
Soil Survey

Kanabec County Minnesota

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SOIL SURVEY OF KANABEC COUNTY, MINNESOTA

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COUNTY SURVEYED

Kanabec County, one of the smallest counties in Minnesota, is in the east-central part of the State (fig. 1). Mora, the county seat, is 65 miles north of St. Paul, the State capital, and about 85 miles southwest of Duluth, the head of navigation on the Great Lakes. The county is nearly rectangular in shape. Its greatest length from north to south is 30 miles and from east to west is 18 miles. It includes 15 townships and has a land area of 523 square miles, or 334,720 acres. About 2 percent of the county is covered by lakes.

The county is largely within the region covered by glacial drift of the middle Wisconsin glaciation. The relief, ranging from nearly level to strongly rolling, has the characteristics of a continental glaciated plain. The only outstanding surface features are the belt of rolling hilly land adjacent to both sides of Snake River, chiefly in the northern townships, and the narrow elongated sand and gravel ridges, or eskers, in the central and

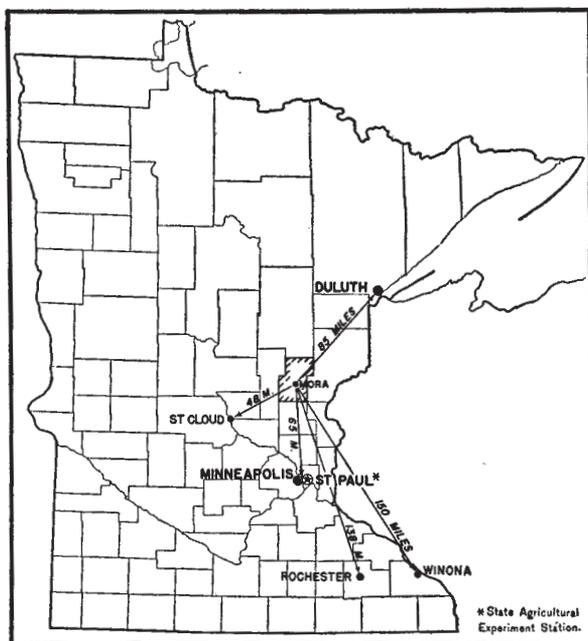


FIGURE 1.—Sketch map showing location of Kanabec County, Minn.

southern parts of the county. Eskers are ridgelike deposits of coarse glacial drift, from which the finer materials have been washed. They range from less than one-fourth to nearly 1 mile in length, and many of them are so nearly symmetrical in outline that they resemble railroad grades. Bodies of sandy soils, ranging in width from less than one-fourth to more than 1 mile, border parts of Snake River and some of its tributaries. Back of these areas and in other places are comparatively large smooth gravel plains underlying a 16- to 24-inch surface layer of finer textured material. Areas of clayey soil, the parent material of which was laid down in glacial lake beds during the retreat of the glacier, are distributed in some of the southern townships and in the aggregate make up a considerable part of the total area of the county. For the most part these clayey soils are free from stone on and below the surface. Peat bogs, which range in size from less than 1 acre to more than 640 acres, are numerous in all parts of the county. Peat occurs in large bodies along many of the streams.

Owing to the comparatively short time that has elapsed since deposition of the surface materials, natural surface drainage is not well established. Although much of the land has been artificially drained, a large part remains poorly drained. The many peat bogs, together with low-lying bodies of mineral soil, occupy a large part of nearly every township. The most extensive areas of peat are in Hay Brook, Knife Lake, Ann Lake, Hillman, Kroschel, and Pomroy Townships. Bottom lands occur along many of the stream channels and drainageways and at times are subject to flooding. The smooth sandy plains, irregular in width, parallel many of the streams and, in many places, slope gently toward them. Most of these sandy plains are stone free and have a smooth relief. Nearly everywhere the sand and gravel beds, which occur at a depth ranging from 12 to 30 inches, are overlain by finer textured material that enhances the agricultural value of the land.

Surrounding the town of Ogilvie and extending south to the county line is the largest body of the sand and gravel outwash plains. Bodies of hilly land, ranging from one-half mile to more than 2 miles in width, occur on both sides of Snake River for nearly the entire distance of its course across the county. Many of the hills have steep slopes that abruptly terminate in small deep pot holes or larger peat bogs. South of Mora the hills are less prominent and the river has a wider flood plain that often is flooded during times of high water in the stream.

Snake River, the largest stream, rises in Aitkin County, which is north of Kanabec County, and flows in a general southerly direction through Kanabec County to a point about 5 miles south of Mora, where it turns eastward and leaves the county just south of Grass-ton. Thence it crosses the southern part of Pine County and empties into St. Croix River. Its principal tributaries are Knife River, with its source in Mille Lacs County, and Ann River which rises in Ann Lake in Ann Lake Township. Knife River drains most of the area northwest of Mora, and Ann River drains the area west of that town. Ann River parallels Snake River for a distance of about 6 miles in Arthur Township, flows through Fish Lake south of Mora, and finally empties into Snake River. All the streams of the county dis-

charge their waters into Mississippi River through its tributaries. Groundhouse River, which has many small branches, rises in the west-central part, flows through Kanabec, South Fork, and Brunswick Townships and finally joins Snake River $1\frac{1}{2}$ miles north of Brunswick. Most of Kroschel, Pomroy, and Whited Townships, in the northeastern part of the county, are drained by streams that flow into St. Croix River after crossing the southern part of Pine County. The largest of these is South Branch Grindstone River which rises in a spring-fed lake in northeastern Kroschel Township.

With the exception of Snake River, most of the streams are sluggish and have meandering channels, and in the drier months of the year water ceases to flow in most of them. The channel of Snake River is well defined for most of its distance through the county, and its current is rather rapid. The river bed, in most places, consists of bouldery till and gravel with occasional outcroppings of sand rock and granite along its banks.

Kanabec County has within its borders several lakes. The largest are Knife Lake, Fish Lake, Ann Lake, Lewis Lake, and Lake Eleven. All have outlets. Smaller lakes, in many of which the water has receded gradually during the recent dry years, are scattered over the county, especially in Kroschel Township.

The mean elevation of the county is approximately 1,100 feet above sea level. The highest land, between 1,250 and 1,300 feet, is in Hay Brook and Ford Townships, and the lowest, 937 feet, is in Grass Lake Township, at the point where Snake River leaves the county.

This county lies within the mixed coniferous and deciduous forest section of the State, and originally the land was heavily wooded. The sandy lands were covered with jack and red pines and the heavier lands with a mixed growth of hardwoods and white pine. Some of the peat bogs support mixed hardwoods, and in others spruce, tamarack, and willow grow. A few are open bogs, with a few trees scattered among heaths, mosses, and grasses. The original trees were logged off many years ago, and now practically no merchantable timber remains. Since the virgin pine was cut, a young forest of birch, oak, and aspen has taken its place, and, where these tracts are protected from forest fires, the trees are making rapid growth. In many places, however, recent fires have burned much of the second growth, leaving only charred stumps and partly burned fallen trees. In such places, weeds and undesirable trees and shrubs are gaining a foothold. Some of the bottom lands, which at times are subject to flooding, support a growth of elm, ash, cottonwood, alder, and willow trees.

Mora, the county seat, is the largest village. It is located on the Great Northern Railway in the south-central part of the county and is about 65 miles north of Minneapolis, the principal market for the agricultural products. Among other incorporated towns and villages are Ogilvie, Grasston, and Quamba.

Two lines of the Great Northern Railway cross parts of the county. One connects St. Cloud with Duluth, passing in turn through Ogilvie, Mora, and Quamba; the other, the main line between the Twin Cities and Duluth, crosses the extreme eastern part of Grass Lake Township through Grasston. The extreme northwestern part is

served by the Minneapolis, St. Paul & Sault Ste. Marie Railway which crosses Mille Lacs County near the northwestern corner of Kanabec County. The northeastern part is served by the Northern Pacific Railway in Pine County. This railroad is not more than 6 miles from the northeastern corner of Kanabec County.

A system of well-maintained graveled and hard-surfaced roads radiate from Mora, connecting the villages with other trading centers and outlying farm districts. Roads in some of the sparsely settled sections in the northern part receive little attention and are often impassable to automobiles. In the winter the trunk highways and some of the main county roads are kept free of snow and are open for travel the year around. The public-school system is, in general, adequately provided for, and schools are conveniently located in the country districts where there are centers of population. All the villages have one or more churches, and a few churches are located in the outlying country districts. Telephone service is available to nearly all sections. The county is well served with rural mail routes which make regular deliveries. Creameries, cream stations, and cheese factories are located at various places, and trucks are used for collecting cream and milk along established routes.

Prior to 1849, the area now included in Kanabec County was a part of St. Croix County, Wis. From that date until 1852 it was a part of Ramsey County, Minn.; until 1854, a part of Chisago County; and, until its organization in 1858, a part of Pine County. Brunswick was the original county seat and remained so until 1882, when, by popular vote, Mora was selected as the county seat. Brunswick was the first organized village. It was plotted in 1856. Mora was plotted in 1882, at the time the first general store was established in that locality. The first permanent settlers were James Pennington and George L. Staples, who came to Kanabec County in 1854. Staples planted the first crop in the county, opened the first store, and named the town of Brunswick. Pennington engaged in the lumber business besides operating a farm. The early settlers were chiefly of German and Swedish descent, although a large proportion were born in the United States. The 1930 census reports 81.4 percent of the inhabitants as native-white persons and the remaining 18.6 percent, foreign-born whites. The nationalities most largely represented in the population are Swedish, German, Norwegian, Canadian, Dutch, and Danish.

According to the Federal census, the population of the county has increased steadily since 1840. In 1880, there were 1,326 inhabitants and in 1930, 8,558. The density of the population, all of which is classed as rural, is about 16 persons to the square mile. Nearly three-fourths of the inhabitants live in the southern and central townships, excluding Ann Lake. The most thickly populated township is Brunswick, with 957 persons, and the least populated, Ford, with 98. Mora, the largest village, had 1,014 inhabitants in 1930, Ogilvie had 344, and Grasston, 229.

CLIMATE

The climate is characterized by wide variations in temperature between winter and summer. The winters are rather long, and the weather is extremely cold for short periods. Snow covers the ground

throughout most winters. Freezing temperatures usually prevail from the middle of October to early April. The mean annual temperature is 41.6° F., the same as that for the State as a whole. Temperatures above 90° during the day are common in midsummer, although periods in which these high temperatures prevail are of short duration, in general not lasting more than 3 or 4 days. The highest temperature recorded for the county is 99° and the lowest -48°. The average date of the last killing frost is May 17, and of the first, September 22, giving an average frost-free period of 128 days. The latest recorded killing frost occurred on June 9, and the earliest on August 27. In some of the peat bogs frost may occur in any month of the year. The mean annual precipitation, including melted snow, is 26.47 inches, nearly two-thirds of which comes during the spring and summer, the greatest amount in June. The prevailing winds are northwesterly, and they are rarely of such velocity as to be destructive to crops.

The climate is favorable to the production of small grains, forage crops, root crops, and potatoes. The growing season is in general too short and too cool to grow corn for grain, except the early maturing varieties. Corn can, however, be grown successfully as a forage crop. The susceptibility of the peat soils to summer frosts limits the production of tender crops on them, but clovers and tame grasses are very satisfactorily grown on properly fertilized bogs.

Table 1, compiled from records of the United States Weather Bureau station at Mora, gives the more important climatic data for the county.

TABLE 1.—Normal monthly, seasonal, and annual temperature and precipitation at Mora, Kanabec County, Minn.

(Elevation, 1,001 feet)

Month	Temperature			Precipitation		
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year (1910)	Total amount for the wettest year (1916)
December.....	° F. 16.1	° F. 57	° F. -30	<i>Inches</i> 0.69	<i>Inches</i> 0.66	<i>Inches</i> 0.54
January.....	9.2	51	-48	.86	.99	2.32
February.....	13.8	52	-44	.84	.93	1.20
Winter.....	13.0	57	-48	2.39	2.58	4.06
March.....	27.7	82	-26	1.17	.09	1.48
April.....	43.3	86	6	1.89	.71	3.72
May.....	54.1	96	15	3.35	1.05	6.65
Spring.....	41.7	96	-26	6.41	1.85	11.85
June.....	64.3	99	29	4.05	1.68	5.92
July.....	69.2	98	37	3.57	2.61	3.46
August.....	66.6	96	31	3.06	1.91	6.03
Summer.....	66.7	99	29	10.68	6.20	15.41
September.....	58.4	94	22	3.29	1.97	2.60
October.....	45.8	86	9	2.11	.67	1.28
November.....	31.2	70	-26	1.59	.59	.12
Fall.....	45.1	94	-26	6.99	3.23	4.00
Year.....	41.6	99	-48	26.47	13.86	35.32

AGRICULTURAL HISTORY AND STATISTICS

The agricultural development of the county dates back to about the time the village of Brunswick was plotted in 1856. The first farms were located in the present township of Brunswick close to the village bearing the same name. Afterward farming gradually spread to the adjoining townships of Grass Lake, Comfort, South Fork, and Arthur and then extended northward into the townships of Knife Lake, Whited, and Kanabec. The agricultural development of the more northerly townships, Hillman, Hay Brook, Peace, Pomroy, Kroschel, and Ford, is more recent. Much of the land in these townships is still in a wild state, and the settlers are widely scattered. Table 2, compiled from the Federal census reports, gives the acreage of the leading farm crops and shows the general trend in the agriculture from 1879 to 1934, inclusive.

TABLE 2.—*Acreage of principal crops in Kanabec County, Minn., in stated years*

Crop	1879	1889	1899	1909	1919	1929	1934
	<i>Acres</i>						
All corn.....						7,886	19,364
For grain.....	30	89	410	1,226	1,471	275	449
For silage and fodder.....						7,516	18,915
Oats.....	49	593	1,119	3,499	8,622	13,210	12,810
Wheat.....	193	70	2,234	1,527	1,922	320	366
Barley.....	15	14	98	508	1,915	4,309	1,789
Rye.....		226	169	144	1,216	345	479
Potatoes.....		177	1,152	2,652	7,838	5,526	4,563
Soybeans.....						50	1,144
All hay.....	211	1,843	5,833	18,903	33,166	36,550	27,630
Timothy and clover.....			136	11,302	24,668	19,014	1,346
Alfalfa.....						46	2,960
Grains cut green.....			72	127	128	585	4,568
Legumes for hay.....						60	1,127
Other tame hay.....			2,366	1,067	1,477	3,356	673
Wild hay.....			3,259	6,385	6,817	10,575	17,765

¹ All hay and sorghums for forage.

² Includes tame and wild grasses.

In table 3 are given selected data concerning the acreages of improved and unimproved land in farms and land tenure in the county.

TABLE 3.—*Statistics on farm land in Kanabec County, Minn., in stated years*

Year	Farms				Land in farms			Improved land in farms		
	Total	Operated by—			Total	Per-centage of county area	Per farm	Total	Per-centage of farm land	Per farm
		Owners	Ten-ants	Man-agers						
	<i>Number</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Acres</i>	<i>Percent</i>	<i>Acres</i>	<i>Acres</i>	<i>Percent</i>	<i>Acres</i>
1880.....	65	96.9	3.1		8,680	2.5	134.0	837	9.6	12.9
1890.....	215	96.7	3.3		20,450	6.0	95.1	3,369	16.5	15.7
1900.....	749	96.2	2.9	0.9	127,475	37.3	170.2	13,832	10.8	18.4
1910.....	1,017	92.6	5.9	1.5	116,370	34.1	114.4	37,370	32.1	36.7
1920.....	1,568	89.5	9.6	.9	182,311	53.3	116.3	67,535	37.0	43.1
1930.....	1,535	80.6	19.3	.1	192,242	56.3	125.2	78,614	40.9	51.2
1935.....	1,727	75.0	24.7	.3	216,932	63.5	125.6	86,736	40.0	50.2

Accompanying the increase from year to year in the amount of improved land a farm, there also has been a substantial increase

in the acreage devoted to corn, oats, barley, and tame hay. In some sections, potatoes are the chief cash crop. Until 1919 the acreage devoted to this crop increased annually, but the acreage in subsequent years was reduced. The acreage in wheat reached its peak in 1899, and very little wheat was grown in 1929 or 1934. The production of tame hay has shown the greatest expansion. Each census period has shown also a marked increase in the acreage used for the production of wild hay. The increase in the numbers of livestock has been fairly steady, although the numbers reported in the 1935 census were somewhat less than those reported in 1930. Table 4 shows the number of livestock on farms in the census years 1880 to 1935, inclusive.

TABLE 4.—*Number of principal kinds of livestock on farms in Kanabec County, Minn., in stated years*

Livestock	1880	1890	1900	1910	1920	1930	1935
	<i>Number</i>						
Cattle.....	295	1,488	6,143	10,810	22,357	21,341	20,789
Swine.....	94	288	1,379	1,524	5,077	5,932	3,307
Sheep and goats.....	15	500	3,336	3,736	8,355	12,611	8,355
Horses.....	46	209	1,298	2,435	4,827	4,377	4,288
Poultry.....	255	2,914	14,506	27,460	68,065	94,882	99,421

¹ Chickens only.

Dairying is the chief farm enterprise in this county. According to the Federal census of 1930, 74 percent of the farms were classed as dairy farms, 10 percent as general farms, on the majority of which dairying was undoubtedly the largest single source of income, 3.6 percent were classed as crop-specialty farms, on which potatoes were the principal crop, and less than 2 percent were poultry farms. Dairying is more generally adapted to conditions in this county than any other type of farming. The climate is favorable to the production of tame-hay and forage crops, and good pasture is provided in the uncleared areas. Dairy farming is favored also by the proximity of good markets for dairy products. The income derived from the sale of cream and milk is supplemented by that obtained from the sale of potatoes, poultry products, livestock, and some small grains, although most of the small grains produced are fed to livestock on the farms. In point of acreage devoted to them, hay and pasture are the principal sources of feed. Good legume hay and pasture are assured, except in periods of extreme drought. Most of the hay produced is mixed timothy and clover, but the trend is toward the production of more hardy legume hays, among which alsike clover is the most popular. The acreage devoted to alfalfa is increasing gradually.

Most of the corn produced is utilized as forage. In years when unfavorable weather in the spring prevents the early sowing of oats, some of the land originally intended for oats is planted to corn as an emergency forage crop. A few root crops, such as mangels and rutabagas, are grown. Some millet and Sudan grass are produced on many farms, generally as emergency hay crops. Every year wild hay, consisting largely of redtop and native marsh grasses, is harvested from a considerable acreage of the open peat bogs and natural

meadows along the streams. The area from which wild hay is cut varies from year to year. In a dry season it is possible to gather hay on land that would be flooded in years of normal rainfall. In some places, the farmers mow the wet meadows with a scythe and put up the hay by hand. During the last few years the acre yields of tame hay have been greatly lowered on account of insufficient precipitation during the growing season. This has necessitated the harvesting of more wild grasses from many of the peat bogs and poorly drained areas, which, under ordinary circumstances, are left untouched. A lowered water table has made possible the use of power machines and horses in mowing, although during years of normal precipitation the poorly drained areas are too wet and boggy to support the heavy weight. In the last few years all the accessible wild-hay meadows have been utilized, even though they yield only a poor or fair quality of hay. In some places, the wild-hay meadows are filled with so many overturned trees, roots, snags, branches, and stumps, resulting from fires, that, in order to harvest the hay, hand scythes are used, a method both arduous and time consuming. Frequently baled hay is imported. In unusually dry years a considerable proportion of the small grains, especially oats, is cut green and utilized as forage.

The leading small grain is oats, and barley ranks second in importance. Both are used almost exclusively as feed for livestock. In most years, corn ranks second among the crops in point of acreage. On farms that are not equipped with silos, it is cut and fed as fodder. Corn, with the exception of the early-maturing varieties, is an uncertain crop for grain because the growing season is not long enough to assure its maturity. In 1934, less than 3 percent of the total corn acreage was allowed to ripen for grain, and the rest of the crop was cut for silage and fodder. That from only a very small acreage is "hogged or grazed off."

Both the soil and the climate are favorable to the growing of potatoes. On newly cleared land or following clover, the yields are large and the quality excellent. On many farms potatoes provide some cash income. The present tendency is toward a more conservative production of potatoes, because of the low average market price prevailing during the last few years. Potatoes are marketed at the local village warehouses, whence they are shipped by freight or truck to the Twin Cities and Chicago markets.

The acreage in fall-sown rye varies from year to year. This crop is not grown very extensively. In 1929, the acreage about equaled that in wheat. Rye is grown most extensively on the lighter textured soils. Some is used as feed, and the rest is sold.

Many of the farmers in the older settled districts have small mixed orchards of apple and plum trees. The small bush fruits are less commonly grown than orchard fruits, but good yields are obtained when some care is given to their culture. Red raspberries grow wild along ditch banks in peat bogs and in other poorly drained areas which originally had a thin layer of peat that has been burned off. Blueberries thrive in some areas where sandy soils predominate. Nearly every farm includes a garden, in which vegetables of many varieties are grown, mostly for consumption in the home. A few

farmers have surplus vegetables and fruits, which are sold to tourists or are marketed in the nearby towns.

The increasing importance of dairy farming may readily be understood by referring to table 5, which gives creamery statistics for the county in the years 1910, 1915, 1920, 1925, 1930, 1933, 1935, and 1936. Three cheese factories are in operation, and powdered butter-milk is produced at the creamery in Mora.

TABLE 5.—*Creamery statistics for Kanabec County, Minn., in stated years*¹

Year	Cream-eries	Butter made	Amount paid patrons for butterfat	Year	Cream-eries	Butter made	Amount paid patrons for butterfat
	<i>Number</i>	<i>Pounds</i>	<i>Dollars</i>		<i>Number</i>	<i>Pounds</i>	<i>Dollars</i>
1910.....	3	169,060	40,584.64	1930.....	5	1,832,209	572,470.56
1915.....	4	288,603	67,106.98	1933.....	6	1,823,069	319,842.72
1920.....	4	791,800	412,104.69	1935.....	6	1,925,126	521,964.82
1925.....	5	1,894,546	739,795.75	1936.....	6	2,025,344	635,897.73

¹ Data from Agriculture Dairy and Food Department of the State of Minnesota, Bulletins of Information on Creameries.

The production of hogs is of minor importance. A few are kept on almost every farm to utilize the skim milk, cull potatoes, and other nonmarketable products. They are slaughtered on the farms and are used mainly for a home supply of meat. The surplus hogs are marketed through local shipping associations or are trucked directly to the packing plants in South St. Paul. The raising of beef cattle is unimportant. Nearly every farm has from three to five horses which are the principal source of power on most farms. On the larger farms, trucks and tractors have replaced some of the horses. The number of sheep has steadily increased. The larger flocks are kept in the rougher districts which are suitable only for grazing. The wool produced is one of the chief sources of income to many of the farmers who have little cleared land suitable for cropping.

Every farmer keeps a flock of poultry, primarily for the production of eggs. In 1935, 99,421 chickens were reported, and 743,497 dozen eggs were produced in 1934. The eggs are marketed chiefly at local creameries and stores. During the last few years, the raising of turkeys has received considerable attention, and many farmers are realizing handsome profits from their sale. In 1935 they were raised on 264 farms. Bees are kept on only a small number of farms, and most of the honey produced is sold locally.

Many farmers derive some income from the sale of forest products cut on their farms, such as sawlogs, pulpwood, fence posts, railroad cross ties, and firewood. The census of 1930 reports 12,354 cords of firewood cut on 913 farms and 691 cords of pulpwood on 15 farms. There were 33,730 fence posts cut on 278 farms, and several farms produced railroad ties. Sawlogs measuring 143,000 board feet were cut on 43 farms.

The farmers derive their largest income from the sale of dairy products, the value of which in 1929 was slightly more than \$1,-

000,000. Next in importance are poultry and eggs. The values of agricultural and livestock products produced in the county in 1929 are shown in table 6.

TABLE 6.—Value of agricultural and livestock products by classes, in Kanabec County, Minn., in 1929

Agricultural products	Value	Livestock products	Value
Cereals.....	\$246, 106	Dairy products sold.....	\$1, 062, 807
Other grains and seeds.....	10, 619	Poultry and eggs.....	365, 264
Hay and forage.....	519, 663	Honey.....	1, 796
Vegetables (including potatoes).....	364, 537	Wool.....	17, 933
Fruits.....	3, 621		
All other field crops.....	245	Total.....	1, 447, 900
Farm garden vegetables (excluding potatoes) for home use only.....	21, 073	Total agricultural products.....	2, 703, 997
Forest products.....	90, 333		
Total.....	1, 256, 197		

Commercial fertilizers are used on only a few farms. In 1929, 27 farmers used 48 tons of commercial fertilizer, most of which was used on some of the reclaimed peat bogs where phosphate and potash are needed. All the barnyard manure produced is used chiefly on the land intended for potatoes and corn. Tame-hay meadows and land to be seeded to small grains receive some. Practically no crops are grown expressly for green manure. Lime has proved beneficial on some of the upland acid sandy soils where alfalfa or sweetclover is grown, but very little has been used so far.

Most of the labor on the farms is performed by the farmer and members of his family, but on many farms, during the busy part of the season, arrangements are made with neighbors for an exchange of help. On some of the larger dairy farms where extra help is employed, wages with board and room range from \$20 to \$35 a month. Higher wages are paid on farms where potatoes are grown extensively. The prices are based on the number of bushels picked or are calculated by the hour. On many of the smaller farms, the farmer and his family supplement their income by doing outside work, such as lumbering, cooking, mining, and road construction.

Approximately 125 acres is the most common size of farm in this county. In the northern part 40- and 80-acre farms are most common. The larger farms, including 300 or more acres, are located in the older settled districts in the central and southern parts.

The great majority of the farms are operated by owners. There were less than 25 percent operated by tenants in 1935. Farms are rented either for cash or on shares. The latter is the more popular agreement. The proportion of the products due the owner of farms rented on shares ranges from one-third to two-thirds, depending on the details of the agreement as to provision of seed, implements, and other farming necessities. The most common agreement provides that one-half the products be paid to the owner for the use of the land, and the tenant bears all the expenses. Usually a cash rental is paid for hay and pasture land. Cash rentals range from \$2 to \$5 an acre, depending on the location and condition of the land, the kind of improvements, and the character of the soil.

Many of the farms are well improved and are equipped with modern labor-saving machinery. The buildings are painted and kept in a good state of repair, and most of the fields are enclosed with fences. In the newer and more sparsely settled parts of the county, buildings for living quarters consist of temporary buildings to be replaced later by more permanent structures. Electrical energy, generally supplied by power companies, is in use on some of the more modern farms. More than one-half of the farms have stationary gas engines for pumping water and for grinding feed. About 10 percent of the farms are equipped with motortrucks.

Good water is plentiful at a depth ranging from 25 to 150 feet. The deeper wells are drilled and are enclosed with steel casings.

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 soil¹ and its content of lime and salts are determined by simple tests. The drainage, both internal and external, and other external features, such as the 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, especial 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 in 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 of these groups 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 Milaca, Brickton, and Onamia 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

¹ 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.

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, Milaca very fine sandy loam and Milaca fine sandy loam are soil types within the Milaca 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 subgroup of soils within the type, which differs from the type in some minor soil characteristic that may, nevertheless, have an important practical significance. Differences in relief, stoniness, and the degree of accelerated erosion frequently are shown as phases. For example, within the normal range of relief, for a soil type, there may be parts which 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 differences 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 areas of the soil type may be segregated on the map as a sloping 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 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

The present agriculture is directed toward dairying by the characteristics of the soil and climate, which favor the growth of grasses and legumes valuable for feed. Alsike clover is well adapted to most of the soils and commonly grows voluntarily in the woods, along old tote roads, and in small openings cleared of trees and brush, successfully competing with the wild grasses. Good stands are obtained in many places from seedings on stump land or light brushland, with little or no preparation of the soil. In many places, merely scratching the surface with a light farm implement and broadcasting the seed by hand results in a satisfactory stand. Red-top, bluejoint, and other nutritious wild grasses grow luxuriantly on some of the treeless shallow peat bogs and poorly drained mineral soil areas, provided the land is not too wet. Among the small-grain crops, oats and barley grow well. Both yields and the acreage devoted to wheat, formerly grown on a more extensive scale, have declined within the last decade. The growing season is somewhat too short and too cool for the growing of corn for grain, except some of the earlier maturing varieties. A considerable proportion of the corn is grown either for silage or for fodder.

Milaca very fine sandy loam, the dominant well-drained upland soil of the county, does not return so high an average yield of alfalfa as do Brickton silt loam and Brickton very fine sandy loam, al-

though it is apparently as productive of the common clovers and other farm crops. The yields from the first cutting of alfalfa are about equal on these three soils, and, in seasons with liberal rainfall following the first cutting, yields from the second cutting also are similar, but if dry weather prevails there is ordinarily very little second growth on the Milaca soil, whereas the Brickton soils usually return a fair yield. The explanation of this difference is found in the difference in root development. The roots of 2- to 4-year-old alfalfa plants on the Brickton soils extend to a depth ranging from 7 to 10 feet, whereas few roots are found below a depth of 4 feet on the Milaca soil, owing to the difficulty of penetrating the hard lower B horizon, locally referred to as "hardpan." Notwithstanding this disadvantage the Milaca soils have for the production of alfalfa, they return higher average yields of alfalfa than of the common clovers. In unusually dry seasons, alfalfa more frequently gives a satisfactory stand when sown with small grains than do the common clovers or sweetclover, provided it is properly inoculated, as by a liberal application of soil from a well-established field of alfalfa or sweetclover, a precaution that is unnecessary with common clovers. Although both the surface soil and the upper part of the subsoil are in general decidedly acid, no beneficial effect from liming has resulted, except in fields where inoculation had not been cared for properly.

Owing to the gravelly subsoils of Onamia very fine sandy loam and Greenbush very fine sandy loam, the behavior of alfalfa is similar to that on the Milaca soils; that is, the first cutting is usually good, and subsequent cuttings are dependent on the rainfall in July and August. Both soil and climate are favorable to the growing of potatoes, and a considerable acreage of the Onamia and Milaca soils is devoted to this crop. The yields are usually high, and the quality is excellent if the potatoes are grown on newly cleared land or following clover. Root crops, such as rutabagas, mangels, turnips, and stock carrots, commonly grown as feed for livestock, are better adapted to the heavier soils. Rutabagas are the most popular root crop and have proved the most satisfactory, as they can be grown under a wider range of soil conditions and on land in a poorer state of preparation than that demanded by other root crops.

On account of the adaptability of the soils and the climate to the production of tame grasses and legumes as a source of forage and to oats and barley as feed, together with the favorable location with respect to good markets, the soils of this county are well adapted to dairy farming. In a general way the farmers recognize the more outstanding crop adaptations of the various soils. The poorly drained mineral soils, with fine-textured surface soils, and the undrained shallow peat soils are considered better suited to hay and pasture crops than to small grains and cultivated crops, and the well-drained upland soils are recognized as better adapted to corn, potatoes, and alfalfa than the wetter soils. It is common knowledge that potatoes do better on the lighter textured sandy soils and that corn matures more quickly on them. The sandier soils are well suited to fall-sown rye, although the yields in general are not so large as on the medium-textured soils.

There are great differences in the productivity of the soils of Kanabec County. Some are better adapted to certain crops than others, and some, which are unsuited for agriculture, are better adapted to forestry. The productivity of a certain soil depends on several factors, important among which is its ability to hold moisture and withstand drought. Other differences are in the texture and structure of the surface soil and subsoil, composition of the material from which the soil has developed, and thickness of the successive layers which make up the soil profile. On the basis of similarity in productivity, which is influenced to a large extent by the texture of the surface soil and subsoil, the soils are placed in four groups as follows: (1) Soils with medium-textured surface soils and clay loam subsoils, (2) soils with medium-textured surface soils and sand and gravel subsoils, (3) soils with sandy surface soils and sand or gravel subsoils, and (4) poorly drained soils.

In the following pages the soils of the county are described in detail, and their agricultural relationships are discussed; their location and distribution are shown on the accompanying soil map; and their acreage and proportionate extent are given in table 7.

TABLE 7.—*Acreage and proportionate extent of the soils mapped in Kanabec County, Minn.*

Type of soil	Acres	Per- cent	Type of soil	Acres	Per- cent
Milaca very fine sandy loam	139, 328	41. 6	Kroschel loamy sand	5, 312	1. 6
Milaca very fine sandy loam, rolling phase	5, 376	1. 6	Emmert loamy sand	2, 944	. 9
Santiago silt loam	2, 048	. 6	Freer silt loam	21, 760	6. 5
Brickton silt loam	11, 200	3. 3	Warman very fine sandy loam	8, 384	2. 5
Brickton very fine sandy loam	512	. 2	Adolph loamy sand	1, 088	. 3
Milaca fine sandy loam	10, 560	3. 1	Bluffton silty clay loam	14, 720	4. 4
Milaca fine sandy loam, hilly phase	5, 120	1. 5	Bluffton silty clay loam	3, 008	. 9
Onamia very fine sandy loam	21, 504	6. 4	Knife Lake silt loam	1, 792	. 5
Onamia fine sandy loam	2, 944	. 9	Alluvial soils, undifferentiated	9, 728	2. 9
Onamia fine sandy loam, rolling phase	2, 240	. 7	Peat	53, 440	16. 0
Greenbush very fine sandy loam	7, 168	2. 1	Peat, shallow phase	2, 240	. 7
Onamia loamy sand	2, 176	. 7	Beach sand	128	. 1
			Total	334, 720	

SOILS WITH MEDIUM-TEXTURED SURFACE SOILS AND CLAY LOAM SUBSOILS

The soils of this group, which are the most productive and extensive soils of the county, occupy a large part of the well-drained drift plain section. They have light-colored surface soils, are low in organic matter, and have many stones on and below the surface of many of them. They are productive soils, comparatively high in plant nutrients except nitrogen, and, under favorable climatic conditions and good management, yield well. Most of the grain and forage crops are produced on them, and all the general-farm crops suited to this general region can be grown on them with good results. The relief in general ranges from nearly level to undulating or rolling. In some places along Snake River, where the river has cut through the glacial drift, the relief is hilly, and in some parts of the southern townships the land is so level that artificial drainage must be provided, in order to remove the surplus water from the ground in the spring. In general, however, most of the soils have adequate surface and internal drainage.

The group includes Milaca very fine sandy loam, Milaca very fine sandy loam, rolling phase, Santiago silt loam, Brickton silt loam, and Brickton very fine sandy loam. The Milaca and Santiago soils have developed on well-drained stony drift of the middle Wisconsin glaciation. The middle Wisconsin drift is also called the "young red drift" on account of the reddish-brown color of the unweathered soil material. The Brickton soils have developed on water-laid material deposited by the late Wisconsin glaciation. The late Wisconsin drift is commonly referred to as "young gray drift" because of the yellowish-gray color of the unweathered till. Together these five soils constitute 47.3 percent of the total land area of the county.

Milaca very fine sandy loam.—Virgin areas of Milaca very fine sandy loam are covered by a 1- to 3-inch layer of dark-brown leaf-mold. Beneath this, and almost inseparable from it, is a dark-colored thin layer of humus, from one-half to 2 inches thick, underlain by a layer, from 6 to 12 inches thick, of gray or light grayish-brown very fine sandy loam, faintly mottled with rusty brown. The material is strongly acid in reaction. On crushing, the almost dry soil breaks down very readily into a silty powder-like mass. The cultivated surface soil consists of a 6- to 9-inch layer of light grayish-brown structureless or very finely granular very fine sandy loam or silt loam. Below this is a distinct 6- to 8-inch layer of gray, grayish-brown, or light yellowish-brown strongly acid sandy clay loam or silt loam, strongly mottled with rusty brown. This rests on a transitional layer of yellowish-brown, grayish-brown, or reddish-brown fine sandy loam or sandy loam, ranging from 6 to 20 inches in thickness, in which there are rusty-brown patches. The material is somewhat cemented and contains pebbles and stones. The upper layer of the parent material is reached at a depth ranging from 24 to 40 inches and consists of slightly weathered reddish-brown stony glacial till which, when dry, becomes indurated and very difficult to penetrate by pick or soil auger. The texture of this material ranges from sandy clay to clayey sand, but fine sandy loam and sandy loam predominate. In many places dark stains are noticeable in the cracks and fissures in the upper part of this layer, and sand and gravel veins and pockets are common. Granite, gneiss, basalt, schist, and gabbro cobbles and boulders are abundant throughout the northwestern part of the county. Ferruginous sandstone boulders are numerous in places, but limestones and shales are absent. The reaction of this material is slightly or very slightly acid but changes abruptly to alkaline at a depth ranging from 6 to 11 feet. Boulders and stones of all sizes are scattered abundantly over the surface of the ground and, in some places, are so numerous as to prevent cultivation.

Milaca very fine sandy loam is by far the most extensive soil in the county and forms the predominant upland soil of the till plain. The relief is gently undulating or gently rolling. In wet years the natural surface drainage of the flatter areas is somewhat deficient, but, on the whole, drainage of this soil compares favorably with that of the better drained soils of the county. Internal drainage ranges from fair to good.

At one time this soil supported an excellent stand of white pine, together with mixed hardwoods. The pine has been almost entirely cut off, however, and in many places the succeeding growth has been

ironwood, white birch, red oak, bur oak, basswood, red maple, sugar maple, mountain maple, ash, elm, several varieties of dogwood and willow, and a few white pine. Red pine and white spruce occur to a less extent.

This is a productive soil for the crops commonly grown and is well suited to dairying which is the prevailing type of farming on this soil. The leading crops are hay, oats, potatoes, corn, and barley. Hay yields from 1 to 3 tons to the acre; oats, 40 to 75 bushels; potatoes, 100 to 150 bushels; barley, 35 to 60 bushels; and corn, which is grown chiefly for silage, 6 to 10 tons. From 35 to 40 bushels to the acre of ear corn are obtained during favorable seasons.

The soil is naturally low in nitrogen and shows marked response to applications of barnyard manure, to legumes in a rotation, and to nitrates for most of the ordinary crops. Barnyard manure is the only kind of soil enrichment used to any extent, and its value is well recognized. This is used about once in every 4 or 5 years, or as frequently as the supply will allow.

Milaca very fine sandy loam, rolling phase.—The rolling phase of Milaca very fine sandy loam differs from typical Milaca very fine sandy loam chiefly in relief, surface drainage, and depth of surface soil. Although most of the land is gently rolling, some areas are hilly and unsuitable for cultivation. If the steep slopes are cultivated, considerable damage results from washing, and the finer soil particles are carried to the lower places. Except for a thinner surface soil the profile of the rolling soil is similar to that of the typical soil. The farming practices on it are, in general, similar to those on Milaca very fine sandy loam.

Santiago silt loam.—In a virgin condition the surface soil of Santiago silt loam is covered by a 2-inch layer of leafmold and humous soil. Beneath this is a 6- or 8-inch layer of medium-acid light-gray very finely laminated silt loam. When dry this material is readily pulverized to a structureless mass. It is underlain by a layer of strongly acid brown silt loam, from 4 to 8 inches thick, which is slightly mottled with darker brown and has the same structure as the material in the layer above. Under cultivation a grayish-brown plowed layer is produced. A zone of pronounced concentration occurs at a depth ranging from 12 to 16 inches, which is from 6 to 12 inches thick and consists of strongly acid yellowish-brown or brown coarsely granular clay loam. The presence of this yellowish-brown subsoil distinguishes Santiago silt loam from Milaca very fine sandy loam. Beneath this is an acid 8- to 12-inch transitional zone of brown slightly granular sandy loam or sandy clay loam. It rests on the stony red drift sandy clay loam substratum at a depth ranging from 24 to 36 inches. Stones are not abundant, except in a few places where the substratum lies close to the surface.

Santiago silt loam occurs almost exclusively in Brunswick, South Fork, and the southwestern part of Kanabec Townships. It is closely associated with Milaca very fine sandy loam.

The relief of Santiago silt loam is undulating or gently rolling. Surface drainage is good, and underdrainage is moderately good.

The remaining virgin forest consists of a heavy stand of hardwoods, such as sugar maple, basswood, ironwood, red oak, ash, elm, and aspen. A few white pine trees still stand in places.

A large part of the soil is under cultivation. Very good yields of the general-farm crops are produced. Hay, oats, corn, potatoes, and barley are the most important crops grown, yields of which are about the same as those obtained on Milaca very fine sandy loam. No special soil-management methods are followed. Applications of barnyard manure are made periodically, and a leguminous hay crop is used in the crop rotation on most farms.

Brickton silt loam.—Brickton silt loam, in a virgin condition, has a 1- or 2-inch layer of leafmold over slightly acid light-gray silt loam which extends to a depth of 6 or 8 inches. This is underlain by a medium-acid grayish-brown layer, ranging from 3 to 7 inches in thickness, of the same texture and similar, though more pronounced, structure. It rests on a layer of heavier materials, at a depth ranging from 10 to 15 inches below the surface, consisting of coarsely granular clay loam or silty clay which is light brown with yellowish-brown markings in its upper part and much darker brown and more coarsely granular below. A brownish-yellow color is apparent on examination of the freshly cut surface of the granules. The material of this layer is distinctly acid throughout. At a depth ranging from 3 to 4 feet the parent material, which consists of highly calcareous brownish-yellow very fine sandy loam or silt loam of very uniform texture, is reached. Layers of dark-brown silty clay are common at different levels in the parent material. Concretions of impure calcium carbonate occur in irregular layers between depths of 4 and 5 feet, the nodules ranging from a fraction of an inch to more than 3 inches in length. Stones, pebbles, and gravel are lacking throughout the profile.

Brickton silt loam is the predominating upland soil of Grass Lake and the eastern part of Brunswick Townships. In most places the relief is undulating, and surface drainage is good and internal drainage fair. In some places, however, the soil is somewhat inadequately drained. A variation in soil profile is noticeable in the more steeply sloping areas, where erosion has removed some of the surface soil, as a result of which the heavy upper subsoil layer lies closer to the surface of the ground.

The virgin forest on this soil is far denser and includes much taller trees than those commonly found on Milaca very fine sandy loam. At one time red oak, basswood, American elm, ironwood, sugar maple, butternut, black ash, bur oak, and wild plum trees were abundant.

From 60 to 75 percent of Brickton silt loam is now under cultivation, and it is one of the most productive soils of this general region. Corn, grown chiefly for silage, yields from 12 to 15 tons to the acre; oats, 45 to 90 bushels; barley, 35 to 65 bushels; potatoes, 100 to 250 bushels; red clover, 2 to 3 tons; and alfalfa, 2½ to 4 tons. The rotation most widely practiced consists of oats or barley, clover, potatoes, and corn. For potatoes and corn, the land is plowed in the fall or spring, preferably in the spring, in order to avoid baking, and for smaller grains it is commonly only disked. Dairying is the predominant type of farming, and potatoes are an important supplementary cash crop. This soil is well adapted to alfalfa, and the highest yields of this crop in the county are produced on it.

Brickton very fine sandy loam.—Brickton very fine sandy loam under forest conditions has the following surface layers: A 1- to 2-inch layer of forest floor and leafmold; a very thin layer of nearly black humus; and an 8-inch layer of light-gray very fine sandy loam, slightly acid in reaction. When plowed these layers form the surface soil. Below is a grayish-brown layer, ranging from 12 to 18 inches in thickness, of medium-acid silt loam with a pronounced blocky or cubical structure. The parent material, consisting of light yellowish-gray calcareous very fine sandy loam or silt loam, is reached at a depth ranging from 24 to 36 inches. As in Brickton silt loam, layers of dark-brown silty clay are common at different depths in the parent material. Some concretions of calcium carbonate are present in the parent material. The soil throughout is comparatively free of cobblestones and boulders.

Brickton very fine sandy loam occurs in small bodies associated with Brickton silt loam. Its relief is more rolling than that of Brickton silt loam. Surface drainage is good, and internal drainage is excellent. Most of this soil is in cultivation. The farming methods practiced and crop yields produced are similar to those of Brickton silt loam. The smaller rougher areas are left in woods.

SOILS WITH MEDIUM-TEXTURED SURFACE SOILS AND SAND AND GRAVEL SUBSOILS

The soils of this group occupy 14.7 percent of the total area of the county, principally in the southern two tiers of townships. The physical properties of their surface soils range from fair to good, but the lower part of the subsoil, which consists of mixed sand and gravel, makes the soil droughty. The relief ranges from nearly level to moderately rolling. The more nearly level areas are in the vicinity of Ogilvie. All the soils have adequate surface and subsoil drainage. Run-off of surface water is rapid on some of the steeper slopes, and erosion is active.

The surface soils are light colored and are low in organic matter and nitrogen. Owing to the rather large quantities of sand contained in the surface soils, they are loose, mellow, and easy to till. Because of the presence of pervious gravel beds in the subsoils, the soils are somewhat droughty. The degree of droughtiness depends to a great extent on the nearness of the gravel to the surface. In places where the finer textured topmost layers are 3 or more feet thick the soils are only slightly more droughty than the soils of the first group. In general, however, the soils of this group are easily cultivated and in years of normal precipitation are productive.

Included in this group are Milaca fine sandy loam, Milaca fine sandy loam, hilly phase, Onamia very fine sandy loam, Onamia fine sandy loam, Onamia fine sandy loam, rolling phase, and Greenbush very fine sandy loam. Milaca fine sandy loam occurs on the rolling land of the upland drift plain and is developed on material from which a large part of the finer materials—silt and clay—were removed at the time of deposition. Onamia very fine sandy loam, Onamia fine sandy loam, and Greenbush very fine sandy loam occupy extensive areas in Comfort, Arthur, Knife Lake, South Fork, and Kanabec Townships, and small bodies are scattered throughout some of the northern townships. The Onamia and Greenbush soils are

similar to Milaca very fine sandy loam to a depth ranging from 15 to 36 inches. At this depth stratified cobbly gravel and gravelly sand are reached in the Onamia and Greenbush soils.

The soils which occupy the level or undulating areas have practically no stone on the surface or throughout the soil, but, in the more rolling areas, as those of Milaca fine sandy loam, stones are abundant.

Milaca fine sandy loam.—In uncultivated areas the profile of Milaca fine sandy loam consists of four or five layers. A 2-inch layer of dark-brown leafmold and humus overlies a 6- to 8-inch layer of leached light grayish-brown platy fine sandy loam or loamy fine sand. This layer is strongly acid. These upper two layers are intermixed under cultivation to form the surface soil. The upper subsoil layer of gray strongly acid very fine sandy loam, stained with rusty brown, begins at a depth ranging from 8 to 12 inches and continues to a depth ranging from 18 to 24 inches, where it is underlain by mottled rusty-brown and gray very strongly acid fine sandy loam or loamy gravelly sand. The upper layers of the parent material lie between depths of 30 and 36 inches and consist of very pale reddish-brown or yellowish-brown slightly acid or neutral loamy sand or sandy loam containing stones and gravel.

Bodies of Milaca fine sandy loam are scattered largely throughout the northern townships of the county. The relief is gently rolling or sharply rolling, and drainage is good. At the present time a large proportion of the land supports a stand of mixed hardwoods, but white pine was abundant in the past. A few sugar maple, ironwood, basswood, red oak, bur oak, hazel, white and large-toothed aspen, red maple, mountain maple, white birch, and green ash grow on this soil. A very small proportion of the land is under cultivation. It produces fair yields of the common crops when rainfall is ample.

Milaca fine sandy loam, hilly phase.—The virgin soil of Milaca fine sandy loam, hilly phase, is covered with a 1- to 2-inch layer of leaf litter over a very thin layer of humus one-half or 1 inch thick. Underlying this is a layer, about 8 inches thick, of gray or light brownish-gray fine sandy loam which is strongly acid in reaction. When dry, the platelike structure in which the soil particles are arranged is readily discernible, but on handling the aggregates break down to a loose mellow mass. The subsoil is somewhat indurated brownish-gray fine sandy loam ranging from 10 to 20 inches in thickness. Distributed throughout this layer are rusty-brown stains which are more pronounced in the lower part. The material in this layer also is acid in reaction. Below a depth ranging from 26 to 36 inches the pale reddish-brown sandy loam or sandy clay parent material, containing stone and gravel, is reached.

Milaca fine sandy loam, hilly phase, is not very extensive. It occupies the sharply rolling land in the north-central part of the county, and very little of it is under cultivation. At present most of it supports a mixed stand of second-growth deciduous trees and a dense underbrush. Numerous boulders on the surface and throughout the soil render much of the land unfit for farming.

Onamia very fine sandy loam.—Onamia very fine sandy loam, under forest conditions, consists of the following layers: A 1- or 2-inch layer of leafmold; a very thin layer of nearly black humus; a 5-

to 10-inch layer of light grayish-brown strongly acid very fine sandy loam; grayish-brown slightly mottled weakly cemented strongly acid very fine sandy loam, from 6 to 10 inches thick; reddish-brown acid slightly cemented somewhat clayey gravelly sand, from 4 to 10 inches thick, containing pebbles and small stones; and strata of brown stony gravel or gravelly sand, lying at a depth ranging from 20 to 40 inches. The underlying coarse material is composed of water-worn noncalcareous crystalline rocks and is strongly acid in reaction to a depth of more than 6 feet. In some places the water table lies at a depth of 4 feet or more, the depth depending on the time of year and the position of the land with respect to stream channels. The gravel layer in most places is not waterlogged above a depth of 6 feet, and, in many places, the depth to the water table is very much greater. Stones are few on this soil; in some places entirely lacking. The cultivated soil varies from the virgin soil described only in the upper 6 to 10 inches, in which the material becomes mixed and forms a plow soil of loose friable grayish-brown very fine sandy loam.

This soil occurs chiefly along Snake and Knife Rivers and some of their branches. Scattered level areas also occupy outwash plains, dissected high terraces, and old stream channels in other parts of the county.

Surface drainage of Onamia very fine sandy loam ranges from poor to good, and underdrainage, in most places, is very good. During a spring of normal rainfall the soil can be worked somewhat earlier than soils having less perfect internal drainage, but in a spring of heavy rainfall excessive moisture, owing to inadequate surface drainage, may seriously delay seeding.

Very little virgin timber remains on the land, and the present forest consists chiefly of aspen, birch, red oak, bur oak, hazel, and sumac. Red pine and white pine were at one time abundant. Because of its level surface and freedom from stones, Onamia very fine sandy loam is usually one of the first soils to be cleared.

Farms consisting entirely of this soil are common. Somewhat better crop yields are reported than those obtained on the nearby Milaca soils, but hay is likely to suffer from drought during years of less-than-normal precipitation. Farming methods similar to those in use on Milaca very fine sandy loam are followed by farmers on this soil. Heavy applications of barnyard manure are recognized as especially valuable as soil amendments.

Onamia fine sandy loam.—Beneath a 2-inch layer of leafmold and a thin layer of dark-colored humus, the surface soil of Onamia fine sandy loam is grayish-brown strongly acid fine sandy loam to a depth ranging from 5 to 8 inches. Below this is a 6- to 8-inch layer of slightly coherent grayish-brown sandy loam which rests on stony gravel or gravelly sand at a depth ranging from 12 to 16 inches. The subsoil is noncalcareous crystalline rock material and is strongly acid to a depth of more than 5 feet. Stones are not very numerous on the surface in the southern part of the county, but in some of the central and northern sections they are fairly abundant. In no place, however, are there as many stones as on the heavier Milaca soils. The relief is, in general, more undulating than that of Onamia very fine sandy loam, and natural surface drainage is adequate. Internal drainage is excessive, owing to the coarser texture

of the soil material. This soil is distributed chiefly along Snake River and its tributaries. It is closely associated with the heavier Onamia very fine sandy loam. Bodies of this soil are small, and the land is farmed in conjunction with more extensive soils. There is very little virgin timber remaining, and the present forest consists chiefly of aspen, birch, oak, hazel, and sumac. Red pine and white pine were abundant at one time.

Dairying is the prevailing type of farming on this soil. Crop yields are reported as averaging much lower than those obtained on Onamia very fine sandy loam and Milaca very fine sandy loam. Short-rooted crops, such as the common clovers and small grains, particularly, are likely to suffer from drought during years of sub-normal and even normal rainfall, whereas, in very dry years, crop yields are decidedly low or complete failures.

Onamia fine sandy loam, rolling phase.—The rolling phase of Onamia fine sandy loam differs from the typical soil chiefly in relief, stoniness, surface drainage, and, to less extent, in the character of the substratum. In some places, more particularly in the southern townships, stones are entirely absent on the surface, but in the area in Ann Lake Township surface boulders are nearly as numerous as on the adjacent Milaca very fine sandy loam. The relief ranges from strongly rolling to hilly. Both surface drainage and under-drainage are excessive. The substratum varies; in a few restricted areas it is composed of a much finer textured material than is typical. Soil of this phase is developed on morainic deposits and dissected terraces.

This soil occurs mainly in Knife Lake, Comfort, and Arthur Townships, and small areas are scattered throughout the central and southern parts of the county. In some places mixed hardwoods grow on the land, but the unimproved areas support chiefly a scrubby stand of birch, poplar, oak, sumac, pin cherry, and hazel. A rather large proportion of the land is under cultivation, but the rougher areas are devoted mainly to grazing, for which purpose they are best suited. This is an inferior agricultural soil, owing to its generally rough relief and droughtiness.

Greenbush very fine sandy loam.—The soil profiles of Greenbush very fine sandy loam and Santiago silt loam are very similar to a depth of 2 feet. A 1- or 2-inch layer of leafmold overlies the uppermost mineral soil layer of Greenbush very fine sandy loam, which is light-gray, light grayish-brown, or dark grayish-brown very fine sandy loam and extends to a depth ranging from 10 to 15 inches. This is a leached layer and is slightly darker in its upper part, owing to the presence of some organic matter. The subsoil is yellowish-brown or light reddish-brown coarsely granular silt loam or sandy clay loam, similar to, although in many places thinner than, the subsoil underlying Santiago silt loam. In most places this layer reaches a depth ranging from 15 to 36 inches and rests on a thick bed of brown or reddish-brown stratified gravel, sand, or gravelly sand. The reaction is strongly acid throughout the profile. Cultivation produces a grayish-brown friable easily cultivated plow soil.

This soil is extensively developed on level or undulating nearly stone-free uplands or terraces adjacent to existing or ancient stream

channels in the southeastern part of Kanabec Township surrounding Ogilvie, the eastern one-third of South Fork Township, and the central part of Arthur Township. Surface drainage ranges from fair to good, and underdrainage is excellent. This soil is of considerable agricultural importance, as many farms are composed entirely of it, and it occurs in the more highly developed parts of the county. From 60 to 70 percent of the land is under cultivation, and the remainder is in woodland pasture. It supports a forest of white pine, maple, basswood, elm, butternut, oak, and birch. Most of the crops common to the section are grown, and yields compare very favorably with the average for the county. Because of the moisture-retaining capacity of the upper 2 or 3 feet of this soil, it is tilled in the spring, seeded, and harvested at the same time as is Santiago silt loam. In exceptionally dry years crops growing on Greenbush very fine sandy loam are slightly handicapped by excessive underdrainage, but under ordinary conditions yields are similar to those returned by the Santiago soil. The usual crop rotations, more rigidly adhered to, are practiced on this soil.

SOILS WITH SANDY SURFACE SOILS AND SAND OR GRAVEL SUBSOILS

The soils of this group occupy 3.2 percent of the total area of the county, mainly along Snake River and its tributaries. All have shallow sandy surface soils underlain by material which, in general, is coarser textured than the surface soil. They are among the most droughty soils of the county. Included in this group are Onamia loamy sand, Kroschel loamy sand, and Emmert loamy sand. Onamia loamy sand is related to Onamia very fine sandy loam and Onamia fine sandy loam of the preceding group, but it differs from those soils in that it has a shallower covering of finer textured material overlying the sand and gravel subsoil. Its relief and natural drainage are also similar to those features of the other Onamia soils, but, because of the coarser texture of its surface soil and looser consistence, it is more subject to washing. Where the cultivated fields are not protected by groves of trees, there is some tendency for the soil to blow. Kroschel loamy sand occurs on gently sloping hills adjacent to Snake River. It is developed on deep sand or mixed sand and gravel deposits which, in some places, have been shifted by winds. Emmert loamy sand is a dark-colored stony coarse-textured soil, developed on prominent ridges of sand and gravel, with a large number of boulders at and below the surface.

Onamia loamy sand.—Onamia loamy sand, under a forest cover, has a shallow surface layer of leafmold underlain by a 4- to 8-inch layer of strongly acid dark grayish-brown loamy sand. Beneath this is a layer of somewhat lighter grayish-brown loamy sand or light sandy loam, from 4 to 6 inches thick, containing some pebbles and coarse gravel. In some places this layer is somewhat mottled with brown iron stains, and the material is weakly cemented. This layer, in turn, is underlain by reddish-brown gravelly sand, in which there are many cobblestones. The upper part of the soil profile probably is less uniform than that of any other soil in this county, owing to differences in the thickness of the finer textured surface layer. In some places the coarse sand and gravel is at the surface,

and the finer material, if ever it was present, has been removed by water erosion. The surface soil, which contains little organic matter, is loose and incoherent, and, in some places, where the land has been cleared and cultivated but not protected by groves or buildings, it is subject to blowing.

The generally smooth level relief of this soil is broken in some places by low ridges, knolls, and sand dunes and in other places by narrow stream valleys. Stones are scattered over the surface in places, but they are not numerous enough to interfere seriously with cultivation. Onamia loamy sand occupies the higher well-drained situations above the first-bottom lands. The largest areas are along Snake River in Arthur and Grass Lake Townships and along some of the tributaries of that river in the central and southern parts of the county. Many smaller bodies are scattered among the other sandy soils throughout the county. This soil is associated with Onamia very fine sandy loam and Onamia fine sandy loam and has been formed on the same kinds of materials as are those soils. In the many places where bodies of these three soil types adjoin, no sharp lines of demarcation exist, but in most places areas intervene between them, in which the soil is transitional in character. Such areas are not shown separately on the soil map but are included with the soil type which they most closely resemble.

A large part of Onamia loamy sand is cultivated. The areas in woodland are used chiefly for grazing. A mixed type of farming is practiced on this soil, but dairying is the most important activity. A large acreage is devoted to corn and potatoes, because the earliness of the soil favors the ripening of corn and promotes vigorous growth of potatoes when rainfall is plentiful. Alfalfa is grown on many farms, although the average yields are only fair. The common clovers, mostly medium red and alsike, are grown to a limited extent. Some difficulty is experienced in getting or maintaining a stand of legumes unless the rainfall is ample and well distributed during the growing season. Although the greater part of this soil is used for growing all the general agricultural crops produced in the county, its range of adaptability is narrow, owing chiefly to the low water-holding capacity of its surface soil and subsoil.

The crop rotation most commonly, though not strictly followed, on this soil consists of corn; rye or oats seeded to clover; hay; and potatoes. Barnyard manure is applied in the fall for land to be planted to corn or potatoes, but the supply usually is inadequate. The most important problems in managing this soil are maintenance of fertility and prevention of soil blowing. The former problem is taken care of, in part, by using barnyard manure, but the latter receives little attention.

Kroschel loamy sand.—The profile of Kroschel loamy sand varies, but, in most places, it has the following characteristics: Beneath a thin cover of leafmold, the surface soil consists of a 5- to 8-inch layer of strongly acid dark-gray loamy sand underlain by somewhat reddish brown strongly acid loamy sand which continues to a depth ranging from 16 to 24 inches and is weakly cemented and slightly mottled with rusty-brown stains in many places. This layer rests on grayish-brown or reddish-brown loose loamy coarse sand which, in some places, is mixed with fairly large quantities of gravel, pebbles,

and cobblestones. The lower part of the subsoil, in places, consists of sandy clay, especially in the small areas of this soil adjacent to heavier textured soils.

Kroschel loamy sand occupies a large part of the rolling land adjacent to Snake River and some of its tributaries. Generally it occupies narrow strips, ranging from less than one-fourth mile to more than one-half mile in width, on both sides of the streams, back of the narrow strips of bottom land bordering the stream channels. A very few comparatively large isolated areas lie some distance away from streams or lakes, but most areas are in close proximity to some other sandy soil type. The relief ranges from gently sloping to sharply rolling. The sloping areas grade gently toward the streams, and the soil is subject to some washing if not carefully managed. The rougher areas are subject to erosion, and, in some places, small gullies have cut the fields and made the land more difficult to farm. More than one-half of this land is under cultivation. Where the larger cultivated fields are unprotected from the wind, soil blowing is likely to damage planted crops.

As this soil is naturally well drained, it returns good yields except during the drier years. The coarse texture of the surface soil and subsoil favors ready absorption of rainfall on the smoother areas and rapid percolation through the soil. On the more rolling areas a large quantity of rain water is lost through rapid surface run-off.

This soil is less productive, however, than the Milaca or Brickton soils. Its resistance to drought is far less than of those soils, because the surface soil and subsoil do not retain moisture although they absorb it readily. Yields are less certain, particularly of crops having shallow root systems, such as clover. A large acreage is devoted to corn and potatoes, and some of the land is planted to alfalfa, a crop which seems to be well adapted to the more level areas where moisture conditions are more favorable. Continuous cropping of this soil to corn, potatoes, and small grains without the addition of much barnyard manure tends to deplete its fertility, and the renewal of the nitrogen supply is made difficult by the uncertainty of obtaining and maintaining good stands of clover.

Emmert loamy sand.—Emmert loamy sand has a dark-colored surface layer which ranges from 1 to 6 inches in thickness. The material in this layer is dark grayish-brown or dark-brown structureless loamy sand or gravelly loamy sand, containing numerous stones and small boulders. It is underlain by a yellowish-brown or reddish-brown slightly stratified layer of similar material which contains more gravel and less organic matter. Some slight evidence of an accumulation of iron exists in this layer which reaches a depth ranging from 10 to 14 inches, where it grades into the unchanged parent material consisting of a mass of boulders, cobblestones, gravel, and sand. The soil material is medium acid throughout.

Emmert loamy sand occurs only as eskers, eskerlike ridges, and kames, which are narrow more or less continuous ridges scattered throughout the drift-covered part of the county. Two conspicuous areas are southwest of Mora, one in sections 29 and 32 in Arthur Township, the other in sections 31 and 32 in Brunswick Township south of Lewis Lake. Many areas are associated with Onamia fine sandy loam, rolling phase, along old glacial drainage channels and

present stream valleys. In some places the surface soil is somewhat deeper, and the substratum is more sandy than typical. Such areas are hilly and rough, and both surface and internal drainage are excessive.

Emmert loamy sand is of little agricultural value. Very little of the land is under cultivation. It is used mainly, in conjunction with other soils, to provide wild pasture. In the natural state it is sparsely wooded with scrubby birch, poplar, oak, and a few pine trees. For the most part, the land is covered with a fairly thick but stunted growth of hazel, sumac, pin cherry, and wild grasses. Some of this sand is used for roadbed and building materials.

POORLY DRAINED SOILS

This group includes the mineral and organic soils which, owing to their flat relief or low-lying position, are incompletely drained during all or part of the year. Before settlement and development of the county on an extensive scale, some of these soils were under water most of the year and others were periodically flooded in the early spring and in wet years. The water table of them all was close to the surface. As the country was developed, fields cleared, ditches dug, and roads constructed, a large quantity of water which previously had no outlet except by slow percolation through the soil was removed from the surface and upper part of the soil. This resulted in a generally lowered water table. Thus, large areas of land, formerly too wet for crop production, were reclaimed. Some of this land during the recent dry years has been the most productive in the county, although in seasons of normal or heavy rainfall it is too wet for most crops. The more depressed areas, particularly those without outlets, are still too wet for plow land and are used chiefly for wild-hay meadows or permanent pastures.

The group includes Freer silt loam, Warman very fine sandy loam, Quamba loamy sand, Adolph silty clay loam, Bluffton silty clay loam, Knife Lake silt loam, alluvial soils, undifferentiated, the organic soils—peat and peat, shallow phase—and beach sand. These soils, which occupy 34.8 percent of the total area, are widely distributed over the county, occurring in every township.

For the most part, peat occupies the depressions, especially those which are well-defined basins with no natural outlets. Peat also occurs along many of the streams where the soil material is of variable composition and partly flooded at different times of the year. The poorly drained mineral soils, on the other hand, occupy more generally level or flat areas which are not so depressed as the peat areas and most of which have some natural outlet leading to a creek or river. Beach sand, which borders some of the lakes, is placed in this group.

The development of the poorly drained mineral soils took place under permanently wet conditions which favored the rank growth of grasses and resulted in the accumulation of more organic matter in the surface soils than is present in the surface soils of soils developed under better natural drainage conditions. The poorly drained mineral soils therefore have a darker surface soil. In some areas of Adolph silty clay loam and Bluffton silty clay loam, the moisture

supply has been so excessive that peat has formed, resulting in a shallow layer covering the mineral soil. After these soils are artificially drained and brought under cultivation, the peat becomes mixed with the mineral soil, and the soil then is similar to that of the better-drained areas.

Freer silt loam.—The uppermost layer in virgin areas of Freer silt loam consists of dark-brown leafmold 2 inches thick. Beneath this is a 3- to 5-inch layer of very dark brown or almost black silt loam rich in well-decomposed organic matter. When partly dry, the material in this layer assumes a finely granular structure. Its reaction ranges from medium to strongly acid. It is underlain by a 4- to 10-inch layer of strongly acid fine platy very fine sandy loam or silt loam, which is grayish brown or light gray in the upper part and darker gray, mottled with brown, in the lower part. Within a depth of 12 inches is a heavier layer ranging between 15 and 30 inches in thickness. This consists, in its upper part, of strongly acid grayish-brown heavy silt loam or clay loam, mottled with rusty brown, and in its lower part, of a much brighter and more pinkish-brown somewhat less acid material containing many stains and layers with rusty margins bordering old root passages. In the upper part of the layer a fine distinctly nutlike structure is apparent, and in the lower part a more coarse nutlike structure exists, and the material breaks down to coarser granules on being disturbed. This layer grades into reddish-brown slightly acid or medium acid stony sandy clay loam at a depth ranging from 3 to 4 feet from the surface. Cultivation mixes the uppermost 6 or 8 inches of soil, producing a dark grayish-brown silt loam. In many places where this soil is associated with Brickton silt loam, a layer of calcareous clay, ranging from 6 to 10 inches in thickness, is present at a depth ranging from 8 to 12 inches from the surface.

Freer silt loam is an important soil which is closely associated with the upland soils of the Milaca and Santiago series and the very poorly drained soils of the Adolph series. In general, it is intermediate in drainage characteristics between the first-mentioned soils and the last. This soil occurs, for the most part, as flat or undulating poorly drained areas of the till plain that covers the greater part of the county. It also occupies some old bottom lands adjacent to Onamia very fine sandy loam. In such areas the surface layers are thicker, and gravelly strata are present here and there in the deep subsoil. Boulders are numerous on and below the surface.

From 20 to 25 percent of the land is more or less improved, but probably less than one-half of the improved land is under the plow. The uncleared land in many places is covered with willow, dogwood, and alder thickets, or with fair-sized elm, basswood, ash, sugar maple, red oak, bur oak, and a few white pine trees. Poplar thickets are common on the burned-over areas.

Freer silt loam is farmed in conjunction with the adjoining upland soils, where only small areas of it occur as depressions and strips intermingled with such soils. Many of the larger and wider draws and flats are reserved for meadow and pasture. The more extensive areas of this soil that comprise the greater part of a single farm are farmed in a similar manner as the nearby better drained soils.

Where the land is well drained, excellent yields of the common farm crops are obtained. Silage corn yields from 10 to 16 tons to the acre; ear corn, of which but little is grown, 30 to 50 bushels; oats, 50 to 70 bushels; barley, 35 to 50 bushels; potatoes, 125 to 175 bushels; and clover hay, 2 to 3½ tons. The natural drainage of this soil is inadequate for the most successful production of alfalfa, and losses from winter-killing are serious. During the drier seasons, however, yields superior to those commonly obtained on the better drained soils may be expected.

Warman very fine sandy loam.—Warman very fine sandy loam is similar to Freer silt loam except that beds of stratified sand and gravel underlie it at a depth ranging from a few inches to 3 feet. The texture of the surface soil is somewhat coarser than that of the Freer soil. The Warman soil is intermediate in drainage characteristics between Onamia very fine sandy loam and Adolph silty clay loam, and it is associated with the Onamia soils. This soil varies from place to place, principally in texture of the surface soil and in the depth from the surface at which the sand and gravel occur. In some places the gravel lies within a few inches of the surface and in others within 3 feet, but, in general, it ranges from 18 to 24 inches below the surface.

In virgin areas a layer of forest litter, 1 or 2 inches thick, covers the surface soil which consists of dark grayish-brown very fine sandy loam ranging from 8 to 12 inches in thickness. It is friable and pulverizes readily. Beneath this, averaging 12 inches in thickness, is a layer of mottled grayish-brown or reddish-brown jointed sandy clay loam. This material becomes heavier with depth, and, when it is dry, the sand and gravel particles in it are firmly cemented to the finer particles, making it somewhat difficult to loosen with a spade or pick. The subsoil, consisting of stratified layers of sand and gravel, continues to an undetermined depth. The soil is acid throughout. It is most strongly acid in the first foot or two. In general, the surface is free of boulders which are numerous in a few areas but not nearly so abundant as in the heavier textured Freer silt loam. Under cultivation the uppermost 6 or 8 inches of soil is dark grayish-brown granular material.

Warman very fine sandy loam is widely distributed within areas of Greenbush very fine sandy loam and Onamia very fine sandy loam. Some of the largest bodies are around Ogilvie within areas of Greenbush very fine sandy loam. The land is level or gently undulating or, adjacent to streams or drainageways, more or less sloping. Like Freer silt loam, the virgin soil supports a mixed growth of hardwoods.

This soil is farmed in conjunction with the adjoining upland soils, within which it occurs as small depressions and irregular strips. Some of the larger wider draws and flats, as those in the vicinity of Ogilvie, are cropped to grain, usually oats and corn, whereas others are reserved for meadow and pasture. Very few farms contain this soil exclusively. Where it constitutes most of a farm, cropping and management practices are similar to those prevailing on the better drained soils. Yields average about the same as those obtained on Freer silt loam, except in dry years, when they are some-

what higher, owing to the more favorable moisture conditions prevailing.

Quamba loamy sand.—Quamba loamy sand in its virgin condition has a 1- or 2-inch layer of leaf litter overlying the surface soil which consists of grayish-brown loamy sand, 8 or 10 inches thick. Beneath this is a 24-inch layer of mottled gray and brown loamy medium sand or fine sand, which is increasingly mottled with depth. Narrow strata of finer textured silt and clay materials, ranging in thickness from $\frac{1}{2}$ to 3 inches, are distributed throughout the upper part of the subsoil. Below a depth of 3 feet the soil material is coarser, more mottled, and streaked with colored compounds of iron. In some places the subsoil contains thin layers of cemented iron-bearing material. Most of the soil is free from stone.

This soil occurs in small flat or slightly depressed poorly drained areas along streams. They are several feet higher than the normal level of water in the streams. The largest body, which comprises only 300 acres, borders Mud Creek north of Quamba. This soil also occupies artificially drained beds of ancient lakes, principally in the western part of Pomroy Township. Owing to its occurrence in such situations and to the mixed character of the parent material, this soil does not have definite and consistent characteristics of a profile. Accordingly, the soil is extremely variable, particularly in the texture of the surface soil and subsoil. Some of the bodies at one time were covered with a thin layer of peat, but, where the land is cultivated, most of this has been burned off or mixed with the soil.

In some of the more poorly drained areas, which have not been ditched or which lie adjacent to peat bogs, the soil is waterlogged. Where the soil is surrounded by heavier textured sloping lands, as in the old lake bottoms, run-off from the higher land collects on the Quamba soil. The water table is naturally high, ranging from 3 to 5 feet below the surface, and it fluctuates greatly, depending on the wetness or dryness of the year.

Only a small proportion of this soil is cultivated, most of which is in the better drained areas. The same crops are grown as on Kroschel loamy sand, and the soil is handled in a similar manner as the Kroschel soil. On account of the greater abundance of moisture in the soil, caused by a higher water table, this land is, in general, more productive during dry seasons than the better drained heavier soils.

Adolph silty clay loam.—Under virgin conditions the surface soil of Adolph silty clay loam is dark grayish-brown or black finely granular silty clay loam to a depth ranging from 8 to 15 inches. It is covered in places by a thin layer of peat. When partly dry the granules are readily shaken apart and may be compared in size to bird shot. The material in this layer is medium acid in reaction. Proximity of the soil to active stream channels results in a deeper surface layer, owing to an occasional deposition of alluvium. The surface soil is underlain by gray very strongly acid very fine sandy loam or silt loam of pronounced platy structure. Vertical dark-brown stains are most conspicuous in this part of the profile. At a depth ranging from $2\frac{1}{2}$ to $3\frac{1}{2}$ feet a pinkish-brown layer of fine sandy loam or silty clay loam occurs, which is mottled with gray and, in places,

contains vertical rusty-brown stains, similar to those in the overlying layer. Below a depth of 4 feet, a more or less permanently water-saturated layer is present. This is mottled reddish-brown and gray somewhat coherent laminated strongly acid stony sandy clay loam. This soil includes some of the stoniest land in the county. Reddish-brown sandy or gravelly strata underlie it in a few places. Beaver dams, which blocked the old drainageways, on which much of this soil has formed, have caused marked local variations.

Adolph silty clay loam is widely scattered throughout the county, occupying the most poorly drained positions on the till plain, chiefly in association with the Milaca soils. It occurs in depressions, shallow valleys, along intermittent stream channels, and bordering peat bogs. Most of the areas are flat, depressed, or, in a few places, very gently undulating.

Very little of this soil is under cultivation. Most of the land included in farms is devoted to pasture or to the production of wild hay. Under natural conditions the land supports a forest of elm, ash, basswood, willow, alder, and poplar. The most poorly drained areas are covered entirely by alder, willow, and swamp grasses.

The soil is highly productive when adequate artificial drainage is provided. In a few places this has been accomplished by open ditches, but none of the land has been tilled. Applications of barnyard manure are said to be particularly beneficial to this soil. Owing to its low-lying position, the land is subject to early fall and late spring frosts. Some of the well-drained areas are considered as desirable as the adjacent upland soils.

Bluffton silty clay loam.—Virgin areas of Bluffton silty clay loam have a 4- to 8-inch surface layer of black heavy silty clay loam which contains considerable organic matter and is, in some places, somewhat mucky. When dry the material in this layer is granular, and when wet it is moderately plastic and stiff. The next lower layer, which is about 4 inches thick, is gray heavy clay loam that appears nearly black when wet. It is underlain by light-gray or bluish-gray heavy silty clay loam which is very plastic when moist. In some places the subsoil contains many rusty-brown stains, orange- and lemon-colored compounds of iron, and layers or pockets of sandy material. Pockets of grayish-white highly calcareous material also are present in some of the mottled layers. The soil is stony, with boulders at and below the surface, but it is not nearly so stony as Adolph silty clay loam.

Bluffton silty clay loam occupies poorly drained flats, depressions, and narrow strips along sluggish drainageways in the upland and low foot slopes on the margins of peat bogs. It is associated with Brickton silt loam and Brickton very fine sandy loam. The relative positions of these soils correspond to the association of Adolph silty clay loam and Milaca very fine sandy loam. Some areas, formerly covered with a shallow coating of peat, which has been burned off, exposing the mineral soil, also are included with the Bluffton soil on the map.

Natural drainage of this soil is poor. The flatness of the areas allows practically no surface run-off of rain water or melted snow. Water penetrates the soil very slowly on account of the fine-textured

material of the surface soil and subsoil. In addition the soil receives a large part of the water draining from the surrounding higher soils, and it is more or less completely saturated for long periods. A few of the higher and better drained or artificially drained areas can be worked early in exceptionally dry years and sowed to early spring crops, such as small grains.

The native vegetation on Bluffton silty clay loam is chiefly aspen, alder, black ash, elm, balsam fir, and willow. Where the forest is not too dense there is a luxuriant growth of wild grasses among the trees. In the more or less open areas, from which the trees have been removed, heavy stands of grass are maintained and afford excellent pasture or wild-hay meadows. Many of the open areas have been seeded to mixtures of alsike clover, timothy, redbud, and bluegrass, and the value of the hay grown on them has been greatly enhanced.

Knife Lake silt loam.—Knife Lake silt loam is not an important soil. It occurs in small bodies in the southern part of the county. Under a forest cover it has a 1- to 2-inch layer of forest litter and leafmold overlying a 6- to 9-inch layer of light-gray acid smooth silt loam, faintly stained with reddish-brown iron compounds. This is underlain by a distinctly heavier layer, ranging from 10 to 18 inches in thickness, the upper part of which is gray or grayish-brown strongly acid smooth silty clay loam, and the lower part acid grayish-brown silty clay loam with a pronounced nutlike structure. On drying in a natural position, the soil material assumes a prismatic arrangement, in which the individual prisms consist of cubical aggregates. This layer rests on the parent material which consists of brownish-red gritty silty clay loam that becomes redder and coarser textured with increasing depth. There are practically no stones and cobblestones within the soil, but a few are present on the surface.

In most places the relief is level, but in a few places it is gently rolling. Natural surface drainage is somewhat deficient except on the rolling areas, and internal drainage is only fair. The native vegetation consists of a mixed hardwood forest. Formerly it included considerable white pine. Practically none of the land is under cultivation. Cleared areas included in farms are used chiefly for hay meadows or pastures.

Alluvial soils, undifferentiated.—On the bottom lands of Snake, Groundhouse, and Knife Rivers and some of the smaller streams are mixed soils which have been designated as alluvial soils, undifferentiated. They consist of black mineral soils, ranging in texture from silty clay loam to sandy loam, and light-colored sand, overlain, in places, with a shallow layer of peat or muck. Some organic soils and small areas of Adolph silty clay loam and Bluffton silty clay loam are included with these soils in mapping.

No consistent soil profile has developed in these soils, owing to the periodic flooding to which the bottom lands are subjected. A profile common to many areas is as follows: A 10- to 18-inch layer of brown or black fine sandy loam or clay loam underlain by a 16- to 24-inch layer of grayish-brown sandy loam or clay loam. This material, in turn, is underlain to a variable depth by light or dark sand, gravel, clay loam, or a mixture of these materials. These soils have more or less stratified layers throughout, with sand or gravel beds interposed between layers of finer textured material. In most areas stones are not present above a depth of 2 feet.

Much of the alluvial land is dissected by old river channels, ox bows, and backwater areas which are more or less waterlogged the year around. Here and there are small pot holes and peat bogs. Considerable variations in texture occur within short distances. In many places, areas of clean river-washed sand border tracts of finer textured clay loam with few or no transitional soil areas separating them. In a few places "islands" of better drained soil, lying well above overflow, are within the larger areas of bottom lands.

Most of the alluvial soils are devoted to pasture and wild-hay meadows, except on some of the small higher islands where crops adapted to the better drained upland soils may be grown.

Peat.—Peat occupies 16 percent of the total area of the county. It is composed mainly of plant remains which have accumulated in former lakes, ponds, wet depressed areas, and low-lying situations adjacent to some of the streams and intermittent drainageways. It occurs in all parts of the county, both within areas of sandy soils and within those of finer textured well-drained soils. Most of the peat bogs are covered with a thick layer of sphagnum moss and heath shrubs and support a growth of spruce and tamarack trees, together with some balsam fir and white cedar. Some are covered with sedges, wild grasses, and scattered swamp birch, tag alder, and willow. The thickness of the peat ranges from less than 1 foot to more than 8 feet, but most of it is more than 2 feet thick. In some places where the peat was shallow, fires have destroyed it, thereby exposing the underlying mineral soil. Most of the peat is brown or dark brown and not thoroughly disintegrated. In the northern part of the county the bogs contain much partly decomposed woody material.

In their natural condition the peat soils, which are covered with sedges and wild grasses, are used mainly as meadows, as they are, for the most part, too wet to cultivate. In the southern and central parts of the county a large acreage of peat has been drained and brought under cultivation. A serious handicap to the use of peat for the production of crops sensitive to cold, such as potatoes and corn, lies in their susceptibility to late and early frosts which may occur at any time during the summer.

Peat, shallow phase.—Areas in which the peat is less than 2 feet thick are mapped as peat, shallow phase. The shallow phase of peat is not extensive and is confined to some of the smaller depressions.

Included with the shallow phase of peat on the soil map are a number of areas of muck which consists of black decomposed plant remains intermixed with fine-textured mineral soil particles. Like dry peat, it is light in weight. When wet, it is somewhat spongy, plastic, and, where the mineral content is high, also somewhat sticky. The deposits of muck range from 8 inches to 2 feet in thickness, and they occur only in some of the small depressions and along some streams.

In their natural condition, most of the areas of the shallow peat support a thick growth of willow, alder, and aspen mixed with some of the larger hardwoods. A luxuriant growth of wild grasses has become established in areas from which the trees have been removed accidentally, by fire, or by clearing. Such areas are used for pasture or for wild-hay meadows. Under natural conditions the areas of peat and the included muck are too wet for cropping and must be artificially drained before they can be cultivated. After being drained, they may be used to produce the crops commonly grown, although

most of them must be treated with some form of commercial fertilizer, in order to make them productive.

Beach sand.—Beach sand occurs along the shores of some lakes. It also occupies low ridges which once marked the outer edges of the lakes and flats extending back from the present shore line various distances inland. The total area is very small, and the largest continuous body occupies an area of less than 10 acres around Devils Lake. The sand has no definite soil profile. The character of the material on which it lies is extremely variable in composition, consisting of white water-worked uniform sand or sand mixed with cobblestones. Here and there boulders lie on the surface or are partly or wholly embedded in the soil.

Surface drainage is, in general, poor. The better drained smoother areas are used almost entirely as sites for lake-shore homes and summer camps. None of this land is under cultivation.

AGRICULTURAL METHODS AND MANAGEMENT

Of the 334,720 acres comprising the land area of Kanabec County, 216,932 acres are in farms. Originally the land was heavily timbered, largely by white pine, although, in many places, there was a mixed coniferous and deciduous growth. Clearing was a slow and costly process; the large white pine stumps offered the greatest difficulty, as most of them had to be blasted, whereas the hardwood stumps, if left to decay for a few years, could be removed with comparative ease. Much of the land was covered with boulders, the removal of which had to be accomplished before the land could be plowed. Against such obstacles the agriculture developed but slowly. Even today large stumps and boulders, around which the land is cultivated, still remain to be blasted and hauled from the fields. In the older sections of the county, however, there are many well-established farms with comparatively large acreages of cleared and improved land.

For convenience in discussing their management, the soils of this county have been arranged in groups, on the basis of the same requirements for their improvement and similar methods of management, as follows: (1) Well-drained soils with fine-textured surface soils, some of which are stony; (2) stone-free well-drained soils with fine-textured surface soils; (3) well-drained soils with sandy surface soils and gravelly subsoils; (4) poorly drained mineral soils; and (5) peat which is naturally poorly drained.

The first group includes Milaca very fine sandy loam, Milaca fine sandy loam, Santiago silt loam, Onamia very fine sandy loam, and Greenbush very fine sandy loam. Owing to the fine texture of the surface soils and subsoils, with the exception of Onamia very fine sandy loam and Greenbush very fine sandy loam where gravel occurs in the lower part of the subsoil, crops do not suffer from drought except during prolonged dry periods. Milaca fine sandy loam is the least retentive of moisture of the soils of this group because of its somewhat coarser textured subsoil. All the soils are naturally well drained, with the exception of small flat or slightly depressed areas which could be benefited by tile or small open ditches. On the more rolling areas of Milaca very fine sandy loam, Milaca fine sandy loam, and Santiago silt loam, surface run-off, during heavy downpours, is

rapid enough to cause erosion. These soils are naturally low in organic matter, which, in many places, has been further reduced through cropping, so that the soil has lost its mellowness and becomes caked when the surface soil dries out. These soils are also deficient in nitrogen, the lack of which is the most common limiting factor in growing nonleguminous crops. Boulders on the surface or embedded in the upper part of the soil are obstacles to cultivation on the Milaca and Santiago soils. Frequent pickings of stones from newly prepared land must be made in order that they may not interfere with the use of farm implements.

Milaca very fine sandy loam is not so well adapted to alfalfa as are Brickton silt loam and Brickton very fine sandy loam, but, in years when rainfall is plentiful and well distributed, little difference in yields is noticed. Lower yields in dry years are due to a difference in root development of alfalfa plants in the two groups of soils. Roots can penetrate deeply into the Brickton soils, whereas few roots are found below a depth of 4 feet in the Milaca soils, owing to the difficulty of penetrating the indurated part of the subsoil. On Onamia very fine sandy loam and Greenbush very fine sandy loam, both of which are underlain with gravel, alfalfa, in general, gives a good crop from the first cutting, but if the rainfall in July and August is low there is but little second growth.

On the soils of this group, dairying is the principal type of farming, with mixed farming second in importance. Hay is the leading crop in acreage, followed in order by oats, barley, and potatoes. About one-third of the cropland is devoted to hay, and of this, mixed clover and timothy constitute the major part. Only a little sweet-clover is grown and is used for pasture. The acreage devoted to alfalfa is increasing annually.

The agricultural methods in use on these soils are much alike. For small grains, such as oats or barley, a good seedbed is prepared and the grain drilled in. A mixture of red clover, alsike clover, and timothy is commonly sown with the small grain. Redtop is often included in the mixture, and less commonly alfalfa. Clover and timothy are seeded without a companion crop on new land, from which the trees have been cut recently, but on which the stumps are allowed to decay so that they may be removed easily. Land that has been cleared of brush but not broken is sometimes seeded to clover and timothy. Hay is cut in the year following seeding, and the field is kept in meadow for several years thereafter or is pastured after the removal of the first crop.

Corn is grown largely as a silage crop, and in the southern part of the county some is allowed to mature. On farms not equipped with silos, corn is cut and fed as fodder. Corn commonly follows a hay or pasture crop in the rotation. On some farms it follows potatoes, rutabagas, and, in a few instances, small grain. Some of the land intended for corn is plowed in the fall, but most of it is prepared in the spring. It is considered good management to grow potatoes on clover sod or after alfalfa, although many crops follow corn and some follow small grain or are planted on newly broken land. Most of the land for potatoes is plowed in the spring, although some is plowed in the fall. Insecticides are commonly used to control

the potato beetle. Green Mountain, Irish Cobbler, and Triumph are the principal varieties of potatoes grown.

Very little commercial fertilizer is used, but all the available barn-yard manure is spread on the fields, most of it on land to be planted to cultivated crops. The rest is applied to small-grain land and hay land.

In the development of a cropping system for each farm, attention is given to the requirements and numbers of livestock kept. Some form of rotation is more or less loosely followed on most farms. A good rotation includes a grain crop, a legume-hay or pasture crop, and a clean-cultivated crop grown in regular succession. Clean cultivation is beneficial in controlling weeds, and the crop may serve as a cash crop, as potatoes. On all farms, the nontillable land provides sufficient pasture, and the hay crop grown on tillable land is cut and used for winter feeding. Some of the farmers follow a 4-year rotation including small grain 1 year, hay 2 years, and intertilled crop 1 year. The length of the rotation for any particular farm will depend on many factors and is an individual problem for each farm and farmer.

The stone-free well-drained fine-textured soils of the second group include Brickton silt loam and Brickton very fine sandy loam. Both are well supplied with lime for the production of alfalfa and sweet-clover but are naturally low in organic matter. Yields of small grains, corn, and other nonlegumes are often limited by a lack of nitrogen. The fine texture of the surface soils and subsoils imparts a high water-holding capacity to these soils, therefore they can withstand periods of drought much better than any other well-drained upland soil. They are especially well adapted to growing small grains and hay. They are the most productive soils in the county and respond readily to good farm practices. The methods of farming these soils and their management are the same as those described for the soils of the first group.

The third group, comprising well-drained soils with sandy surface soils and sandy or gravelly subsoils, includes Onamia fine sandy loam, Onamia loamy sand, Kroschel loamy sand, and Emmert loamy sand. The content of organic matter and nitrogen is naturally low in them all. The moisture-holding capacity of these soils also is low, and crops suffer from drought during dry periods. Lack of moisture is the factor that most frequently limits crop yields on these soils, and in unusually dry seasons the crops fail completely. On the other hand, earlier cultivation is possible on these soils than on the soils of the first two groups, owing to their general freedom from stones and to their much coarser textured surface soils. Maturity of corn is more certain on these soils; accordingly, a large acreage is devoted to that crop. They also can be worked under a wide range of moisture conditions. The difficulty of obtaining and maintaining a stand of clover has tended to deplete their fertility. Potatoes are planted on a large acreage, and, in seasons of ample rainfall, high yields are obtained. In general, the quality of the potatoes is excellent. On most farms, there is not sufficient manure available to maintain the fertility of the land particularly where crop rotations, including legumes, are not practiced.

The poorly drained mineral soils of the fourth group include members of the Freer, Warman, Quamba, Adolph, Knife Lake, and Bluff-

ton series. The Adolph and Bluffton soils occupy some basins with no outlets and some level areas with inadequate natural outlets. Some such areas have been provided with artificial drainage and brought under cultivation. Alsike clover, timothy, and redbtop have been seeded in some of the undrained meadows, and in other places these plants, introduced accidentally, are now growing with the wild grasses. In general these soils are supplied with lime and, with the exception of Freer silt loam, are rich in organic matter and nitrogen. Freer silt loam and Warman very fine sandy loam are naturally poorly drained, but most areas of the other soils have either natural outlets or a gentle slope to some stream or lower lying depression so that some form of artificial drainage can be provided at a comparatively low cost. Freer silt loam commonly occurs on the gentle slopes between the better drained uplands and the low depressions, whereas Warman very fine sandy loam occupies comparatively large level flats adjacent to the level slightly higher areas of Onamia very fine sandy loam and Greenbush very fine sandy loam. The deficiency in nitrogen and organic matter in Freer silt loam can be remedied by the use of a legume in the rotation and an occasional application of barnyard manure. Warman very fine sandy loam has a darker surface soil than Freer silt loam, and in general it is equally productive as that soil. The methods employed in farming these soils and the crops are the same as those employed on the well-drained upland soils. In seasons of subnormal precipitation, crop yields are higher on these soils than on the surrounding higher better drained land, owing to a greater supply of moisture.

Most of the peat soils of Kanabec County are similar to those on the Coon Creek high-lime peat experimental field in Anoka County, and the rest are similar to those on the low-lime peat experimental field in northern Mille Lacs County at Page. The former experimental field has been operated by the University of Minnesota since 1919 and the latter since 1924. The results of the experiments on the Coon Creek field are made use of in the discussion of the peat soils of Kanabec County. Satisfactory drainage is the first step in the reclamation of the bogs. Some peat bogs lie so low in relation to streams or lakes that satisfactory drainage is not practicable, and these areas cannot be reclaimed profitably. Other bogs may be satisfactorily drained by open ditches or tile or by a combination of both. Most bogs, even after the installation of drainage sufficient for ordinary seasons, are still flooded occasionally, and crops are drowned out following abnormally heavy rains.

Peat soils are seriously handicapped in their use for sensitive crops, such as potatoes and corn, by the possible occurrence of frosts in any of the summer months, the frequency of which varies greatly from bog to bog. Grasses and common clovers are practically immune to injury from such summer frosts and are the safest crops to be grown on peat soils. These crops are especially adapted to peat soils, for use as tame-hay meadows and, on the better drained ones, as pastures. Another disadvantage of peat soils is that they are subject to damage by fire set accidentally from a dropped cigarette, the exhaust of a tractor, or a grass fire, and, once started, peat fires are very difficult to extinguish. Burning of the peat may so lower the surface of a drained bog or expose such a large number of boulders as to make the soil too wet or too difficult to cultivate. Most of the peat bogs are cov-

ered with spruce and tamarack, others are covered with brush and remnants of dead trees over which fires have run repeatedly, and still others are open bogs supporting sedges and grasses. Many of the latter are used as wild-hay meadows or as poor pastures. Not more than 5 percent of the peat in this county has been drained and brought under cultivation.

Most of these soils are naturally well supplied with lime and nitrogen, but in practically all places they are deficient in phosphate and potash, which, in order to insure satisfactory yields of farm crops, must be supplied in the form of barnyard manure or commercial fertilizers. Commercial fertilizers are preferable, as the manure can be used more profitably on mineral soils, because the nitrogen, its most valuable constituent for the mineral soils, is not needed on the peat soils which are naturally rich in available nitrogen.

Some of the peat soils are of the low-lime type, similar to those of the Page peat experimental field in Mille Lacs County. So far as is known none of these areas is now under cultivation. In addition to phosphate and potash, lime is necessary, and in some instances nitrogen must be added. Farmers who have not yet drained the peat areas on their farms are advised, before going to the expense of drainage, to find out whether the areas are of high- or low-lime content. More detailed information regarding the examination and management of peat soils may be obtained from the Division of Soils, Minnesota Agricultural Experiment Station, St. Paul.

MORPHOLOGY AND GENESIS OF SOILS

The soils of Kanabec County have developed on till of the middle Wisconsin glaciation and, in some parts of the southern townships, on lacustrine deposits of the late Wisconsin glaciation. The well-drained zonal soils have developed under a forest cover of pines or mixed pines and hardwoods and are characterized by light-colored surface soils. They are in the belt designated as the Podzol soil region in the more northern part of the United States, extending from the Atlantic coast westward to central Minnesota. Both mineral and organic soils are represented, the mineral soils comprising 83.3 percent of the total area of the county.

The middle Wisconsin drift, on which most of the soils have developed, is often referred to as the "young red drift," because of the reddish-brown color of the unweathered till. The main body of this drift occupies an irregularly shaped area of about 17,000 square miles in the northeastern and central parts of Minnesota. The drift is derived largely from the crystalline rocks of pre-Cambrian age, which form the rock outcrops of northeastern Minnesota and adjoining parts of Canada. The drift is, in general, very stony, owing to the character of the crystalline rocks from which it has been derived. Limestones and shales form no appreciable part of this drift, and they have contributed little to the soil material. In some places in the southern part of the county there is evidence of some slight mixing of the two drifts. In the profiles of Santiago silt loam and Greenbush very fine sandy loam the upper part of the B horizon consists of a yellowish-brown smooth silty material of variable depth. This is not present in typical Milaca very fine sandy loam or other

associated soil types developed on typical red drift material, and the conclusion has been drawn that, after deposition of the red drift, a thin deposit of gray drift was laid down over it.

In some places exposures of glacial material of late Wisconsin age, modified by assortment and deposition by water, are found. The late Wisconsin drift is commonly referred to as the "young gray drift," owing to the grayish-brown color of the unweathered till. The material composing this drift is derived largely from limestone and shales.

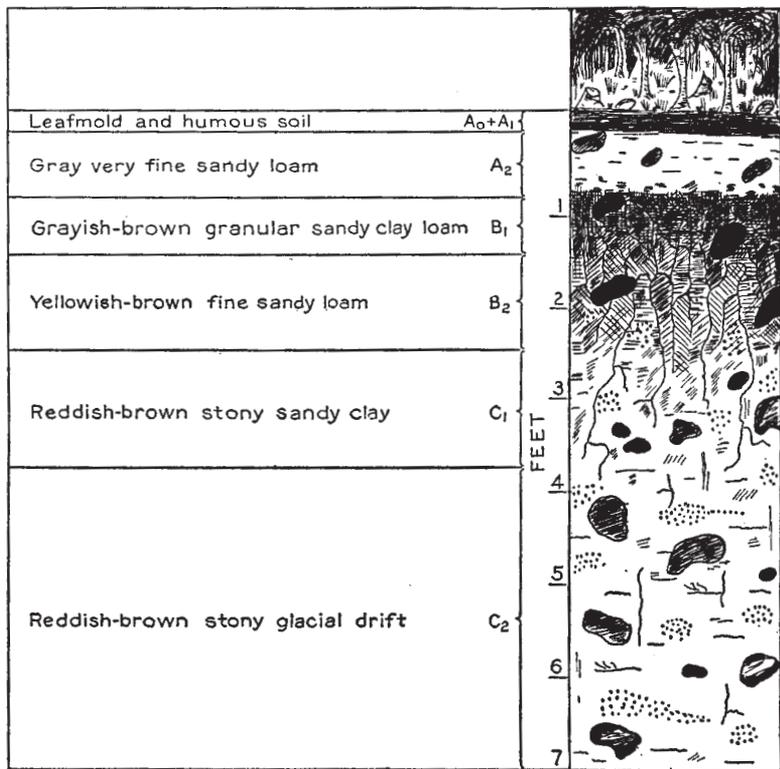


FIGURE 2.—Profile of Milaca very fine sandy loam: The description and diagram indicate the general character of the soil horizons.

The materials of these two drifts constitute the parent materials of the soils of Kanabec County. Variation in the composition of the parent materials is reflected in variations in the morphological characteristics of the soil profiles, particularly of the substratum. The effects of climate and vegetation and the condition of drainage are reflected in the degree of podzolization and in the features of the solum proper, although the character of the geological materials has influenced, to some extent, the activity of the dynamic soil-forming processes.

The principal horizons in a soil profile, of which there are three, are referred to as A, B, and C. The accompanying sketch (fig. 2) of Milaca very fine sandy loam illustrates the soil profile and its var-

ious horizons. It may be said, approximately, that horizon A refers to the surface soil, B refers to the subsoil, and C refers to the substratum of weathered parent material. The A horizon is more or less roughly equivalent to the surface layer that is disturbed in plowing and forms the plow zone or seedbed. In this county, as in other parts of Minnesota where the native vegetation is forest, the A horizon is divided into four principal subhorizons— A_{00} , A_0 , A_1 , and A_2 . The A_{00} horizon consists of the fresh organic matter of the forest floor—the freshly fallen leaves; the A_0 , of the leafmold underneath; the A_1 , of the uppermost very thin black layer of mineral soil rich in organic matter; and the A_2 , of the light-colored leached layer. The thickness of the four subhorizons combined ranges from less than 4 inches to more than 16 inches. Where it is less than the depth of plowing, generally 6 inches, part of the next lower layer, the B horizon, becomes mixed with it and forms part of the surface soil. The A horizon in general is coarser textured than the other horizons because the finer material originally contained in it has been removed by percolating waters and carried downward. The B horizon is the layer just beneath the A horizon and is finer textured and more compact, having received most of the finer material washed out of the A horizon. The C horizon, or parent material, consists of the unchanged material from which the upper two horizons were formed. Even though it is very deep in some places, there is generally very little change in chemical composition.

The well-developed and dominant soil of the county, Milaca very fine sandy loam, has been formed on the young red drift. In its undisturbed condition it has the following profile characteristics:

- A_{00} and A_0 . Dark-brown or black forest litter and leafmold, mostly from deciduous trees and generally about 2 inches thick, where it has escaped recent destruction by fire.
- A_1 . 0 to 2 inches, very dark-brown or black friable very fine sandy loam rich in humus.
- A_2 . 2 to 12 inches, light-gray or pale grayish-brown floury loose very fine sandy loam with platy structure, faintly mottled with rusty brown. The reaction is strongly acid.
- B_1 . 12 to 20 inches, grayish-brown or light yellowish-brown sandy clay loam which is extensively mottled with rusty brown. The soil particles are slightly cemented together. When dry, the structural elements comprising the soil material break into angular fragments about one-half inch thick, many of which are coated with light-gray fine material from the podzolized layer immediately above it. The reaction is acid.
- B_2 . 20 to 32 inches, yellowish-brown, slightly reddish brown, or mottled grayish-brown stony clay loam. The material is coarsely nutlike in structure, somewhat hard when dry, and is medium acid in reaction.
- C . 32 to 48 inches, reddish-brown stony clay or clay loam. When the material dries, it becomes hard and is very difficult to penetrate by pick or soil auger. Pockets and veins of sandy material are distributed throughout the soil mass. The reaction is slightly acid.

A typical profile of Brickton silt loam, which is developed on the young gray drift, shows the following characteristics:

- A_{00} and A_0 . A $1\frac{1}{2}$ -inch layer of dark-brown forest litter and leafmold. This material is slightly acid.
- A_1 . 0 to $1\frac{1}{2}$ inches, dark-gray mellow silt loam or humous soil containing a high proportion of organic matter which is thoroughly decomposed and mixed with grains of mineral soil. The material in this layer is medium acid.
- A_2 . $1\frac{1}{2}$ to 9 inches, light-gray phylliform vesicular smooth flourlike silt loam. The reaction is strongly acid.

- B. 9 to 17 inches, grayish-brown or dark yellowish-brown coarsely granular silty clay loam. The structure is nutlike, and the structure particles are roughly cubical in shape. Each is coated with a dark-brown film of organic matter. The reaction is strongly acid.
- C. 17 to 48 inches, calcareous brownish-yellow massive silty clay loam of uniform texture. Concretions of calcium carbonate are present throughout the layer. The reaction is alkaline.

Associated with Milaca very fine sandy loam is Santiago silt loam which has a similar profile, except that the B horizon is lighter yellowish brown and contains a greater quantity of fine silt and fewer pebbles and stones. This soil apparently is developed on parent material of mixed material of the red and gray drifts, the former material predominating. The soil is acid in reaction in the A, B, and upper part of the C horizons, down to a depth of about 48 inches.

The soils developed on the sand and gravel outwash plains are members of the Onamia and Greenbush series. The Onamia soils are Onamia very fine sandy loam, Onamia fine sandy loam and its rolling phase, and Onamia loamy sand. Overlying much of the sand and gravel of the outwash plain is a layer of modified drift ranging in thickness from 1 to 4 feet, which may owe its accumulation to a readvance of the ice subsequent to the deposition of the gravel outwash. In places where this layer is from 3 to 4 feet thick, the soil has characteristics similar to those of Milaca very fine sandy loam in the A, B, and upper part of the C horizons, with the single exception that it is free from boulders. Where the drift is shallower, however, the upper gravel layers, in places, form part of the lower B horizon. Areas in which the gravel layer is within 12 inches of the surface, are included with Onamia loamy sand on the map. Greenbush very fine sandy loam is developed also on outwash gravel overlain with material resulting from a mixture of red and gray drift, but it differs from Onamia very fine sandy loam in having a lighter yellowish brown and more silty B horizon. In this respect it resembles Santiago silt loam.

Kroschel loamy sand is developed on very sandy drift. This soil has an imperfectly developed profile with considerable range in morphological features. In places where the relief is rolling, some of the surface soil has been removed by washing, and this has hindered full development of the soil horizons. Emmert loamy sand is developed on kames and eskerlike ridges overlying stony gravel which outcrops in many places.

The imperfectly drained and poorly drained soils developed from red drift are Freer silt loam, Adolph silty clay loam, and Warman very fine sandy loam. Freer silt loam is typically semihydromorphic, owing to its occurrence in imperfectly drained bodies which slope gently to the lower depressions, and it is intermediate in drainage between the well-drained upland areas and the most poorly drained bodies of mineral soils or peat bogs. Adolph silty clay loam occurs in the most poorly drained depressions, and much of the land is waterlogged the greater part of the year. Much of it has profile characteristics similar to those of hydromorphic soils in other areas, such as variegated dull colors of the soil material streaked with blotches of bright-orange and lemon-colored iron stains. At variable depths below the surface the glei layer invariably is present. Warman very fine sandy loam is the semihydromorphic associate of

the Onamia soils and is extensively developed in areas where these soils occur.

Quamba loamy sand and Knife Lake silt loam are other semihydro-morphic soils; the former is developed on poorly drained low terraces along some of the streams and small bodies of former lakes and ponds, and the latter occupies poorly drained old glacial lake beds. These soils have been formed from lacustrine deposits of fine silty material admixed with some sand. Bluffton silty clay loam is derived from water-laid glacial material of the young gray drift and occupies the poorly drained flats and depressions within areas of Brickton silt loam and Brickton very fine sandy loam. It is strictly a hydro-morphic soil and occupies situations similar to those occupied by Adolph silty clay loam. The soil is well supplied with lime. In most places the upper part of the subsoil contains a large quantity of carbonates and effervesces freely with dilute hydrochloric acid.

The results of pH determinations on samples of four soils from this county are given in table 8.

TABLE 8.—pH determinations on four soil profiles from Kanabec County, Minn.¹

Soil type and sample No.	Depth	pH	Soil type and sample No.	Depth	pH
Milaca very fine sandy loam:	<i>Inches</i>		Kroschel loamy sand:	<i>Inches</i>	
322663.....	0 -15	4.6	322630.....	0 - 5	5.7
322664.....	15 -22	5.3	322631.....	5 -19	5.8
322665.....	22 -40	5.9	322632.....	19 -38	5.7
322666.....	40 -60	7.1	Knife Lake silt loam:		
Greenbush very fine sandy loam:			322606.....	0 - 3½	4.9
322614.....	0 - 5	4.7	322607.....	3½-11	5.0
322615.....	5 -16	4.7	322608.....	11 -20	4.8
322616.....	16 -23½	4.8	322609.....	20+	4.8
322617.....	23½-30	5.2			
322617a.....	30 -40	5.4			

¹ Determinations made by the hydrogen-electrode method in the laboratories of the Bureau of Chemistry and Soils.

Peat occurs in permanently wet situations or bogs and consists largely of vegetable matter in various stages of decomposition. It supports a forest and grass vegetation. The undifferentiated alluvial soils along the stream channels are brown and black material. Most of the alluvial soils are fine textured, but large areas of sandy alluvium are associated with them.

Mechanical analyses of two soil types from this county are given in table 9.

TABLE 9.—Mechanical analyses of samples of two soils from Kanabec County, Minn.

Soil type and sample No.	Depth	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Santiago silt loam:	<i>Inches</i>	<i>Percent</i>						
322622.....	0 - 1½	0.5	2.5	3.3	5.3	9.8	65.0	13.7
322623.....	1½-10½	.4	1.9	2.8	5.4	12.2	65.4	11.9
322624.....	10½-19½	.9	2.7	4.4	9.8	15.2	45.0	21.9
322625.....	19½-40	4.8	12.0	14.7	23.4	10.5	22.8	11.9
Freer silt loam:								
322618.....	0 - 5	.9	3.5	2.7	2.9	5.1	44.2	40.7
322619.....	5 - 9	1.9	7.9	5.9	3.3	3.7	56.1	21.2
322620.....	9 -17	2.4	9.7	7.2	4.1	5.2	54.8	16.7
322621.....	17+	25.5	36.4	16.9	10.4	1.8	3.9	5.2

¹ Includes organic matter.

SUMMARY

Kanabec County is in the east-central part of Minnesota. The county is a comparatively smooth plain with the exception of some areas of hilly land along Snake River and some ridges and knolls of stony gravelly material in some of the southern and central townships. Peat bogs occupy a large part of the total area. The climate is temperate with rather long cold winters and short pleasant summers. The average length of the frost-free season is 128 days, and the average annual precipitation is 26.47 inches. The climate is favorable for the production of small grains, forage crops, root crops, and potatoes. The growing season is too short to grow corn for grain, except the early-maturing varieties; therefore, most of the corn is used for silage and fodder. Both the soil and climate are favorable to the growing of potatoes of excellent quality, and on newly cleared land or land previously in clover the yields are large. Grasses and clovers grow abundantly. More than one-third of the plowed land is devoted to the production of tame-hay crops, mixed clover and timothy ranking first among them. Dairy farming is the prevailing type of agriculture, and butterfat is the chief dairy product sold.

Dairy cattle are the principal kind of livestock on the farms. Many of the herds are grades, but purebred sires are used almost exclusively. The gross income on the majority of the farms is derived from the sale of dairy products, poultry products, potatoes, and wool. The value of all agricultural products produced in 1929 amounted to more than \$2,700,000. Practically all the grain produced is fed on the farm.

The materials on which the soils have developed were accumulated by glacial processes and are both ice-laid and water-laid. For the most part, fine-textured soils, such as very fine sandy loams and clay loams, have been formed from the ice-laid materials, whereas coarser textured soils, such as sandy loams and sands, have been formed from the water-laid material, with the exception of those laid down in glacial lakes.

This county lies within the Podzol soil region which occupies the more northern latitudes of the United States, extending from the Atlantic coast westward to north-central Minnesota. The original vegetation of this region was a forest of coniferous and deciduous trees, although, in some places, pines alone formed the cover. Most of the mineral soils are well drained, with the exception of small depressions and areas along some of the streams. The upper layers of the well-drained soils which have been developed on the finer textured ice-laid material are thoroughly weathered and leached, and much of the plant nutrients and of the soluble bases, including lime and magnesia, have been removed from the surface soil. This has resulted in a strongly acid condition in the upper layers of the soil. The dense forest cover, under which these soils have developed, has hindered the accumulation of organic matter and nitrogen. Hardwoods and white pines grew on the moister and more fertile soils, whereas jack pines covered the more droughty soils.

The chief obstacle to cultivation of the heavier textured soils is the great number of boulders lying on the surface and embedded in the soil. The amount of labor required for their removal has limited the acreage of land devoted to the production of agricultural crops necessary for the winter feeding of livestock. Most of the sandy soils contain fewer boulders than the heavier textured soils, but, owing to their droughty character, they seldom return high yields of grain and forage crops.

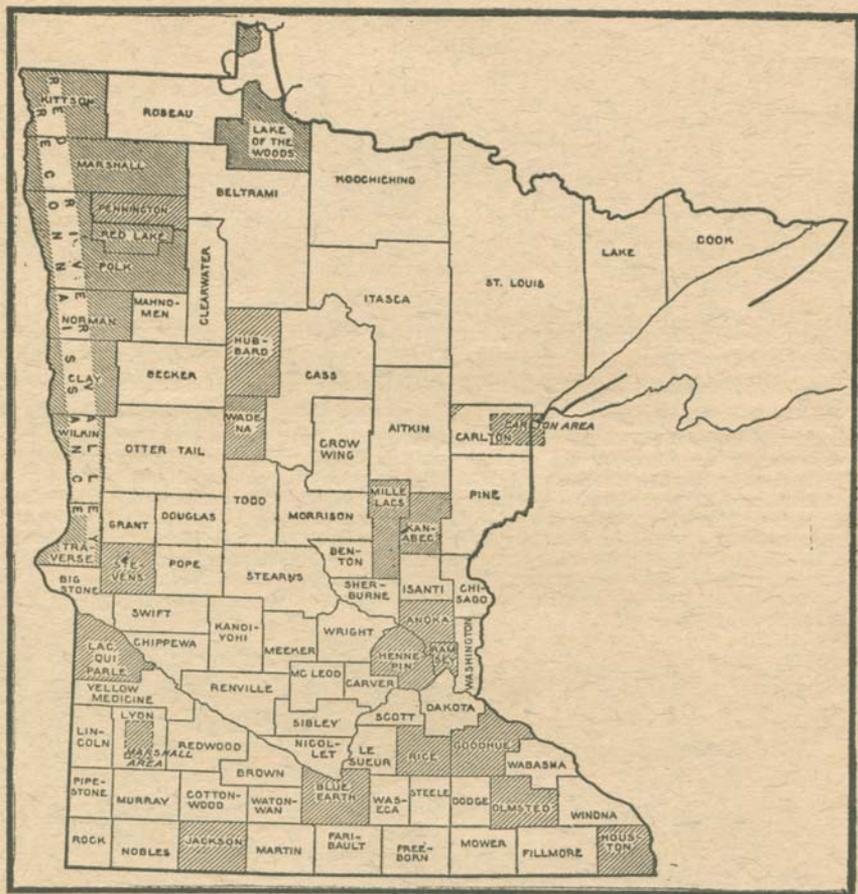
The soils have been placed into four broad groups on the basis of productivity. The first group comprises the soils with medium-textured surface soils and clay loam subsoils and includes Milaca very fine sandy loam and its rolling phase, Santiago silt loam, Brickton silt loam, and Brickton very fine sandy loam. These constitute the most productive soils of the county. The Brickton soils are practically stone free. They are best adapted to all the crops commonly grown and are the choice agricultural soils. The second group comprises soils with medium-textured surface soils and sand and gravel subsoils. They are Milaca fine sandy loam and its hilly phase, Onamia very fine sandy loam, Onamia fine sandy loam and its rolling phase, and Greenbush very fine sandy loam. With the exception of Milaca fine sandy loam, which occupies the strongly rolling upland, the soils are, in general, free from stone. The sand and gravel in the lower part of the subsoils make them somewhat droughty, and, unless the rainfall is ample and well distributed over the growing period, crop yields are low. The third group includes soils with sandy surface soils and sand or gravel subsoils. The members of this group, Onamia loamy sand, Kroschel loamy sand, and Emmert loamy sand, are the least productive soils of the county. They are droughty and, at times, subject to drifting. Emmert loamy sand occupies stony ridges and sandy knolls and is practically worthless for farming. Poorly drained mineral soils in the depressions and flats within areas of soils of the other groups, extensive bodies of peat which occur in all parts of the county, alluvial soils, undifferentiated, and beach sand constitute the fourth group—the poorly drained soils. Aside from peat, the most extensive soil type of this group is Freer silt loam. Associated with it are Warman very fine sandy loam, Adolph silty clay loam, Bluffton silty clay loam, Knife Lake silt loam, and Quamba loamy sand. The variable bottom-land soils along the streams are designated as alluvial soils, undifferentiated. Some of these poorly drained soils can be artificially drained and made highly productive with no great outlay of capital, but others are enclosed in basins, lie so low, or are so stony that drainage is neither practicable nor profitable.

The greatest agricultural development has taken place in the central and southern parts of the county. These soils were the first to be farmed because of their relative accessibility, higher degree of fertility, and comparative freedom from stone. Much of the land in the southern and central parts is still in forest or remains unimproved, largely because of the great number of stones and stumps on it. The northern part is far less developed, because of the expense necessary to clear and remove the stones from the land, in addition

to the general inferiority of the soil. Somewhat more than 60 percent of the land area was reported in farms in 1935. The improved land represents about 25 percent of the total area of the county. The average size of the farms is 125.6 acres, of which an average of 50.2 acres is cleared and in crops. This is not all tillable land, however, as a large part of the hay land is burdened with rocks and stumps. About 75 acres of land on each farm is used for pasture, most of which is covered with scattered trees, brush thickets, stumps, or stones.

Authority for printing soil survey reports in this form is carried in the Appropriation Act for the Department of Agriculture for the fiscal year ending June 30, 1933 (47 U. S. Stat., p. 612), as follows:

There shall be printed, as soon as the manuscript can be prepared with the necessary maps and illustrations to accompany it, a report on each soil area surveyed by the Bureau of Chemistry and Soils, Department of Agriculture, in the form of advance sheets bound in paper covers, of which not more than two hundred and fifty copies shall be for the use of each Senator from the State and not more than one thousand copies for the use of each Representative for the congressional district or districts in which a survey is made, the actual number to be determined on inquiry by the Secretary of Agriculture made to the aforesaid Senators and Representatives, and as many copies for the use of the Department of Agriculture as in the judgment of the Secretary of Agriculture are deemed necessary.



Areas surveyed in Minnesota shown by shading. Detailed surveys shown by northeast-southwest hatching; reconnaissance surveys shown by northwest-southeast hatching.

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