as the soil in areas bordering the Judson soil.

Soil mapped as Marshall silt loam 4 miles southwest and 2½ miles south of Audubon, on some narrow rounded divides, has a lighter colored surface layer than is typical. Otherwise the soil on these ridges is identical with Marshall silt loam in other parts of the county. These areas are somewhat less productive than typical Marshall silt loam because of their lower content of organic matter.

Most of the slopes in areas of Marshall silt loam are between 6 and 10 percent gradient, although they range from 4 percent to as much as 25 percent. In places where the slopes are very steep, the normal dissection of the land surface by streams has removed all the loess originally present, the glacial till is exposed, and the Shelby soils have formed. The relief of the Marshall soil everywhere is strong enough to provide adequate external drainage and in a few places allows excessive run-off. Internal drainage is good over the entire area occupied by this soil.

This soil is susceptible to erosion because of its relief, and this is particularly noticeable on the steeper slopes, where former methods of management of the soil have included the growing of a large proportion of intertilled crops. Wherever the soil has a slope exceeding 5 or 6 percent, it has been affected to some extent by sheet erosion, and gullies also may occur. There are light-brown spots on the steeper slopes in many fields, indicating that run-off and consequent erosion have been active. The soil material exposed on these eroded patches is low in content of organic matter, has less favorable structure for the growth of plants, and produces smaller crops. The more rolling areas, which are consequently more susceptible to erosion and require more careful management, are west of Audubon and in the southwestern part of the county. Smaller areas with distinctly rolling relief are scattered here and there over the county.

The removal of the surface soil of Marshall silt loam by erosion is not so serious a loss as it would be if the material in the lower part of the profile were much heavier in texture. The lower layers of the Marshall soil contain much smaller quantities of organic matter and nitrogen but have favorable texture and fair structure. As a rule, sweetclover and alfalfa can be grown successfully on the subsoil, and after a few crops of these legumes have been grown, fair yields of corn and the other grains can be produced.

The use of longer rotations with a smaller proportion of intertilled crops, contour cultivation and strip cropping on the steeper slopes, and the addition of organic matter in the form of barnyard or green manures will aid in reducing erosion on this soil. Wherever possible, slopes exceeding 15 percent should be seeded down permanently and used for hay or pasture. Similarly, waterways should be seeded to grass, to prevent the development of gullies in their channels and the extension of such gullies into the uplands.

Marshall silt loam is well adapted to the production of corn, oats, and the common hay crops. It has high natural fertility and good moisture-holding capacity and is readily workable. Corn yields obtained on this soil range from 25 to 75 bushels an acre, depending on the season and on the fertility and past management of the given field. Average yields of about 45 bushels an acre can be obtained from fields that have been well managed. Oats commonly follow corn in the rotation, and the yields obtained average about 35 bushels an acre, although on some of the better farms from 65 to 75 bushels are obtained in favorable seasons. Oats and barley, though the latter crop is grown less often, are used as nurse crops for sweetclover or alfalfa. In good years, yields of alfalfa are approximately 2½ to 3 tons an acre. This soil is particularly well adapted to the growing of legume crops because of the excellent drainage and the presence of lime in the lower part of the soil profile in many places. Sweetclover is used largely for pasture and ordinarily is left on the land 2 years. Very little permanent pasture is grown on this soil. Most of the pasture consists of sweetclover or red clover and timothy in rotation. Soybeans or Sudan grass are grown occasionally as an emergency hay or forage crop.

Rotations used on most farms consist of corn, oats, and clover, although on many farms where the land is less rolling a 4-year rotation of corn, corn, oats, and sweetclover is used. During the last few years, when a number of seasons have been abnormally dry, seedings of clover have failed and, consequently, a corn and oats rotation has been used on most farms.

**Tama silt loam.**—Tama silt loam occupies a total area of 72 square miles in the eastern half of the county. The largest bodies are in the townships of Viola, Audubon, Melville, and Greeley. Tama silt loam differs from Marshall silt loam in that only in a few places does it contain calcium carbonate within the profile.

Where the relief is slight, Tama silt loam consists of dark grayish-brown silt loam to a depth ranging from 10 to 15 inches, where it grades into brown or yellowish-brown friable silty clay loam. The soil remains friable throughout the entire soil mass but gradually changes toward a lighter color with increasing depth. A few iron stains and faint gray mottlings appear between depths of 36 and 40 inches and become numerous at lower depths.

In this county Tama silt loam has developed on loess which overlies Kansan till lying at a depth ranging from 3 to 8 feet. In a few places outcrops of till, too small to be shown on the soil map, occur in areas mapped as Tama silt loam, but glacial till normally lies at a depth of 30 or more inches. Where the layer of loess persists but is shallower than 30 inches, the soil is mapped as Shelby silt loam.

Two variations in the profile occur within areas mapped as Tama silt loam. Where the slopes become steeper, the thickness of the dark-colored surface soil decreases and may be as thin as 6 inches or even less in the more rolling areas. The thin surface layer may be due to a greater run-off of water during formation of the soil and the less active growth of native grasses or to accelerated erosion that has followed cultivation of the soil on the steeper slopes. Calcium carbonate, normally absent from the soil material of Tama silt loam, may be found in places in the subsoil of areas on the steeper slopes or ridges. Some areas are of small extent, however. Most of them occur in the form of irregular patches.

The entire soil mass of Tama silt loam is leached of carbonates where the relief ranges from undulating to gently rolling; whereas the Marshall soil generally contains calcium carbonate. The separation of the two soils is based on this distinction of the presence or absence of lime in the soil, but in the field their separation is extremely difficult because of the many characteristics the soils have in common. The change from one soil type to another is gradual rather than abrupt; consequently, boundary lines are drawn in the transitional zone between the two soils and may be arbitrarily placed.

Where the slopes are long and gentle, Tama silt loam is gently rolling to rolling. Low hills with gently rounded tops are numerous, and only a few divides are nearly flat. The slopes range from 3 to 12 percent, with most of them about 6 percent and very few exceeding 10 percent.

A branching network of drainageways is well developed within areas of Tama silt loam, providing adequate external drainage; and the soil material is comparatively permeable, allowing very good internal drainage. Much of this soil has been affected to some extent by accelerated erosion. On the steeper slopes the dark-colored surface layer has in some places been entirely removed; in other places its thickness has been reduced by sheet erosion so that some subsoil is now included within plow depth. A few gullies have formed, but most of them are shallow, very few being more than 3 feet deep, and most of them range from 2 to 6 inches in depth. Shallow gullies are formed in unprotected fields by the late fall and early spring rains, but these are plowed in each year and the deeper gullies are widely separated.

Practically all of this soil is under cultivation. It can be worked early in the spring, has excellent moisture-holding capacity, and is free of stones and boulders.

Corn is grown extensively, but the yields differ widely, depending on the season and the previous cropping history. Where the soil has been well managed, yields ranging from 50 to 60 bushels an acre may be obtained in favorable seasons and as high as 80 or 90 bushels in extremely good years. Where little effort has been made to maintain the fertility and favorable physical condition of the soil, yields of 25 to 30 bushels are more common. In seasons of severe drought extremely low yields, many falling below 5 or 10 bushels, result. Severe droughts are not common, and even in the most unfavorable years some corn will grow on the protected slopes.

Oats rank next in importance to corn in acreage. The average yield of oats is about 36 bushels an acre, but in favorable seasons yields ranging from 45 to 60 bushels are not uncommon. Hot winds at the time oats mature greatly reduce the yields, and damage from this cause is especially heavy on the upper parts of slopes that face the south and southwest.

A mixture of red clover and timothy is the principal hay crop grown on Tama silt loam, although alfalfa and sweetclover are grown to some extent. The total acreage in hay, mainly mixed clover and timothy, is approximately three-fifths of that of oats. Yields of clover and timothy or of red clover alone range from 1 to 2 tons an acre in normal years. Alfalfa generally is grown in 5- to 10-acre patches, and the yields obtained range from 2½ to 3½ tons an acre. The various hay crops commonly are sown with oats, which act as a nurse crop for the legume. Liming Tama silt loam is necessary in most places if legumes are to be grown successfully, and inoculation of the seed is desirable.

Barley is grown on a small acreage, approximately 10 or 12 percent of that of oats. The grain is used largely for feed, and some is sold for malting purposes. Other crops, such as rye, wheat, millet, Sudan grass, and sorghums, are grown on very small acreages, the acreage varying with the season. Rye and Sudan grass are commonly used as emergency pasture. Soybeans also are grown to a small extent, but the crop is not well adapted to the rolling areas of this county and can be grown successfully in only a few places. The cultivation of soybeans promotes erosion on the more rolling land and, consequently, they must be sown only on the smoother areas.

Longer crop rotations, including seedings of legumes and keeping the land in legumes for a period of time, plus the addition of barnyard manure, will assist in maintaining the productivity of Tama silt loam. The soil in many places will benefit from the addition of lime, particularly where legumes are to be grown. The growing and turning under of red clover or sweetclover systematically will tend to maintain the content of organic matter within the soil. Phosphatic fertilizers have been used to a very small extent on this soil, chiefly superphosphate, applied where sweet corn is grown commercially. The use of both lime and phosphate has shown fair returns on experimental fields of the Iowa Agricultural Experiment Station, and the experiments indicate that crops respond to both lime and phosphate but more markedly to applications of barnyard manure.

**Tama silt loam, light-colored phase.**—The light-colored phase of Tama silt loam generally occupies more rolling areas than the typical soil and, as its name indicates, is somewhat lighter colored, particularly in the surface layers. The upper horizon of the light-colored soil is dark grayish-brown or brown silt loam to a depth ranging from 5 to 8 inches, where it grades into yellowish-brown silty clay loam, somewhat mottled with rust-brown or dull-orange stains. The soil material shows little change in texture throughout its entire depth, the principal change being the decrease in the content of organic matter with increasing depth and the resulting lighter color of the material in the lower horizons. On the slopes leading down to the larger creeks in the southeastern part of the county, a few small groves of trees, principally oaks, are growing on areas of the light-colored phase of Tama silt loam. In such places the material in the upper horizons is somewhat lighter colored than in other parts of the eastern half of the county.

The slopes, in general, are more pronounced on the light-colored phase than on typical Tama silt loam. They range in gradient from 5 to 16 percent, a few being steeper, with the dominant slope probably between 7 and 10 percent. As a result of the steeper slopes, external drainage on this soil ranges from good to excessive. Internal drainage is adequate.

This light-colored phase of soil is more susceptible to erosion than that of typical Tama silt loam, principally because of the steeper slopes on which it occurs. The steeper slopes promote more rapid run-off, which, in turn, results in greater erosion. Damage through sheet erosion, where it occurs, becomes evident sooner on the light-colored Tama soil because the surface horizon is rather thin. Small gullies are more numerous on this soil than on Tama silt loam, and some gullies on the steeper slopes range from 3 to 4 feet in depth.

Practically all of this soil is farmed. It produces crop yields somewhat below those obtained on typical Tama silt loam. All the common farm crops, including corn, oats, and hay, are grown, in practically the same order as is followed on the other soils of the upland, although some farmers grow fewer intertilled crops in the rotation on the light-colored Tama soil.

The use of measures for the control of erosion is more necessary on the light-colored phase of Tama silt loam and should include longer rotations of suitable crops, strip cropping and contour cultivation on steeper slopes, and the retirement of the steepest areas and the waterways from cultivation. Rotations should include smaller proportions of intertilled crops and larger proportions of legumes, which should stay on the land for longer periods of time. The plowing under of legumes as green-manure crops would be distinctly beneficial, and the addition of barnyard manure would aid greatly in maintaining the content of organic matter. Most of the areas of this soil would be benefited by the application of lime, but the soil on a few of the steeper slopes contains lime near the surface. The farmer should determine the lime requirement of any particular field before applications of lime are made.

**Shelby silt loam.**—Soils of the Shelby series are extensively developed on the slopes leading down to streams and drainageways in the rolling parts of the county. The two members of the Shelby series, Shelby loam and Shelby silt loam, occur in all the townships and are fairly extensive, except in the north-central and northwestern parts of the county. Shelby silt loam commonly occurs where a thin covering of loess overlies the gritty clay loam of the glacial till, whereas Shelby loam is developed where the loess materials are entirely or almost absent. The total area occupied by Shelby silt loam is 34.4 square miles.

The surface soil of Shelby silt loam, to a depth of about 12 inches, is dark grayish-brown friable silt loam containing appreciable quantities of very fine sand. This grades into yellowish-brown friable clay loam that is somewhat darkened by organic matter. Below a depth of 18 or 20 inches the soil is normally lighter in color, although in places it is reddish brown rather than light yellowish brown. In places, the lower part of the profile consists of heavy gray clay, probably Kansan gumbotil. Glacial gravel and boulders are commonly present throughout the soil mass, but they become more numerous with increasing depth. The upper layers of the soil have been leached free of carbonates and are acid, whereas in a few places streaks and splotches of calcium carbonate may be present in the lower layers.

The thickness of the surface layer of Shelby silt loam differs from place to place, depending on the steepness of the slope occupied by the soil. On the more rolling land or steeper slopes, the surface layer may be very thin or entirely absent, but on some smooth slopes it may be thicker than normal. Small areas with a loam texture have been included with Shelby silt loam in mapping; all are too small to be mapped separately, and some are simply badly eroded spots on hillsides consisting predominantly of Shelby silt loam.

The slopes on which Shelby silt loam occurs range from 3 to 18 percent, with most of them between 5 and 12 percent. A considerable number of the hill slopes are greater than 12 percent, however, and a small number are less steep than 5 percent. Natural drainage is excessive over much of this soil because of the rolling relief. Much of the Shelby soil has been subjected to severe sheet erosion, partly because of the slopes that it occupies and partly because of the less permeable character of the glacial till underlying the lower part of the soil. The combination of the steep slopes and the less permeable underlying material make this soil readily susceptible to erosion, and consequently, wherever Shelby silt loam is to be cultivated, care must be taken in soil management so as to minimize damage to the soil.

Most areas of Shelby silt loam are cultivated in association with the adjoining Marshall or Tama soils. In most places, this soil occurs in a band around the slope, lying just below either the Tama or the Marshall soil on the ridge. The common crops of the section—corn, oats, and hay—are grown on this soil, and yields are slightly lower than those obtained on the Tama and Marshall soils. Corn yields in favorable seasons range from 30 to 45 bushels an acre but decrease sharply from these figures in seasons of low rainfall. The Shelby soils perhaps are better adapted to the production of small grains and hay crops than they are to corn. A number of the steeper areas are used for pasture, and some of the areas now under cultivation might well be put to the same use.

**Shelby loam.**—Shelby loam for the most part, occupies small narrow bands or disconnected areas on the sharper slopes, and it occurs in all parts of the county, commonly in close association with Shelby silt loam. Shelby loam occupies the steeper slopes on which all loess materials are absent and the glacial till is exposed, and the soil parent material is, therefore, glacial till alone or till plus a slight admixture of loess.

The surface soil of Shelby loam consists of dark-brown gritty loam extending to a depth of 6 or 8 inches, where it grades into grayish-brown clay loam streaked and slightly stained with organic matter.

Below a depth of 15 or 18 inches the soil material is yellowish-brown clay loam containing much coarse sand, some glacial gravel, and a few boulders. The amount of coarse material increases slightly with increasing depth. Lime, in the form of irregular splotches and small concretions, is present in places at a depth ranging from 30 to 60 inches. Shelby loam, as described, occurs on the more gentle slopes; on the steep slopes the depth of the surface layer is much less, and the carbonates may occur at or near the surface.

The yellowish-brown clay loam constituting the soil parent material, probably till of the Kansan glaciation, is absent in places from the lower part of the Shelby profile and is replaced by reddish-brown or gray clay. This heavier material generally is present at depths between 3 and 4 feet, and it corresponds, perhaps, to the Kansan gumbotil.

Along the boundaries between the Shelby and Marshall or Tama soils there is a zone of transitional soil, and this renders the placing of boundary lines somewhat arbitrary. In places, a narrow strip of Shelby silt loam lies just below the Marshall or Tama soils and is included with Shelby loam in mapping because of the difficulty of separating the small area.

Small areas of soil mapped as Shelby loam in sections 2 and 3 of Viola Township in the northeastern part of Audubon County join with areas of Carrington loam mapped just across the line in Carroll County. The profiles of these two soils are similar in many respects, both having developed under prairie conditions on glacial till. The soil parent materials of the Shelby soils are commonly the older tills of the Nebraskan or Kansan glaciation, whereas those of the Carrington soils are of the early Wisconsin glaciation. Because the total area of Carrington loam in Audubon County is very small, and because the two soils are similar in so many characteristics, the Carrington soil has been included with Shelby loam in mapping.

The slopes on which Shelby loam occurs range from 5 to 20 percent in gradient, probably most of them being between 7 and 10 percent. As a result of the comparatively steep slopes, run-off is commonly excessive, and the soils in their natural state have shallower surface layers than do the soils of the Tama or Marshall series.

Damage by sheet erosion is more widespread on Shelby loam than on Shelby silt loam and has affected much of the soil, particularly on the steeper slopes. A few small areas have been so thoroughly dissected by gullies that they have been abandoned for farming purposes, but these areas comprise only a small proportion of the total area of the soil. Gullies develop very rapidly on these steeper slopes, once they have started, and care must therefore be exercised in order to prevent formation of small new gullies and extension of the existing ones.

A large proportion of the total area of Shelby loam is in cultivation, and part of it is kept in pasture. Yields of crops obtained on the cultivated areas are somewhat lower than those obtained on Shelby silt loam, especially where the areas of the loam are steep or have been damaged by erosion. On the whole, Shelby loam is better adapted to the cultivation of small grains, hay crops, and pasture than to corn. Intertilled crops should not be grown more than once in a rather long rotation. Methods of cultivation, such as contour tilling and strip cropping and the seeding down of steep slopes and waterways, would help to decrease erosion and maintain soil productivity.

Because of the greater amount of run-off under natural conditions and the smaller quantities of water available for plant growth, the content of organic matter in Shelby loam is somewhat lower than in Shelby silt loam or in the Tama and Marshall soils. Shelby loam, therefore, could be improved materially for crop production by applications of farm manure or the plowing under of green-manure crops, especially legumes.

**Lindley silt loam.**—The largest areas of Lindley silt loam are in the western and southern parts of the county. This soil is a light-colored correlative of Shelby silt loam, the parent materials of the two soils being similar. The Lindley soils presumably were developed under forest cover, part of which remains in the southeastern part of the county.

The surface soil of Lindley silt loam is friable grayish-brown silt loam containing much very fine sand. At a depth of 10 inches the material in this layer grades into light yellowish-brown silt loam which is compact in place but rather friable when removed. At a depth of 16 or 18 inches the soil material is gritty yellowish-brown clay loam containing some coarse sand, rock fragments, and a few glacial boulders. The proportion of coarse material increases slightly with increasing depth.

Areas mapped as Lindley silt loam include a number of variations. In the southeastern part of the county little or no lime is apparent in the lower part of the soil mass, whereas in the west-central part effervescence occurs at the surface in some places and at a depth of 2 or 3 feet in many places. At a number of places in the western part of the county the surface layer is highly calcareous pale-yellow silt loam resembling the lower layers of the Marshall soils. On these highly calcareous spots on hillsides, crops burn rather badly during droughty periods. In addition to the variations in content of and depth to lime, the texture of the surface layer may vary also, approaching a loam in a number of spots, particularly on the steeper slopes. These areas are so small and so closely intermingled with those occupied by the typical soil that they could not be separated on the map.

Lindley silt loam commonly lies below the Marshall soils on slopes ranging from 6 to 16 percent or even steeper. Most of the slopes probably are between 8 and 10 percent. This soil occupies slopes leading down to the drainageways, especially where the land surface is distinctly rolling.

Much of the area of Lindley silt loam has been severely eroded, as the surface soil is loose and floury and washes rather easily. The subsoil resists cutting to a much greater degree than does the surface soil, but heavy rains rapidly deepen gullies that have once been started. Considerable gullying has occurred in some fields on the steeper slopes, and the depth of the gullies ranges from 3 to 6 feet.

A considerable proportion of this soil is in cultivation, probably less than one-half being kept permanently in grasses or forest. Yields of crops are considerably lower than those obtained on the Marshall or Tama soils on the smoother slopes and about equal to those obtained on Shelby loam. In favorable seasons, corn yields range from 20 to 35 bushels an acre and oats from 20 to 40 bushels, but in somewhat dry seasons, yields are greatly reduced.

In those areas where Lindley silt loam is cultivated, careful management must be practiced to keep the soil productive and to prevent erosion. The growing of green-manure crops, the addition of barnyard manure, and the plowing under of all crop residues are desirable practices to raise the level of fertility and to aid in maintaining an erosion-resisting soil structure. Of the various legumes, sweetclover can be grown without the application of lime on much of this soil in the western half of the county. Red clover and timothy will grow better than sweetclover in the extreme southeastern part, where the soil is acid. Most of this soil is better adapted to the growing of pasture grasses and trees than it is to cultivated crops, and it should be used for intertilled crops only where small areas must be included in large fields of the better soils.

**Lindley loam.**—Lindley loam occupies the steeper parts of the stream slopes, in close association with Lindley silt loam. Where Lindley loam is associated with the Tama soils in the southeastern part of the county, it apparently developed under a heavy forest-brush cover; where it is associated with the Marshall soils in the western part, it supported small patches of open forest, together with some brush, when the first settlers arrived.

The surface soil of Lindley loam consists of grayish-brown loam to a depth of 10 inches, below which it grades into light yellowish-brown gritty clay loam. At a depth of 16 or 18 inches the soil material becomes bright yellowish-brown or reddish-brown silty clay mottled with rust-brown iron stains, which increase in number with depth. The texture of the surface soil varies somewhat, partly because of the variation in the character of the glacial drift that formed the parent material and partly because of the removal of the surface soil and exposure of the heavier subsoil in a number of places. Although the lower part of the soil material of Lindley loam is predominantly yellowish brown, it has a somewhat red cast in many places, and in some places there are thin layers of gray clay in the subsoil. Coarse sand, some gravel, and a few boulders are scattered throughout the soil mass in almost all areas.

Lindley loam generally occupies somewhat steeper slopes than does Lindley silt loam. Most of the slopes range from approximately 10 to 15 percent in gradient, but some are as steep as 25 percent. Most of the steeper slopes are short and extend down into the stream valleys, but because of their steepness and the impermeability of the glacial till Lindley loam is subject to severe erosion.

Most of the areas of Lindley loam are kept in pasture or forest, but some small areas are cultivated. Yields of corn are lower than those obtained on Lindley silt loam. They range from 15 to 18 bushels an acre. Yields of other crops also are low, and the best practice is to maintain Lindley loam in pasture or in forest wherever possible. If the soil is cultivated, care must be practiced, in order to prevent erosion. Incorporation of quantities of organic matter through the use of green-manure crops, crop residues, and barnyard manure will aid in preventing erosion and in maintaining soil fertility. Where areas of this soil, ranging from as little as 1 to as much as 5 acres, have been severely gullied, the planting of trees, such as black locust, is recommended to retard further cutting of the gullies and thus prevent them from deepening and becoming larger. The productivity of this soil when used for pasture or for trees will exceed that which can be maintained under any system of cultivation.

**Waukesha silt loam.**—Waukesha silt loam has developed on comparatively smooth terraces, which occur principally along the East Nishnabotna River, but also along creeks in the southeastern and northwestern parts of the county. The total area is not large.

The surface soil consists of friable dark grayish-brown silt loam to a depth of 14 inches. Below this is a transitional layer of brown heavy silt loam ranging from 4 to 6 inches in thickness. At a depth of 18 or 20 inches the material is yellowish-brown silty clay loam, which is uniform in color and very friable. This soil contains no gritty materials to a depth of 6 feet or deeper. The texture of the surface soil is very uniform over most of the area occupied by Waukesha silt loam, although in a few depressed spots the soil is slightly heavier than a silt loam. In general, this soil is very similar to Marshall silt loam or Tama silt loam on the uplands.

The terraces, upon which Waukesha silt loam normally occurs, have a slight slope toward the streams and lie from 10 to 20 feet above the first bottoms. In a few areas the land is very gently undulating, but the slope is sufficient to provide fair, though not good, external drainage. Internal drainage is excellent because of the pervious character of the soil mass. This soil has a high moisture-retaining capacity and ability to provide moisture to crops; consequently, grains and corn are seldom injured by drought.

In the northwestern part of section 1, Viola Township, in the extreme northeastern part of the county, a small area that is not typical Waukesha silt loam is included with the latter in mapping, because of its small extent. The soil in question has a moderately heavy lower subsoil layer, and in Carroll County to the north it is mapped as Bremer silt loam. The profile resembles Waukesha silt loam in many ways, but the soil has slightly less adjequate natural drainage and is not quite so productive as the Waukesha soil unless it is artificially drained.

Erosion is not a serious problem on areas of Waukesha silt loam, because of the flat or gently undulating surface. In a few places, however, drainage waters from upland slopes have concentrated and have cut fairly deep channels through the terraces. The slopes along these channels have become seriously eroded, and precautions are necessary to prevent the extension of the gullies farther into the terraces or possibly even into the uplands. Permanent seeding of the banks of the channels and of a strip of land adjacent to the bank would check the present cutting and slope wash.

Waukesha silt loam is one of the most productive soils in the county, as it is mellow, easily tilled, and has excellent water-holding capacity. Corn is commonly grown on this soil for 2 successive years, followed by oats and a seeding of clover. As a rule, the soil is slightly acid, and lime should be applied before growing legumes. A 3-year rotation of corn, oats, and clover would be desirable, in that it would assist in maintaining the present organic-matter content. Management of this soil need not be so careful as that of

Shelby silt loam, Marshall silt loam, or Tama silt loam, because the soil occupies a more favorable topographic position and therefore is not so susceptible to erosion.

**Judson silt loam.**—Judson silt loam, in small isolated bodies ranging from 3 to 10 acres in size, is widely scattered along the large streams and their principal tributaries. It normally occupies disconnected strips at the base of slopes bordering the first bottoms. The soil material has originated largely as slope wash from upland soils at higher elevations and forms fan-shaped terraces with a slight slope toward the stream. These low fans or benches are affected by overflow only in periods of extremely high floods. The boundaries between the Judson and the Wabash soils of the first bottoms are necessarily arbitrary, as the two merge gradually and have no abrupt break or boundary. Judson silt loam is not extensive.

The surface soil of Judson silt loam is dark grayish-brown friable silt loam extending to a depth ranging from 22 to 26 inches. Below this depth the soil material is dark-gray or grayish-brown silt loam, less mellow and friable than the material in the surface layer. The entire soil mass of Judson silt loam consists of materials that were once formed in the surface horizons of the nearby upland soils. The soil is, therefore, highly fertile and very productive.

External drainage of Judson silt loam is adequate but not excessive, and internal drainage is fair. This soil is highly permeable, and water can move within the material very readily, but the moisture-holding capacity is very high. The soil readily furnishes water to growing plants.

Nearly all of Judson silt loam is under cultivation, and where the areas are large enough to be operated by themselves, corn is grown a number of years in succession. Corn yields range from 40 to 75 bushels an acre, depending on seasonal conditions. Oats produce well but are likely to lodge because of the high content of nitrogen in the soil. Hay crops grow luxuriantly, and a small proportion of Judson silt loam is maintained in bluegrass pasture. This soil is better adapted to the production of corn than to the production of small grains.

**Judson-Wabash silt loams.**—Judson-Wabash silt loams (intermingled) occupy the drainageways of intermittent streams in the upland in all parts of the county. Definite channels have not been formed by many of these streams, but low swales or shallow draws extend from the uplands toward the larger stream valleys. The soil materials within these upland intermittent streamways are primarily of local origin and consist chiefly of alluvium washed down from the adjacent slopes.

Surface drainage is excellent in most places, and internal drainage also is good because of the permeability of the soil material. In most places the land has a slight slope, ranging from 2 to 4 percent toward the stream in the upper courses, but in a few pockets natural drainage is not adequate. Tile is used in some of the more depressed and poorly drained areas and provides adequate artificial drainage. Untiled areas of this character are suitable only for pasture.

Judson-Wabash silt loams consist of dark grayish-brown silt loam to a depth ranging from 16 to 20 inches, where they grade into very dark gray silty clay loam. At a depth of 24 to 30 inches the soil material changes to dull yellowish-brown silty clay loam mottled with gray and brown. The surface soils are thickest near the base of the slope, where they attain a depth of 24 to 30 inches in places. The material of the lower horizons varies somewhat in color, ranging from dark gray, with numerous mottlings in some of the depressions, to the normal dark grayish-brown silty clay loam in the better drained areas. Judson-Wabash silt loams are mellow throughout the entire soil mass, have excellent moisture-holding capacity, and supply water readily to plants. The reaction of the soils in general is neutral or very slightly acid.

Practically all of the areas of these soils are now under cultivation or in pasture. Most of the areas are planted and cultivated with the soils on the adjacent slopes and upland divides, and they generally form only a small part of a field. Where well drained, these soils are, perhaps, the most productive soils in the county for corn, with yields ranging from 50 to 90 bushels an acre in favorable seasons. The level of fertility is very high, owing in part to the high content of organic matter. Small grains are apt to lodge because of the luxuriant vegetal growth resulting from the rather large content of nitrogen. The handling of areas of Judson-Wabash silt loams should include precautions to prevent development of gullies within the drainageways and to maintain the content of organic matter not far below its present level.

**Wabash silt loam.**—Wabash silt loam is extensively developed along the principal streams in this county. Many areas of this soil are subject to periodic overflow, but the floodwaters seldom cause serious damage to crops, as they usually remain on the land for only a few hours. The channels of the East Nishnabotna River in the central part of the county and of the East Branch of the West Nishnabotna River in the extreme northwestern part have been deepened and straightened so that they now carry away the floodwaters rapidly enough to eliminate flood damage almost entirely. In a few years floodwaters cover the entire bottoms, but this usually occurs before the crops are planted. In spite of these measures, damage from flood is still the principal hazard to crop production on Wabash silt loam. The soil is highly fertile and, in normal years, has a very favorable supply of moisture for the growing of corn and other grains.

The surface soil of Wabash silt loam is dark grayish-brown friable silt loam to a depth of 15 inches, below which the soil material is dark-brown or very dark gray silty clay loam. This changes, at a depth of 20 to 24 inches, to very dark gray or almost black heavy silty clay loam or silty clay, which grades into grayish-brown or gray silty clay at a depth ranging from 30 to 36 inches. Between depths of 36 and 40 inches the soil is highly mottled with iron stains. Neither the surface soil nor the material in the lower layers show effervescence with dilute acid.

Along the western side of the county, where Marshall silt loam is the predominant upland soil, Wabash silt loam of the bottoms is prevailingly neutral and in some places even slightly calcareous. Along the eastern edge of the county, however, where the bottoms are occupied by materials washed from Tama silt loam and other acid soils, Wabash silt loam is slightly acid, but even here none of it is strongly acid.

A number of textural variations are included in the areas mapped as Wabash silt loam. These variations are common in soils developed on alluvium because of the many different materials washed from the surrounding uplands. In this county the alluvial materials have been derived both from loess and from glacial till, so that particle sizes range from coarse sand to fine clay. Near the base of upland slopes leading down to the flood plain or where small streams have formed alluvial fans out on the bottoms, the soil materials are more sandy, whereas the reverse is true in the swales and small depressions generally well back from the stream channels. Within the swales the soil in some places may have a silty clay loam or silty clay texture. In a few places on the bottoms light-colored silty material, ranging from 2 to 8 inches in thickness, covers the surface of the darker colored Wabash silt loam. These included areas are of small extent, but had they been large enough to show on the map, they would have been mapped as Ray silt loam.

Much of the bottom land is now in pasture, particularly along the smaller streams. Within the pastured areas a few scattered trees, including ash, cottonwood, willow, and post oak, grow near the stream courses. Where Wabash silt loam is cultivated, it produces good crops of corn and is perhaps inherently one of the more productive soils in the county. The natural fertility of this soil is very high, and it can be cropped continuously to corn for long periods without appreciable reductions in yield. This land is subject to some hazard from overflow of the streams in the spring and at other times when the rainfall is unusually high. Corn yields range from 45 to 90 bushels an acre, and small grains do well, oats yielding from 30 to 60 bushels. Alfalfa and wheat are grown to some extent, but the total acreage occupied by these two crops is small. The small grains, particularly oats and barley, can be grown more successfully on Wabash silt loam than on Judson-Wabash silt loams, because they are less susceptible to lodging on the Wabash soil. Protection from damage due to overflows of streams is the principal problem in connection with the farming of the Wabash soil. Maintenance of productivity is not difficult, because the soil is extremely fertile and deteriorates very slowly; but less frequent cropping to corn and the introduction of other crops into the rotation is desirable.

## LAND USES AND AGRICULTURAL METHODS

According to the United States census of 1930, animal-specialty farms comprised about 60 percent of the total number of units within the county, followed by general and cash-grain farms, comprising about 18 and 11 percent, respectively. Cash-grain and animal-specialty farms are defined as those that derive 40 percent or more of their income from the sale of a group of particular products, such as corn and oats, from the former type. The fact that most of the farms are devoted to the breeding and raising of animals is emphasized by these data, and it is clearly brought out that the agriculture of this county is centered around the production of livestock. Corn, oats, and hay are the principal crops grown, and they are used as feed for the different kinds of livestock.

Most of the corn grown in the past has been of the open-pollinated varieties, although hybrids are increasing in popularity. Among the open-pollinated varieties of corn, yellow dents, including Williamson, Reid, Krug, and Black Hawk, are most popular. Small acreages of white varieties of corn, chiefly Iowa Silvermine, Champion White Pearl, and Boone County White, are grown on a few farms. Practically all of the corn crop is planted between May 1 and 15, and most of it is planted in checkrows. Small acreages, which are to be used for silage or hogged down, are drilled rather than checkrowed. Shortly after the corn is above the ground and usually before the plants are more than an inch tall, the land is cultivated with a harrow. Three cultivations generally are enough, and the corn is laid by between July 10 and July 15 in ordinary years. Harvesting of the crop begins about October 15, and most of the corn is picked before Thanksgiving. In the past, picking has been done chiefly by hand, but increasing numbers of mechanical corn pickers are being used. Covered cribs, used for storage of corn on most farms, are supplemented by open cribs of wire or slats when the crop is large.

Sweet corn is grown on small acreages in the vicinity of Audubon, where a canning factory contracts for the crop before it is planted. The varieties commonly grown are Evergreen, Country Gentleman, and Little Yellow Bantam. Popcorn is grown in a few small patches for local consumption.

Generally, oats are planted after corn in the rotation, and a number of farms have used a rotation including only corn and oats. In preparing the land for oats, farmers drag the field to break down the cornstalks, and then disk the field in order to cut up the cornstalks. Oats usually are sown with an endgate seeder, the grain being broadcast at a rate of 2½ to 3 bushels an acre. The grain is ordinarily cut with a binder, shocked, and then allowed to stand in the shock until cured. Oats generally are threshed from the shock. Most of the oats are fed to livestock within the county, being ground when they are to be used for hog feed, and sometimes being mixed with barley.

Barley is grown on an acreage amounting to about one-tenth of that ordinarily used for oats. The crop is used principally for feed, mainly for hogs or calves, within the county, but some is sold for malting purposes. Other minor crops include rye, wheat, millet, Sudan grass, sorghum, and soybeans. Rye, Sudan grass, and sorghum are used for emergency pastures, and millet is used as a catch crop to provide hay. Wheat, chiefly of the Turkey variety, is grown as a cash crop on a number of the bottoms occupied by Wabash silt loam, but the total acreage occupied by this crop is small. Soybeans have been used on a number of farms, but they are not well adapted to rolling lands, because rather rapid erosion may follow the growing of the crop.

There are a number of small orchards, ranging in size from less than 1 to as much as 3 acres on the individual farm. Apples, plums, cherries, peaches, and pears are grown to a very small extent for local consumption. Other fruits, such as grapes, strawberries, and raspberries, are grown in small patches of one-eighth acre or less, primarily for home use.

Hay was produced on 30,796 acres in 1929. About one-half of this acreage was in mixed timothy and clover or in timothy alone, and about one-third in clover alone. Most of the clover and timothy are produced in the eastern part of the county, as they can be grown more successfully than alfalfa or sweetclover on the slightly acid Tama soils. Some alfalfa, mainly in small acreages, is grown on many farms. Most of the alfalfa and sweetclover are grown in the western half of the county on the Marshall soils. The principal varieties of alfalfa are Cossack, Grimm, and some South Dakota No. 12. The more wilt-resistant varieties can be grown most successfully.

About 20 carloads of ground limestone are used in the county annually. Practically all of the lime is applied to land to be sown to alfalfa. Soils in individual fields should be carefully tested before lime is applied, as a few are calcareous and really do not require limestone for the successful growing of legumes. As a general rule, the Tama soils and associated Shelby soils in the eastern part of the county are more apt to be acid than are the Marshall soils and associated Shelby soils in the western part.

Permanent pastures are mainly of bluegrass, and most of them are in the eastern half of the county. The number of permanent pastures is comparatively small, as indicated by the total area devoted to this type of land use. Sweetclover is commonly used for pasture in the western half of the county, as the crop thrives on the Marshall soils with their calcareous lower horizons. Generally livestock are turned into the pastures early in the spring, and in ordinary seasons they can be grazed on the same pastures until late fall, at which time, the corn having been picked, they can be turned into the cornfields. The feed that the livestock find in the cornfields generally will keep them in good condition until the middle of December, after which supplementary feeds and hay must be used.

The hay crops, such as alfalfa, timothy and clover, and sweetclover, usually are sown with barley or oats as a nurse crop. The land sown to alfalfa generally is left in that crop for several years before it is again plowed. Sweetclover may be pastured or may be plowed under in the spring following the oats crop. Where the sweetclover is to be plowed under on the more rolling land it is wise to plow in the spring so as to minimize the danger of erosion.

Crops, with the possible exception of wheat, which is grown chiefly on the bottoms along the principal streams, are not grown predominantly on any particular soil type. Corn is grown on the more rolling land as well as on the bottom land and terrace land, but most of the steepest slopes are left in pasture or in trees. Where the steeper slopes are cropped to corn or other grains, the land usually is put into such a crop less often than the more level land. The permanent retirement of the steeper land from the growing of corn or intertilled crops is desirable, however, and intermediate slopes should be used for corn only now and then in a long rotation.

Some form of crop rotation is used on every farm, but many of the farmers simply alternate corn and oats. Corn followed by oats with a seeding of sweetclover is popular in the western part of the county. Sweetclover is plowed under the following spring, and the land is planted to corn. This type of management, however, is only slightly better than alternating corn and oats. A rotation of corn, corn, oats, and clover would be preferable to corn and oats over all the county.

The use of a rotation that includes legumes and that maintains the land in a close-growing crop for several years is desirable, particularly on the rolling lands. In the southwestern part of the county and directly west of Audubon the land is definitely rolling, and precautions ought to be exercised in order to minimize erosion hazards. The gradual breaking down of the granular structure of the soil and a lowering of fertility often follow short rotations, and once the land has deteriorated in quality it is much more susceptible to erosion. Methods of maintaining favorable soil structure and keeping fertility at a high level will greatly aid in combating loss of the soil through erosion. In addition to desirable rotations and the application of fertilizers, such tillage practices as contour cultivation and strip cropping may be advisable in the steeper areas.

Experiments dealing with the fertilization of different crops on various soils have been carried on by the Iowa Agricultural Experiment Station. These fertilizer trials were made on groups of plots laid out within farm fields on soils that occupy rather large areas in a given section of the State. Materials such as manure, lime, and phosphate are applied to $\frac{1}{10}$-acre plots by a fieldman from the experiment station, who also harvests the crop and records yields. Careful note is taken of seasonal factors and other conditions that might affect crop yields. As the plots are laid out in a farmer's field, and as he plants and cultivates them with the rest of the field, the crops grown receive ordinary field treatment except for the addition of the fertilizer materials.

Data from a number of field experiments on Marshall silt loam and Tama silt loam, two of the predominant soil types in Audubon County, are presented in tables 6 and 7.

TABLE 6.—*Average crop yields per acre and increases due to fertilizer treatment on Marshall silt loam on Iowa experiment fields* [1]

| Treatment | Corn [2] | | Oats [3] | | Wheat [4] | | Alfalfa [5] | |
|---|---|---|---|---|---|---|---|---|
| | Average yield | Increase from treatment | Average yield | Increase from treatment | Average yield | Increase from treatment | Average yield | Increase from treatment |
| | *Bushels* | *Bushels* | *Bushels* | *Bushels* | *Bushels* | *Bushels* | *Tons* | *Tons* |
| Check | 57.2 | | 48.5 | | 14.7 | | 3.5 | |
| Manure | 62.6 | 5.4 | 55.2 | 6.7 | 20.3 | 5.6 | 4.0 | 0.5 |
| Manure+limestone | 63.7 | 6.5 | 57.1 | 8.6 | 20.6 | 5.9 | 4.5 | 1.0 |
| Manure+limestone+rock phosphate | 63.5 | 6.3 | 56.7 | 8.2 | 23.3 | 8.6 | 4.9 | 1.4 |
| Manure+limestone+superphosphate | 63.4 | 6.2 | 61.3 | 12.8 | 25.2 | 10.5 | 4.9 | 1.4 |
| Manure+limestone+complete commercial fertilizer | 62.7 | 5.5 | 60.0 | 11.5 | 21.8 | 7.1 | 4.9 | 1.4 |
| Limestone | 60.0 | 2.8 | 55.2 | 6.7 | 18.2 | 3.5 | 3.8 | .3 |
| Limestone+rock phosphate | 59.9 | 2.7 | 56.3 | 7.8 | 18.3 | 3.6 | 4.0 | .5 |
| Limestone+superphosphate | 60.2 | 3.0 | 59.1 | 10.6 | 20.4 | 5.7 | 3.9 | .4 |
| Limestone+complete commercial fertilizer | 59.6 | 2.4 | 56.2 | 7.7 | 20.3 | 5.6 | 3.8 | .3 |

[1] Avoca field No. 2, series 1, in Pottawattamie County, and Red Oak field No. 3, series 1, in Montgomery County.

[2] Corn yields averaged from 12 crops on 2 fields.

[3] Oat yields averaged from 5 crops on 2 fields.

[4] Wheat was grown 3 different times on Red Oak field No. 3, and the average yields are given.

[5] Alfalfa crops were harvested 4 years on Red Oak field No. 3, and the average yields are given.

TABLE 7.—*Average crop yields per acre and increases due to fertilizer treatment on Tama silt loam on Iowa experiment fields* [1]

| Treatment | Corn [2] | | Oats [3] | | Clover and timothy [4] | | Alfalfa [5] | |
|---|---|---|---|---|---|---|---|---|
| | Average yield | Increase from treatment | Average yield | Increase from treatment | Average yield | Increase from treatment | Average yield | Increase from treatment |
| | *Bushels* | *Bushels* | *Bushels* | *Bushels* | *Tons* | *Tons* | *Tons* | *Tons* |
| Check | 56.8 | | 53.9 | | 1.62 | | 1.68 | |
| Manure | 59.9 | 3.1 | 60.8 | 6.9 | 1.68 | 0.06 | 2.17 | 0.49 |
| Manure+limestone | 60.5 | 3.7 | 60.7 | 6.8 | 1.69 | .07 | 3.28 | 1.60 |
| Manure+limestone+rock phosphate | 62.2 | 5.4 | 65.1 | 10.2 | 1.94 | .32 | 3.62 | 1.94 |
| Manure+limestone+superphosphate | 60.9 | 4.1 | 64.5 | 10.6 | 1.92 | .30 | 3.42 | 1.74 |
| Manure+limestone+superphosphate+potassium | 60.4 | 3.6 | 66.6 | 12.7 | 1.92 | .30 | 3.40 | 1.72 |
| Manure+limestone+complete commercial fertilizer | 59.6 | 2.8 | 61.9 | 8.0 | 1.85 | .23 | 3.31 | 1.63 |

[1] Winterset field, series 1, in Madison County, and Greenfield field, series 1 and 2, in Adair County.
[2] Corn yields averaged from 14 crops on 3 fields.
[3] Oat yields averaged from 6 crops on 3 fields.
[4] Clover and timothy yields averaged from 4 crops on 3 fields.
[5] Alfalfa yields obtained in 1936 from the field at Winterset.

The older experimental plots were laid out so as to provide a comparison between livestock and grain systems of farming, but on the newer fields only a livestock system is used. Under the livestock system, barnyard manure is applied at the rate of 8 tons an acre once in a 4-year rotation. The lime requirement of the soil is also determined once during each rotation, and whenever necessary, limestone is applied in sufficient quantity to neutralize the acidity. Under a grain-crop system of farming, the only organic matter added is that derived from the plowing under of such crop residues as remain on the land. No barnyard manure is added at any time. In some years, the second crop of clover is plowed under, the first crop having been cut for hay. Prior to 1925, rock phosphate was applied at the rate of 1 ton an acre once in a 4-year rotation. During the years 1925–32, 1,000 pounds of rock phosphate an acre was applied once during the 4-year rotation. Since 1932, only 500 pounds an acre has been used. Superphosphate (16 percent) was applied at the annual rate of 200 pounds an acre until 1923. In 1923 the application was reduced to 150 pounds and made 3 years out of 4, being omitted the year the legume crop was produced. Since 1929 an equivalent quantity of 20-percent superphosphate (120 pounds an acre) has been used.

Complete commercial fertilizer, a 2-8-2 mixture,[5] was applied at the rate of 300 pounds an acre annually when the experiments were first started. This was changed in 1923 to a 2-12-2 mixture, applied at a rate equivalent to 150 pounds of 16-percent superphosphate. During the last 10 years a 2-16-6 mixture has been applied at the rate of 200 pounds an acre.

Potash, in the form of muriate of potash, has been applied at a rate of 50 pounds an acre in 3 years of the 4-year rotation. This fertilizer was not used in some of the older experiments.

[5] Percentages, respectively, of nitrogen, phosphoric acid, and potash.

The set of experimental plots as first established included a total of 13, with 3 check plots. The new fields, which operate under a livestock system of farming, include 9 plots, 3 of which are used as checks. All these plots are laid out within farm fields in cooperation with the farm owner.

The data presented in table 6 indicate the value of applications of manure, particularly in growing corn. The increase in the average yield of corn obtained by the use of manure alone was nearly as great as that obtained when lime or phosphate was applied in addition. The small-grain crops also responded to applications of manure but seemed to do better when additional phosphate was applied in one of the more soluble forms. The increase in yield of small grains following the application of rock phosphate was somewhat lower than that obtained with superphosphate or complete commercial fertilizer. The experimental results would indicate that oats are benefited by the application of phosphate and that appreciable increases in yield can be obtained.

All data for yields of alfalfa were obtained from the Red Oak field during the seasons of 1927 to 1930, inclusive. An increase in yield was indicated following application of manure, but a more substantial increase was obtained when manure and limestone were applied together. An even greater gain was observed when phosphorus, either in the form of rock phosphate or the more soluble superphosphate, was applied. Legume crops, as a general rule, are more efficient in the utilization of the phosphorus contained in rock phosphate than are the small grains. Oats and other small-grain crops derive more benefit from a more soluble form of phosphorus, such as is contained in superphosphate.

The Marshall soils in Audubon County are, in general, similar to those on the Avoca and Red Oak fields. Some differences might be expected, however, and, consequently, data obtained on the two fields are not strictly applicable to all areas of Marshall soils in this county. Crops such as corn or oats will respond to the application of manure on all the Marshall soils, but it will usually be wise to determine the need for lime before it is applied. On some of the steeper areas in the western part of the county the soils are calcareous, even on the shoulders of the slopes, and here no lime is needed. Similarly, it would be desirable to carry out trials with fertilizers on representative areas of soil within the particular field that is to be fertilized, before fertilizer materials are applied. Certain types of fertilizers will be more efficient and profitable on any given field than will others. Small strips laid out across the field, where the relief, drainage, and soils of the entire area are well represented, will give comparable results and will show what fertilizers can be used to the best advantage. The use of barnyard manure and of green manure, as has already been stressed, are important practices in maintaining the content of organic matter and in supplying additional plant nutrients. Liming will be of most benefit where legumes are to be grown, particularly near the boundaries between the Marshall and Tama soils, where the Marshall soil is more apt to be somewhat acid.

As has been stated, average acre yields of crops and the increases that follow fertilizer treatments are summarized for two fields on

Tama silt loam in table 7. The yields obtained for individual crops on the fields located on Tama silt loam at Greenfield, Adair County, are given in table 8.

TABLE 8.—*Acre yields in field experiments on Tama silt loam at Greenfield, Adair County, Iowa*[1]

| Plot No. | Treatment | Corn 1922 | Corn 1923 | Oats, 1924 | Clover and timothy,[2] 1925 | Corn 1926[3] | Corn 1927[4] | Oats, 1928 | Clover and timothy, 1929 |
|---|---|---|---|---|---|---|---|---|---|
| | | *Bushels* | *Bushels* | *Bushels* | | *Bushels* | *Bushels* | *Bushels* | *Tons* |
| 1 | Check | 78.6 | 50.9 | 54.1 | ------- | 45.0 | 41.1 | 70.4 | 2.04 |
| 2 | Manure | 84.0 | 53.7 | 57.0 | ------- | 50.1 | 44.3 | 79.5 | 2.39 |
| 3 | Manure+limestone | 90.4 | 56.9 | 57.0 | ------- | 48.8 | 48.1 | 79.5 | 2.54 |
| 4 | Manure+limestone+rock phosphate | 84.5 | 60.1 | 57.0 | ------- | 44.3 | 52.9 | 93.1 | 3.02 |
| 5 | Check | 85.7 | 51.3 | 46.8 | ------- | 43.3 | 39.2 | 65.9 | 2.48 |
| 6 | Manure+limestone+superphosphate | 78.7 | 60.4 | 59.1 | ------- | 49.3 | 58.4 | 88.6 | 2.98 |
| 7 | Manure+limestone+superphosphate+muriate of potash | 82.9 | 57.2 | 70.6 | ------- | 45.9 | 50.3 | 93.1 | 3.07 |
| 8 | Manure+limestone+complete commercial fertilizer | 89.4 | 52.9 | 58.4 | ------- | 48.8 | 56.0 | 86.2 | 2.94 |
| 9 | Check | 86.6 | 50.6 | 51.8 | ------- | 48.2 | 48.3 | 77.1 | 2.49 |

| Plot No. | Treatment | Corn 1930 | Corn 1931 | Oats, 1932 | Clover and timothy,[5] 1933 | Corn 1934[6] | Corn 1935 | Corn 1936[7] | Winter wheat, 1937 | Sweetclover, 1938 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Bushels* | *Bushels* | *Bushels* | *Tons* | | *Bushels* | | *Bushels* | *Tons* |
| 1 | Check | 63.3 | 56.6 | 70.3 | 0.53 | ----- | 47.8 | ----- | 10.3 | 1.47 |
| 2 | Manure | 65.1 | 58.2 | 71.5 | .65 | ----- | 48.3 | ----- | 14.8 | 1.56 |
| 3 | Manure+limestone | 60.4 | 58.9 | 70.9 | .59 | ----- | 51.6 | ----- | 15.1 | 2.10 |
| 4 | Manure+limestone+rock phosphate | 66.0 | 60.2 | 75.4 | .71 | ----- | 51.0 | ----- | 15.4 | 2.20 |
| 5 | Check | 60.2 | 50.6 | 72.6 | .70 | ----- | 46.6 | ----- | 10.9 | 1.40 |
| 6 | Manure+limestone+superphosphate | 59.7 | 56.6 | 76.6 | .64 | ----- | 47.1 | ----- | 16.4 | 2.44 |
| 7 | Manure+limestone+superphosphate+muriate of potash | 60.6 | 52.6 | 74.9 | .67 | ----- | 47.8 | ----- | 16.4 | 2.27 |
| 8 | Manure+limestone+complete commercial fertilizer | 58.8 | 55.3 | 79.4 | .70 | ----- | 47.8 | ----- | 16.9 | 2.30 |
| 9 | Check | 58.9 | 53.2 | 64.7 | .63 | ----- | 42.3 | ----- | 12.7 | 1.37 |

[1] Data from 1922 to 1929, inclusive, are from Greenfield field, series 1, located, in the fall of 1921, in the NE¼ sec. 32, T. 76 N., R. 31 W. Data from 1930 to 1938, inclusive, are for Greenfield field, series 2, located on the same farm in 1929, in the SW¼NE¼ sec. 32, T. 76 N., R. 31 W.

[2] Clover winter-killed, timothy pastured.

[3] Stand poor because of cutworms and moles.

[4] Stand damaged by wireworms.

[5] Late spring pasturing and hot dry weather in June damaged the crop.

[6] Corn cut for fodder.

[7] Dry season, corn cut for silage.

The data presented in table 7 for Tama silt loam are comparable to those presented for Marshall silt loam in table 6. The largest increase in the yield of corn was obtained from the application of manure, although some additional increase was obtained from the use of phosphate. The increased yield of oats obtained from the application of phosphate was especially noticeable, and the superphosphate again showed a slight advantage over the rock phosphate. Yields of timothy and clover hay were increased almost as much by the application of manure alone as they were by the addition of limestone and manure to the soil. A somewhat greater response in yield of timothy and clover was indicated by the data for rock phosphate or superphosphate plus manure and limestone.

Data on crop yields following fertilizer treatments on both Marshall silt loam and Tama silt loam seem to indicate that corn will respond primarily to the application of manure, in short, to an addition of organic matter. Oats and wheat respond markedly to the application of phosphate, and this is particularly true for the legumes also. Additional information on soil management, control of erosion, and the results of experiments with various fertilizers is given in the Iowa Agricultural Experiment Station Bulletins 269 and 280 and Special Reports 2 and 3; and recommendations for pasture mixtures are given in the Iowa Agricultural Experiment Station Bulletin 331.

## PRODUCTIVITY RATINGS

In table 9 the soils of Audubon County are rated according to their capacities to produce the more important crops of the region and are listed in the approximate order of their general productivity under current farming practices.

TABLE 9.—*Productivity ratings of soils of Audubon County, Iowa*

| Soil [1] | Crop productivity index [2] for— | | | | | | General productivity grade [4] | Land classification [5] |
|---|---|---|---|---|---|---|---|---|
| | Corn | Oats | Clover and timothy | Alfalfa: With lime | Alfalfa: Without lime | Pasture [3] | | |
| Judson silt loam | 110 | 95 | 100 | 95 | 80 | 110 | 1 | Excellent cropland. |
| Judson-Wabash silt loams [6] | 105 | 90 | 100 | 95 | 75 | 110 | | |
| Wabash silt loam [6] | 100 | 95 | 100 | 95 | 50 | 110 | | |
| Waukesha silt loam | 100 | 95 | 100 | 95 | 40 | 100 | | |
| Marshall silt loam | 95 | 90 | 95 | 95 | 60 | 95 | | |
| Tama silt loam | 95 | 90 | 95 | 95 | 40 | 95 | | |
| Shelby silt loam | 85 | 85 | 85 | 85 | 35 | 90 | 2 | Good cropland |
| Tama silt loam, light-colored phase | 80 | 85 | 90 | 85 | 40 | 80 | | |
| Lindley silt loam | 60 | 65 | 60 | 70 | 50 | 65 | 4 | Fair cropland. |
| Shelby loam | 55 | 65 | 60 | 65 | 30 | 70 | | |
| Lindley loam | 45 | 60 | 50 | 55 | 30 | 50 | 5 | |
| Wabash silt loam, poorly drained areas | | | | | | 110 | 8 | Pasture land. |
| Judson-Wabash silt loams, poorly drained areas. | | | | | | 110 | | |

[1] The soils are listed in the approximate order of their general productivity under the average current practices, the most productive first.

[2] The soils of Audubon County are given indexes that indicate the approximate average production of each crop in percent of the standard of reference. The standard represents the approximate average yield obtained without use of amendments on the more extensive and better soil types of the regions in which the crop is most widely grown.

[3] Owing to limited data these ratings are estimates.

[4] This classification indicates the comparative general productivity of the soils under dominant current practices. Refer to text for further explanation.

[5] This is a general classification to indicate the physical suitability of the soils for farming or grazing uses. In the actual delineation of land classes on a map other considerations, such as the pattern of distribution of soil types, are important.

[6] Refers only to better drained areas. Poorly drained areas are used largely for pasture.

The rating compares the productivity of each soil type for each crop to a standard of 100, which represents the approximate average yield obtained without amendments on the more extensive and better soil types of the regions in which the crops are most widely grown. The standard index of 100 is used as a base to which the productivities of all the soils are compared for any particular crop. An index of 50, for example, indicates that the soil is about half as productive for the specific crop as those with the standard index. Soils given amendments, such as lime, commercial fertilizers, or irrigation, and some unusually productive soils of comparatively small extent may have productivity indexes of more than 100 for some crops.

In establishing the ratings for the soils of Audubon County it has been assumed that current practices did not ordinarily include such amendments as limestone or commercial fertilizer. The application of barnyard manure produced on the farm and the occasional plowing under of green-manure crops were considered normal practices rather than amendments.

The following tabulation gives the acre yields that have been established as standards of 100 for the various crops. These yields represent long-time average yields of crops of satisfactory quality on the better soils without the use of amendments.

| Crop: | | |
|---|---|---|
| Corn | bushels | 50 |
| Oats | do | 50 |
| Clover and timothy | tons | 2 |
| Alfalfa | do | 4 |
| Pasture | cow-acre-days [1] | 100 |

[1] Cow-acre-days is a term used to express the carrying capacity of pasture land. As used here it is the product of the number of animal units carried per acre multiplied by the number of days the animals are grazed without injury to the pasture. For example, the soil type able to support 1 animal unit per acre for 360 days of the year rates 360, whereas another soil able to support 1 animal unit on 2 acres for 180 days of the year rates 90. Again if 4 acres of pasture support 1 animal unit for 100 days the rating is 25.

Because of the undulating to rolling relief of the uplands and the comparatively permeable materials comprising the soils, drainage is not an important problem in this county, except in a few small depressed areas in the bottom land. These depressed areas generally have heavier textured soils than the surrounding higher land and are most numerous within areas of Wabash silt loam and Judson-Wabash silt loams. They range in size from 1 to 5 acres and have not been separated from the surrounding soil because of the rather small size of the individual areas. Two ratings have been given for Judson-Wabash silt loams and Wabash silt loam on the basis of these differences in drainage. These two ratings represent the estimated yields obtained under extremes of good and poor drainage; some areas of intermediate drainage are between the two in productive capacity. A few of the areas of Judson-Wabash silt loams have been drained by means of tile, principally to facilitate the cultivation of the surrounding land. Ratings given for the well-drained Judson-Wabash silt loams will apply to such areas.

The principal factors determining the productivity of land are generally considered to be climate, soil, slope, drainage, and management, and each of these factors in itself may include a rather complex group of influences. Actually, no one of the factors operates distinctly from the others, although some one factor may dominate. For instance, in this county, extreme variations in yield from one season to another are due to the influence of climate. In years of optimum rainfall, crop yields are much higher than they are in the dry seasons. Also, the degree of slope and direction of exposure may affect yields obtained very markedly. In a season when rainfall is barely adequate or is inadequate for crop needs, slopes facing to the south and southwest and that are open to the hot southwest winds produce much lower yields of corn or small grain, a fact that was noticeable in the fall of 1938.

Crop yields themselves over a long period of years furnish the best available summation of the effects of the associated factors that govern productivity, and they are used wherever they are available. Data on the average acre yields of crops, both for the entire county and for various townships, have been used as guides in establishing productivity ratings. These yield data do not apply directly to specific soil types, and some interpretation of them is required. Consequently, in this rating of the soils of Audubon County, many of the indexes are based on inductive estimates rather than on actual reported yields. It is considered, however, that the rating does give a fairly accurate picture of the relative productivity of the soils of the county.

The soils are listed in the order of their general productivity under dominant current practices, and productivity grade numbers are assigned in the column "General productivity grade." The general productivity grade is based on a weighted average[6] of the indexes for the various crops, using the approximate areal extent and value of the different crops in the county as bases, except in a few instances where some of the crops are not grown on particular soils. If the weighted average is between 90 and 100, the soil type is assigned a grade of 1, if it is between 80 and 90 it is assigned a grade of 2, and so on. Because it is difficult to measure mathematically the exact significance of a crop in a local agriculture, or the importance and adaptability of certain soil types for specific crops, the established weightings were used only as guides. Personal judgment has been allowed to operate in making certain modifications in the general productivity grades.

The last column, "Land classification," summarizes in a simple way the productivity and use capabilities of the various soil types by placing them in a few groups on the basis of their relative suitability for farming and grazing. It will be noticed that only the poorly drained areas of Wabash silt loam and Judson-Wabash silt loams have been listed as grazing land in the table.

Productivity ratings do not present the relative roles that soil types may occupy in the agriculture of the county; the ratings give a characterization of the productivity of individual soil types. They cannot picture the total production of crops on a given soil type within the county without the additional knowledge of the acreage of that particular type devoted to each of the specified crops. In addition to the actual productivity of the soil, the area and the pattern of distribution are important in determining agricultural production.

Economic considerations have played no part in determining the productivity indexes, so the indexes cannot be interpreted directly into land values except in a very general way. Distance to market, relative prices of farm products, location with respect to schools, and various other features within the community are factors that influence the value of land over and above the productivity of the soil type.

---

[6] The weights in percentage given each crop index in setting up the general productivity grade were, with few exceptions, as follows: Corn, 50; oats, 25; hay crops, 15; pasture, 10.

## MORPHOLOGY AND GENESIS OF SOILS

Soil is the product of the forces of environment acting upon the soil materials deposited or accumulated by geologic agencies. The characteristics of the soil at any given point are determined by (1) the physical and mineralogical composition of the parent soil material; (2) the climate under which the soil material has accumulated and existed since accumulation; (3) the relief, or lay of the land, which determines the local or internal climate of the soil, its drainage, moisture content, aeration, and susceptibility to erosion; (4) the biologic forces acting upon the soil material, that is, the plants and animals living upon and in it; and (5) the length of time the climatic and biologic forces have acted on the soil material.

Audubon County is in the Prairie soil region of the United States, lying within the transitional zone between the Podzolic soils to the east and the Chernozem soils to the west. The conditions of rather high temperature and a moderate supply of rainfall during the growing season have favored the growth of a tall-grass prairie type of vegetation. The presence of a grass vegetation on the soil during its development has resulted in the formation of a dark-colored surface horizon, which is the most striking single characteristic of the group of Prairie soils. This dark-colored surface horizon is formed as the result of the gradual accumulation and decay of organic matter arising both from the vegetative parts of the grasses and from their roots.

Within Audubon County the thickness of the surface horizon of the various Prairie soils ranges from about 5 to as much as 24 inches, depending on topographic position. On the steeper slopes in the more rolling areas the surface horizon is not so thick as it is on the smoother areas in the gently undulating parts of the upland. In depressed areas or in some of the drainageways, the upper layer is very thick, partly because of the more active growth of plants and the less active decomposition of the organic matter, and partly because of the accumulation of local wash from surrounding uplands. Differences between the soil types in the county are due primarily to two of the factors of soil formation—parent materials and relief.

The three types of soil parent materials in this county are Peorian loess, glacial drift referred to the Kansan age, and alluvium derived from these two materials. Loess, consisting of a mixture of silt and clay, covers the uplands throughout the county, and glacial materials underlie the entire county and are exposed on many of the lower slopes. Alluvial materials are along the stream channels in the upland and on the flood plains and terraces of the larger valleys.

After the glacial materials had been deposited, the land surface was gradually changed to a rolling plain, probably much like the one now existing in Audubon County, and a covering of loess was then deposited by wind on this plain many thousands of years ago. This loess, known as Peorian, formed a mantle or covering, probably ranging from as few as 10 to as many as 18 feet in thickness at one time. After the loess had been laid down, the same processes of dissection of the landscape by streams, which gave rise to the Kansan till plain, began to operate once more to remove loess and drift materials and to carve out the rolling landscape that now characterizes the area. The depth of the loess materials on the uplands ranges from a few inches to as much as 18 feet in a few places that have been well protected. In the present landscape the loess occurs over the higher parts of the upland and on the shoulders and upper parts of slopes, whereas the till outcrops in bands or strips on steeper slopes leading down to the stream valleys. The total depth of the loess in protected places is about 18 feet along the western side of the county and slightly less along the eastern side. Where the covering is thinner, it is commonly more completely leached of carbonates. Marshall silt loam and Tama silt loam are members of the Prairie group of soils, which have developed on the loess, and are separated from the Shelby and Lindley soils, which have developed on glacial till.

The soils that have formed or are forming on alluvial materials include those in the bottom lands and on terraces. The flood plains of the larger streams are occupied by the members of the Wabash series, predominantly Wabash silt loam, and the Judson-Wabash complex occurs in the channels of the intermittent drainageways in the upland. Waukesha silt loam and Judson silt loam occupy the terraces and alluvial fans, which lie at elevations somewhat above those of the flood plains. All these soils have been formed from alluvium derived primarily from redeposition of the loess and till materials of the uplands. Such soil as the Judson-Wabash silt loams consists of local alluvial materials washed down from the surface horizons of surrounding higher lying soils.

Marshall silt loam and Tama silt loam are selected as examples of the Prairie soils in this county, and their profiles are described in detail. The profiles of these two soils are similar in many respects, differing chiefly in that Marshall silt loam normally contains calcium carbonate in the subsoil and Tama silt loam does not. Both soils have dark grayish-brown silt loam surface horizons, ranging from 12 to 14 inches in thickness, which have a uniformly fine granular structure. The lower layers of the profiles are yellowish-brown silty clay loam, which in the Marshall soil changes to pale yellow and generally contains calcium carbonate and lime nodules at a depth ranging from 45 to 60 inches. The surface layer of Tama silt loam is slightly to medium acid, and that of Marshall silt loam is slightly acid to neutral.

Following is a description of a typical profile of Marshall silt loam, as it occurs in the SE¼ sec. 25, T. 80 N., R. 36 W.:

1. 0 to 3 inches, dark grayish-brown silt loam filled with a dense mat of grass roots. The soil clings to the roots in small granules.
2. 3 to 15 inches, dark grayish-brown friable finely granular silt loam, which breaks into still finer aggregates and loose silt. When crushed between the fingers, the soil material is lighter colored.
3. 15 to 24 inches, dark-brown silt loam, which is not so uniform in color as that in the layers above. Organic materials have penetrated this layer and colored it unevenly, the darker colors being around plant roots, insect burrows, and worm holes. In the soil mass itself the organic material appears as a coating around small granules. The soil materials are light brown after they have been crushed between the fingers.

4. 24 to 45 inches, yellowish-brown light silty clay loam, which breaks to aggregates from one-sixteenth to one-eighth of an inch in diameter. A few dark streaks occur along worm holes or animal burrows.
5. 45 to 60 inches, light yellowish-brown or grayish-yellow smooth silt loam reticulately mottled with rust-brown iron stains. The material in this layer effervesces slightly with hydrochloric acid, and small soft lime nodules are scattered through this structureless material.
6. 60 to 85 inches, grayish-yellow structureless mellow silt loam. The material in this layer is marked by flecks of lighter gray and some reddish-brown iron stains. It is highly calcareous, with the lime occurring in a finely divided state.

The depth to carbonates in the areas mapped as Marshall silt loam varies widely. On sharp eroded slopes, lime may be present within a few inches of the surface, whereas on the more gentle slopes it may be as far down as 6 feet. The smaller amount of leaching and more active erosion, due to greater run-off on the steeper slopes, have resulted in keeping the lime layer nearer the surface.

Following is a description of a representative profile of Tama silt loam, as observed in the NE¼ sec. 10, T. 80 N., R. 34 W.:

1. 0 to 3 inches, very dark grayish-brown friable silt loam, which contains a dense network of grass roots. When wet, the soil in this horizon is darker and appears almost black.
2. 3 to 16 inches, dark grayish-brown mellow silt loam with a granular structure. The aggregates are small, about one-sixteenth of an inch in diameter, and much of the material is loose silt when the soil is fairly dry. The material in this layer is black when wet and appears slightly darker than that in the same horizon in Marshall silt loam.
3. 16 to 22 inches, dark-brown friable silt loam highly colored by organic matter. The soil granules are slightly coarser than those in the layer above, ranging from one-sixteenth to one-eighth of an inch in diameter. When crushed between the fingers, the soil is brown rather than dark brown, indicating that the dark coloring is a coating around the granules.
4. 22 to 48 inches, yellowish-brown silty clay loam, very uniform in color. The material is compact in some places but generally is friable, breaking into aggregates ranging from one-eighth to one-fourth inch in diameter. Organic matter has penetrated this layer along a few root channels.
5. 48 to 60 inches, light yellowish-brown silty clay loam containing some very fine sand and mottled with rust-brown iron stains.
6. 60 to 75 inches, grayish-yellow heavy silt loam, faintly mottled with gray and containing many rust-brown iron stains and some concretions. This layer contains slightly more very fine sand than the layer above.

The transition from the Marshall to the Tama soil is very gradual, and, consequently, any boundary lines shown on the map are more or less arbitrary. Soils on the two sides of the boundary line are very much alike, but with distance from the boundary line into the main body of either soil the differences become more noticeable. Farmers recognize the difference between the two soils in Audubon County as a difference in adaptability to the growing of legumes. Red clover is grown more commonly along the eastern side and sweetclover along the western side of the county because of differences in the calcium content of these two soils.

Prairie soils, in addition to Marshall silt loam and Tama silt loam, include members of the Shelby, Waukesha, and Judson series in the group of well-drained soils, and Wabash silt loam and Judson-Wabash silt loams are soils with incomplete drainage. The Shelby soils have developed on glacial till with or without a thin covering of loess. Shelby silt loam is mapped where a thin layer of loess formed part of the parent material, and Shelby loam where the parent material included little or no loess. As a rule, the surface layers of the Shelby soils are less dark and less deep than are those of the Marshall and Tama soils. Gravel, sand, and a few stones may be on the surface or within the soil mass of the Shelby soils.

Waukesha silt loam on the terraces is very similar to both the Marshall and Tama soils of the uplands. It differs primarily from those soils in the topographic position that it occupies. The various horizons of the profile average a little thicker than the corresponding horizons of the upland Prairie soils; but aside from this difference, few features distinguish the individual profiles of the several series.

The profile of Judson silt loam is even thicker and darker than that of Waukesha silt loam. The Judson soil has been formed and still is forming from silt and similar materials that are being washed down from the surface horizons of Marshall, Tama, or Shelby silt loams on the higher slopes. The principal difference between the profile of Judson silt loam and the Prairie soils on loess on the uplands is the much thicker surface horizon of the Judson soil.

Internal drainage of Wabash silt loam and Judson-Wabash silt loams is not so good as it is in the other Prairie soils of the county. As a result of the slightly restricted drainage, the soils show a tendency toward a gray color, with numerous mottlings in the lower parts of their profiles. The upper horizon of the Wabash soil is as dark and as thick as that of any other soil. The Judson-Wabash areas consist of narrow strips of Wabash silt loam lying directly in a drainageway flanked by narrow bands of Judson soil on each side. As the individual areas of each soil type are too small to be separated on a map of the scale used, these soils are mapped together as a complex.

All the soils mapped, with the exception of those of the Lindley series, belong to the group of Prairie soils or their poorly drained equivalents. Lindley loam and Lindley silt loam are the lighter colored analogues of the Shelby soils, having developed under forest vegetation in most of the areas of their occurrence. In the southeastern part of the county, the Lindley soils apparently were formed under a moderately heavy forest vegetation and belong to the Gray-Brown Podzolic group of soils. In the rest of the county, the native vegetation seems to have been a mixture of grass, brush, and trees. The Lindley soils have developed from similar parent materials, but are characterized by lighter colored surface horizons than the Shelby soils. Lindley loam occurs where the soil parent material included little, if any, loess, whereas Lindley silt loam is developed where an appreciable mantle of loess was present. Some of the areas included with the Lindley soils in the western part of the county apparently are small eroded areas of Shelby soil; the material now exposed at the surface is neutral in reaction and contains very small quantities of organic matter. These areas would have been mapped as eroded phases of the Shelby soils in more recent and more detailed surveys. The Lindley soils, however, are, to a great extent, light colored because of their development under a forest vegetation.

## SUMMARY

Audubon County is in the west-central part of Iowa, about 70 miles west of Des Moines. It comprises an area of 443 square miles, or 283,520 acres.

The relief is characterized by gently rolling to strongly rolling hills with moderately long slopes and gently rounded tops. Soil parent materials consist of Peorian loess, Kansan till, and local alluvium derived from the former two materials. The loess occurs on the gently undulating to gently rolling upland areas and on the upper parts of slopes in the more rolling country, whereas the till is exposed on the lower slopes and along the small deeply trenched drainageways. Alluvial materials occupy the flood plains and the terraces of the larger streams, also the drainageways of small intermittent streams, which extend into the uplands.

Natural drainage is good over nearly all of the county and is excessive on the steeper slopes. Except for a few square miles in the extreme northeastern part, which are drained by streams leading directly to the Mississippi River, all the county lies within the drainage basin of the Missouri River.

Altitudes recorded range from 1,209 to 1,350 feet above sea level, giving a maximum range in relief of 141 feet.

The first settlements were established in 1851, and practically all of the land in the county was taken up by settlers within the next 20 to 30 years. The total population in 1930 was 12,264, with 2,255 living in Audubon, the county seat and largest town.

Transportation facilities include spur lines of the Chicago, Rock Island & Pacific Railway, which enters the county from the south, and of the Chicago & North Western Railway, which enters from the north. Paved highways cross the county from east to west and from north to south, and a number of the more important secondary roads are graveled.

The climate is characteristically continental, with hot summers and rather cold winters. The mean annual temperature is 47.4° F.; for the summer months it is 71.2°, and for winter 21.1°. The maximum and minimum temperatures recorded are 105° and −35°, respectively. The mean annual rainfall is 30.87 inches, most of which falls during the growing season.

Agriculture has been the chief industry in the county since its first settlement, and the cash income on most of the farms is derived principally from the sale of livestock and livestock products. The principal crops grown are corn, oats, and hay, ranking in importance in the order named, and the total acreage of these crops constitutes more than 95 percent of all crops produced. Most of the grain and hay crops are fed to the livestock.

According to the Federal census of 1935, the total number of farms in the county was 1,879, and the average acre value, including buildings, was $79.70.

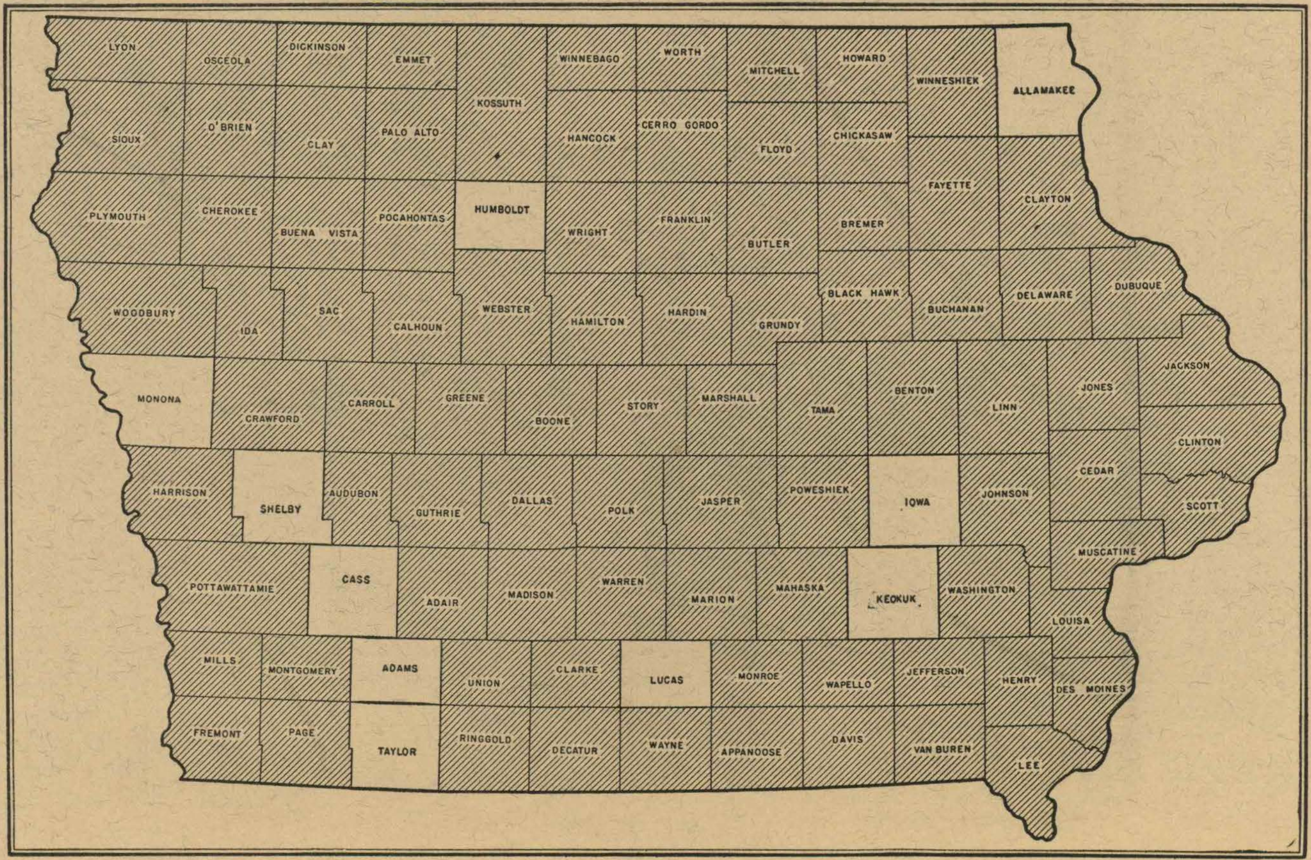
Upland soils occupy 74.6 percent of the total area of the county, and include the Marshall, Tama, Shelby, and Lindley soils. All these soils, except the Lindley, are dark-colored Prairie soils. The Lindley differs from the others in that they have light-colored surface layers, either as the result of development under forest cover or because of removal of the dark surface layer of the Shelby soils by erosion. The Marshall and Tama soils are highly productive, the Shelby soils moderately productive, and the Lindley soils low in natural productivity.

Waukesha silt loam is a dark-colored soil occurring on terraces along the principal streams. Judson silt loam occupies lower lying benches and alluvial fans and is slightly darker and thicker than Waukesha silt loam. These two soils are highly productive.

The Judson-Wabash soils have profiles similar to the Prairie soils, and they have been developed on local alluvium within the uplands, occupying narrow drainageways and the immediately adjacent lower slopes. In some places this soil complex occupies slightly depressed areas where natural drainage is inadequate. Aside from these few areas, however, all the upland soils are normally well drained.

The first bottoms, or flood plains, are occupied by the Wabash soils. These soils are characterized by very thick dark-colored surface layers, which are underlain by yellowish-brown mottled materials. Where natural drainage is adequate, Wabash silt loam is very productive and is used intensively for the growing of corn. In some years, however, crops on this soil are damaged by overflow.

U. S. GOVERNMENT PRINTING OFFICE: 1940




**Areas surveyed in Iowa shown by shading.**