Series 1933, No. 35 Issued October, 1940

Soil Survey

Steuben County Indiana

By
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United States Department of Agriculture
and
T. M. BUSHNELL and H. P. ULRICH
Purdue University Agricultural Experiment Station

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SOIL SURVEY OF STEUBEN COUNTY, INDIANA

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United States Department of Agriculture in cooperation with the Purdue University Agricultural Experiment Station

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COUNTY SURVEYED

Steuben County is in the extreme northeastern part of Indiana (fig. 1). Its shape is that of a rectangle, about 20 miles from east to west and 16 miles from north to south. The total area is 305 square miles, or 195,200 acres. Angola, the county seat, is about 135 miles east of Chicago and 145 miles northeast of Indianapolis, the State capital.

The county occupies a partly hilly and partly smooth broad glaciated plain, which extends from the southern parts of Noble and De Kalb Counties north through Steuben and Lagrange Counties to the Michigan State line. The elevation is about 1,100 feet above sea level in the northeastern part, from which the land slopes toward the southern border where the elevation is 900 feet. The United

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

States Weather Bureau station at Angola is located at an elevation of 1,060 feet. The upland ranges from 150 to 300 feet above the adjoining plains to the northwest and to the southeast. Although the greater part of the county consists of comparatively smooth farm land, diversity is added to the landscape by the numerous small areas of woodland, the many lakes, and the hilly lands surrounding most of them. East of the New York Central Railroad the relief in general is slight. With the exception of the somewhat hilly land bordering lakes and peat beds, the contours are comparatively smooth and local differences in elevation in few places exceed 75 feet. Even the roughest lands do not include slopes too steep for cultivation. So diverse, however, are the surface forms that all the terms — undulating, rolling, and moderately hilly— may be required in describing, with any approach to topographic accuracy, an area including only a few square miles.

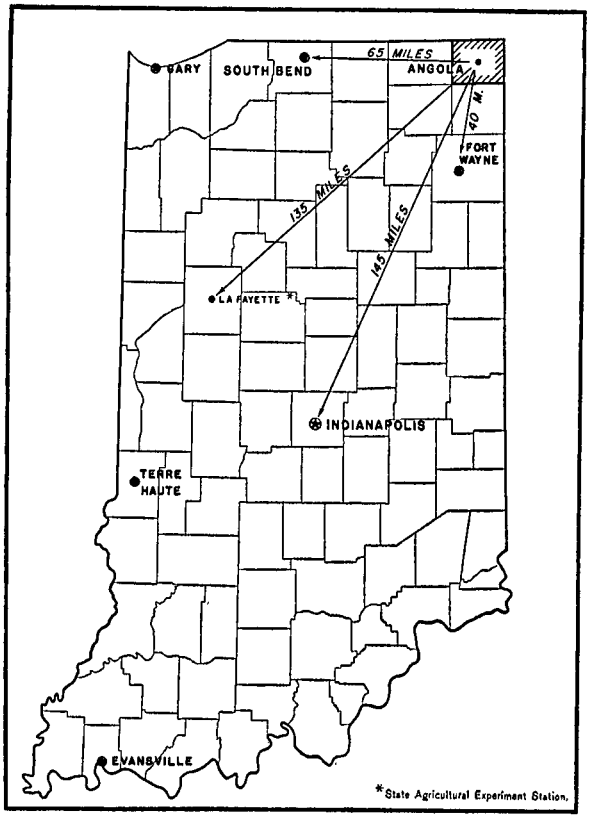

FIGURE 1.—Sketch map showing the location of Steuben County, Ind.

Around the headwaters of Pigeon Creek are level tracts ranging from one-fourth to more than 1 mile in width, which include some large peat areas. Toward the south these flat lands grade into terraces lying considerably above the level of the creek and ending in steep slopes ranging from 30 to 40 feet down to Pigeon Lake. A few miles farther south these terraces again expand to form wide level lands around Pleasant Lake. Hilly to very rough uplands border Lake Hamilton, except on the south, where low terraces extend into De Kalb County.

The extreme southeastern part of the county has very mild relief and includes many nearly flat upland areas of several hundred acres each. Most of the land for several miles north and northwest of Steubenville and Hudson, in the southern part, is undulating upland

interrupted by only a few sharp slopes or prominent elevations. In the northwestern quarter most of the numerous lakes and extensive peat beds are bordered on one or more sides by steep slopes or by morainic ridges and moundlike elevations. Much of this section, however, is fairly smooth. A considerable area consists of flat terraces, lying only slightly higher than the waterways, and of high uplands hardly more uneven than the terraces.

The most rugged relief characterizes the land on the eastern side of Lake James. Here the differences in elevation range from 100 to 200 feet and the more prominent hilltops overlook the entire county to the south and southwest but are little if any higher than the comparatively level land a few miles to the north and east. This succession of different surface levels is observable throughout the western half of the county and becomes very apparent near the western boundary. The slopes north of Crooked Creek are the escarpment of a plain extending into Michigan. South of this stream the plain on which Orland is located is a rather low terrace, which, farther south, becomes the uneven tableland in which Lake Gage and neighboring lakes and marshes are situated. The southern and southwestern margins of this plain overlook the Pigeon Creek chain of lakes and peat deposits. To the southwest, low terraces and comparatively smooth uplands extend to Turkey Creek and its connected lakes.

Most of the county is drained by three streams, Crooked Creek, Pigeon Creek, and Turkey Creek, which traverse the county from east to west. Each stream occupies a glacial channel and, with its tributaries, connects a nearly continuous chain of lakes. Crooked Creek, which flows out of the county at its northwestern corner, passes through James, Jimmerson, Snow, Crooked, and Gage Lakes. Pigeon Creek flows south from Fremont to the village of Pleasant Lake and thence west, through Pleasant, Long, Golden, and Hogback Lakes, past Flint to the county line. Turkey Creek heads in De Kalb County and flows northwestward across the southwestern part of the county through Little Turkey and Turkey Lakes.

The streams mentioned are the principal ones, and they empty into the Pigeon River, which flows into the St. Joseph River (in Michigan), which in turn discharges into Lake Michigan. At various times their channels have been artificially deepened so that they serve as outlets for many shorter ditches. There are few natural terraces. Most of the lakes have been lowered, many ponds have disappeared, and the greater part of the peat deposits and other low areas have had their former high water table lowered several feet.

Fish Creek drains an area of about 70 square miles in the eastern part of the county. Unlike the streams previously described, Fish Creek flows in a narrow troughlike valley from one-eighth to one-fourth mile wide. Fish Creek includes Lake Hamilton in its drainage basin and flows south to the St. Joseph River (a different river from the one mentioned above), a branch of the Maumee River, which discharges into Lake Erie.

Stream channels are comparatively shallow, and, although the tendency is toward a dendritic system of drainage, dissection is moderate and uniform. All these creeks are clear, gravel-bottomed streams

with a brisk flow. Water power is developed at Orland and Nevada Mills.

Prior to the extension of ditches and enlargement of the creek channels, most of the excess rainfall found its way into nearby lakes and marshes. These still receive much local drainage, but in most places they have more or less direct connections with creeks or lakes. Progressive deepening of streams and extension of ditches have considerably lowered the water tables along stream channels, as well as in depressions.

This county was settled almost entirely by people from Ohio and States farther east. Residents of foreign birth are comparatively few. The total population, according to the census of 1930, is 13,386. Angola has 2,665 inhabitants, Fremont 802, Ashley 623 (of whom 287 live within Steuben County and 336 within De Kalb County), Hudson 431, Hamilton 357, and Orland 310.

Angola, the county seat, is situated approximately in the geographical center of the county. The New York Central Railroad, crossing from north to south, serves Angola and Fremont. Ashley, Hudson, and Hamilton are on the Wabash Railway, which crosses the extreme southern part from east to west. United States Highways Nos. 20 and 27 extend through the county, the former from east to west and the latter from north to south, intersecting at Angola. Gravel roads are well distributed, and some hard-surfaced roads are near the villages. Each township supports a consolidated school. Telephone service is fairly common.

The transient summer population at the lake resorts is estimated at several thousand. With improvement of automobile roads and increase of accommodations, the resort trade is increasing steadily, thus creating local markets for poultry, dairy, and vegetable products.

CLIMATE

The climate of Steuben County is continental, and the variations between winter and summer temperatures are wide. Droughts of 2 weeks' or more duration may occur in the summer.

The slightly higher average monthly rainfall during June, July, and August is favorable for the production of corn and alfalfa, particularly on the sandy soils. The somewhat larger reserve of moisture in the heavier soils renders them less in need of frequent rain, but equitable distribution rather than total seasonal amount is desirable, especially on all light-colored soils devoted to pasture and hay.

The average date of the last killing frost is April 30, and of the first is October 16, giving an average frost-free period of 169 days. The latest killing frost recorded in recent years was on May 23, and the earliest was on September 23.

Frost damage varies considerably as influenced by local situations. Many areas of muck and of the dark mineral soils are surrounded by higher land. The greater likelihood of injury from frost in such situations is sometimes offset by mist or fog settling into these basins. This is especially true near the lakes.

Table 1, compiled from the records of the United States Weather Bureau station at Angola, gives the salient facts concerning the climate.

TABLE 1.—*Normal monthly, seasonal, and annual temperature and precipitation at Angola, Steuben County, Ind.*

[Elevation, 1,060 feet]

Month	Temperature			Precipitation			
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year (1934)	Total amount for the wettest year (1896)	Snow, average depth
	°F.	°F.	°F.	Inches	Inches	Inches	Inches
December	27.5	65	−13	2.65	1.83	1.53	8.1
January	24.6	65	−20	2.43	1.40	2.37	10.8
February	25.2	65	−20	2.26	.54	2.01	9.0
Winter	25.8	65	−20	7.34	3.77	5.91	27.9
March	35.6	79	−6	3.32	2.38	3.12	7.8
April	47.2	90	13	3.08	3.23	5.91	2.8
May	58.9	100	26	3.56	1.65	4 35	.1
Spring	47.2	100	−6	9.96	7.26	13.38	10.7
June	67.8	104	38	3.56	2.02	3.58	0
July	72.7	104	45	3.39	.51	12.78	0
August	70.6	105	43	3.29	3.32	7.60	0
Summer	70.4	105	38	10.24	5.85	23.96	0
September	64.0	100	28	3.29	4.61	5.90	0
October	52.4	90	18	3.21	1.01	.75	.3
November	39.4	76	7	2.78	2.40	2.12	4.7
Fall	51.9	100	7	9.28	8.02	8.77	5.0
Year	48.8	105	−20	36.82	24.90	52.02	43.6

AGRICULTURAL HISTORY AND STATISTICS

Agriculture developed very slowly in northern Indiana until the construction of the railroads. Subsistence farming was the basis for agriculture in Steuben County in the early years of settlement—the 1830's. During this period, corn, wheat, hay, and oats were the principal crops. As the population increased and railroads were built, the production of grain for feed and for cash expanded rapidly. Diversification of farming activities resulted in the partial displacement of wheat and oats by rye and barley. Corn and oats attained their maximum acreage about 1910, whereas wheat was at the height of its importance at the turn of the century. During the last quarter century the acreage devoted to the principal grains has been reduced, especially the acreage in wheat, which has fallen off more than one-half.

The production of hay increased fairly rapidly until about 1900, since which time it has increased more slowly and less constantly.

The soil and climate are very favorable for bluegrass. Along the roads, in yards, and on uncultivated lands that are neither shaded nor exceptionally wet, it forms a fresh green cover during the spring and autumn and tenaciously endures in less vigorous form throughout the summer. It spreads into woodlands wherever the woods are thinned, displaces the native grasses on reclaimed peat soils, and encroaches on clover and alfalfa fields. Without cultural care of any kind it furnishes more grazing than all other grasses and legumes combined. This "junegrass," as it is called, includes both the Kentucky and Canada species of bluegrass. The latter is the hard, flat-

stemmed species, which will grow on very light sandy soils, whereas the Kentucky bluegrass has a decided preference for loams and the dark-colored soils.

The acreage in timothy and clover increased until 1920, after which it declined somewhat. Alfalfa has become economically important within the last 20 years. These hay crops have gained in total area at the expense of the common bluegrass.

Competition from the prairie States farther west has put a premium on the efficient production of the more important grains, in spite of rising labor costs and the spread of plant diseases, and on the development of special cash-income crops and industries. As a result of this economic pressure, farming is becoming more intensive, and, since 1880, more attention has been given to rotation of crops, growth of cover crops, artificial drainage, liming, and fertilization, as well as to the careful selection of seed. A further result has been the development of truck gardening, especially the growing of onions and cucumbers for distant markets, and melons, small fruits, shrubs, and flowers for local markets. The emphasis placed on the production of hay, minor grains, and truck crops, however, has not been sufficient to compensate for the decline in the production of the major grains, although they continue as the foundation for cattle, hog, and poultry raising.

The total value of all field and orchard crops and vegetables in 1929 was $2,039,063, of which the most important items were cereals, $903,040; hay and forage, $501,968; and vegetables, including potatoes and sweetpotatoes, $433,341. In addition, forest products cut on farms for home use and sale were valued at $60,945, and nursery and greenhouse products were valued at $43,120.

Table 2 gives the acreages of the most important crops in stated years.

TABLE 2.—*Acreages of the principal crops in Steuben County, Ind., in stated years*

Crop	1879	1889	1899	1909	1919	1929	1934
	Acres	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
Corn	22,288	22,105	26,531	29,461	24,251	17,399	21,130
Wheat	28,251	25,225	32,675	16,896	14,345	10,293	15,993
Oats	6,021	9,637	6,581	15,286	11,237	13,151	10,702
Barley	62	----------	443	2,129	6,427	5,671	859
Rye	89	985	492	4,759	16,458	462	1,323
Potatoes	----------	1,213	1,185	1,360	870	1,370	2,082
All hay	16,612	23,832	25,415	23,149	23,543	25,923	26,863
Alfalfa	----------	----------	16	194	1,589	8,733	13,817
Timothy, and timothy and clover mixed	----------	----------	(1)	19,815	19,138	9,903	11,316
Clover alone	----------	----------	9,863	2,776	1,876	6,974	[2] 86
	Trees	*Trees*	*Trees*	*Trees*	*Trees*	*Trees*	*Trees*
Apples	----------	[3] 112,488	[3] 90,565	53,789	18,783	[3] 12,376	[3] 15,118

[1] Not reported separately.
[2] Includes all clover alone, except sweetclover.
[3] Numbers of apple trees are for the years 1890, 1900, 1930, and 1935.

In addition to the crops listed in table 2, vegetables and melons for sale were grown on 1,504 acres in 1929, of which 1,180 acres were devoted to onions and 92 acres to cucumbers. Strawberries were grown on 111 acres, clover seed on 7,494 acres, alfalfa seed on 585 acres, timothy seed on 145 acres, and mint on 133 acres. In 1934, market vegetables were grown on 644 acres and strawberries on 67 acres. Seeds and mint were not reported by the 1935 census. Small

acreages are devoted to beans and orchard fruits for home and local markets.

The total number of cattle in 1935 was 15,538, and the number of cows milked during 1934 was 9,684. The proportion of dairy cattle is increasing, whereas that of beef cattle varies with market prospects but is declining. The sale of cream and milk is an important and dependable source of income on a majority of farms. In 1929, 4,220,542 gallons of milk was produced, and the value of the butter, cream, and milk sold was $705,482. The production of milk increased to 4,277,832 gallons in 1934. In addition to the local creameries, a milk condensery at Angola provides a local market for milk.

On most of the farms having a considerable acreage adapted to corn growing, the sale of fattened hogs is the largest single item of income. There were 27,905 swine on farms in 1930; this number was reduced to 15,160 in 1935. Many small flocks of sheep are kept for the wool clip and sale of lambs to local livestock buyers. These flocks included 31,787 sheep in 1930 and 22,050 sheep in 1935. The value of the 141,335 pounds of wool (unwashed) shorn in 1929 was $49,467; the comparable production in 1934 was 143,992 pounds. Several thousand western-raised lambs are bought in carload lots and finished for eastern markets each year.

Practically every farmer sells more or less poultry and eggs, and many owners of small farms specialize in poultry. The 245,924 chickens raised in 1929 were valued at $228,709; and the 999,725 dozen eggs produced, at $299,918. In 1934 the number of chickens raised was 181,739, and 714,222 dozen eggs were produced.

Other livestock on farms in 1935 included 3,596 horses and 294 mules.

Even though large numbers of livestock are fed on farms, only small quantities of concentrated feed are commonly purchased. The purchase of feed was reported in 1929 by 863 farms in amount of $156,671, or $181.54 per farm reporting, but this includes expenditure for grain and hay obtained from local sources. In recent years dairymen have been almost the sole users of imported or mixed feeds.

According to the 1935 census, tenants operate 32.6 percent of the farms. This represents an increase over the proportion of tenancy in 1900, which was 24.5 percent. The prevailing terms are an equal share of products sold and a similar division of expenses for seed, fertilizer, and hired labor. As a rule the tenant furnishes the horses and usual equipment of implements for ordinary farm operations. Hay and pasture land generally rent for cash.

Little labor is hired on farms except in summer for work in the onion fields. In 1929, 733 farms reported the hire of labor at a cost of $209,215, or $285.42 per farm reporting. An expenditure of only $59,570 for fertilizer was reported by 792 farms, or $75.21 per farm reporting.

According to the 1935 census, 179,099 acres, or 91.8 percent of the area of the county, is included in farms, of which 96,207 acres are devoted to crops, 29,836 acres are plowable pasture, 17,371 acres are woodland pasture, 18,281 acres are other pasture, 4,878 acres woodland not pastured, and 12,526 acres, all other land in farms. The area of improved land—cropland and plowable pasture—has decreased slightly in recent years, being 139,657 acres in 1900, 140,560 acres in 1920, 131,583 acres in 1930, and 126,043 acres in 1935.

About 20,000 acres consists of lakes, marshes, and very rough or stony land. Much of this untillable land is included in the steep and slope phases of several soils, but considerable discrepancy is to be expected in any attempt to correlate the census classifications with the soil map. Parts of the steep and sloping land are improved and cultivated, and very small patches of wasteland occur throughout the upland. The actual boundaries of the lakes and ponds are indicated as accurately as the scale of the map admits. The lakes, together with the areas of peat, represent very nearly the total proportion of the entire county that does not in some measure contribute to agriculture. Lake frontage suitable for cottages or recreational purposes has a very high value, particularly if well wooded.

The 1935 census reports 1,703 farms with an average size of 105.2 acres. The trend is toward fewer and larger farms. This is due almost entirely to the purchase of small holdings by owners of adjoining larger ones. In 1920 there were 1,787 farms with an average size of 102.4 acres; in 1900, 1,956 farms with an average size of 95 acres. A farm of less than 40 acres must be devoted largely to some specialized industry, in order to obtain profitable returns, and an 80-acre farm is less efficiently managed than one two or three times as large. About 526 farms embrace from 100 to 174 acres each, and 175 farms embrace from 175 to 259 acres.

On most farms, farm buildings include a comfortable house, large barn, corncrib, hog and poultry houses, and a garage. Many farmers have silos, and a considerable number have lighting systems in the houses and barns. Machinery equipment is very similar to that of the average farm in the Corn Belt, but the use of very large implements operated by four or six horses is not so practicable here as on large prairie farms. Many farmers own tractors and supplementary equipment.

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 [2] and its content of lime and salts

[2] 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. For convenience soil-reaction values may be grouped as follows:

Acidity or alkalinity:	*pH range*
Extremely acid	Below 4.5
Very strongly acid	4.5 to 5.0
Strongly acid	5.1 to 5.5
Medium acid	5.6 to 6.0
Slightly acid	6.1 to 6.5
Neutral	6.6 to 7.3
Mildly alkaline	7.4 to 8.0
Strongly alkaline	8.1 to 9.0
Very strongly alkaline	9.1 and higher

are determined by simple tests.[3] Drainage, both internal and external, and other external features, such as relief, or lay of the land, are taken into consideration, and the interrelation of soils and vegetation is studied.

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 crop plants, grasses, and trees. On the basis of these characteristics soils are grouped into mapping units. The three principal ones are (1) series, (2) type, and (3) phase. Areas of land, such as beach sand, that have no true soil, are called (4) miscellaneous land types.

The most important group is the series, which includes soils having the same genetic horizons, similar in their important characteristics and arrangement in the soil profile, and developed from a particular type of parent material. Thus, the series includes soils having essentially the same color, structure, and other important internal characteristics and the same natural drainage conditions and range in relief. The texture of the upper part of the soil, including that commonly plowed, may vary within a series. The soil series are given names of places or geographic features near which they were first found. Thus, Miami, Brookston, and Fox are names of important soil series in this county.

Within a soil series are one or more soil types, defined according to the texture of the upper part of the soil. Thus, the class name of the soil texture, such as sand, loamy sand, sandy loam, loam, silt loam, clay loam, silty clay loam, and clay, is added to the series name to give the complete name of the soil type. For example, Miami loam and Miami fine sandy loam are soil types within the Miami series. Except for the texture of the surface soil, these soil types have approximately the same internal and external characteristics. The soil type is the principal unit of mapping, and because of its specific character it is usually the soil unit to which agronomic data are definitely related.

A phase of a soil type is a variation within a type, which differs from the type in some minor soil characteristic that may have practical significance. Differences in relief, stoniness, and the degree of accelerated erosion are frequently shown as phases. For example, within the normal range of relief for a soil type, there may be areas that are adapted to the use of machinery and the growth of cultivated crops and others that are not. Even though there may be no important difference in the soil itself or in its capability for the growth of native vegetation throughout the range in relief, there may be important differences in respect to the growth of cultivated crops. In such an instance the more sloping parts of the soil type may be segregated on the map as a slope or hilly phase. Similarly, soils having differences in stoniness may be mapped as phases, even though these differences are not reflected in the character of the soil or in the growth of native plants.

The soil surveyor makes a map of the county or area, showing the location of each of the soil types, phases, and miscellaneous land

[3] 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.

types, in relation to roads, houses, streams, lakes, section and township lines, and other local cultural and natural features of the landscape.

SOILS AND CROPS [4]

For the most part, the pattern of distribution of the soils of Steuben County is very complex. The soils are closely associated, and marked agricultural as well as developmental differences are apparent within short distances. In more than one-half of the county a well-diversified system of crop production is carried on, and cropping on any one farm is influenced by soil differences if these differences affect large enough areas to make such adaptations advantageous and expeditious. In the soil province to which the soils of the county belong, drainage is of utmost significance. The height of the water table bears directly on aeration, weathering of parent material, accumulation of fine particles washed from the surface soil, tendency toward droughtiness, and biological activity within the soil. All these processes combine to govern the development of a soil, and their lack or excess in different combinations contribute to the wide variations in soils within this county.

Because of the significance of natural drainage conditions, the soils will be discussed in the following groups: (1) Well-drained soils; (2) imperfectly drained soils; (3) poorly drained soils; (4) organic soils, all of which are poorly drained; and (5) miscellaneous land types. The soils of the first group are developed on the uplands and valley terraces and advantageously support the production of the major and minor grains, an increasing acreage of alfalfa, as well as good pasture. The shallow depressions of the uplands and terraces, occupied by soils of the second group, produce fair yields of oats and better yields of corn than do the well-drained soils. The deeper depressions of the uplands and terraces, and those along the stream channels, in which the soils are members of the third group, return heavy yields of corn and grass. The organic soils occupy old lake beds and stream channels. Truck gardens are maintained on the reclaimed land; but grazing is the only use made of the unreclaimed land.

Wide differences in inherent productivity exist between the soils of each group. Soil texture is an important factor in the tilth, availability of plant nutrients, and the water-holding capacity of the soil. Generally speaking, the greater the proportion of silt and clay, the more productive is the soil for most crops. Each drainage category includes three subgroups for a broad discussion of the soils: (1) The heavy-textured soils, including the silt loams; (2) the medium-textured soils, comprising the loams and fine sandy loams with heavy subsoils; and (3) the light-textured soils, including the more sandy and gravelly soils.

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[4] Steuben County adjoins Branch County, Mich., along most of its northern boundary. The mapping of the soils, chiefly the types and phases of the Bellefontaine series, in Steuben County was made in somewhat greater detail than in Branch County. In Branch County all the Bellefontaine soils were included on the map with Bellefontaine sandy loam; in Steuben County the following types and phases of the Bellefontaine series were recognized: Bellefontaine loamy sand, Bellefontaine gravelly sandy loam, Bellefontaine cobbly fine sandy loam, Bellefontaine fine sandy loam, and Bellefontaine fine sandy loam, steep phase. Owing to this refinement of classification, there is some discrepancy in the joining of soil areas along the State line.

The soils are described in detail in the following pages, their distribution is shown on the accompanying soil map, and their acreage and proportionate extent are given in table 3.

TABLE 3.—*Acreage and proportionate extent of the soils mapped in Steuben County, Ind.*

Soil type	Acres	Percent	Soil type	Acres	Percent
Miami silty clay loam	22,720	11.5	Crosby loam	832	0.4
Miami silty clay loam, slope phase	3,776	1.9	Bronson sandy loam	1,152	.6
Miami loam	32,704	16.8	Berrien loamy fine sand	896	.5
Miami fine sandy loam	11,200	5.7	Brookston silty clay loam	28,288	14.5
Miami fine sandy loam, slope phase	704	.4	Washtenaw silty clay loam	1,664	.9
Fox sandy loam	10,496	5.4	Clyde silty clay loam	2,880	1.5
Fox sandy loam, slope phase	6,144	3.1	Griffin silt loam	1,088	.6
Warsaw sandy loam	768	.4	Griffin fine sandy loam	1,856	1.0
Bellefontaine fine sandy loam	7,168	3.6	Brady sandy loam	7,424	3.8
Bellefontaine cobbly fine sandy loam	11,136	5.7	Maumee fine sandy loam	512	.3
Bellefontaine fine sandy loam, steep phase	4,800	2.5	Newton loamy fine sand	832	.4
Bellefontaine gravelly sandy loam	1,280	.7	Carlisle muck	4,736	2.4
Bellefontaine loamy sand	2,112	1.1	Houghton muck	10,432	5.3
Oshtemo loamy sand	2,752	1.4	Edwards muck	1,600	.8
Coloma loamy fine sand	3,072	1.6	Kerston muck	384	.2
Plainfield loamy fine sand	1,472	.8	Wallkill silt loam	448	.2
Crosby silty clay loam	2,176	1.1	Rifle peat	2,624	1.3
Conover loam	2,624	1.3	Beach sand	128	.1
			Marl beds	192	.1
			Gravel pits	128	.1
			Total	195,200	

WELL-DRAINED SOILS

The subgroup of heavy-textured well-drained soils is represented by only two soils—Miami silty clay loam, which is the most fertile and productive well-drained soil in the county, and Miami silty clay loam, slope phase. Typical Miami silty clay loam is well distributed, comparatively free from stone and cobbles, well adapted to growing corn and small grains, and comparatively smooth.

The medium-textured well-drained soils—Miami loam, Miami fine sandy loam, and Miami fine sandy loam, slope phase—combine high inherent fertility with excellent tilth and ease of management. The lighter textured soils are affected by long periods of drought.

The subgroup of light-textured well-drained soils have surface soils ranging from fine sandy loam to loamy sand. The subsoils are, for the most part, loose and tend to be excessively drained, especially those of the Oshtemo, Coloma, and Plainfield soils. The subsoils of the Fox and Warsaw soils are slightly heavier than is characteristic of this subgroup and retain moisture to some degree. With good management the Fox and Warsaw soils produce well; whereas the productivity of the other soils in this subgroup is average or below average.

Miami silty clay loam.—Miami silty clay loam as mapped includes soils that are developed on two somewhat different kinds of parent materials and, as a consequence, it also includes soils having somewhat different profile characteristics. It proved impracticable to separate these two soil conditions, inasmuch as the soils are so intimately intermixed. If one should draw a line from Steubenville on the south county line northeastward through Angola to a point on the Michigan line almost directly north of Fremont, it would approxi-

mately separate the areas of Miami silty clay loam that are developed on unusually heavy parent materials from those developed on parent materials normal for the type. East of this line, much of the calcareous glacial till that is the parent rock on which the Miami soils are developed, contains a moderate to high percentage of shale fragments, which tend to weather into rather sticky and heavy clay materials. West of the line, much of the till is composed of a mixture of finely ground sandstones, limestones, granite, gneiss, and many other kinds of rocks, with an insignificant proportion of shale fragments. Although the data just presented represent the facts in a general way, it is also true that a considerable proportion of the glacial till east of the line is of the type that gives rise to normal Miami soils, that a part of the till west of the line has a fairly high percentage of the shale materials and, consequently, that some of the soils have heavier-than-normal subsoils. Field observations indicate also that the glacial till within a mile or two of the lakes of the eastern part of the county is lighter in texture and contains less shale than the till farther from the lakes.

Since the proportion of Miami silty clay loam developed on heavy glacial till seems to be at least as great if not greater than the proportion developed on less heavy materials, it will be described first. The surface soil, to a depth of 6 inches, is very friable light grayish-brown silt loam or light silty clay loam, containing some grit but no gravel. Below this and continuing to a depth of 20 inches the material is heavier—a light-gray crumbly noncompact silt loam or light silty clay loam, containing some pale-yellow mottlings and faint brown stains. Between depths of 20 and 30 inches the material is dark-brown heavy silty clay loam, faintly stained with brown in the lower part. The partly dry material breaks into small somewhat angular pieces along minute cleavage planes. A dull-gray, with a slightly brown cast, hard, partly weathered highly calcareous glacial till, containing a moderately high proportion of fine shale fragments, is reached at a depth of about 30 inches. When a hand sample of a dry surface soil in old fields is pulverized, it is very light colored and has an ashy feel. Such soils clod rather easily or may form a hard but somewhat porous crust after rains. The dull-brown subsurface layer offers much resistance to downward movement of moisture but is not impervious. The tendency to break into angular fragments on drying indicates a joint structure, favoring better moisture properties than exist in the lower unweathered material. As a rule, calcium carbonate is present at a depth ranging from 30 to 40 inches, and in many places it is even nearer the surface.

West of the imaginary line already described and in many places east of it, Miami silty clay loam is developed on somewhat lighter textured till and, consequently, is characterized by a less heavy and somewhat more permeable subsoil. The layer corresponding to the third layer just described consists of brown or yellowish-brown silty clay loam or clay loam, which is more or less uniform in color, except that the angular fragments ranging from about one-fourth to one-half inch in diameter are coated with somewhat darker brown colloidal organic material. Calcareous glacial till with a moderate to low content of shale fragments occurs in most places at a depth ranging from 30 to 40 inches. In general, this variety of Miami silty clay loam, which more nearly represents Miami silt loam as mapped else-

where in the State, is more tractable and therefore is considered slightly better from an agricultural point of view.

Miami silty clay loam occupies 11.5 percent of the total area of the county. Except in the northwestern quarter, bounded by United States Highways Nos. 20 and 27, distribution is fairly even, with somewhat more extensive development in the northeastern and southeastern parts. The land generally is smooth.

A well-marked belt of boulders extends northeastward for several miles from about 1 mile southwest of Berlien. Granite boulders and metamorphic rocks several feet in diameter are numerous in places. Many have been removed, so that in most fields they no longer obstruct tillage operations. Small stones and gravel are unimportant.

With the exception of possibly as much as 10 percent in wood lots, all the land is cultivated. It cannot be cultivated satisfactorily so soon in the spring or so soon after rains as most of the medium-textured soils. The tendency to crust after rains or to become cloddy in dry weather can be obviated largely by care in tillage and by the addition of organic matter of any kind. The growth of clover and the use of barnyard manure improve this soil rapidly. The general cultural requirements, besides those mentioned, and the crop adaptations are similar to those of the subgroup of medium-textured well-drained soils. Discussion of these factors will be taken up when the medium-textured well-drained soils are presented.

The price of farms and rental values are practically the same as those of the medium-textured well-drained soils, when improvements and corresponding locations with respect to markets are the same.

Miami silty clay loam, slope phase.—Miami silty clay loam, slope phase, embraces some rolling and hilly areas, in which there are a few short steep slopes and narrow ridges with one or both flanks so sharply inclined as to be practically untillable. In such places, drainage is even better than in the typical soil, and a reddish-brown subsoil is developed, which is in contrast to the dark-brown or grayish-brown subsoil of normal Miami silty clay loam. The 4-inch surface soil of the slope phase is yellowish-brown friable loam, and the upper subsoil layer is light-brown crumbly silty clay to a depth of 15 inches. Below this is brown hard silty clay, which tends to crack very finely when dry and which gives way to light-brown more friable highly calcareous silty clay loam at a depth of 25 inches. Sheet erosion is active on the steeper slopes. In many places, the surface soil is very thin, and in some places the silty clay subsoil is exposed by washing. Stones are strewn over the surface in many places, and a few boulders are present. The few sandy spots probably are remnants of severely eroded soils. Gullying, owing to the cutting action of sharp sands carried by running water, is not common or, as yet, beyond control.

Much of the soil of this phase is devoted to pasture, and practically all of it that has not recently been seeded to clover is well sodded with bluegrass. Clover does well wherever a stand is obtained, and many farmers find it does best on steep slopes where the soil is so thin that other crops fail. This, of course, is due to the slight depth to lime in such locations.

Miami silty clay loam, slope phase, presents the same variations in texture of the subsoil and substratum as does the typical Miami silty clay loam.

Miami loam.—The surface soil of Miami loam in cultivated fields is grayish-brown loam containing more than the average amount of silt. The subsurface layer is grayish-yellow friable silt loam, which contains less sand and is more compact than the surface soil. Below a depth of 15 inches the material is heavier than it is above and consists of dull-brown rather compact faintly mottled silty clay. The color of the moist material approaches a Vandyke brown. This material tends to crack during dry periods but, under conditions of normal rainfall, maintains a somewhat impermeable barrier to percolating water. At a depth of 25 inches a hard silty clay is reached, which is somewhat lighter colored than the overlying material and is so slightly disintegrated and leached that it is highly calcareous. The subsoil and parent material of Miami loam are heavier textured than in most of the Miami loam areas elsewhere in Indiana. This description covers the greater part of the Miami loam that lies east of an imaginary line drawn from Steubenville north-northeastward to the Michigan line north of Fremont. West of this line the subsoil and substratum in most places are friable clay loams, as are normal for Miami loam.

A slight variation in texture of the surface soil, tending toward a silt loam, is included with Miami loam in mapping, on account of an admixture of coarse sand. Scattered spots of gravel and small rounded stones, together with a few boulders, are common in many areas. The original organic-matter content of the virgin soil was low and directly affected the surface layer to a depth of only 5 or 6 inches. In cultivated land the organic matter has disappeared to a great extent, except in slight depressions where enough humus remains to impart a dark color and slightly crumbly structure.

Numerous tests for acidity indicate a reaction ranging from medium to slightly acid. The pH value of the surface and subsurface soils ranges from 6.0 to 6.5 and of the subsoil, from 6.5 to 7.0.

Miami loam is very closely associated with an included soil throughout its distribution, except in the northwestern corner of the county where there are only a few isolated areas. This inclusion comprises roughly 6 percent of the total area mapped. Although very similar in appearance to Miami loam the included soil is developed from much lighter textured till, which affects the profile to a considerable degree. The surface soil is grayish-yellow friable loam, and the subsurface layer is light yellowish-brown friable silt loam with a slight degree of compaction. This gives way, at a depth of 18 inches, to heavier material, light reddish-brown silty clay loam, which breaks into small angular fragments when nearly dry. At a somewhat variable depth, but generally less than 30 inches below the surface, hard silty clay is reached, which is much lighter colored than the overlying material. It is considerably looser in structure and contains less clay than does the Miami loam subsoil of the eastern part of the county, but it is just as calcareous as the typical subsoil. The surface soil tends toward a light loam in most places and is slightly easier to work, and the heavy layer is considerably more porous and consequently is more perfectly drained than are the corresponding layers in the typical soil.

In some areas, the depth to calcium carbonate is greater than is typical. The principal ones are 1 mile southeast of Flint and in the

extreme southwestern corner of the county, and in both calcium carbonate lies more than 40 inches below the surface. Cultural operations can be started earlier in the spring and less care is required to work the soil soon after rains than on the typical soil. The same crops are grown and about the same yields are obtained on the two soils. The included soil has some slight disadvantage during droughty periods, as it tends to dry, owing to the lighter subsoil. This disadvantage can be eliminated to a great extent, however, by building up the organic-matter content of the soil so as to prevent evaporation. Other physical features of the two soils are practically the same. The surface and subsurface layers of the included soil are slightly acid, and the heavy layer is medium acid in reaction.

Large areas of Miami loam occur throughout the eastern and southern parts of the county, and small areas are scattered throughout the northwestern and north-central parts. This is the most extensive soil in the county, comprising 16.8 percent of the entire area. The relief ranges from undulating to rolling or very moderately hilly. The latter form of relief most commonly characterizes the areas near lakes and peat deposits, which are also, as a rule, more stony than the smoother areas. Smooth almost stone-free areas predominate in the southwestern part. The original forest cover was a growth of mixed hardwoods, in which sugar maple was one of the dominant trees. Many wood lots remain, but their total area probably includes less than 10 percent of the land.

The physical features of Miami loam are favorable to good cultivation and the maintenance of excellent moisture conditions. As previously mentioned, the heavy brown subsoil is not impervious to water and affords moisture storage for the use of plants. The underlying calcareous clay, as indicated by deep exposures, contains much moisture throughout the upper 3 to 4 feet, where the material is more or less checked, or minutely fissured, as a result of partial weathering. Farmers state that crops on this soil, where the soil is well managed, withstand dry weather remarkably well.

Yields of corn are estimated to range from 30 to 40 bushels per acre, not considering returns from the included small spots of more productive dark soils. The yields on land that has been well manured or has received considerable addition of humus from bluegrass or clover may be 60 or 70 bushels per acre if conditions are favorable. In short, yields of corn and, to less extent, perhaps, of small grains, are determined very largely by the content of organic matter in the soil. Some oats are grown, but seasonal conditions greatly affect this crop, regardless of fertilization. Barley does well and is frequently used as a nurse crop for clover and sometimes for alfalfa. These legumes thrive as well on this soil as on any of the lighter colored soils. The abundance of calcium carbonate at such a slight depth insures a good growth of legumes if conditions are favorable during the early stages of growth. The production of minor crops is fairly successful. Many farm orchards contain very old trees, and there is every indication of suitable soil conditions for apples as well as for most other tree fruits.

Miami fine sandy loam.—Miami fine sandy loam, to a depth ranging from 6 to 10 inches, is light-brown friable fine sandy loam. It is underlain by lighter colored somewhat heavier very friable yellowish-

brown fine sandy loam or brown loam of somewhat coarse texture. In most places the material in the subsurface layer has a slightly laminated structure and tends, when partly dry, to break into friable fragments along horizontal planes, although it is permeable to water. The subsoil is brown or reddish-brown loam. In most places this layer is rather crumbly and has a considerable degree of porosity, owing to the comparatively large proportion of sand and silt. Oxidation has been effective to a depth ranging from 40 to 50 inches in most areas, with the consequent development of uniformly brown coloration. Below this is grayish-yellow or grayish-brown calcareous till. Small rounded stones are strewn over the surface of many areas. They are most numerous, as a rule, on slopes and small elevations, but piles of stone are conspicuous in some level fields.

The areas of Miami fine sandy loam lie chiefly west and southwest from Lake James and constitute 5.7 percent of the total area of the county. Throughout the rest of the county, small isolated areas are closely associated with areas of Miami loam, from which this soil differs in the greater average depth of the surface soil, coarser texture, and looser consistence of the subsoil. There is considerable variation in all these features, but in most places farmers recognize the fine sandy loam as a somewhat lighter textured soil than the loam.

Areas totaling less than 2 square miles, with a heavier and darker subsoil than typical, were recognized but not separated on the map. The included soil occupies fairly level land, principally just south of Lake George and about 1½ miles directly north of Flint. The surface soil is essentially the same as that of typical Miami fine sandy loam, but the material in the subsurface layer is deeper brown and is a heavier loam than in that soil. The subsoil is dark-brown granular clay loam, somewhat impervious to water. In the lower part of this horizon, just above the limy till, are yellow and brown mottlings. This variation of Miami fine sandy loam has about the same crop adaptations and requirements for management as the typical soil, but it has the advantage of greater resistance to drought. The heavier subsoil tends to retard the downward percolation of water and provides better moisture conditions for deep-rooted crops.

A few small areas of soil closely resembling Hillsdale fine sandy loam are included on the map with Miami fine sandy loam. Soils of these areas are similar to Miami fine sandy loam, except that the parent material contains a high proportion of sandstone fragments and less lime, so that leaching of lime extends to a depth of 5 feet or more. The largest of these areas is about one-half mile east of Lake George on the Michigan State line.

In slight depressions of Miami fine sandy loam drainage is imperfect, and here the presence of organic matter imparts a dark color to the surface soil. Few such areas, however, require artificial drainage in order to be tillable, as do the small associated spots of muck or Clyde silty clay loam. Some areas of heavier texture include flat spots of light-colored silty soil, which is practically identical with Miami loam. In wood lots the accumulated organic matter imparts a very dark color to the topmost few inches of material, but this humous soil has almost entirely disappeared from cultivated fields.

The areas in the vicinity of the larger lakes are more sandy and generally carry more stony material than those farther south. Some of the areas near the larger lakes include considerable sandy loam and a few spots of Coloma loamy fine sand and Bellefontaine cobbly fine sandy loam. The large area between Lake Gage and Pigeon Creek is level to undulating. Though less stony than the adjoining Bellefontaine soil, piles of rounded boulders in many fields give evidence of their former abundance. The areas south of Pigeon Creek are less stony, and those near Salem Center are comparatively free from stones. Most of the small isolated areas near Metz and in the extreme southern part of the county consist of brown loamy sands or light sandy loams overlying rather loamy subsoils. They contain little gravel or stony material.

Between Lakes Pleasant and James, in the northwestern part of the county, are included numerous small bodies of rather loose deep loamy sand and stony areas similar to the Bellefontaine soils, but most of this area—a broad, undulatory divide—is a sandy loam, which is very similar in crop adaptations to the normal soil. It is all included in well-improved farms.

All the Miami fine sandy loam is in cultivation, except the wood lots and the few very stony spots and steep slopes around small muck areas. Farmers designate it sandy land in comparison with the heavier Miami soils. Many prefer it to the latter soils because it is easily tilled and is ready for plowing earlier in the spring. The inconvenience caused by stones in some places offsets the advantages mentioned; and crops on the lightest textured areas are sometimes injured by the effects of dry weather. With frequent cultivation, good moisture conditions can be maintained in the cornfields, and the deep-rooted crops, such as clover and alfalfa, are seldom seriously affected by drought.

The average yields of corn are estimated to be approximately 40 bushels per acre in well-cultivated fields. So much depends, however, on the quantity of organic matter returned to the soil, methods of tillage, and summer rainfall, that an average yield is difficult to determine. Returns of 60 bushels and more per acre are obtained regularly on some farms, whereas on others less than half this quantity is harvested. This soil puts a high premium on good management and fertilization. Wheat, oats, and rye give very satisfactory returns in normal seasons, but the effects of dry weather are soon observable on the highest areas or in areas where the soil is not properly prepared before seeding. Commercial fertilizer is applied very generally for wheat but is not so commonly used for other small grains. Several excellent fields of alfalfa are on this soil. A good stand of alfalfa, once obtained, holds for many years. Red clover does well. Much of the soil is too light for best results with timothy, and this is true in some fields of all tame grasses. Bluegrass takes possession of uncultivated ground and thinly covered wood lots. In the more sandy areas the effect of drought is apparent sooner than in areas of Miami loam and the dark-colored soils. A few fields of soybeans and numerous patches of sorghum, millet, and Sudan grass indicate the adaptability of this soil to such crops. Some watermelons, cantaloups, potatoes, and sweetpotatoes are grown on the lightest textured areas.

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Fruits and garden vegetables of many varieties are grown on all well-kept homesteads.

Miami fine sandy loam, slope phase.—The slope phase of Miami fine sandy loam is developed in small areas near lakes and in larger areas embracing considerable moderately hilly or strongly rolling land. Differences in elevation are most pronounced near the lakes where steep slopes and a few high narrow ridges rise 100 feet or more above the shore lines. These areas, however, are less steep and stony than the adjoining areas of Bellefontaine cobbly fine sandy loam.

The areas west of Lake James are cultivated in about the same manner as are the smoother lands, with possibly longer periods for clover in the rotation. Much stony material occurs on the surface in most places. The areas near Lake James include many sandy spots similar to the Coloma soils, and the demarcation between the Miami and Bellefontaine soils is not so clear here as in the areas farther south. In the latter, particularly west of Angola and south of Silver Lake, soil of this phase has a heavy subsoil, and in places the surface soil is loam.

A somewhat larger proportion—about 20 percent—of this sloping soil is in woodland pastures and wood lots than of the smoother typical soil. A considerable proportion of the land is in permanent bluegrass pasture.

With such limitations as the rough terrain imposes, soil of this phase is adapted to the common farm crops, and very good yields often are obtained. On most well-managed farms the present tendency is to use such land for hay or pasture for longer intervals than was formerly the practice. The bluegrass pastures are valuable for use in the raising of cattle and sheep. Except in sandy spots, as good yields of clover and alfalfa are obtained as on the smoother land, owing to the comparatively slight depth to calcium carbonate in the subsoil. Although the depth differs from place to place, it generally does not exceed 30 inches in the heavier textured areas, that is, those having a clayey subsoil at a depth of a few inches. In gravelly or sandy areas, calcareous material lies at a somewhat greater depth. The value of this sloping land for purely agricultural purposes is less than that of the more level land.

Fox sandy loam.—The 10-inch surface soil of Fox sandy loam is very friable sandy loam, which is dark grayish brown when moist. The freshly plowed surface soil has a slightly red cast. It is underlain by a somewhat lighter colored slightly heavier but friable sandy loam. At a depth of about 20 inches is reddish-brown gravelly sandy clay, which is decidedly sticky when wet and firmly cemented when partly dry. These properties are due to the rather high proportion of clay, which contains much colloidal material and iron oxide. The coarse constituents include much sand and gravel and various proportions of small rounded stones. This reddish-brown layer averages about 2 feet in thickness. The substratum of gray loose calcareous sand and gravel continues to an undetermined depth. The line of contact between the reddish-brown layer and the gray gravel is well defined but irregular. This is very noticeable in gravel pits where pockets of the brown oxidized material, in places, extend down into the gray unoxidized gravel to a depth of several feet. Calcium carbonate is so abundant in places that it forms thin irregu-

lar veins and, in some places, cements the lower strata into a fragile conglomerate.

This is the predominant soil on the level benchlands along the creeks and on the higher terraces near the lakes. The land is flat or gently undulating. The surface invariably is gravelly, and some small rounded stones are present.

Many variations exist in the texture of the surface soil and in the depth to and thickness of the reddish-brown clayey layer. In some places where the surface soil is very sandy and contains less than the average proportion of gravel, the subsoil is friable sandy loam with a diminished capacity for holding moisture. An excessive proportion of coarse gravel in both surface soil and subsoil has a similar effect on moisture relationships. As a rule, an abundance of surface pebbles is indicative of much clay in the subsoil.

Some areas of Fox sandy loam, as mapped, differ from the typical soil in containing a somewhat higher proportion of coarse gravel and small stones and in having a lighter, or less clayey, texture of the subsoil, which, in many places, is sandy loam or somewhat sticky sand with less capacity to hold moisture than the normal heavy subsoil possesses.

East of Orland small areas include some low sandy ridges resembling shallow phases of Coloma loamy fine sand, another member of the subgroup of light-textured well-drained soils. Practically all of the land is in cultivation, and, although susceptible to the effects of dry weather, good crops are obtained in most years. More careful tillage is necessary than with the typical soil, and liberal additions of organic matter are necessary. These areas also include many spots of a light-textured soil, but none is especially droughty. Toward the southeast the soil extends onto the high terraces around Lake Gage and, in the rougher areas, grades into the Bellefontaine soils. The areas east of Crooked Lake are typically developed and are somewhat more stony than the areas near Pleasant Lake in the south-central part of the county. North of Pigeon Lake much of the soil is underlain by a heavy stratum of clay, and the layer of calcareous gravel is less than 10 feet thick in many places and gradually thins toward the north. The areas along Fish Creek as well as those on lower Pigeon Creek include some light sandy spots, particularly near the areas of Plainfield soils of this subgroup.

The original forest cover consisted chiefly of red oak, with more or less bur oak, but very little sugar maple, beech, or poplar. Very few wood lots remain on the level land, and probably more than 80 percent of this soil is in cultivation or open pasture.

Corn, wheat, clover, and alfalfa are the principal crops. The meager supply of humus and the tendency to low moisture content after prolonged dry weather do not commend this soil especially for corn, but good crops are obtained in most years. Farmers state that, with frequent shallow cultivation, adequate moisture may be maintained in normal seasons. Field observations during a dry summer revealed a fairly high moisture content in the cornfields, whereas closely grazed pasture and stubblefields became very dry. The soil responds very promptly to manure and commercial fertilizers, but the former gives the best results with corn. Wheat is the favorite nurse crop for clover, the success of which depends much

on late summer rains. Some excellent fields of alfalfa are maintained. The abundance of lime at a depth of less than 4 feet favors the growth of clover and alfalfa, as their roots readily penetrate the reddish-brown layer.

On a farm near Pleasant Lake, where a crop rotation including clover is practiced regularly, the yields of corn in normal seasons are about 50 bushels an acre. Winter wheat has yielded 22 bushels per acre after being damaged by an accumulation of ice in low spots. Soybeans also are grown successfully on this farm.

Similar returns are obtained on most well-managed farms. Frequent light showers are needed for best results with most crops maturing late in the summer or fall, especially with watermelons, cantaloups, tomatoes, potatoes, and other truck crops. This soil is not entirely safe for strawberries, which make heavy demands on soil moisture at fruiting time. The land seems better adapted to peach, cherry, and pear trees than to apple trees, although there are old apple orchards on some farms. In general, this land is better adapted to cultivated crops than to clovers and tame grasses. Many farmers prefer it to heavier soils because of its easy tillage and quick response to fertilization.

Fox sandy loam, slope phase.—The steep slopes at the margins of the higher benchlands and larger tracts of rough gravelly or sandy land are separated as Fox sandy loam, slope phase. The marginal slopes are very steep in many places, and the higher terraces include many long uneven stony inclines. Most of the narrow areas near the lakes are steep and stony and lie from 10 to 50 feet above the water. The largest of these include some flat land but consist chiefly of irregular ridges and mounds with sharp declines to adjoining waterways and marshes. In all these rougher areas, the depth to and the thickness of the reddish-brown subsoil are variable. The layer is commonly present, however, and is sufficiently developed to arrest the downward movement of soil water, thus increasing the potential productivity for cultivated crops and tame grasses. The stonier spots resemble Bellefontaine cobbly fine sandy loam, and many small areas are so gravelly as to approach Bellefontaine gravelly sandy loam.

Soil of this phase is not extensive. The largest areas are north and west of Lake Gage extending to the county line. Several large areas are north and northeast of Pleasant Lake in the south-central part, and smaller bodies are scattered throughout the county along the streams and in constructional valleys.

Perhaps less than 15 percent of the land is forested. Although much of it is used chiefly for pasture, nearly all of the open land either is cultivated regularly or as often as is necessary to seed to clover. Red clover, sweetclover, and alfalfa do well and thrive most vigorously on steep inclines where calcareous material lies less than 20 inches below the surface. Bluegrass is stunted or killed by dry weather sooner than on heavier soils, and overgrazed pastures become weedy. This soil is not well adapted to timothy and summer forage crops.

Many locations on lake fronts are valued as sites for summer cottages, particularly if they are partly wooded. For this reason as well as for more utilitarian purposes, the planting of trees is to be encouraged on much of this soil.

Warsaw sandy loam.—The 10-inch surface layer of Warsaw sandy loam is very dark-brown friable sandy loam generally free from stones. It is underlain to a depth of about 20 inches by a subsurface layer, which is slightly lighter colored and includes more coarse material. The subsoil, to a depth of about 30 inches, is dark reddish-brown sandy gravelly loam or clay loam. In places it contains enough clay to render the material very sticky when wet and firmly cemented when dry. In general it is friable or crumbly and has a high degree of porosity, which allows the penetration of roots and the capillary movement of water. The proportion of sand and gravel increases with depth, and, from 30 to 40 inches below the surface, gray loose calcareous sand and gravel are reached.

The dark color of the surface soil is due to organic matter, which is much more abundant than in Fox sandy loam and related soils. It was derived from grassy vegetation, for all this soil as the pioneers first saw it was open grassy land with scattered bur oak trees. The large area south of Orland is still locally known as Jackson Prairie.

The surface is level, relieved by a few slight depressions and low swells on which the soil may be lighter colored and somewhat gravelly. This is an inextensive soil. One area is at Orland, and one is about 3 miles south of that town.

Mapped with this soil is an area in which the soil approximates a development halfway between the Warsaw and Fox soils. Organic matter is much less apparent than in typical Warsaw sandy loam, and crop adaptations are about the same as those of the Fox soil, although this included soil produces slightly better yields and resists drought somewhat more successfully than does the Fox soil.

Warsaw sandy loam easily reduces to a fine state of tilth, and in such condition it maintains a good moisture content down to the gravelly substratum. This land is well adapted to wheat and general farm crops. Corn yields of 60 to 70 bushels per acre are not exceptional, when moisture conditions are most favorable. Poor returns on some farms are attributable to continual planting to this crop with little rotation and little use of barnyard manure. Wheat and oats, especially the latter, are affected by unfavorable seasons, but good yields are obtained in most years. Clover and alfalfa produce well, and late cuttings are not greatly reduced by dry summer weather.

Bellefontaine fine sandy loam.—Bellefontaine fine sandy loam differs from Fox sandy loam in its finer texture, greater depth to lime, and position on uplands instead of terraces. The surface layer consists of loose mellow brown fine sandy loam. The subsurface material is yellowish-brown friable sandy loam, changing with depth to reddish-brown heavier sandy loam or, in some locations, to sticky sandy gravelly clay. At a depth ranging from 2 to 3 feet this material gives way more or less abruptly to coarse light-colored calcareous sand and gravel. The surface soil contains considerable gravel, and in many places small rounded boulders are abundant.

The relief is undulating to gently rolling and includes many small kettles, or depressions. The circular kettles are about 30 feet in diameter, whereas most of the elliptical ones are about 30 feet wide and 100 feet long. Bodies of this soil are well distributed, and their total area is not large.

The small areas in section 24, 1½ miles northeast of Angola, are situated on a high benchlike margin of an upland where gravel underlies the layer of sandy loam at a depth ranging from 6 to 8 feet. Smaller areas with reddish-brown rather heavy subsoils are a few miles north of Lake Hamilton. In places, these are somewhat rolling and carry much stony material.

A total area of less than 1 square mile of flat land, mapped as Bellefontaine fine sandy loam, presents an interesting example of the system of overlapping terraces extending northward from Pigeon Creek into Michigan. A short distance northward, in Branch County, Mich., this partly rolling and partly flat land north of Orland levels into flat terrace occupied by Fox soils. The included soil cannot be considered a typical Fox soil, since cobblestones are too numerous on the surface and in the surface soil. The agricultural uses and value of this included soil are essentially the same as those of normal Bellefontaine fine sandy loam with the additional advantage of a nearly level surface.

Crop adaptations of typical Bellefontaine fine sandy loam are similar to those of Fox sandy loam. The advantages of finer texture and slighter depth to lime are offset by a weaker resistance to drought and an uneven relief as compared with the Fox soils.

Bellefontaine cobbly fine sandy loam.—The surface soil of Bellefontaine cobbly fine sandy loam is dull-brown or slightly reddish-brown light fine sandy loam. On the surface and also within the surface soil are many cobblestones ranging from the size of marbles to small rounded boulders. As a rule, rock fragments 1 foot or more in diameter are comparatively rare. There is little difference between the surface and the subsurface layer, although in places the latter is slightly lighter colored and less stony. The subsoil, between depths of 20 and 40 inches, is reddish-brown medium to coarse sandy clay or, in some places, friable sandy loam. Variations in the texture and structure can be noted in the subsoil, which ranges from slightly dense sandy clay loam to sandy loam. In most locations it contains so much gravel and so many small rounded stones that a pick is necessary to obtain a sample of the subsoil. Oxidation has been effective in most places to a depth of 40 inches in the areas of heavier textured soil and to a somewhat greater depth in the areas of lighter textured soil. The underlying material consists of more or less sandy and highly calcareous till. Bellefontaine cobbly fine sandy loam is low in organic matter and is slightly to moderately acid with a pH range of 6.2 to 6.4.

Bellefontaine cobbly fine sandy loam is the most widely distributed member of the Bellefontaine series. The largest single area is that just north and northeast of Orland, adjoining the county line. Large areas are in the northwestern and north-central parts of the county. Smaller areas are scattered along the constructional valleys and stream channels. Bodies, ranging from 10 to several hundred acres in size, are common in the lake sections, between Angola and Orland, and they lie well above the lakes, marshes, and tracts of Fox sandy loam. Here the surface is uneven. The small areas include some Miami fine sandy loam, and no very accurate boundaries can be drawn between the smooth and the rough areas. The area west of Chesboro Lake is the somewhat hilly margin of the high plateau extending north from

Pigeon Creek. The surface is stony, but nearly all of this area is in cultivation.

The original forest cover, which consisted chiefly of red oak, together with some bur oak, black cherry (locally called wild cherry), and poplar, has been cleared from all except scattered small wood lots.

Yields of corn are somewhat lower than those obtained on Bellefontaine and Miami fine sandy loams, and cultivation is less satisfactory on account of stones. Stones also interfere to some extent with the harvesting of clover and small grains. All legumes, including alfalfa, do well wherever a good stand is obtained. Wheat and oats are not grown so commonly as on the Miami soils, and phosphoric acid generally is applied at a rate of about 200 pounds per acre.

Bellefontaine fine sandy loam, steep phase.—Areas of Bellefontaine fine sandy loam, which are so steep as to be practically untillable, are separated as a steep phase. This soil is closely associated with the typical soil but is less extensive.

Much of this land has been cleared and is now open pasture, well set to bluegrass or to clover. The nurse crop for the clover is either wheat or rye. Barring the difficulties of tillage owing to the hilly relief, very satisfactory yields of corn and wheat often are obtained. On many of the slopes the depth to calcareous material is less than 25 inches, and both clover and alfalfa thrive particularly well. In many places sweetclover has spread into gullied fields where the lime-filled substratum is exposed.

The areas east of Lake James include some very rough land. As a rule, the larger ridges and steeper slopes have more stone on the surface than do the somewhat gentler slopes. Near the lakes are patches of sandy loam and deep loose sand, the latter evidently wind-drifted material. Most of this soil occurs in depressions and on the sides of ridges. Not much forest growth remains on the areas. The small tracts between Lake Gage and Hogback Lake are mostly in open pasture and are too hilly and stony for the convenient use of labor-saving implements. In general, the surface soil is less sandy and the subsoil heavier than in the areas near Lake James.

Bellefontaine gravelly sandy loam.—As typically developed, Bellefontaine gravelly sandy loam consists of a 6- to 10-inch layer of brown or dark-brown friable gravelly sandy loam underlain by a few inches of yellowish-brown sandy loam, which grades into reddish-brown rather stiff sandy clay containing, in most places, considerable gravel and some small stones. At a depth of a few feet lies the calcareous material ranging from gray loose sand and gravel to sandy clay, in which there is more or less stony material. Where gravel is present, the soil is similar to Fox sandy loam, whereas the variations with a clayey substratum resemble Miami fine sandy loam. Boulders and cobblestones are not numerous.

The bodies of this soil are small and widely scattered. Nearly all of the land is cleared, and much of it is in cultivation. Heavy fertilization is required for best results with corn and wheat. The lightest textured spots endure dry weather remarkably well if frequently cultivated. Such spots, however, become droughty during the summer in the bluegrass pastures, but the pastures and clover fields on the typical soil compare favorably with those on the Belle-

fontaine and Miami fine sandy loams. Alfalfa also does well. It is used mostly for these crops or given over to bluegrass pasture. Corn and small grains are grown sometimes. This soil does not resist drought nearly so well as does Fox sandy loam. It is better adapted to growing bluegrass, clovers, and alfalfa than to cultivated crops.

Bellefontaine loamy sand.—Bellefontaine loamy sand is dark grayish-brown loamy sand to a depth of 15 inches. The subsurface layer consists of light-colored friable fine sandy loam, which, at a depth of 30 inches, passes into reddish-brown sandy clay. This lower layer includes much stony material ranging from gravel to small stones. Most of the stones are hard, resistant, rounded rock fragments, more or less coated with iron oxide. The clay contains considerable ferruginous and colloidal material, but in most places the proportion of these constituents is less than in Bellefontaine gravelly sandy loam. Light-colored gravelly material is reached in most places at a depth of 50 inches below the surface and continues to a considerable depth. All this material is highly calcareous, and deep exposures show stratification and many rounded stones, including limestone, shale, and sandstone. Characteristic of this soil are the piles of rounded stones in most fields and along the fences. In some places the small stones and large boulders are not so numerous, but in most places they are abundant.

The moisture-holding properties of this soil are better than the light texture of the surface soil would indicate. The upper subsoil layer contains enough silt and clay particles to impart a fineness of texture favorable to good capillary exchange of water between the subsoil and the surface soil. The subsoil is nowhere compact but is heavy enough to check excessive underdrainage. Moisture is held mostly within reach of plant roots, and material of such relatively coarse texture will give up to plants a much larger proportion of the total water content than material with finer, or heavier, texture. Farmers state that, with good surface cultivation, corn and other cultivated crops endure much longer periods of dry weather than do bluegrass, clover, and alfalfa. In normal seasons, yields compare favorably with those obtained on the Fox and Miami soils.

Like Bellefontaine gravelly sandy loam, Bellefontaine loamy sand is widely distributed in small bodies, and the total area is small.

Nearly all of this land is cultivated, and, although the common farm crops are grown satisfactorily, the land requires more careful tillage than somewhat heavier soils and should be seeded more frequently to clover, or other means should be taken to increase the supply of humus. The naturally limited content of organic matter tends to produce rapid oxidation in such a loose warm soil. Soybeans, vetch, rape, and Sudan grass do well and afford means of increasing the supply of humus. Some strawberries and truck crops are grown. Of the latter, watermelons, cantaloups, and early potatoes give best returns.

Oshtemo loamy sand.—The 9-inch surface layer of Oshtemo loamy sand is grayish-brown medium to coarse loamy sand or very light sandy loam, containing considerable gravel and scattered small stones. The subsurface layer consists of pale brownish-yellow slightly sticky loamy sand grading, at a depth of 23 inches, into a reddish-brown sandy loam subsoil. As a rule, the material below a depth of 40

inches becomes heavier, but the variation in texture is considerable. In places, the texture is so light that it is practically a loamy sand to a depth of several feet, whereas, in other places, the texture is somewhat heavier and, at a depth of 40 inches, the subsoil is similar to the reddish-brown sandy gravelly clay underlying Fox sandy loam. Calcareous gravelly material lies within 5 feet of the surface in most places. In some places low sandy swells suggest that the parent material is wind-blown. In most places, however, the mixture of sand of various grades with more or less stratified gravel indicates water-laid materials. Generally, the more gravelly spots have a heavier or more sticky subsoil and endure dry weather better than do the sandy spots.

This soil is developed on terraces along the main streams, in close association with the Fox soils. Its total extent is small. A number of areas occupy situations somewhat removed from the streams on the upland and are associated mainly with old lake beds, which represent a brief halt in the recession of the ice sheet and now are filled with muck.

This soil is not so good as Fox sandy loam for the production of crops. Texturally and structurally, it is comparable to Bellefontaine loamy sand, but it is superior to that soil in its freedom from cobblestones and in its flatness, although it is inferior to that soil because of its greater depth to gravel. Practically all of this land is cultivated. Liberal fertilization is required for corn and wheat. Clover does well, and some alfalfa is grown.

Coloma loamy fine sand.—In open fields the surface soil of Coloma loamy fine sand is light-brown loamy medium sand containing sufficient finer material to cohere very feebly when moist. At a depth of about 4 inches, this changes to yellowish-brown light loamy fine sand. In some places the material shows brown or dull reddish-brown splotches and streaks, but as a rule the color and other characteristics change very little down to the line of contact with the underlying material, which, in most places, is brown well-oxidized silty clay till. The underlying material is calcareous at a slightly greater depth. The loamy fine sand itself, however, shows few traces of calcium carbonate, even in the deepest parts.

Small areas of Coloma loamy fine sand are scattered widely over the uplands, except in the southeastern part where they are comparatively few. The areas in the southeastern part occur at the margins of the uplands, at their juncture with the terraces occupied by the Fox and Plainfield soils along the main stream channels. A large area a few miles south of Orland is at the margin of the high plain, which overlooks the lowlands on the western boundary of the county. The Coloma soil consists of wind-drifted sand superimposed on this high plain. The relief is undulating to gently rolling and, in some places, sloping, with dunelike contours. This area formerly was forested, predominantly with oak, and wild cherry and a smooth-barked hickory also grew. A few wood lots remain, but from 80 to 90 percent of the land is cleared. In depressions as well as in places where the depth to the underlying till is but a few feet, the moisture conditions are much more favorable for the production of crops than on the higher ridges. The areas on the ridges include a few blowouts, or small patches, from 5 to 10 acres in size, in which pits, rang-

ing from a few feet to several yards in depth, have been formed by the wind. Many isolated areas lie east of marshes or lakes, where billowy contours suggest wind-blown sand.

Although much of this land is regularly cultivated, it is poorly adapted to the production of corn, wheat, timothy, or any crop requiring a rather long growing season. With frequent cultivation and liberal fertilization, corn makes fair returns in seasons of normal rainfall. In places where the supply of humus is good, as in some of the small depressions, cultivated crops do much better than on the higher land. This is also true of areas where the depth to clayey material is less than 3 feet and the supply of subsoil moisture is higher than elsewhere. These areas are distinguishable in places by the stones on the surface. Rye does well on the shallower soil, but some fields of the deeper soil are consistently poor under normal to low rainfall. Excellent locations for the production of watermelons, cantaloups, early potatoes, tomatoes, and other truck are available. Some peaches are grown, but the trees require much fertilizer. A few old apple trees are seen on old home sites, but the soil is not well suited to this fruit. Clover and, in a few places, alfalfa are grown but not extensively.

With careful management, all this land, except the coarsest and deepest soil, will produce fair yields of most of the crops mentioned, but the advantages of warmth, ease of tilling, and early crop maturity must be balanced against the heavy requirements for fertilizer and humus and liability to injury by drought.

Plainfield loamy fine sand.—Plainfield loamy fine sand has a 4-inch light-brown loose friable loamy fine sand surface layer like that of Coloma loamy fine sand. This grades into pale-yellow loose light loamy sand. Below a depth of 18 inches the material is single-grain yellow sand to a depth ranging from 3 to 4 feet, where it is interstratified with gravel. In many places, medium sand instead of fine sand predominates in the profile.

The principal areas of this soil are along Pigeon Creek and northeast of Clear Lake, where it is associated with Coloma loamy fine sand. In general it occupies flat plains along the stream channels, and it differs from the soils in similar situations in that it has no layer of accumulated heavy material to retain moisture. It is definitely porous throughout, and the underlying gravel and sands further promote excessive subsoil drainage.

Corn, wheat, and oats are rarely grown on this soil, as the yields of these crops depend directly on the abundance and evenness of precipitation during a long growing season, as well as on the addition of fertilizers and the quantity of humus in the soil. Garden truck and small fruits do well if liberal applications of manure and commercial fertilizers are made and cover crops grown to provide organic matter for the surface soil.

IMPERFECTLY DRAINED SOILS

The imperfectly drained soils are characterized by their slowly pervious substrata, which check normal downward movement of subsoil water. As in the well-drained soils, three subgroups may be distinguished: (1) Heavy-textured soils including Crosby silty clay

loam and Conover loam; (2) medium-textured soils with one member, Crosby loam; and (3) light-textured soils including Bronson sandy loam and Berrien loamy fine sand. The last two soils mentioned, with their sandy surface soils and partly impervious subsoils, tend to be droughty.

Crosby silty clay loam.—The distinguishing features of Crosby silty clay loam are its flatness and the light color of the dry surface soil. In many cultivated fields the surface soil has an ashy appearance if dry and tends to run together after rains, forming a rather hard but somewhat porous crust. When moist, the surface soil is gray friable silty clay loam, which forms hard porous clods when it becomes dry. At a depth of 4 inches the texture is slightly heavier, although the consistence is still friable, and faint yellow and brown stains appear. Between depths of 8 and 20 inches the material consists of heavy silty clay, which breaks, on drying, into hard angular fragments. Minute cleavage planes are lined with dark organic matter. Below this is dull yellowish-gray slightly mottled heavy silty clay, which allows very slow movement of water. Below a depth of about 30 inches is stiff heavy clayey till containing an accumulation of lime nodules in many places.

Crosby silty clay loam, as just described, probably represents a fairly large proportion of the soil as mapped in this county. The glacial till on which it is developed contains a high proportion of fine shale fragments, which weather to form rather heavy clayey material. In consequence, the entire profile is somewhat heavier than is typical for Crosby silt loam, the dominant type of the Crosby series as mapped in other parts of the State. It closely resembles Crosby silty clay loam that was mapped in Randolph County, Ind., but probably has a somewhat higher shale content, and some areas are developed on somewhat lighter textured glacial till that contains a smaller proportion of shale fragments and, consequently, the profile is more nearly like that of Crosby silt loam. Since the two soils are intimately intermixed, it was not considered practicable to separate them when Steuben County was mapped. In general, the proportion of Crosby silty clay loam developed on heavy parent materials and containing a somewhat larger proportion of clay in the subsoil is more common east of a line extending from Steubenville through Angola north-northeastward to a point on the Michigan line almost directly north of Fremont than it is west of this line. The heavier Crosby silty clay loam is more difficult to cultivate and somewhat less productive than the lighter textured soil.

Although an inextensive soil, Crosby silty clay loam is well distributed over the eastern and southern parts of the county and is especially well developed in the southeastern part where some individual areas are fairly large.

A number of areas in the extreme southeastern part have a rolling relief, which is exceptional for the soil as typically mapped. The profile presents no marked differences, but the soil extends down over the caps of gently rolling slopes instead of occurring only in flat areas, as elsewhere. Compared with the normal soil, surface run-off is adequate, but, as is indicated by the mottled subsoil, internal drainage is imperfect. This variation is intermediate between the Crosby

and Miami soils and should be slightly better for crops than the typical Crosby soil.

Most of the upland areas of Crosby silty clay loam are in cultivation. They require more careful management than the adjoining soils but respond so well to tillage and drainage in normal seasons that the returns of small grains and forage crops are about the same as on Miami silty clay loam. For good yields of corn the deficiency in organic matter must be met by liberal fertilization. In pastures the poorer growth of bluegrass as compared with that on the Miami soils is noticeable in places but generally is not so pronounced as between the pastures on the Miami soils and those on the poorly drained dark-colored soils.

Conover loam.—The surface soil of Conover loam has no well-defined structure. The arrangement of the horizons and their structure is much the same as in Crosby silty clay loam, but the color is much darker gray throughout.

The total area of this soil is only slightly greater than that of Crosby silty clay loam, with which it is closely associated in the eastern and southern parts of the county. Much of it occupies the same topographic position as Crosby loam, but some of it represents an intermediate stage between the Crosby and Brookston soils, the latter of which belong to the group of poorly drained soils.

Most of the smaller areas of Conover loam adjoining areas of Clyde silty clay loam and muck are flat spots at the bottoms of gentle upland slopes or are low areas surrounded by darker colored soils. In such situations the present drainage conditions are satisfactory, but formerly, when the water table of the adjoining soils was high, the soil in these flat areas was saturated for long periods, and relief from excess soil water was chiefly by evaporation from the surface. Such conditions gave rise to the gray surface color, mottled subsoil, and lack of crumb structure. The present drainage conditions are much improved, however, even where no artificial drains extend into the areas. The opening of ditches and deepening of established streams has tended to lower the water table of the upland as a whole during the last two decades.

Included with this soil are a few small areas which would be mapped as Conover silt loam and Conover fine sandy loam, had their size warranted such a separation.

Conover loam is acid and, although dark colored, is not high in humus, and it is therefore difficult to keep in a state of satisfactory tilth. Although not so tolerant of seasonal extremes as the darker colored soils, this soil responds well to tillage, manure, and artificial drainage. Good crops of grain, timothy, and clover are often obtained. Many areas are rendered more productive by installing tile drains and plowing under liberal quantities of vegetable matter. Liming also increases the productivity of this soil.

Crosby loam.—The surface soil of Crosby loam, although a loam in texture, has practically the same color and structure characteristics as Crosby silty clay loam. The subsoil is slightly sandier and is slightly better drained than that of Crosby silty clay loam. This soil is as widely distributed over the same parts of the county as the silty clay loam but covers a much smaller total area. As mapped it

includes minor proportions of soil, in which the subsoil is heavier than normal. Most of such variations occur in association with the areas of Miami loam that have unusually heavy subsoils.

Crosby loam is associated closely with the Miami and Brookston soils.

Like Crosby silty clay loam, Crosby loam requires drainage, the addition of organic matter, and fertilization, in order to produce corn and small grains. Yields are slightly less than those obtained on Miami loam. This soil occupies a position intermediate between Miami loam and Brookston silty clay loam. Owing to its texture, it is easier to manage and warms more readily in the spring than Crosby silty clay loam. Cultivation is not so critically dependent on moisture conditions of the surface soil as in the heavier textured silty clay loam.

Bronson sandy loam.—The surface soil of Bronson sandy loam is grayish-brown mellow single-grain heavy sandy loam containing considerable organic matter. The soil develops, at a depth of 9 inches, a slight structure and a pale brownish-yellow color. At a depth of 12 inches is yellowish-brown friable nut-structured sandy loam which breaks down very easily. The material assumes a slightly tough lump structure and becomes mottled grayish-brown sandy clay loam at a depth of 16 inches. The next lower horizon, beginning at a depth of 40 inches, consists of mottled yellowish-brown friable easily broken lump-structured gritty sandy loam. The reaction ranges from strongly acid in the surface soil or subsurface soil to neutral in the lowest horizon.

This soil occurs in close association with the Fox soils. The largest areas are about 2½ miles northeast of Angola and east of Lake George. Most of the other areas are extremely small. The relief is the same as that of the Fox soils, and the water table is slightly higher than in those soils, being controlled by adjacent ponds and bogs. A zone of fluctuating moisture is set up in the subsoil, which causes a condition of imperfect drainage for a part of the time.

A few areas included with this soil would be separated as Bronson loam, were they more extensive. On account of the heavier texture of the surface soil these areas are slightly more productive than the typical soil.

The same crops are grown and the same agricultural methods are used on Bronson sandy loam as on Fox sandy loam, but, owing to its higher moisture content, the Bronson soil produces heavier yields of corn, oats, and grass than does the Fox soil. Most of the land is farmed.

Included on the map with Bronson sandy loam are a few small areas of a somewhat better drained soil forming a narrow belt, totaling less than 320 acres, northeast and east of the village of Pleasant Lake. This included soil presents a very unusual profile as compared to that common along most drainageways and in constructional valleys. Absence of gravel throughout and extreme thickness of the underlying layer of sand are characteristic. The surface soil is dark brownish-gray single-grain sandy loam, which changes abruptly to brownish yellow. At a depth of 7 inches, the texture lightens to loamy sand and the color fades to pale yellow. This material gives way, at a depth of about 22 inches, to brownish-yellow friable nut-struc-

tured sandy clay loam. Below a depth of 34 inches the texture, in most places, is loamy sand and the color ranges from yellow to yellowish brown. The reaction ranges from only slightly acid in the surface soil to very strongly acid in the lower part of the subsoil. A boring was made 90 inches below the surface, but no calcium carbonate was present at that depth. Crop adaptations are about the same as for Oshtemo loamy sand. The soil supports a fair stand of oak and maple.

Berrien loamy fine sand.—The topmost 6-inch layer of Berrien loamy fine sand is grayish-brown loose single-grain loamy fine sand or sand. Below this is a lighter colored and slightly lighter textured material. Between depths of 18 and 28 inches, the color is yellow; other characteristics remain the same. Slight mottlings appear below this horizon, become stronger at a depth of 40 inches where the loamy fine sand is much heavier, and fade away at a depth of 47 inches as the texture again becomes lighter. The water table in the area described is present at a depth of about 60 inches. The reaction is very strongly acid in the surface soil and scarcely less acid thoughout the profile.

This soil is closely associated with soils of the Oshtemo and Plainfield series and occupies flat to gently inclined plains. It is not extensive. The areas just north of Angola and west of Flint, near the county line, are typical, whereas those northeast of Clear Lake represent a common variation developed on a gently inclined upland. At a depth of about 40 inches, the included soil has a heavier subsoil consisting of light sandy clay.

The prevailing imperfect drainage is caused either by the comparatively high water table or by the slow subsoil drainage induced by an impermeable layer of sandy clay. The soil is naturally infertile but is slightly superior to the Plainfield soil in productivity, owing to the abundance of available moisture. Fertilizer, manure, and lime are required to obtain even fair yields of corn or the small grains.

POORLY DRAINED SOILS

The poorly drained mineral soils constitute the third major group and are separated into three textural subgroups. Brookston silty clay loam, Washtenaw silty clay loam, Clyde silty clay loam, and Griffin silt loam are the heavy-textured soils. There is but one medium-textured poorly drained soil—Griffin fine sandy loam. In the subgroup of light-textured soils are Brady sandy loam, Maumee fine sandy loam, and Newton loamy fine sand. These light-textured soils are not so subject to drought as are soils of similar texture in other groups, owing to the comparatively high water table. Their fertility depends, to a great extent, on the accumulation of organic matter in the upper part of the soil.

Brookston silty clay loam.—The surface soil of Brookston silty clay loam is grayish-brown or nearly black heavy loam or silty clay loam. In most places, it has a soft crumbly feel when moist, and the freshly plowed land is mellow, with little tendency to clod on drying. The subsurface layer is dark yellowish-gray crumbly heavy silt loam or silty clay loam, mottled with rust brown. This passes abruptly into silty clay, in which gray or drab is the basic color and

yellowish-brown and rusty-brown stains are numerous. The tendency toward a granular structure is apparent when the material is partly dry. In many areas, the proportion of coarse material is so large that the soil is a heavy loam. In all these variations the physical features are very favorable to easy tillage and good moisture conditions, provided the soil is drained. Boulders are few, and small stones or gravel are scarce. The surface and subsurface layers are approximately neutral in reaction, and the subsoil is alkaline. Calcareous material is reached at a depth ranging from 30 to 40 inches. Included with Brookston silty clay loam is a loam soil that is too inextensive to justify separation on the map.

This agriculturally important soil occurs in the slight sags and broad shallow depressions in the uplands of the eastern and southern townships. Although most of the individual bodies are small, their distribution is wide, especially in the southeastern part, and their total area is 44.2 square miles, or 14.5 percent of that of the entire county. The position of this soil is lower than that of either the Miami or the Crosby soils, and the water table is consistently high except where artificial drainage is provided.

The Brookston, Miami, and Crosby soils are so thoroughly intermixed that they are managed and cropped in much the same manner, although the Brookston soil is somewhat the easiest to till. Where areas of Brookston silty clay loam are large enough to form entire fields, however, its characteristics, apart from those of the Miami and Crosby soils, can be given full consideration by the farmer. Most of the larger areas have been improved by tile drains, and many of the small ones would benefit from drainage. The surface soil contains much organic matter, and the productivity of this soil is high, once adequate drainage is provided.

Corn, clover, alfalfa, and bluegrass are well adapted to this soil. Yields of corn as high as 70 bushels per acre are obtained, although they average between 45 and 50 bushels. In general, wheat and other small grains make a stronger growth than on the adjacent Miami soils, but the yields of grain are not always increased to a corresponding degree, except possibly during dry seasons. The tendency of wheat and oats to lodge accounts for the rather small use of the soil for these crops.

Washtenaw silty clay loam.—Washtenaw silty clay loam has developed since the encroachment of farming operations on the original forested soils and represents the result of mild sheet erosion. It comprises a normal Brookston profile covered by a 5-inch or thicker surface layer of light grayish-brown friable silty clay loam washed from adjacent rolling Miami soils. Mixture of the surface overwash and the original surface soil gives a mixed grayish-brown and dark-gray color to the present subsurface layer. The subsoil has not been affected appreciably by the superimposed material. Included with this soil on the map are a few areas of loam and fine sandy loam.

Although its total area is small, Washtenaw silty clay loam has the same general distribution as Brookston silty clay loam, to which it is closely related. The smaller organic-matter content and greater depth to the water table make this soil inferior for the production of corn but probably better for the production of oats and other small grains, as compared with the Brookston soil. There are areas

of the Washtenaw soil associated with undrained areas of Bellefontaine soils, and some of them are nonagricultural.

Clyde silty clay loam.—Occupying deeper depressions than Brookston silty clay loam, Clyde silty clay loam is a dark heavy-textured soil intermediate in development between Brookston silty clay loam and muck. The surface soil is very dark gray when dry and nearly black when wet. It varies in texture between heavy silt loam and silty clay loam, and in most places it has a soft-crumb structure, owing to the absence of coarse material and to the high content of organic matter. At a depth of 5 or 6 inches, the color is somewhat lighter and the material less crumbly than that above. This material grades into bluish-gray stiff tenacious clay, which, when partly dry, separates into angular fragments along well-defined cleavage planes. Some dull-brown iron stains occur along these minute cleavage planes, but yellow or rusty-brown mottlings are few. The color of the subsoil is indicative of the almost constant saturation and consequent lack of oxidation, which prevailed before the installation of tile drains.

Small areas of Clyde silty clay loam are scattered throughout the county except in the northwestern quarter. Areas are especially numerous near the village of York.

As mapped, this soil includes small spots of shallow muck over clay. Most of the areas adjacent to Miami fine sandy loam contain more coarse material than do those surrounded by Miami silty clay loam. Many of the latter have a decidedly heavy silty clay subsoil, the tenacious properties of which are very apparent within plow depth. The narrow strips along open ditches receive more or less silt and sand from overflows, but injury to crops from this cause generally is confined to the lowest spots.

The soil shown as Clyde silty clay loam on the map includes several areas which are more clayey than the normal soil. The surface layer of this included soil, to a depth of 8 or 10 inches, is black crumbly clay or heavy clay loam. The subsurface layer consists of very dark drab or dull bluish-gray clay, which becomes lighter colored with depth and, at a depth ranging from 20 to 30 inches below the surface, gives way to light-blue tenacious clay faintly mottled with yellow and rusty-brown stains. Below a depth ranging from 30 to 40 inches, the material is light-blue clay containing thin seams of gray sand and sandy clay. All these lower layers are calcareous, whereas the materials above the mottled zone are neutral or slightly acid in reaction. The surface soil generally is acid. The largest area of this included soil lies a few miles southeast of Fremont in sections 34 and 35. The land is nearly level, but there are broad shallow depressions, in which the soil is richer in organic matter and less sandy than the higher ground. Toward the south the soil passes into clay loam or, in places, shallow sandy clay over a subsoil somewhat less tenacious than that in sections 34 and 35. The largest of such areas have been improved by ditches and tile drains, and nearly all of the land is cultivated. The granular structure of the subsurface soil and subsoil allows comparatively free movement of water toward the tile drains. Where lateral drains are placed within a few rods of each other the ground water level is held effectively below a depth ranging from 3 to 4 feet. On one farm, where the included clayey soil predominates, the average yield of corn is about 75 bushels an

acre. No fertilizer or lime is used, but the soil responds well to barnyard manure. Clover and timothy make a strong growth wherever a good stand is obtained. The young clover sometimes is injured by heaving during open winters. Small grains do well, and the soil is suitable for alfalfa.

The granular structure of the subsoil of Clyde silty clay loam facilitates artificial drainage. Tile drains operate well, and open ditches lower the water table for a distance of several rods on each side. This structure also affords good aeration and deeper penetration by plant roots than would be expected from borings made in the wet soil. Wherever properly drained this is a strong productive soil, to which corn, clover, and alfalfa are admirably adapted. In many years, excellent yields are obtained without the use of fertilizer, and some farmers pay little attention to crop rotation. Many farmers do, however, rotate crops and use superphosphate on wheatland. As on the Brookston soil, wheat tends to lodge. In many seasons corn yields as high as 70 bushels per acre, and wheat may return 25 or 30 bushels in ordinary seasons. Very few, if any, farms consist exclusively of this soil, and improvements on it, other than fences and drainageways, are rare.

Griffin silt loam.—In most places, Griffin silt loam has a dark-brown surface soil and a more or less mottled subsoil streaked with gray sand, particularly in the lower part. In narrow areas along the edges of streams, this mottling in the subsoil is lacking or very faint. The stratified layers of sand and silt in the lower horizons have no definite arrangement, but the water table seldom is more than 40 inches below the surface and generally is much higher. The surface soil in most places is neutral in reaction, and the subsoil is definitely alkaline.

Griffin silt loam is developed on poorly drained bottom lands, principally along Fish Creek and, to less extent, along the upper part of Pigeon Creek. Its position is similar to that of Kerston muck, with which it is associated in places. The large areas along Fish Creek represent comparatively recent deposits of materials washed from the upland immediately bordering the stream valley, which is a narrow trough-shaped depression, with short steep slopes rising from 30 to 40 feet above the bottom land. The width of the valley ranges from about one-fourth mile to less than one-eighth mile.

All this soil is subject to overflow. During heavy overflows, new channels form and overburdens of coarse sand and gravel are deposited. This feature seriously limits the production of cultivated crops. The wider areas are tillable and, excluding the likelihood of injury by overflows, are admirably suitable for growing corn, clover, and alfalfa. Bluegrass does well and forms a tough sod along the channel, wherever the ground is not shaded. Clover, alfalfa, timothy, or bluegrass generally are not injured by overflow. Some of the land is covered with hardwoods and some willows, but the greater part supports good pasture.

Griffin fine sandy loam.—Griffin fine sandy loam is developed in small stream valleys and where the larger valleys become narrow. Meandering streams constantly cut the bottoms, washing material from one place and redepositing it elsewhere. Overflow waters are

turbulent owing to the limited area, and only the coarser particles are deposited. The texture of the soil material in areas mapped as Griffin fine sandy loam ranges from loam to fine sandy loam, the latter predominating.

The total area of this soil is only slightly larger than that of Griffin silt loam. Owing to the lighter textured material, the inherent fertility is less and the cover of forest and pasture is poorer, compared with Griffin silt loam. The small area north of Pleasant Lake in the south-central part of the county is characterized by a light surface soil and, in places, considerable gravel, and the lower layers are the same as in the typical soil. Here, the pasture is excellent, although tillage is hardly profitable.

Brady sandy loam.—The 10-inch surface soil of Brady sandy loam is dark-gray crumbly sandy loam with a slight organic-matter content. It is underlain by pale yellowish-gray or grayish-yellow silty fine sandy loam, which is somewhat compact but not impervious to water. This passes into stiff silty clay, which is less pervious to air and water and becomes more sandy and gravelly with depth. The mottled color indicates obstructed movement of water, doubtless owing to the high water table, which in places is known to be caused by the presence of bluish-gray stiff clay about 6 feet below the surface. Near the margins, where the material is more sandy, the indications of poor underdrainage in the subsoil are less pronounced and the surface soil is brown rather than gray. All the sandy part of the soil profile is slightly acid, but the underlying clay is very calcareous. Other areas show differences in detail of soil profile and various degrees of acidity.

Brady sandy loam is closely associated with soils of the Fox and Bronson series, principally on the gravel outwash plains and terraces and to some extent in the upland depressions. The small but widely scattered bodies have a small total area. The position of areas of this soil is lower than that of Bronson sandy loam, and the depth to the water table is less than in that soil, resulting in poor natural drainage. Even in unusually high situations, the semi-impervious subsoil tends to create a condition of poor drainage. All the land requires artificial drainage. If the water table can be held permanently below a depth of about 40 inches, the soil is in condition for further improvement by additions of manure and commercial fertilizer.

Crops are less heavy than those grown on the Bronson and Fox soils, especially in wet seasons. As it occurs in such close association with the Fox and Bronson soils and in such relatively small areas, the Brady soil of necessity must be used for the same cropping routine as the large areas of adjacent soils. In several fairly large areas consisting exclusively of the Brady soil, the staple crops do fairly well on improved and well-managed land. Nearly all of the Brady sandy loam has been rendered tillable by artificial drainage. It is a fairly strong soil and is well adapted to growing corn, clover, and alfalfa, especially in the deep areas rich in humus, underlain by calcareous sandy gravelly clay, with the permanent water table at a depth ranging from 30 to 40 inches. Such land is nearly drought-proof. Some included areas with a lighter colored surface soil and a brown or mottled subsoil have a lower water table but are not

droughty. Wheat, oats, and barley do not make so rank growth on the typical soil as on the darker included areas, but they yield well in normal seasons. This is also true with respect to potatoes, garden crops, and cucumbers. Bluegrass, timothy, and redtop thrive wherever they become established. No fields of alsike clover were seen during the course of this survey, but this crop should do well in the mucky areas and wet spots.

Maumee fine sandy loam.—Maumee fine sandy loam is a coarse-textured loose fine sand or sandy loam containing some very coarse sand in most places. The color ranges from grayish black to black, the latter color prevailing where the content of humus is high. In the darkest areas the organic matter is finely divided carbonaceous material similar to muck. The thickness of the surface soil varies but is less than 12 inches in most places. The typical subsoil is sandy clay loam or stiff sandy clay, which is less friable and less dark than the surface soil. This material grades into gray, drab, or mottled brown and gray stratified sandy clay, which, at a depth ranging from 30 to 40 inches, gives way to gray water-soaked highly calcareous sticky sand. This lower layer everywhere either is saturated or is marked by its former high water table. Although both fine sand and medium sand are represented in the sand fraction of the soil, it is believed that fine sand is dominant.

The surface and subsurface layers contain white sand grains and clear quartz pebbles, which have remained after more soluble materials have been removed by organic acids. In a few small spots the subsoil, at a depth ranging from 10 to 15 inches, is hard or firmly cemented into a hardpan.

Maumee fine sandy loam is developed along Pigeon Creek, and a few very small areas are around Angola and north of Clear Lake, in close association with Plainfield loamy fine sand, Newton loamy fine sand, and Oshtemo loamy sand. This soil occupies moderately shallow sags and is characterized by a highly organic surface soil and a poorly drained light-colored sandy subsoil.

As mapped, this soil includes a dark-colored soil at the margins of muck areas and along small drainageways. In such places, large accumulations of organic matter and spots of shallow muck over sand are common. The subsoil, to a depth of 40 inches, is grayish-white sandy loam mottled slightly with pale yellow. The water table stands below this horizon in strongly mottled grayish-white loamy sand. The reaction is neutral to slightly acid down to the water table, where it is mildly alkaline.

Plant nutrients, other than the nitrogen of the humus, are lacking, and any system of soil management must take cognizance of that fact. Commercial fertilizers to supply potash are used in connection with the growing of special crops, such as onions, cabbage, and mint. Corn is the only staple crop grown in large quantities.

Maumee fine sandy loam compares favorably with Brady sandy loam in productivity but is inferior to Fox sandy loam. It doubtless is more productive than the associated Plainfield, Berrien, and Newton loamy fine sands.

Newton loamy fine sand.—Newton loamy fine sand includes those very dark grayish-brown soils which have so high a water table that the subsoil is saturated almost constantly and the surface soil is so

moist that finely divided black carbonaceous organic matter similar to muck has accumulated. This organic residue is intimately intermixed with the mineral constituents, forming a very dark gray loose mellow loamy fine sand surface soil. Little or no coarse material is evident, but the larger sand grains are noticeably bleached by organic acids and impart the gray cast to the very dark colored organic matter. Below a depth of 6 inches the material becomes lighter colored as the quantity of organic matter decreases, and it grades into gray loose loamy fine sand or sand which becomes slightly coarser in the lower part. Below a depth of 20 inches the soil is loose loamy coarse sand mottled with rusty brown and dull reddish brown. Between depths of 30 and 65 inches, saturation is constant and the gray sand is so moist that it is barely coherent. This horizon rests on gray tight calcareous clay, which evidently is a sedimentary deposit and is practically impervious to water. The water table now stands at an average depth of 36 inches below the surface, but it was nearer the surface before artificial drainage was established. None of the sand contains enough lime to react with hydrochloric acid. In most places the surface soil and subsurface soil are very strongly acid.

This soil is associated with Plainfield loamy fine sand and Maumee fine sandy loam. Its total area is very small. Its development in flats and in shallow depressions is intermediate between that of the Berrien and the Maumee soils.

Included with Newton loamy fine sand on the map is a small area of a similar soil, with a mildly alkaline subsoil, owing to its location either adjacent to limy till or in a position to receive seepage from it.

Under normal rainfall Newton loamy fine sand produces fair crops of corn and clover, but it does not endure excessive rain or very dry weather so well as do the Maumee and the heavier upland soils.

ORGANIC SOILS

Soils in which decomposed plant remains represent about one-half or more of the soil material are classed as organic soils. These soils have high water tables.

Sixty or seventy years ago nearly all of the present areas of muck and peat were swamps, marshes, or shallow lakes. The swamps were covered with forest and the marshes with sedges and grasses. During the intervening years, the land has been cleared of timber, and water levels have been considerably lowered in many of the marshes and shallow lakes. The lowering of the water tables has been accompanied by the encroachment of coarse grasses in many places and by cultivation in others. It is probable that before settlement of the county the water tables fluctuated considerably and that these fluctuations were attended by alternate advancements of a forest cover and a sedge-reed-grass cover.

Where the forest or the sedge-reed-grass cover predominated, as determined by the average position of the water table over a considerable period of time, a distinct kind of organic soil developed, known as peat. Peat occurs where the water table has been consistently close to the surface and the organic accumulation has not de-

composed. Cumulose materials, exposed to aeration by periodic lowering of the water levels, on the other hand, became well decomposed. They give rise to various types of muck, depending on the original vegetation and the underlying material.

Using these criteria, the following separations are made: Carlisle muck, from woody peat; Houghton muck, from sedge and reed peat; Edwards muck, underlain by marl; Kerston muck, mixed with alluvial material; Wallkill silt loam, a mineral overwash on muck; and Rifle peat, in part from sedges and grasses and in part from wood.

Carlisle muck.—The 8-inch surface layer of Carlisle muck is very dark brown or black well-decomposed amorphous woody muck containing some small hard flakes of black nonfibrous peat. The underlying horizon is a black nonfibrous material breaking with lustrous fracture into somewhat angular fragments about one-half inch in diameter. Below a depth ranging from 18 to 36 inches the soil is a dark-brown soft mixture of sediments and well-decomposed fibrous materials. With great depth it becomes reddish brown and contains sedge roots and other coarse woody plant remains below the water table. The material in the surface layer is moderately firm and retains moisture well, and there is little tendency to assume a dry loose condition near the top. Where the surface layer itself is derived chiefly from trees and woody shrubs it is almost invariably a dark-brown rather loose material, in which the woody remains are recognized readily. In many places, the finer constituents consist of well-oxidized plant fibers, together with more or less granular peat. Small hard flakes of water-laid organic debris are abundant, where for any reason a high water table has contributed sedimentary finely divided organic material.

Proper drainage is everywhere a prerequisite to cultivation. In finely divided well-oxidized muck, with a more or less macerated or black aquatic decomposed peat subsoil, a water table held from 30 to 36 inches below the surface maintains good surface-moisture conditions. Excessive drainage results when the level is lower, and crop yields are reduced if the weather is dry. Corn is especially susceptible to drought on excessively drained Carlisle muck.

Carlisle muck is closely associated with Houghton muck, though it is of much smaller extent. The largest areas are southwest of Clear Lake and north of Pigeon Lake.

The original tree growth was dominantly elm, ash, and red maple, although the more distinctly upland species encroached on the margins of the areas and drier spots. The extremely varied undergrowth includes huckleberry, dogwood, poison sumac, greenbrier, bog-rosemary, azalea, and spirea, and many kinds of ferns, mosses, and flowering plants. The occurrence of the latter group of plants was governed largely by light and moisture conditions. Tamarack was more prevalent formerly in places where deciduous trees could not grow in quaking bogs.

There are few undrained areas in the southern part of the county. Here, the largest part of the land is used for pasture, but much is cultivated on an intensive scale. The cultivated areas produce good crops of corn, with yields of 75 or more bushels an acre in many

seasons. Small grains seldom are sown. Truck growing is well established in this section, with onions as the chief crop. Cucumbers and celery are grown very successfully but not on a commercial scale.

Local truck growers prefer woody or Carlisle muck to the reedy and sedgy Houghton muck, provided other features are favorable. With one-half ton of commercial fertilizer this soil is capable of producing 500 bushels of onions an acre. Constant cropping must be managed carefully because of the rapid multiplication of toxic fungi and bacteria, the control of which requires rotation of crops.

Houghton muck.—The surface layer of Houghton muck, where cultivated, is dark-brown or black well-decomposed granular muck. From the subsurface downward it is less well decomposed and is saturated with water. Reed and sedge remains are recognizable but are well macerated and mixed with mineral material. The color is more brown than black. Where the soil is unreclaimed because of drainage difficulties, the surface is covered with a variable mat of coarse grasses, which has formed probably within rather recent times. Where developed in standing water, the original pond weed and pond lily associations gave rise to a soft nonfibrous material, which is entirely macerated and partly decomposed. This material is mixed with various proportions of fibrous roots, rhizomes, and mineral sediments. Partly decomposed fragments of wood are scattered through the upper part of most areas, and these few remains probably represent minor encroachments of trees on the areas during prolonged periods when the water table was low, but they are not present in sufficient quantities to affect materially the fertility of the soil.

Houghton muck is the most extensive organic soil in the county and is considered the best for the production of crops. It is used extensively for truck gardening. A total of 16.3 square miles is mapped, several areas occupying about 1 square mile each. The most important areas are the original Cedar Lake, just east of Fremont, and the large areas northeast and southwest of Pleasant Lake in the south-central part of the county. Areas of approximately 200 acres each border most of the streams and lakes, and smaller areas are scattered over the upland.

The control of the level of the water table is as important and is similarly managed as in Carlisle muck. Artificial drainage is invariably followed by considerable shrinkage or settling of the superficial layers, and this condition favors the invasion of plants requiring less water than did the original vegetation. Kentucky bluegrass is one of the most aggressive invaders in shaded places where the water table has been permanently lowered. This grass affords excellent pasturage. The trampling of animals firms the surface, and their manure enriches the muck. Old pastures, therefore, are brought into condition for tillage more easily than is muck from which the original vegetation has been removed very recently.

Onions and potatoes are important crops on Houghton muck. Mint and hemp also are grown—the latter being most important in the south-central and southwestern parts of the county. In many locations, gardens are planted on muck, and celery, cabbage, sweet corn, and various other crops are grown very successfully. The land, where well drained, gives fair to good yields of the crops named.

Edwards muck.—Edwards muck consists of shallow Houghton muck superimposed on marl. In pastures the surface soil is an amorphous and cohesive black muck supporting a heavy turf of bluegrass. The water table stands from 6 to 18 inches below the surface, and the material at this depth is adhesive and cohesive. The underlying material is either shell or chara marl. The latter is secreted chiefly by stonewort, which is common in many developing peat areas, in association with bladderwort, water milfoil, and other aquatic plants and algae. The surface soil is slightly acid, and the subsoil is highly alkaline. Where the water table is lowered to a depth of 36 inches by ditching, the acidity increases slightly, owing to leaching and a decrease in the capillary rise of lime-bearing soil waters. A faint white efflorescence appears on the surface occasionally after periods of dry weather, but, according to truck growers, this causes no injury to plants.

The total area of Edwards muck is much smaller than that of Carlisle muck, although some of the individual areas are almost as large. Edwards muck is developed chiefly along Pigeon and Turkey Creeks and to a small extent on the uplands.

Truck gardening is very successful in places where the water table can be lowered and controlled conveniently. Yields are very similar to those obtained on Carlisle and Houghton mucks. Both clover and alfalfa do well on this soil, provided drainage is not excessive and the crops get a good start.

Several areas of burned-over muck are included with Edwards muck. In places where burning does not reduce the thickness of the overlying organic surface soil to a depth of less than 12 inches and the marl can be mixed with it by deep plowing, very successful crop production can be attained. Reduction of the surface soil to a thickness of less than 12 inches, however, impoverishes the soil to a degree below its original productivity.

Kerston muck.—Kerston muck to a depth of 24 or more inches is interbedded muck, sand, and silt. The organic material is well decomposed and dark brown, and the mineral matter is grayish black, friable, and inherently fertile. The subsoil includes less muck than the surface soil and is highly saturated with water. The organic matter in the soil is fully or partly decomposed woody peat and, for the most part, has accumulated in place, although stream deposition probably has accounted for a small amount.

A small total area of Kerston muck is mapped. It lies along Pigeon Creek, principally near Flint. Its position is similar to that of the Griffin soils, but it probably has been subjected to inundation only occasionally. Most of the land is subject to frequent overflow, which detracts somewhat from its value as a producer of staple crops, but where the stream channels are sufficiently deep to insure consistent drainage, cultivation is undertaken with fair success. This type of muck supports a heavy forest growth and good pasture.

Wallkill silt loam.—The surface soil of Wallkill silt loam is dark grayish-brown friable silt loam and is slightly darker than that of Washtenaw silty clay loam. The upper part of the subsoil is a mixture of mineral and organic materials, and the lower part is muck. Very small widely scattered areas, totaling only 448 acres, are mapped, principally in the southern part of the county.

In places where the water table is more than 25 inches below the surface, the soil is very productive, as it is naturally fertile. The use of Wallkill silt loam depends to a great extent on the crop adaptations of the soils immediately surrounding it.

Rifle peat.—The 12-inch surface layer of Rifle peat is a mat of coarse grass, grass roots, and recent remains of various aquatic plants. In some places woody fragments are also present. In general, this layer is dark brown and contains some lighter brown spots. The subsoil, which extends to a depth of about 20 inches, is free from woody material in most places and contains a considerable quantity of peaty muck. Below this, the fibrous material consists of coarse undecomposed remains of sedges, reeds, and other aquatic plants. The water table is very close to the surface.

The largest areas are southeast of Fremont, south and northeast of Clear Lake, and northwest of Angola. Small bodies are along Crooked and Pigeon Creeks and are widely scattered throughout the uplands, where most of them are surrounded by areas of Houghton muck or Carlisle muck.

Most of the land is devoted to pasture, and some of it supports a good stand of tamarack. This type of organic soil presents greater difficulties to drainage than do the muck soils because of the relatively higher water table, and it is poorly adapted to agricultural uses even where reclamation is practicable. Burned-over areas of Rifle peat are worthless.

As mapped, Rifle peat includes certain areas of peaty muck which are intermediate between the muck soils and Rifle peat. These are, for the most part, borders around lakes, on which cattails, rushes, and waterlilies dominate the vegetation. Many areas around the lake borders, in which marsh symbols appear, are of this character. The color is slightly darker brown than that of Rifle peat, owing to its greater content of well-decomposed organic and mineral matter. A large proportion of the subsoil consists of sedimentary peat, which is so well macerated and lacking in fiber as to resemble a muck. This material represents peat in its formative stage and would occupy a much larger area, were it not for the continually lowering water table. High water is essential to its development. This included soil has practically no agricultural use except for pasture in those places where it has developed nearly to the point of being a true peat.

MISCELLANEOUS LAND TYPES

Beach sand.—Very gently sloping former beaches exposed as a result of lowering of the lake levels are mapped as beach sand. In most areas the surface material consists chiefly of sand, gravel, and small stones. In some places, the proportion of fine material is larger and the soil is a sandy loam or, rarely, a silty or fine sandy loam. Many places were noted where small rounded stones entirely cover the surface. All this material is calcareous and the water table is close to the surface. Many kinds of weeds and grasses thrive on the less stony areas, and bluegrass is well established in many places. The chief agricultural value of this land type is for pasture.

Marl beds.—Exposures of marl, such as those along Balls Lake near Hamilton (within areas of Brookston silty clay loam and not sep-

arately mapped), along Turkey Lake, and at various places along the Pigeon Creek chain of lakes readily afford supplies of limy material suitable for local agricultural use. Most of the marl, especially the chara variety, is very pure and is so friable that it pulverizes on drying. When plowed up in the shallow muck areas, the lumps soon become finely divided and well mixed with the soil. Marls average about 90 percent of pure calcium carbonate (lime), in few places running as low as 84 percent. Table 4 gives analyses of samples of marl.

TABLE 4.—*Chemical analyses of samples of marl in Steuben County, Ind.*[1]

Origin of sample	$CaCO_3$	$MgCO_3$	Al_2O_3	Fe_2O_3	$CaSO_4$	Insoluble inorganic matter	Organic matter
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Hog Lake, average sample	90.42	2.83	0.14	0.28	--------	0.68	4.13
Small lakes in secs. 6 and 7, T. 37 N., R. 12 E. (average sample)	93.29	2.67	.04	.12	--------	.47	1.56
James Lake, 3 lower basins (average sample)	92.41	2.38	--------	.29	0.15	1.16	1.97
Silver Lake	84.00	6.46	--------	[2] 1.34	--------	4.52	3.68

[1] Data compiled from the following: BLATCHLEY, W. S., and ASHLEY, GEO. H. THE LAKES OF NORTHERN INDIANA AND THEIR ASSOCIATED MARL DEPOSITS. Ind. Dept. Geol. and Nat. Resources. Ann. Rpt. 25: 31–321, illus. 1901.
[2] Ferrous carbonate.

Gravel pits.—Gravel pits are mapped, with a total area of only 128 acres, principally north of Pleasant Lake. The pits that are too small to outline on a map of the scale used are indicated by symbols.

MORPHOLOGY AND GENESIS OF SOILS

Steuben County is in the northern part of the region of Gray-Brown Podzolic soils of the United States. The dominant soils of the county are developed almost entirely from inorganic material consisting of the weathered products of glaciation. Although the glacial drift itself is partly weathered material, there has been further definite alteration and development of true soil profiles consistent with the environment. The humid temperate climate characteristic of the region prevails uniformly throughout the county. The native vegetation was, for the most part, a deciduous hardwood forest.

The relief is diversified, and drainage conditions likewise are variable. Steep slopes are marked by rapid run-off, even under a forest cover, and in such places the soils are shallow, owing to natural erosion. On undulating to gently rolling upland areas the factors of soil development express themselves fully on the parent materials. Other nearly flat upland areas under natural conditions are alternately wet and dry. Numerous depressions are, or at one time were, wet throughout most of the year. Some of the depressions are characterized by dark-colored mineral soils, high in organic matter, which is mixed with the mineral materials and is preserved under the influence of the high moisture content and in some places by the high lime content of the soil material. Still other depressions are filled with organic deposits, which, in some places, are in the form of

peat, and, in others, where better drainage favors weathering, are in the form of muck. Ponds and lakes still occupy some of the larger and deeper depressions.

The mineral soils of the county, as a result of differences in environment, may be classed in three broad divisions: (1) Well-drained soils, or soils that retain average amounts of moisture for the region; (2) imperfectly drained soils, which are subject, under natural conditions, to periodic saturation or high moisture content; and (3) poorly drained soils, which are subject under natural conditions, to almost continuous saturation.

The well-drained soils, or those soils developed on undulating or gently rolling relief from medium- to heavy-textured parent materials, are representative of the Gray-Brown Podzolic soils of the eastern United States. These soils are marked by the removal of fine colloids, soluble bases, including calcium salts, and iron from the surface soil layers, or A horizon. Some organic matter has accumulated, in the form of forest litter, on the surface, and generally a 1- to 2-inch layer of moderately dark-gray humous soil has developed. The process of soil development, with the eluviation of colloids, bases, and sesquioxides from the surface layers, has been accompanied by a correlative accumulation of the colloids and sesquioxides in the subsoil, or B horizon. The soluble bases have been leached for the most part below the B horizon. The depth to which carbonates are leached ranges from 20 to 30 inches in the heavier soils.

The following description of a profile of Miami loam illustrates the various horizons of the well-developed well-drained soils of the uplands:

1 (A_0). An accumulation, in most places 1 or 2 inches thick, of loose forest litter from deciduous trees. The reaction generally is neutral or slightly alkaline.

2 (A_1). A 2- or 3-inch layer of very dark-gray friable loam or humous soil containing a large proportion of organic matter, which is thoroughly disintegrated and incorporated in the soil. The material has a marked soft-granular or crumb structure. The reaction is neutral or slightly acid.

3 (A_2). A 6- or 8-inch layer of grayish-yellow or light grayish-yellow loose friable loam with a high silt content. The structure is definitely platy or phylliform. The material crumbles readily to a fine-grained mass. The reaction ranges from medium acid to strongly acid.

4 (A–B). A 4- or 5-inch transitional layer, which generally is light-yellow or grayish-yellow loose friable loam with a platy structure in the upper part and a more definitely yellow and heavier loam with an indefinite nutlike structure in the lower part. The reaction is strongly acid.

5 (B_2). Yellow or yellowish-brown acid clay loam with a very definite breakage into irregular angular particles, one-fourth to one-half inch in diameter. The particles have a thin coating of brown gelatinous material on the outside and are yellowish brown within. When wet, the soil material is sticky and plastic; but when dry the soil particles are definitely hard. In general, this layer occurs at a depth ranging from 12 to 16 inches and is from 15 to 20 inches thick. The lower part of this horizon is slightly darker on the faces of structure particles and is approximately neutral in reaction.

6 (C). Grayish-yellow partly weathered calcareous medium-textured glacial till. This till is composed of many kinds of geologic material as indicated by the variable composition of the pebbles and stones, which are scattered throughout. Many of the pebbles and stones are derived from granitic rocks; others, from sandstone, shale, or limestone.

Miami silty clay loam is similar to Miami loam except that it has a heavier texture throughout, as its parent material contains much more clay than the parent material of Miami loam. This heavier texture is also reflected in the soil colors, which are definitely grayer and less yellow or brown than those of Miami loam.

Another subgroup of well-drained soils is characterized by clayey B horizons, which are at the same time definitely sandy. The C horizons of these soils differ from the C horizon, or parent material, of Miami loam, in that they consist of sandy gravelly calcareous loose glacial drift, generally stratified by water. The Fox, Bellefontaine, Warsaw, and Oshtemo soils have such B and C horizons.

The Coloma and Plainfield soils are developed from glacial till and assorted glacial drift, respectively, and are composed almost entirely of quartz sand. As little or no clay-forming minerals are present in the parent materials, these soils lack the clayey B horizon of Miami loam. The color profile, however, is developed and is similar to that of the other well-drained forested soils.

The imperfectly drained soils of the uplands differ from the Miami soils chiefly in the development of a heavier, more impervious B horizon, which in most places is intermediate between the B horizon of the Miami soil and a claypan. The color of the A horizon is lighter gray. They occur in nearly flat areas. A characteristic profile of Crosby loam is as follows:

1 (A_0). A thin layer of forest litter from deciduous trees, similar to that on Miami loam.
2 (A_1). A 1- or 2-inch layer of very dark gray friable loam with a high organic-matter content and a soft-granular structure. The material generally is slightly acid or neutral in reaction.
3 (A_2). A 6- or 8-inch layer of light-gray loose friable loam with a definitely platy or phylliform structure. The reaction is medium to strongly acid. Stains, generally yellow or yellowish brown, or soft concretionary material occur in places.
4 (A–B). A very thin transitional layer, in most places mottled with light gray and yellow. The material is loose and friable in the upper part and heavier below.
5 (B_2). A definite B horizon, which approaches the character of a claypan. It consists of acid heavy clay loam, ranging from 12 to 18 inches in thickness, which breaks on drying into hard angular fragments. These fragments or structure particles are mottled with dull yellow, brown, and gray. The lower part of this horizon is approximately neutral in reaction.
6 (C). Calcareous glacial till similar to that under Miami loam.

The Conover soils are similar to the Crosby soils but have developed under a slightly higher average moisture content with an A_1 horizon, which in most places ranges from 3 to 6 inches in thickness. The dark-colored A_1 horizon presumably is due to the influence of a cooler climate than that characteristic of the large areas of Crosby soils farther south. The A_2 horizon is correspondingly thinner than in the Crosby soils, but the B horizon is very similar to the Crosby. The Bronson soils also resemble the Crosby soils but are underlain by stratified gravel and sand. The Berrien soils are imperfectly drained and are developed in a layer of sand, which overlies clay till at a depth ranging from 4 to 6 feet.

Typical of the third group of mineral soils is Brookston silty clay loam. The profile of this soil is as follows:

1. A thin layer of forest litter, generally neutral in reaction.
2. A 6- to 10-inch layer of very dark brownish-gray silty clay loam with a soft-granular or crumb structure. The reaction is neutral or slightly acid.
3. A 10- to 15-inch layer of dull-gray, grayish-yellow, or mottled gray and yellow silty clay loam containing streaks of dark-colored material from the layer above. The material has an indefinite nutlike structure and is about neutral in reaction.
4. Gray clay loam, mottled with yellow and rusty brown, which breaks into sharply angular particles, most of them more than one-half inch in diameter, and becomes essentially massive below. It grades, at a depth ranging from 40 to 50 inches, into the underlying material.
5. Calcareous glacial till similar to that under the Miami and the Crosby soils.

Clyde silty clay loam, another poorly drained soil, is similar to the Brookston soil but it has a darker colored surface layer and a higher content of organic matter. It was developed apparently under wetter conditions than the Brookston soil and possibly under marsh vegetation rather than forest. Brady sandy loam, Maumee fine sandy loam, and Newton loamy fine sand are dark-colored poorly drained soils developed over light-textured water-laid materials.

Mechanical analyses of samples of several soils in this county are given in table 5.

TABLE 5.—*Mechanical analyses of several soils in Steuben County, Ind.*

Soil type and sample No.	Depth	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
	Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Miami silty clay loam:[1]								
37288 (parent material)	30-42	1.1	2.4	2.6	5.9	6.8	28.2	53.0
37289 (parent material)	36-42	2.3	2.9	3.3	7.8	8.1	34.5	41.2
37290 (parent material)	60-66	2.5	2.5	2.6	6.0	6.6	37.1	42.7
Miami fine sandy loam:								
283673	0- 6	1.3	5.3	6.0	31.8	20.4	29.0	6.3
283674	6-15	1.6	5.2	6.2	30.5	18.9	29.8	8.5
283675	15-30	1.4	4.6	4.8	28.8	15.5	24.4	20.2
283676	30-36	1.6	4.0	3.8	20.4	17.6	30.0	23.0
283677	36-40	1.6	3.9	3.5	19.0	19.0	35.0	18.4
Fox sandy loam:								
283622	0-12	2.6	11.8	13.8	41.9	6.2	19.2	4.9
283623	12-20	2.3	11.4	12.9	42.1	6.0	20.0	5.5
283624	20-40	4.5	15.6	13.8	33.6	5.6	12.8	14.6
283625	40-45	6.0	14.0	11.0	36.1	7.9	10.6	14.9
Bellefontaine cobbly fine sandy loam:								
283678	0-12	1.0	5.6	10.6	54.0	7.4	16.9	5.1
283679	12-20	1.0	5.4	10.0	55.0	6.5	17.3	4.8
283680	20-36	.8	5.1	6.7	37.4	12.6	21.6	16.1
283681	36+	5.6	12.6	9.9	27.6	10.1	20.5	14.3
Plainfield loamy fine sand:								
283642	0- 6	0	3.1	10.4	63.2	4.0	14.8	4.3
283643	6-18	0	2.9	10.2	63.2	5.9	13.5	4.4
283644	18-50	0	3.2	9.8	59.0	5.7	15.4	7.3
283645	50-80	.8	9.3	20.0	63.5	1.7	2.9	1.9
Crosby silty clay loam:								
283647	0- 4	1.1	2.9	4.3	8.4	5.1	41.1	37.1
283648	4- 8	.6	2.8	4.6	9.0	5.5	42.4	35.1
283649	8-20	0	.3	.5	1.4	1.3	28.0	68.5
283650	20-40	.1	.2	.4	.9	.8	35.0	62.6

[1] These samples also showed the following analysis for CO_2 from carbonates: Sample No. 37288, 7.52 percent; No. 37289, 9.42 percent; and No. 37290, 13.66 percent.

About 10 percent of the county is covered by organic deposits. These deposits range in thickness from a few inches to more than 25 feet. The mineral substratum is variable, but in most places it con-

sists of heavy clay till. A few areas mapped as Edwards muck are underlain by marl. Practically all of the organic soils in Steuben County contain 75 percent or more of cumbustible materials. A wide range in such characteristics as texture, structure, color, stage of decomposition, character of parent material, depth of water table, and chemical composition are exhibited in these organic soils. On the basis of such characteristics the deposits have been separated into a number of types. Of these, Houghton muck is dominant and is characteristic of the more thoroughly decomposed materials.

MANAGEMENT OF THE SOILS OF STEUBEN COUNTY

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The farmer should know his soil and have a sound basis for every step in its treatment. Building up the productivity of a soil to a high level, in a profitable way, and then keeping it up is an achievement toward which the successful farmer strives. As in any other enterprise, farming should be conducted intelligently and carefully, and every process must be understood and regulated in order to be uniformly successful. A knowledge of the soil is highly important, as different soils present different problems of treatment, and the soils must be studied and understood in order that crops may be produced in the most satisfactory and profitable way.

The purpose of the following discussion is to call attention to the deficiencies of the several soils of the county and to outline in a general way the treatments most needed and most likely to yield satisfactory results. No system of soil management can be satisfactory unless in the long run it produces profitable returns. Some soil treatments and methods of management may be profitable for a time but ruinous in the end. One-sided or unbalanced soil treatments have been altogether too common in the history of farming in the United States. A proper system of treatment is necessary in making a soil profitably productive.

PLANT NUTRIENTS IN THE SOILS OF STEUBEN COUNTY

Table 6 shows the results of chemical analyses for the important plant nutrients in the different types of soil, expressed in pounds of elements in the 6- to 7-inch layer of plowed surface soil of an acre, estimated at 2,000,000 pounds for the mineral soils and 1,000,000 pounds for the mucks.

The quantity of phosphorus soluble in weak acid is considered by many authorities a very good indication of the relative availability of this element. Where the weak-acid soluble phosphorus runs less than 100 pounds to the acre, phosphates generally are needed for high crop yields. The more intensive the crop the greater is the need for large quantities of available phosphorus. Everything else being equal, the more of this soluble phosphorus a soil contains the less it is apt to need phosphates. The deeper a soil is the less it needs phosphates. Subsoils contain less available phosphorus than surface soils. A soil which has had the surface soil eroded, exposing the subsurface layers, is apt to be in need of phosphates.

TABLE 6.—*Approximate quantities of phosphorus, potassium, and nitrogen in certain soils of Steuben County, Ind.*

[Elements in pounds per acre of surface soil 6 to 7 inches deep]

Soil type	Phosphorus [1]	Potassium [1]	Phosphorus [2]	Potassium [2]	Nitrogen [3]
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Crosby silty clay loam	30	100	1,100	32,400	3,000
Crosby loam	30	65	1,000	30,000	2,400
Conover loam	25	95	1,100	30,780	3,600
Bronson sandy loam	35	55	800	23,000	2,000
Berrien loamy fine sand	65	70	600	18,300	1,800
Miami loam	70	45	900	28,200	2,400
Miami fine sandy loam	90	80	900	26,400	1,600
Miami silty clay loam	45	80	1.000	31,400	2,800
Bellefontaine fine sandy loam	120	80	700	26,500	2,200
Bellefontaine cobbly fine sandy loam	100	70	1,100	16,700	1,800
Bellefontaine gravelly sandy loam	100	60	1,200	19,500	1,800
Bellefontaine loamy sand	80	70	900	15,000	1,400
Fox sandy loam	70	40	700	28,200	1,600
Warsaw sandy loam	60	50	1,050	21,800	2,600
Oshtemo loamy sand	105	60	600	22,500	1,400
Coloma loamy fine sand	80	75	800	16,800	1,000
Plainfield loamy fine sand	60	60	1,100	14,100	1,400
Brookston silty clay loam	260	230	1,600	23,700	4,600
Clyde silty clay loam	345	160	2,200	38,000	6,000
Maumee fine sandy loam	210	50	1,700	22,700	7,000
Brady sandy loam	200	40	1,000	28,000	4,200
Newton loamy fine sand	100	35	1,000	18,100	4,000
Griffin silt loam	150	175	1,400	23,800	4,200
Carlisle muck	260	60	1,500	2,700	35,600
Houghton muck	200	80	1,100	3,300	24,100
Edwards muck	175	65	1,000	1,430	36,800
Rifle peat	90	50	700	2,300	25,000

[1] Soluble in weak nitric acid (fifth normal).
[2] Soluble in strong hydrochloric acid (specific gravity 1.115).
[3] Total elements.

The quantity of potassium soluble in weak acid is considered by some authorities significant of the need for potash. This determination, however, is not so reliable an indicator as is the determination for phosphorus. In general, however, the lower the soluble potassium the greater is the need for potash. Contrary to the case of phosphorus, however, the potassium of the subsoil is fairly available, and potash is more apt to be needed on flat uneroded land than on sloping eroded soils. Sandy soils and muck soils are more often in need of potash than clay and loam soils. Poorly drained soils with impervious subsoils usually need potash more than well-aerated, deep soils.

The strong-acid soluble phosphorus, the total potassium, and nitrogen are given as indications of the plant-nutrient content of the soil. The total amounts of phosphorus and potassium are more valuable as an indication of the origin of the soil than they are of the need of the soil for these elements, as much phosphorus and potassium in soils is very insoluble and extremely slow in availability. Total nitrogen is to a large extent indicative of the nitrogen and organic-matter content of the soil. Soils of low nitrogen content soon wear out and need to have this and other elements replenished by legumes, manure, and fertilizers. The darker the soil the higher it is in organic matter and nitrogen and the longer it may be cropped without the addition of nitrogenous fertilizer.

No one method of soil analysis will definitely indicate the deficiencies of a soil. These chemical data, therefore, are not intended to be the sole guide in determining the needs of the soil. The thickness of

the surface soil, the physical character of the subsoil and surface soil, and the previous treatment and management of the soil are all factors of great importance and should be taken into consideration. Pot tests indicate that nitrogen and phosphorus are much less available in subsurface soils and subsoils than they are in surface soils. On the other hand, potassium in the subsoil seems to be of relatively high availability. Crop growth depends largely on the amount of available plant nutrients with which the roots may come in contact. If the crop can root deeply, it may be able to make good growth on soils of relatively low analysis. If the roots are shallow, the crop may suffer for lack of nutrients, particularly potash, even on a soil of higher analysis. The better types of soils and those containing large quantities of plant-nutrient elements will endure exhaustive cropping much longer than the soils of low plant-nutrient content.

The nitrogen, phosphorus, and potassium contents of a soil are not the only chemical indications of high or low fertility. One of the most important factors in soil fertility is the degree of acidity. Soils that are very acid will not produce crops common to this section well, even though there be no lack of plant-nutrient elements. Although nitrogen, phosphorus, and potassium are of some value when added to acid soils, they will not produce their full effect where calcium is deficient. This is particularly true of phosphorus.

Table 7 shows the percentage of nitrogen and the acidity of certain soils. The acidity is expressed as pH, or approximate hydrogen-ion concentration. A soil of pH 7 is neutral and contains just enough lime to neutralize the acidity. If the pH value is over 7, it indicates that there is some lime in excess. Soils ranging from pH 6 to 7 are slightly acid, and those from pH 5 to 6 are of medium acidity. If the pH value runs below 5 the soil is very strongly acid. As a rule, the stronger the acidity the more a soil needs lime.

TABLE 7.—*Percentage of nitrogen in and acidity of certain soils in Steuben County, Ind.*

Soil type	Depth	Nitrogen	pH	Average depth to neutral material	Indicated lime requirement per acre
	Inches	*Percent*		*Inches*	*Tons*
Crosby silty clay loam	0–6	0.15	5.0	24	2
	6–24	.07	5.6		
	24–36	-------	(1)		
Crosby loam	0–6	.12	6.0	30	2
	6–18	.05	5.6		
	18–30	.04	6.8		
Conover loam	0–6	.18	6.7	34	0–1
	6–19	.08	6.5		
	19–36	.07	7.0		
Bronson sandy loam	0–6	.10	5.4	40	2–3
	6–16	.05	5.6		
	16–40	.06	5.8		
Berrien loamy fine sand	0–6	.09	6.0	60	2–3
	6–18	.05	5.6		
	18–40	.03	5.7		
Miami loam	0–7	.12	6.0	30	2
	7–18	.05	6.2		
	18–30	.05	6.2		
Miami fine sandy loam	0–7	.08	5.8	40	2–3
	7–18	.05	6.0		
	18–36	.03	5.6		
Miami silty clay loam	0–6	.14	5.9	24	2
	6–18	.08	4.6		
	18–24	.06	6.0		

TABLE 7.—*Percentage of nitrogen in and acidity of certain soils in Steuben County, Ind.*—Continued

Soil type	Depth	Nitrogen	pH	Average depth to neutral material	Indicated lime requirement per acre
	Inches	*Percent*		*Inches*	*Tons*
Bellefontaine fine sandy loam	0-7	.11	6.1	32	1-2
	7-18	.04	6.5		
	18-32	.04	6.3		
Bellefontaine cobbly fine sandy loam	0-8	.09	5.4	44	2
	8-18	.04	5.2		
	18-36	.03	5.0		
Bellefontaine gravelly sandy loam	0-6	.09	6.6	0	0
	6-18	.05	6.2		
	18-36	(2)	------		
Fox sandy loam	0-8	.08	5.6	32	2
	8-18	.03	5.8		
	18-36	.03	5.2		
Warsaw sandy loam	0-8	.13	5.4	32	2
	8-18	.10	5.3		
	18-36	.06	5.3		
Oshtemo loamy sand	0-6	.07	5.9	50	2
	6-18	.05	5.8		
	18-36	.04	5.8		
Coloma loamy fine sand	0-6	.05	5.4	70	2
	6-18	.02	6.0		
	18-36	.02	6.4		
Plainfield loamy fine sand	0-7	.07	6.0	70	2
	7-18	.04	5.6		
	18-36	.02	5.6		
Brookston silty clay loam	0-6	.23	6.3	0	0
	6-16	.11	6.9		
	16-36	.06	6.9		
Clyde silty clay loam	0-6	.30	6.6	0	0
	6-18	.17	6.8		
	18-36	.08	6.8		
Maumee fine sandy loam	0-6	.35	6.4	0	0
	6-18	.08	6.2		
	18-32	.06	6.6		
Brady sandy loam	0-6	.21	6.5	0	0
	6-18	.09	6.8		
	18-36	.05	6.8		
Newton loamy fine sand	0-8	.20	5.0	45	3
	8-18	.06	5.2		
	18-36	.03	5.2		
Griffin silt loam	0-6	.26	6.6	0	0
	6-18	.09	6.8		
	18-36	.08	7.0		
Carlisle muck	0-8	3.56	5.2	0	0
	8-18	2.50	5.4		
	18-36	2.42	5.2		
Houghton muck	0-8	2.41	6.2	0	0
	8-16	2.28	6.0		
	16-30	2.44	5.8		
Edwards muck	0-6	3.68	6.1	0	0
	6-18	2.40	7.0		
	18-30	.50	(1)		

[1] Calcium carbonate.
[2] Gravel.

The acidity is reported for the surface soil (0 to 6 inches), for the subsurface soil, and for the subsoil. It is important to know the reaction, not only of the surface soil, but of the lower layers of the soil as well. Given two soils of the same acidity, the one with the greater acidity in the subsurface layer is in greater need of lime than the other. Furthermore, the more organic matter and nitrogen a soil contains and the greater the depth to which these elements extend, the less will be the need for lime. The slighter the depth of acid soil, the less apt it is to need lime. Therefore, in determining how much an acid soil is in need of lime, it is necessary to know the pH value, or intensity of acidity, and the amount of nitrogen and organic matter that accompany it. It is well to remember that sweetclover, alfalfa, and red clover need lime more than do other crops. As it is advisable to grow these better soil-improvement legumes in the

rotation, it is in many places desirable to lime the land so that sweetclover or alfalfa will grow. A soil of pH 7 to 8 is ideal for these legumes. Grain crops do well on slightly acid soils.

In interpreting the soil-survey map and soil analyses, it should be borne in mind that a well-farmed, well-drained, well-fertilized, well-manured soil, which is naturally low in fertility, may produce larger crops than a poorly farmed soil that is naturally higher in fertility.

SOIL MANAGEMENT

For convenience in discussing the management of the several soils of this county, they are arranged in groups according to certain important characteristics, which indicate that in many respects similar treatment is required. For example, several of the silt loams and silty clay loams of the uplands and terraces, which have practically the same requirements for their improvement, may be conveniently discussed as a group, thus avoiding the repetition that would be necessary if each were discussed separately. Where different treatments are required they are specifically pointed out. The reader should study the group including the soils in which he is particularly interested.

LIGHT-COLORED LOAMS, SILT LOAMS, AND SILTY CLAY LOAMS OF THE UPLANDS

The better drained loams, silt loams, and silty clay loams of the Miami, Crosby, and Conover series cover more than one-third of the total area of the county.

DRAINAGE

The Miami soils generally have fair to good natural drainage, owing to their more or less rolling relief. The more level areas with heavy subsoils would be benefited by tile drainage. Wherever there is a tight subsoil the land should be tiled. Without underdrainage, erosion of the surface soil is more apt to take place. Surface run-off should be prevented as much as possible because it carries away large quantities of available plant nutrients, which should go into the production of crops. Most of the rain water should be absorbed by the soil, and the surplus should pass away through underdrainage. Tile drainage increases the capacity of the heavy soils to absorb water and thus lessens surface run-off and consequent erosion. It also facilitates soil aeration, which helps to render the plant nutrients in the soil available, and it encourages deeper rooting of crops, which enables them to withstand drought better, as well as to obtain more plant nutrients.

The Crosby soils are naturally poorly drained and more or less seriously in need of tile drainage. Their generally flat surface retards run-off, and their tight subsoils make natural underdrainage very slow and difficult. A gray or mottled subsoil is always an indication of insufficient natural drainage. Without tile drainage these soils cannot be managed satisfactorily, and no other beneficial soil treatment can produce its full effect. Results on experiment fields on other soils with similar texture and relief indicate that tile lines laid at a depth of 30 inches and not more than 3 rods apart will give satisfactory results. Where the land is flat, great care must be exercised in tiling, in order to obtain an even grade and uniform fall.

Nothing less accurate than a surveyor's instrument should be used in establishing grade lines, and the lines should be accurately staked and graded before the ditches are dug, to make sure that all the water will flow to the outlet with no interruption or slackening of the current. The rate of fall may be increased toward the outlet, but it should never be decreased without inserting a silt well, as checking the current may cause the tile to become choked with silt. It is an excellent plan, before filling the ditches, to cover the tile to a depth of a few inches with straw, weeds, or grass. This prevents silt from washing into the tile at the joints while the ground is settling, thus insuring perfect operation of the drains from the beginning.

LIMING

All the soils of this group, except some areas of Conover loam, are acid in the surface soil and upper part of the subsoil, and they are more or less in need of liming. The lime requirement should be determined by soil-acidity tests for each particular area. If the farmer himself cannot make the test, he can have it made by the county agricultural agent or by the Purdue University Agricultural Experiment Station at La Fayette. A very acid soil will not respond properly to other needed treatments until it has been limed. The failure of clover to develop satisfactorily indicates a need of lime, although lack of thriftiness in clover may also be due to lack of available phosphorus or a poor physical condition of the soil, due to lack of organic matter. Ground limestone generally is the most economical form of lime to use, except where marl is handy. As a rule, the first application should be at least 2 tons of ground limestone, or its equivalent of other liming material, to the acre. After that a ton to the acre every second or third round of the crop rotation will keep the soil sufficiently sweet for most crops. Where alfalfa or sweetclover is to be grown on an acid soil, a heavier application of limestone will be needed.

ORGANIC MATTER AND NITROGEN

All the soils of this group, except Conover loam, are naturally low in organic matter and nitrogen. Constant cropping without adequate returns to the land, and more or less soil erosion, are steadily making matters worse. In many places the original supplies of organic matter have become so reduced that the soil has lost much of its natural mellowness and readily becomes puddled and baked. This condition in a large measure accounts for the more frequent failures of clover crops and the greater difficulty in obtaining proper tilth in such areas. Wherever these evidences of lack of organic matter and nitrogen occur, the only practical remedy is to plow under more organic matter than is used in the processes of cropping. Decomposition is going on constantly and is necessary to maintain the productivity of the soil. Decomposing organic matter must also supply the greater part of the nitrogen required by crops. For this reason, legumes should provide as much as possible of the organic matter to be plowed under. To accomplish this satisfactorily, the land must first be put in condition to grow clover and other legumes. This means liming wherever the soil is acid. Wet lands must also be tile drained. Clover or some other legume should appear in the rotation every 2 or 3

years; as much manure as possible should be made from the produce that can be utilized by livestock; and all produce not fed to livestock, such as cornstalks, straw, and cover crops, should be plowed under directly. It must be remembered that legumes are the only crops that can add appreciable quantities of nitrogen to the soil, and then only in proportion to the quantity of top growth that is plowed under, either directly or in the form of manure. Wherever clover seed is harvested, the threshed haulm should be returned to the land and plowed under. Cover crops should be grown wherever possible, to supply additional organic material for plowing under. Seeding rye as a cover crop in September on cornland that is to be plowed the following spring is good practice for increasing organic matter and conserving nitrogen. It is important to have some kind of a growing crop on these soils during the winter, in order to take up the soluble nitrogen, which otherwise would be lost through leaching. Without living crop roots to take up the nitrates from the soil water, large losses will occur between crop seasons through drainage, and there will also be more soil erosion on slopes and hillsides. Both of these losses may be greatly lessened by a good cover crop of winter rye on all land that otherwise would be bare during the winter. The rye should be run down with a heavy disk and plowed under before heading.

CROP ROTATION

With proper fertilization, and liming and tile drainage where needed, these soils will produce satisfactorily all the ordinary crops adapted to the locality. On account of the prevailing shortage of organic matter and nitrogen, every system of cropping should include clover or some other legume to be returned to the land in one form or another. Corn, wheat or oats, and clover, or mixed clover, alfalfa, and timothy, constitute the best short rotation for general use on these soils, especially when the corn can be cut and the ground can be disked and properly prepared for wheat as the following small-grain crop. Corn, soybeans, wheat or oats, and mixed hay constitute an excellent 4-year rotation for these soils. The two legumes in the rotation will build up the nitrogen supply. When soybeans are first introduced, the seed should be carefully inoculated with the proper variety of nitrogen-gathering bacteria, and this inoculation should be applied at least 2 years in succession. The soybean straw, if not used as feed, should be spread on the wheatland in the winter. This will not only help the wheat and lessen winter injury, but it will help to insure a stand of clover or other seeding for the hay crop. The soybean is not only a good crop in itself, but it also adds some nitrogen to the soil and improves it for the crop that follows. If more corn is needed, as on livestock farms, the 5-year rotation of corn, corn, soybeans, wheat, or oats, and mixed hay may be used satisfactorily where the second corn crop can be given a good dressing of manure. Where corn follows corn, as in the 5-year rotation, and where soybeans follow corn, as in both the 4-year and 5-year rotations suggested, cover crops of sweetclover or rye, for plowing under the following spring, should be seeded in each corn crop to help maintain fertility. Where, owing to climatic conditions, clover is uncertain in any of these rotations, it has proved to be a good plan to

sow a mixture of seeds made up of about 3 pounds of red clover, 4 pounds of alfalfa, 2 pounds of alsike, and 2 pounds of timothy to the acre. Alfalfa is more drought-resistant than clover, and alsike and timothy are more acid tolerant. As the red clover and alfalfa are the more valuable constituents of the mixture, conditions for their growth should be made as favorable as possible by liming soils that are acid, by maintaining a good physical condition through frequent incorporations of organic matter, and by providing proper drainage.

Alfalfa and sweetclover may be grown on the better drained and more friable areas if the soil is properly inoculated and sufficiently limed to neutralize harmful acidity. These two crops are especially sensitive to soil acidity. Alfalfa is preferable for hay, and sweetclover is excellent for pasture and for soil-improvement purposes. Special literature on the cultural requirement of these crops may be obtained from the Purdue University Agricultural Experiment Station.

FERTILIZATION

All the soils of this group are naturally low in phosphorus, and the available supplies of this element are so low that the phosphorus required by crops should be wholly supplied in applications of manure and commercial fertilizers. The nitrogen supplies in these light-colored soils are also too low to meet satisfactorily the needs of corn, wheat, oats, and other nonleguminous crops, and provisions for adding nitrogen should be an important part in the soil-improvement program. The total quantities of potassium in these soils are large, but the available supplies, especially in the surface soil, are generally low, and in most places the addition of some potash fertilizer would be profitable, especially where little manure is applied.

The problem of supplying nitrogen has been discussed in connection with provisions for supplying organic matter. Legumes and manure are the logical and only really practical means of supplying the greater part of the nitrogen needed by crops, and they should largely be relied on for this purpose. A system of livestock farming, with plenty of legumes in the crop rotation, is, therefore, best for these soils. It will pay on most farms, however, to have some nitrogen in the fertilizer for wheat, regardless of its place in the rotation. Even though wheat follows soybeans or other legumes, it should receive some nitrogen in the fertilizer applied at seeding time to start the crop properly, because the nitrogen in the residues of the legumes does not become available quickly enough to be of much help to the wheat in the fall. The leguminous residue must first decay, and that does not take place to any great extent until the following spring.

Phosphorus is the mineral plant-nutrient element in which all these soils are most deficient. The only practical way to increase the supply of phosphorus is through the application of purchased phosphatic fertilizers, and it will prove profitable to supply the entire phosphorus needs of crops in this way. In rotations of ordinary crops, producing reasonably heavy yields, it may be considered that 20 pounds of available phosphoric acid to the acre are required each year. It will pay well to apply larger quantities at first, so as to create a little reserve. Enough for the entire rotation may be ap-

plied at one time, or the application may be divided according to convenience. Where manure is applied, it may be estimated that each ton supplies 5 pounds of phosphoric acid; therefore, a correspondingly smaller quantity need be provided in the form of commercial fertilizer.

On the soil-fertility experiment field on the Herbert Davis Forestry Farm, belonging to Purdue University and located on Crosby silty clay loam in Randolph County, highly profitable returns have been obtained wherever available phosphate has been applied. During the 16 years since this experiment was begun, applications of 75 pounds to the acre of 16-percent superphosphate in the row for corn and 225 pounds for wheat in a corn, wheat, and clover rotation, have produced crop increases averaging 7 bushels of corn, 8.7 bushels of wheat, and 590 pounds of hay to the acre, at a cost of $3.36 for the phosphate. Manure applied for corn at the rate of 6.4 tons to the acre has produced crop increases averaging 11.6 bushels of corn, 4.3 bushels of wheat, and 272 pounds of hay. But manure alone is not sufficient to produce the most profiitable returns. On land receiving 6.4 tons of manure to the acre, 225 pounds of superphosphate applied for wheat and, since 1931, an additional 75 pounds in the row for corn, has increased the crop yields over manure alone by 5.1 bushels of corn, 6.8 bushels of wheat, and 542 pounds of hay. Similar results from soluble phosphates have been obtained on the Huntington County experiment field which also is located on Crosby silty clay loam, together with some Brookston silty clay loam. On this field 180 pounds of superphosphate applied for corn and wheat in a 4-year rotation of corn, oats, wheat, and hay, where the cornstalks, wheat straw, and oat straw are returned to the land, has produced crop increases averaging 5 bushels of corn, 4.2 bushels of oats, 5.8 bushels of wheat, and 741 pounds of hay to the acre over a period of 20 years. On manured land, the crop increases due to similar applications of superphosphate have averaged 4.1 bushels of corn, 0.9 bushel of oats, 6.9 bushels of wheat, and 552 pounds of hay to the acre. These experiments demonstrate the importance of using liberal applications of phosphate on this type of soil, both with and without manure. Where manure is not available, a good complete fertilizer should be used for wheat and a phosphate-potash mixture for corn.

The quantity of potash that should be applied as fertilizer depends on the general condition of the soil and the quantity of manure used. The flat poorly drained areas of the gray soils are the ones most likely to be in need of potash fertilizer. On soils that have become run-down, any program for their improvement should include potash fertilizer, at least until such time as considerable quantities of manure can be applied or until the general condition of the soil has improved materially. Although large total supplies of potassium are present in these soils, the readily available potash is low in many places. Its availability may be increased by good farm practices, including proper tillage, tile drainage, the growing of deep-rooted legumes, and the plowing under of liberal quantities of organic matter. The better these practices are carried out and the larger the quantity of manure applied, the less potash fertilizer need be purchased.

In the fertilization of these soils, most of the manure should be plowed under for the corn crop, but a part, about 2 tons to the acre,

may be applied profitably on wheatland as a top dressing during the winter. Such use of a part of the manure not only helps the wheat and lessens winter injury but also helps to insure a stand of clover or other seeding in the wheat. As a rule, the manured cornland should also receive some available phosphate in the hill or row at the rate of about 100 pounds to the acre. Without manure, corn should be given from 100 to 200 pounds to the acre of a phosplate and potash mixture, at least as good as 0–14–6[5] or 0–12–12, applied in the hill or row. For hill-planted corn, hill fertilization is most efficient, provided the application is made with a fertilizer attachment that places the fertilizer in two short bands, one on each side of the hill. Wheat should be given from 200 to 300 pounds to the acre of a high-analysis complete fertilizer, at least as good as 2–12–6. On poor soils or where the wheat is backward in the spring, a top dressing of about 100 pounds to the acre of a good soluble nitrogen fertilizer should be applied soon after growth begins. Such top dressing usually will add from 5 to 7 bushels an acre to the yield. Where properly fertilized corn and wheat are included in the rotation, there will be little need of fertilizer for other crops. Oats and soybeans, as a rule, will not give much response to direct applications of fertilizer, and soybeans are rather sensitive to injury to germination when fertilizer is used.

LIGHT-COLORED SANDY SOILS OF THE UPLANDS AND TERRACES

The group of light-colored sandy soils of the uplands and terraces includes Miami fine sandy loam, Bellefontaine fine sandy loam, Bellefontaine cobbly fine sandy loam, Bellefontaine gravelly sandy loam, Bellefontaine loamy sand, Coloma loamy fine sand, Fox sandy loam, Plainfield loamy fine sand, Oshtemo loamy sand, Warsaw sandy loam, Bronson sandy loam, and Berrien loamy fine sand. This group ranks next in importance to the group of light-colored heavy soils, and it, also, occupies about one-third of the total area of the county. These soils are naturally low in phosphorus, nitrogen, and organic matter, except Warsaw sandy loam, which has fair supplies of the last two constituents in the surface soil. All are low in available potassium, and most of them are in need of liming.

In these sandy soils drainage is in most places excessive, so that they frequently suffer from drought. They require an increase in their water-holding capacity. This can be done to some extent by increasing their content of organic matter.

LIMING

With the exception of Bellefontaine gravelly sandy loam and some areas of Bellefontaine fine sandy loam, these sandy soils are acid and are in need of liming before they can produce clover and other lime-loving legumes. Thus, it may be seen that liming generally will be the most profitable investment the farmer can make. The quantity of lime needed on any particular area can be easily determined by a soil-acidity test, as suggested for the light-colored soils of the uplands. If the soil is acid it is unwise to attempt its improvement

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

without liming, as the successful growth of clover and other deep-rooted legumes is an important step in the process of soil improvement. Ground limestone is the most economical form of lime to use on most of these soils. In some mucky areas in this county there are deposits of marl, which may be used instead of limestone. Since marl varies greatly in lime content, it should be tested for acid-neutralizing value, in order to determine how much it takes to equal a ton of ground limestone.

ORGANIC MATTER AND NITROGEN

All light-colored soils are deficient in organic matter and nitrogen. The light-colored sandy soils are particularly in need of organic matter to increase their water-holding capacity and thus protect crops from droughts. These two deficiencies go hand in hand, and both should receive the first attention of farmers on these soils.

On the very poor sandy areas, the cheapest and most effective first aid, if little money is available, is to grow a crop of soybeans. Where grown for the first time, soybeans must be artificially inoculated with their special nitrogen-fixing bacteria. In addition, the land should receive an application of superphosphate or a mixture of phosphate and potash. The seed should be drilled at the rate of 2 bushels to the acre. Immediately after harvesting the soybeans, the ground should be disked lightly and seeded to rye or a mixture of rye and winter vetch, fertilized with a high-grade complete fertilizer. If the soybean straw is not fed, it should be spread on the rye in the fall or winter. The rye should be plowed under the following spring, and the land again seeded to inoculated soybeans.

If these poor sandy soils can be limed and well fertilized with phosphate and potash, they will produce good yields of alfalfa and sweetclover, and these crops can be used advantageously to build up the supplies of organic matter and nitrogen. There is no better crop than sweetclover for green manure.

The most important item to be remembered in the management of sandy soils is that they use up organic matter very rapidly. Their loose, open, excessively aerated condition favors rapid decomposition and oxidation, or the burning out of the soil organic matter. For this reason, more than ordinary quantities of organic materials, such as manure, crop residues, specially grown green-manure crops, and cover crops should be constantly added. The land should never be left without something growing on it.

CROP ROTATION

To make the most satisfactory progress in the improvement of these soils, the land should be limed and put in condition to grow clover, alfalfa, or sweetclover. In most places 2 tons of ground limestone to the acre will counteract the harmful acidity. The liming should be done a year before seeding if possible. Alfalfa is most valuable for these soils, as its deep-rooting system enables it to withstand drought much better than clover. The alfalfa seed must be inoculated. Full instructions concerning the culture of alfalfa, sweetclover, and soybeans may be obtained from the agricultural experiment station at La Fayette.

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An excellent rotation for these sandy soils, after liming, is corn, soybeans, wheat or rye, and alfalfa 1 or more years. Wheat is a better cash crop than rye if the supply of nitrogen is adequate. A light winter dressing of manure on the wheatland will increase the yield greatly and help to obtain a stand of alfalfa. Two tons of manure to the acre for wheat on the sandy experiment field near Culver has increased the yields about 5 bushels to the acre as an average for the last 14 years. A top dressing in April of a soluble nitrogen carrier supplying from 15 to 20 pounds of nitrogen an acre has increased wheat yields from 3 to 8 bushels an acre.

An extra field to remain in alfalfa for several years is a wise provision against failure to obtain stands in some years on the land in rotation.

On unlimed areas that will not produce clover or alfalfa, a rotation of corn, soybeans, and rye may be used, but extra quantities of manure and/or fertilizer will be necessary, in order to obtain satisfactory yields. Potatoes may be used in this rotation by plowing under the soybean crop, seeding to rye, and plowing the rye under in the spring before planting the potatoes.

The sandy loams produce high-quality potatoes. When grown on old well-manured alfalfa sod and well fertilized, potatoes are a profitable cash crop for supplying home markets, and they may well be fitted into the rotation in place of some of the corn. On the more sandy areas, cantaloups for home markets are a good cash crop.

FERTILIZATION

The fact that these sandy soils are deficient in nitrogen emphasizes the importance of growing legumes on them, as has been suggested. Barnyard manure, of course, should be utilized to the fullest possible extent, as fertilizer nitrogen cannot be profitably purchased to a large extent. Such crops as wheat, rye, and potatoes, however, should always receive some nitrogen in fertilizer form, even when they follow legumes.

Phosphates are needed in considerable quantities, because all these soils are low in phosphorus. They are also low in available potassium and require potash fertilizers, the amount depending on the quantity of manure used. Manure supplies about 10 pounds of potash per ton.

The scheme of fertilization on these soils should be such as to supply all the phosphorus required by the crops grown. As a rule, most of the manure should be applied on the small grain, on the young clover or alfalfa after the grain harvest, or on sod several months before plowing for corn or potatoes, at least on the more sandy soils. On the sandy loams with heavier subsoils, the common practice of applying manure through the winter before plowing for corn is justified. Small grains should receive from 200 to 300 pounds to the acre of 2–12–6 fertilizer, or 3–12–12 if manure is scarce. Corn should receive 100 pounds to the acre of 0–12–12 in the row, and potatoes will respond favorably to at least 500 pounds of 3–12–12 applied in the row. Cantaloups also should be heavily fertilized. With such fertilization and a constant and abundant supply of organic matter, including legumes, these soils can be made very productive.

DARK-COLORED SANDY SOILS

The dark-colored sandy soils include Brady sandy loam, Maumee fine sandy loam, and Newton loamy fine sand.

DRAINAGE

All these dark-colored soils developed under more or less wet conditions and need artificial drainage. In putting in tile drains, the same general procedure should be followed as that outlined for the light-colored heavy upland soils, except that the lines of tile may be placed farther apart because water moves more freely in sandy soils.

LIMING

For the most part, the Brady and Maumee soils are only slightly acid and do not need liming. The Newton soil is naturally strongly acid, and it is, therefore, decidedly in need of liming. From 3 to 4 tons per acre of ground limestone or the equivalent in some other form of lime should be applied and worked in as deeply as possible.

ORGANIC MATTER AND NITROGEN

For the most part, these soils have fair to adequate supplies of organic matter and nitrogen, and, with reasonable care in the return to the land of manures and crop residues, these constituents may be satisfactorily maintained. Some areas of the Brady and Newton soils, however, which are not so dark colored, will require watching in this respect.

CROP ROTATION

When properly drained and fertilized, the Brady and Maumee soils may be used satisfactorily for all the common field crops and various truck crops adapted to this section. Because of high acidity to a considerable depth, the Newton soil, even with heavy liming, is not adapted to the deep-rooted legumes. In areas where Newton loamy fine sand predominates, a rotation of corn, soybeans, oats or other small grain, and a mixture of alsike and timothy generally is most practical.

Where the Brady soil predominates and sufficient drainage is provided, the crop rotation may include red clover or other deep-rooted legumes. In areas of Maumee soils, rotations with more emphasis on corn may be practical, if the land is properly fertilized.

Both the Brady and Maumee soils may be satisfactorily used for potatoes, various truck and garden crops, and mint.

FERTILIZATION

All these dark-colored sandy soils are more deficient in available potash than any other fertilizer element. They are naturally fairly well to very well supplied with nitrogen, especially the darker soils. Maumee fine sandy loam and Brady sandy loam show fair supplies of available phosphorus.

In fertilizing crops on these soils, the supplying of potash should be given the chief emphasis. On farms, which also have lighter colored soils, most of the manure should be used on the light-colored

soils and dependence placed on commercial fertilizer high in the mineral elements for the dark-colored soils, which are not so much in need of the organic matter and nitrogen supplied by manure.

In the general plan for fertilizing these dark-colored soils, land for corn should receive from 75 to 100 pounds per acre of 0–10–20 or 0–8–24 placed on both sides of the hill or twice as much drilled continuously in the row. Land for wheat and other small grains should receive from 200 to 300 pounds per acre of 3–12–12 or 2–8–16 drilled with the seed. Oats are not so responsive to fertilizer as are other small grains and might be given about the same fertilization as corn, especially if followed by a seeding of clover. For most truck crops, 500 pounds per acre of 0–8–24 is recommended.

DARK-COLORED HEAVY SOILS

The dark-colored heavy soils are the Brookston, Clyde, and Washtenaw silty clay loams and Wallkill silt loam. Brookston silty clay loam is the most extensive. The Washtenaw soil, though not dark-colored on the surface, is included in this group because of its close relation to and association with the Brookston soil, which constitutes its subsurface soil and subsoil. This group includes the most fertile soils of the county after necessary drainage has been provided. For the most part, these soils are only slightly acid and do not need liming.

DRAINAGE

These soils are naturally wet and in need of artificial drainage. Their dark color indicates a swampy origin where natural drainage was poor. Most of the areas have been drained. Where more drainage is needed, the same procedure should be followed as that suggested for the light-colored heavy silt loam and silty clay loam soils.

ORGANIC MATTER AND NITROGEN

These soils are well supplied with organic matter and nitrogen, and with reasonable care in their management no special provisions for supplying these constituents will be necessary for a long time. The areas of heavier soil, however, will be easier to manage if considerable quantities of organic matter are worked in.

CROP ROTATION

These soils are among the best in the county and will produce all the ordinary crops adapted to this section. They are especially well suited to corn, and this should be the major crop in most places. Among the rotations that may be employed satisfactorily are the following: Corn, wheat or oats, and clover; corn, corn, wheat or oats, and clover; corn, soybeans, wheat or oats, and clover; or corn, corn, soybeans, wheat or oats, and clover. To guard against the hazards of winter-killing of clover, it is advisable to seed some timothy with the clover. These soils are also adapted to alfalfa and sweetclover where sufficient drainage has been provided. Whenever clover fails, the soybean makes a satisfactory substitute crop for legume hay.

FERTILIZATION

These soils are naturally well supplied with nitrogen, and, with legumes in the crop rotation, the fertilizer need not contain nitrogen for the ordinary field crops, except wheat. The total and available supplies of phosphorus are higher than in the light-colored soils. These supplies, however, should not be drawn on to any considerable extent, and as a rule most of the phosphorus required by the crops should be supplied to the land. On farms having both light-colored and dark-colored soils, most of the manure should be applied to the light-colored soil, in which the organic matter and nitrogen of the manure are most needed. Without manure, cornland should receive from 100 to 150 pounds to the acre of superphosphate or a phosphate and potash mixture in the hill or row, and wheatland should receive from 200 to 300 pounds to the acre of a complete fertilizer, such as 2-12-6. Such fertilization will help the clover crop also. In few places will oats respond to nitrogen in fertilizer, and where oats are the small-grain crop a phosphate and potash mixture generally will be sufficient.

MUCKS

The muck soils include the Carlisle, Houghton, Edwards, and Kerston types of muck. The profitable management of these soils involves careful drainage, where drainage is at all possible; the growing of suitable crops; and the application of large quantities of potash. In most places some phosphate also will be profitable, especially after the land has been cropped for several years. The needs for potash fertilizer are especially urgent on the typical muck areas, which are naturally very low in both total and available potassium. The silty mucks are much better supplied with both phosphorus and potassium and may not require much fertilizer for some time.

The question is sometimes asked if muck soils can be improved by burning. They cannot be permanently improved by burning, and they may be seriously injured. Burning adds nothing; on the other hand it destroys much valuable organic matter and nitrogen. The mineral plant-nutrient elements concentrated in the ash remains are not to be considered as gain, as these elements are soon exhausted and the land is left in a poorer condition than it was before burning, because of the destruction of organic matter and the consequent lowering of the land level to such an extent, in many places, as to make drainage more difficult.

DRAINAGE

In the improvement of muck soils, the first requisite is proper drainage. As a general rule the water table should be lowered to a depth ranging from 2 to 3 feet below the surface. For meadows, a depth of 2 feet to the water table may be enough for best results. Muck soils will drain freely if the water has a chance to get away. It is not necessary for ditches and tile lines to be so close together as in the fine-textured soils. Ordinarily, the distance between tile lines or lateral ditches should be about 100 feet. Whether tile or open ditches should be used depends on local conditions. If the subsurface material is sufficiently firm to hold tile in place, tiling is to be pre-

ferred, since open ditches are always a nuisance. In extensive areas, large open outlet ditches may be necessary. These, however, should not be deeper than is necessary to keep the water table at a proper level to meet the needs of crops.

Most muck areas receive considerable surface water and seepage water from the higher lands adjoining, and the plan of drainage should provide for the removal of such waters as well as the excess water that falls on the muck areas. The first thing to be done is to cut a ditch or lay a line of tile along the edge of the marsh next to the higher land adjoining. This will catch the seepage from the higher land and make drainage of the rest of the muck area comparatively easy, provided, of course, that a suitable outlet can be obtained. In areas bordering lakes, sufficient drainage for cultivated crops may be impossible.

It has been stated that muck soils should not be too deeply drained, because the crops grown on them are apt to suffer from lack of water. Where tile drainage is used, however, the lines of tiles must be placed sufficiently deep that subsequent settling of the soil will not leave them too near the surface, as muck settles considerably within the first few years after drainage, and allowance for this should be made. The aim should be, ultimately, to have the water table at a depth of about 3 feet below the surface. Great care should be exercised in establishing an even grade for each line of tile, so that the flow of water will be uniform. Fine materials which wash in at the tile joints settle easily and will soon clog the tile if the grade line is uneven. As a rule, nothing smaller than 5-inch tile should be used for muck soils. It is a good plan to cover the tile with a few inches of straw or grass before filling the ditches, as this will keep much fine material out of the tile while the ground is settling.

In some places it may be desirable to raise the water table when the dry season of the year approaches, especially for shallow-rooted crops. This can be done by temporarily damming up the outlets of the ditches or by blocking the tile outlets, thus holding the water table up until sufficient rains come again.

FERTILIZATION

In the fertilization of muck soils, potash is of first importance. Nitrogen is present in great abundance; hence the addition of nitrogenous fertilizers is not required, except for early truck crops, which need readily available nitrogen, especially in late seasons when nitrification, the bacterial action that makes nitrogen available, does not begin early enough to supply these crops. For the grain and hay crops, the natural soil supplies of nitrogen become available fast enough to meet all needs. Some mucks when first brought under cultivation may produce a few good crops without the addition of potash, but the available potassium soon becomes exhausted and the only recourse is to supply this element from outside sources.

For the common field crops, about 100 pounds of muriate of potash to the acre should be applied each year, or 200 pounds every other year. In many places, especially after several years of cropping, it will pay to add some available phosphate, and a fertilizer, such as 0–8–24, 0–10–20, or even 0–20–20, may be desirable.

For truck crops the rate of application of fertilizers should be much greater than for grain crops. For celery, some growers use as much as 2,000 pounds of fertilizer to the acre. For early planted crops, such as onions, lettuce, and cabbage, large quantities of complete fertilizer, such as 3–9–18 or 2–8–16, are used by many growers.

Farm manure may be used to supply potassium and phosphorus to these soils. On farms including both organic and mineral soils, however, the manure preferably should be applied to the mineral soils, because the organic soils do not need the nitrogen and organic matter it supplies, whereas the mineral soils especially need these constituents. In some places the application of manure on raw muck soils will be helpful in supplying beneficial bacteria, which may be lacking, especially if the material is very raw or the land has always been very wet.

CROPS FOR MUCK SOILS

Muck soils, when properly drained and fertilized, may be satisfactorily used for all the field and garden crops adapted to the climatic conditions of this section, including many crops not adapted ordinarily to the upland soils. Most of the truck and small-garden crops will do better on properly managed organic soils than on mineral soils. It may be said, therefore, that the farmer who has muck soil on his farm has a much greater range in the choice of crops that he may grow.

For the general farmer, corn is the best crop for muck soils, as these soils can endure cropping with corn longer than any other soils, except rich overflow bottom lands. With the addition of plenty of potash and some phosphate, corn may be grown on fields of muck most of the time. It is necessary, however, to use early varieties of corn in order to escape early frosts. For a change in the cropping system, such crops as soybeans, rye, and mixed timothy and alsike, for meadow or pasture, are suggested. Potatoes also may be fitted into the rotation.

On the Pinney-Purdue muck experiment field near Wanatah, in La Porte County, a 4-year rotation of corn, corn, soybeans, and potatoes is giving good results. During the 14 years since this experiment was begun, the crop yields have averaged 56.2 bushels of corn, 24.9 bushels of soybeans, and 137.5 bushels of potatoes to the acre. The fertilizer used is 0–8–24, applied at the rate of 150 pounds to the acre in the row for corn and 300 pounds for potatoes. On a part of this field, where the quantity of potash was doubled, the average acre yield of potatoes has been increased to 171.6 bushels, but increases of the other crops have been small, averaging 4.5 bushels of corn and 1.3 bushels of soybeans.

The small grains are the least suitable crops for muck soils because they are apt to produce a rank growth of weak straw and lodge badly. Liberal applications of potash will aid materially in producing stiffer straw. Other crops adapted to muck soils are mint, hemp, Sudan grass, millet, sorghum, buckwheat, sugar beets, turnips, and mangels. Of the truck crops, onions, cabbage, cauliflower, kale, rutabagas, celery, lettuce, parsnips, beets, carrots, and sweet corn do well on this kind of land, where proper drainage can be arranged and the crops are properly fertilized. Details con-

cerning practices for the production of any particular crop can be obtained from the county agricultural agent or the agricultural experiment station.

IMPORTANCE OF COMPACTING MUCK SOILS

One of the difficulties in managing muck soils is that they are apt to be too loose on the surface. In preparing the seedbed, therefore, it is important to pack the ground thoroughly by the use of a heavy roller, going over the field several times if necessary. Thorough compacting of the muck is not only better for the growth of crops, but it also aids materially in lessening the danger of early frosts.

BOTTOM LANDS

The bottom lands of Steuben County occur only in narrow strips here and there along the creeks. There are no rivers. Only two bottom-land soils are mapped—Griffin silt loam and Griffin fine sandy loam.

The greatest difficulty in the management of these soils is to provide adequate drainage and to prevent damage from flooding. The heavier areas should be tiled wherever suitable outlets can be provided, so that surplus water may drain away more readily. Liming is not required.

Most of this land, when brought under cultivation, is best adapted to corn, but wherever excess water is not troublesome some other crop, such as wheat, clover, and soybeans, should occasionally be included in the cropping system. On certain areas not damaged by flooding, alfalfa and some truck crops also will do well.

Much of this land receives rich sediments from periodic overflows of the streams and hence requires little fertilizer. The poorer and more sandy areas, however, will respond to applications of available phosphates and potash. For truck crops, some nitrogen also will prove profitable.

SUMMARY

Steuben County is in the extreme northeastern part of Indiana. Topographically the eastern and southern townships resemble the comparatively smooth north-central part of Indiana. The surface features of the northeastern four townships are more varied, owing to the number of lakes and the rougher land that surrounds most of them.

Transportation facilities by rail and by automobile roads are good. The latter are highly important with respect to local markets at the summer resorts around the many lakes.

Variations between the summer and winter temperatures are wide. The frost-free season is amply long for maturing the crops commonly grown.

Agriculture is the leading industry, and the principal crops are corn, wheat, and clover. Oats, barley, and rye also are grown. The acreage in alfalfa is steadily increasing. Cattle, hogs, and sheep are the most important sources of income on most farms.

The soils have developed upon glacial, lacustrine, and fluvial deposits of varied mineralogical composition and for the most part rich in carbonate of lime.

The predominant upland soil in the eastern and southern townships is Miami loam. Miami silty clay loam is closely associated with Miami loam and is the predominant agricultural soil in the southeastern part of the county. Miami fine sandy loam is developed extensively in the northwestern four townships, and the Bellefontaine soils, most of which are sandy and contain considerable gravel and stone, occur principally in this section. Fox sandy loam is the prevailing soil on the level sandy plains. The associated soils are Fox sandy loam, slope phase, Warsaw sandy loam, and Plainfield loamy fine sand. All the above-mentioned soils are light-colored and have good natural drainage.

Within areas of the well-drained soils are small areas, in which drainage is poor and in which dark-colored soils are developed. Such are the Clyde and Brookston soils on the uplands and Maumee fine sandy loam and Newton loamy fine sand on the level benchlands. These dark soils contribute largely to the production of corn.

The organic soils cover about 10 percent of the total area of the county and are so generally reclaimed that they furnish considerable pasture and also have a high value for the production of onions and some other truck crops.

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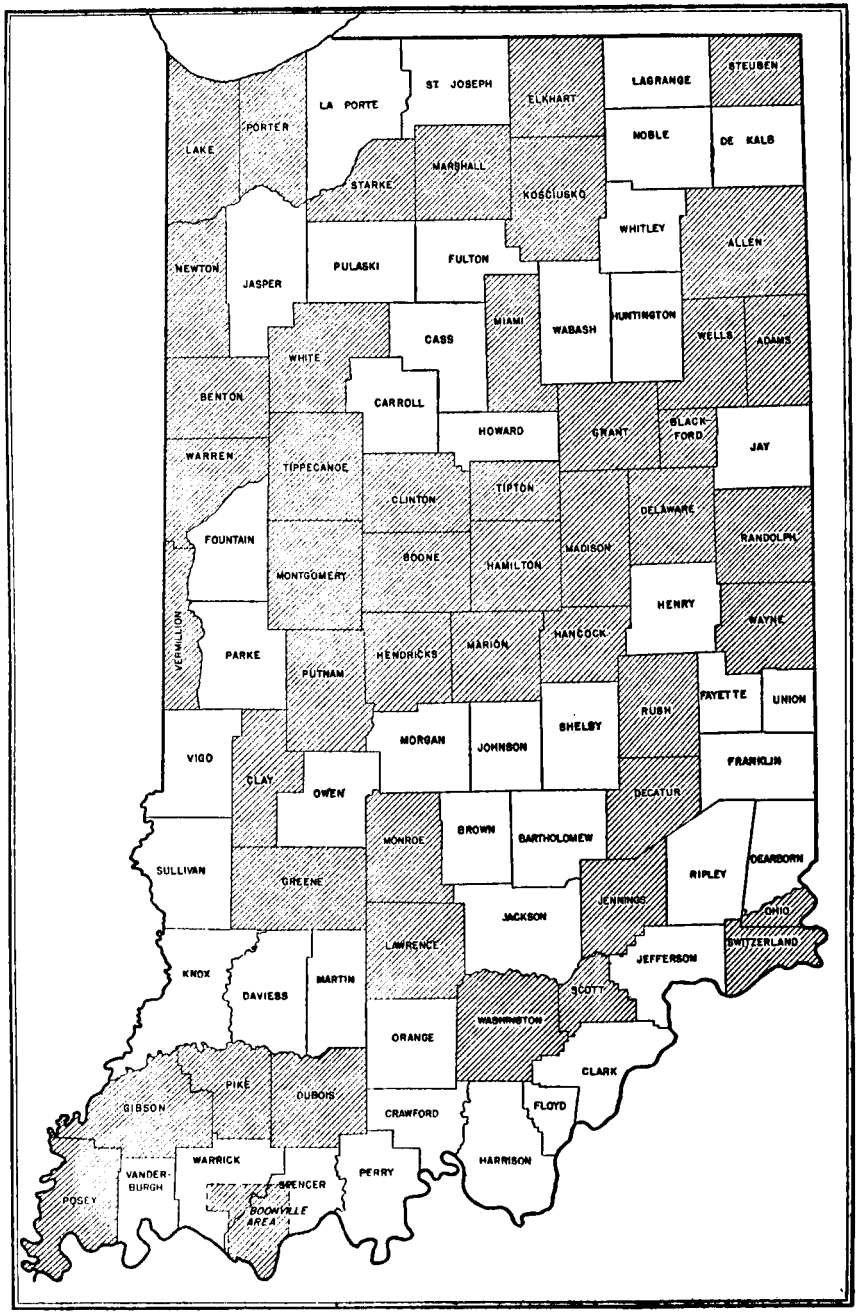

Areas surveyed in Indiana shown by shading.

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