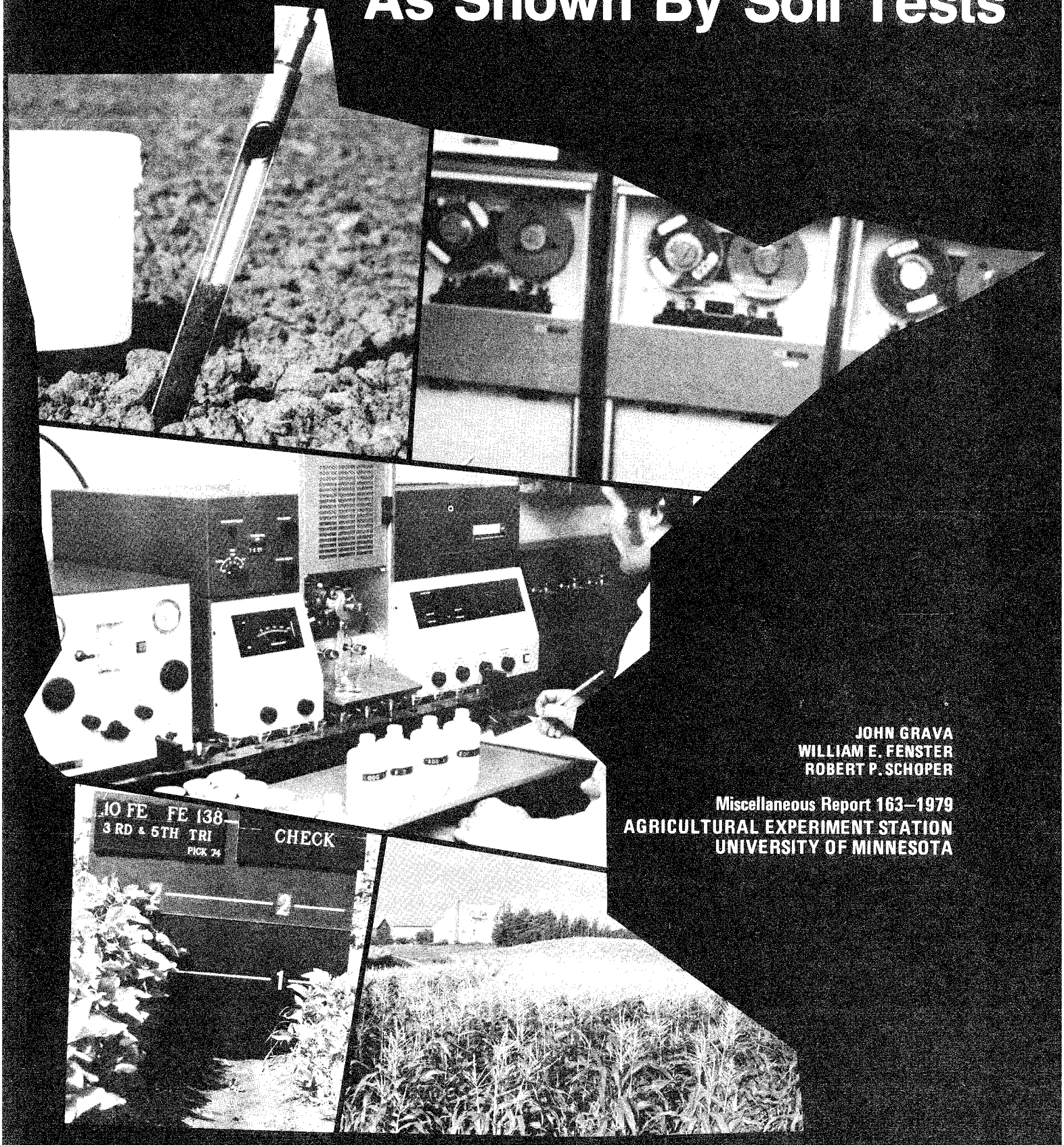
Fertility Status Of Minnesota Soils As Shown By Soil Tests



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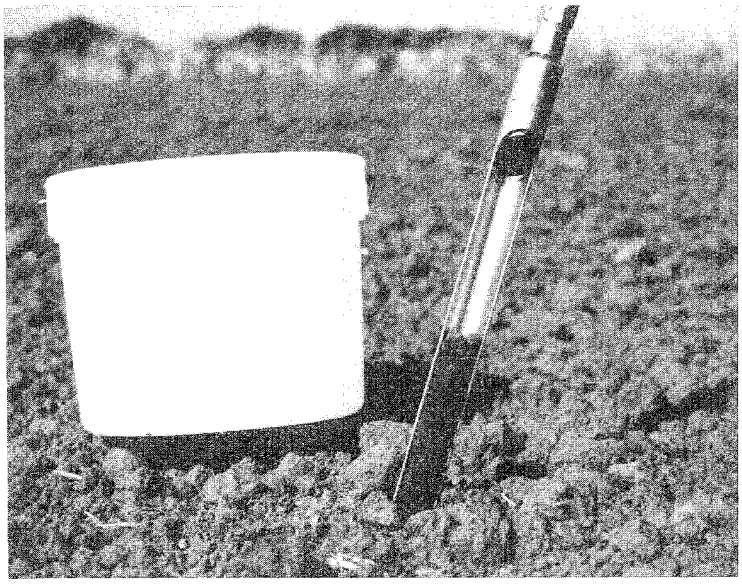
Introduction

An important responsibility of the Soil Science Department, shared with the Agricultural Extension Service, is to provide farmers and homeowners with reliable information on the use of fertilizer and soil amendments. Research by soil scientists provides information which is implemented into soil test analyses and recommendation programs. Soil testing has progressed during the last 28 years from the use of simple color indicators to sophisticated laboratory instruments and computers. Its development reflects changes and needs experienced in farming and the fertilizer industry.

During the 1940s, simple field kits were used by soil scientists for trouble-shooting purposes. In 1949, the Minnesota legislature allotted funds for the University of Minnesota Soil Testing Laboratory. Recommendations for fertilizer use were made at the laboratory after its establishment on January 1, 1950. In 1954, improved methods for phosphorus and potassium were introduced. Staff of the University of Minnesota Soil Science Department and Soils Extension published the first guide to fertilizer use based on soil tests in 1954. This fertilizer guide has been updated at various times as new research information became available. Intensive training sessions on soil fertility were first held in 1955 and county agents started to make recommendations. A chemical organic matter test was introduced in 1956 as a substitute for the nitrogen test desired by farmers and industry.

Soil test results are no better than the sample. It is extremely important that the samples are properly collected.



From 1959 to 1962, more than 300 soil test correlation-fertilizer demonstration trials were established, with county agents and vo-ag teachers tending and harvesting the plots. In 1968, the laboratory started to provide tests for zinc, sulfur, soluble salts, and adopted the SMP (Shoemaker, McLean and Pratt) buffer lime requirement test. A computerized recommendation program for farm crops was introduced in 1968 and expanded to lawns and gardens in 1972. The laboratory started to test for nitrate in 1971. The DTPA method for micronutrients was introduced in 1976. More than a million samples have been processed by the laboratory since 1950. Currently nearly 50,000 samples are tested annually.

A primary purpose of the University of Minnesota soil testing program is to furnish an individual farmer with dependable information on lime and fertilizer needs of each of his fields. In addition to this direct service, summaries of soil test results can be prepared which indicate the overall fertility status of soils in a given area. This information is useful in planning and developing

research, educational and sales programs in soil fertility.

Soil test summaries delineate potential problem areas relating to soil acidity and plant nutrient levels and can serve scientists as guides in orienting their research projects. Extension personnel and teachers find summary data helpful as teaching aids. Summaries are useful to the fertilizer and lime industries by pointing out areas of greatest need for their products.

Soil test results have been summarized periodically since the establishment of the University of Minnesota Soil Testing Laboratory. Burson and co-workers (2) used summaries to illustrate soil fertility problems in the state. Results of soil samples tested during 1954 and 1955 were summarized by laboratory personnel and published in 1956 (5). Most recent summaries were published in 1964 (6) and contained data from 45,346 selected soil samples processed from 1954 to 1962.

The data reported here summarizes 187,991 soil test results for farm soil samples received between September 11, 1968, and December 31, 1976, by the University of Minnesota Soil Testing Laboratory. The summary data are presented on the following pages in tabular and map form.

This report presents, in a general way, the fertility status of various soils of Minnesota.

Laboratory Procedures

Following is a brief description of analytical methods used by the University of Minnesota Soil Testing Laboratory (3).

Sample Preparation. Samples are dried overnight in a metal cabinet equipped with a heating element and an exhaust fan to remove moisture-laden air. The temperature in the cabinet does not exceed 37°C in order to approximate air-drying conditions.

Samples are crushed with a mechanical mortar and auger grinder and passed through a 10-mesh sieve. Samples, submitted for the zinc test, are crushed with a wooden roller and passed through a 10-mesh stainless steel sieve to avoid contamination.

Soil pH and Lime Requirement. The pH is determined with a glass electrode pH meter on a 1:1, soil/water, suspension. Samples of mineral soils with pH values of less than 6.0 are saved for the lime requirement test.

Ten milliliters of SMP buffer solution are added to the samples (5 grams soil: 5 milliliters water). The buffer index of the suspension is determined with a pH meter, after the sample has been stirred intermittently for 20 minutes.

Extractable Phosphorus. The soil phosphorus measured is that which is extracted by a solution consisting of 0.025 *N* HCl and 0.03 *N* NH_4F, commonly referred to as Bray-1 extractant. One gram of soil and 10 milliliters of extractant are shaken for 1 minute. The amount of phosphorus extracted is determined by measuring the intensity of the blue color developed in the extract when treated successively with ammonium molybdate-hydrochloric acid and amino-naphthol-sulfonic acid solutions. An absorption spectrophotometer is used to measure this color which is converted to pounds per acre of phosphorus on the basis of 2 million pounds of soil in the surface 6 inches of an acre.

Exchangeable Potassium. Potassium is extracted from the soil samples with 10 milliliters of normal neutral ammonium acetate mixed with 2 grams of soil. The amount of potassium removed by this reagent in 1 minute is designated as exchangeable potassium and is measured by passing the filtered extract through a flame emission spectrophotometer. Results are expressed as potassium in pounds per acre.

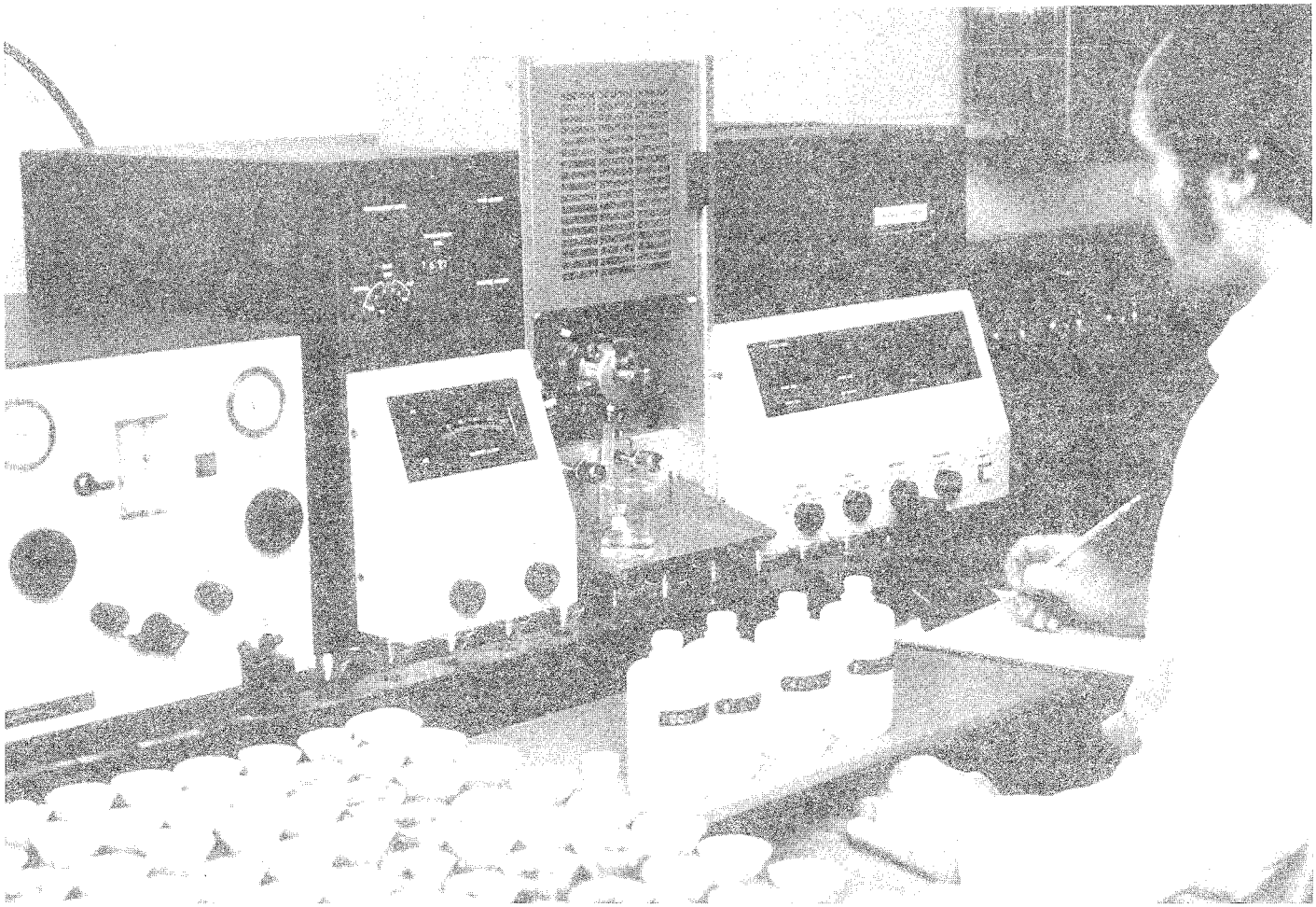
Texture and Organic Matter. The relative amounts of sand, silt and clay are estimated by the feel of the soil in a plastic condition. Clay loam, silty clay loam and clay are termed fine textured soils. Medium textured soils include loam, silt loam and sandy loam. Loamy sand and sand are coarse textured soils. Organic soils include peat and muck.

Organic matter (O.M.), is estimated visually by comparing the color of a dry soil sample with a set of standard soils. The classifications used are: "low" for light colored soils (O.M. less than 3.1 percent), "medium" soils of intermediate color (O.M. approximately 3.1-4.5 percent), and "high" for dark-colored mineral soils (O.M. more than 4.5 percent). The "very high" category is used for peats and mucks.

Extractable Zinc. Zinc is determined by treating 15 grams of a sample with 30 milliliters of 0.01 molar EDTA and 1.0 molar ammonium carbonate. After shaking for 30 minutes, the soil is filtered off and the extract analyzed on the atomic absorption spectrophotometer. The results are reported as parts per million of zinc in the soil. (Note: the University of Minnesota Soil Testing Laboratory adopted the DTPA method for zinc in September, 1976. All samples in the current summary, 1968-1976, were determined by the EDTA method.)

Extractable Sulfur. The readily soluble and the adsorbed sulfates are extracted with a monocalcium phosphate solution containing 500 parts per million of phosphorus. Twelve grams of soil are treated with 30 milliliters of extracting solution and shaken for 30 minutes. The sulfate content in the filtrate is determined turbidimetrically. The results are reported as parts per million of extractable sulfur.

Soluble Salts. A saturation extract is prepared by adding a specific amount of demineralized water to the soil sample. After an equilibration time of 2 hours, about 5 milliliters of the saturation extract-filtrate are removed by suction and collected in a plastic tube. The electrical conductance is determined with a Solu Bridge and reported as millimhos per centimeter at 25°C.



Potassium and zinc contents of soil samples are determined in the atomic absorption spectrophotometer. Analytical methods, equipment, and laboratory personnel determine the reliability of test results.

Interpretation Of Results

Table 1 shows the general interpretation of phosphorus and potassium test levels for Minnesota soils (4). The relative levels, from low to very high, are inversely related to the probabilities for obtaining a yield response to the nutrient in question.

Table 1. Interpretation of phosphorus and potassium contents of Minnesota soils.

Relative level	Extractable phosphorus	Exchangeable potassium
	lb/acre	
Low	Less than 11	Less than 101
Medium	11-20	101-200
High	21-30	201-300
Very high	More than 30	More than 300

Source Of Data And Procedure

The University of Minnesota Soil Testing Laboratory uses a computer to integrate analytical results with data derived from research and information provided by the farmer. The computer calculates and recommends fertilizer and lime for specific crops. Soil test results and recommendation data are placed on data processing punch cards and magnetic tape for summarization at the Computing Center, University of Minnesota, St. Paul Campus[1].

Soil Areas

The map (figure 1) indicates locations of six areas used in grouping summary data. Individual counties were grouped into five areas approximately representing broad soil groups (1). Two counties of the Twin Cities metropolitan area were placed into Area 6. Following is a brief description of the main soil groups used in these summaries (1).

Area 1 — Southeastern (SE). (A) Silty forest and prairie soils of southeastern Minnesota. Fayette, Tama, and Downs soils are the predominant soil series. (B) Medium textured prairie and prairie border soils of southeastern Minnesota. Well known soil series include Kasson, Skyberg, Floyd, Ostrander, Kenyon, and Racine.

Area 2 — South Central (SC). (A) Medium to fine textured prairie soils of south central Minnesota. Well known soils series: Clarion, Nicollet, Webster, Truman, and Marna. (B) Medium to fine textured

[1]The authors are grateful to David G. Schempp, Senior Analyst Programmer and the staff of the Computing Center, University of Minnesota, St. Paul, for their assistance in preparing the data for publication.

prairie border soils of central Minnesota. Well known soil series: Lester, LeSueur, Estherville, Wadena, Hubbard, and Hayden.

Area 3 — West-Central and Southwestern (WC, SW). (A) Medium to fine textured prairie and prairie border soils of western Minnesota. Major soil series: Aastad, Barnes, Flom, Buse, and Waukon. (B) Silty prairie soils of southwestern Minnesota. Well known soil series: Kranzburg, Moody, and Vienna.

Area 4 — Northwest (NW). Coarse to fine textured prairie soils, forest soils, and organic soils of Glacial Lake Plains. Major soil series: Bearden, Glyndon, Fargo, Grimstad, Rocksbury, Ulen, and Sioux.

Area 5 — Northeast and North Central (NE, NC). (A) Coarse, medium, and fine textured forest soils of east-central Minnesota. (B) Medium textured forest soils of north-central Minnesota. (C) Coarse to fine textured forest soils of northeastern Minnesota. (D) Coarse to fine textured forest soils and organic soils of Glacial Lake Plains. Predominant soil series: Flak, Brainerd, Milaca, Mora, Bock, Nebish, Rockwood, Ontonagon, Hiwood, Indus, and Taylor.

Area 6 — Twin City metropolitan includes field samples received from Hennepin and Ramsey counties.

Soil Test Summary Data

This is the most recent summary prepared from soil test results of 187,991 farm samples analyzed by the University of Minnesota Soil Testing Laboratory between September 11, 1968, and December 31, 1976.

The summary data are presented in tabular and map form. Tables 2 to 15 contain soil test results and plant nutrient recommendations for major crops of six soil areas. Soil pH, phosphorus and potassium results also are reported by county in tables 16 to 21, and figures 2, 3, and 4.

Soil tests reflect the present fertility status of a soil and do not evaluate the changes brought about in the native fertility by soil management factors such as liming, fertilization, and cropping. The influence of these factors can be determined accurately only by continuous testing under known conditions.

Previous soil test summaries, published in the 1950s and 1960s (2, 5, 6), reflected, by and large, the native fertility of Minnesota soils. The consumption of fertilizers and liming materials during that period was relatively low. The total consumption of three macronutrients (N, P_2O_5, K_2O) in 1950, for example, was only 71,032 total tons (7). By 1960, it had reached 266,685 tons, and in 1970, had increased to 721,179 tons. The consumption of liming materials in Minnesota, however, has been relatively low. The peak in lime sales was reached in 1958, when nearly 750,000 tons were sold to Minnesota farmers. Currently less than half a million tons of liming materials are used on agricultural lands in the state each year.

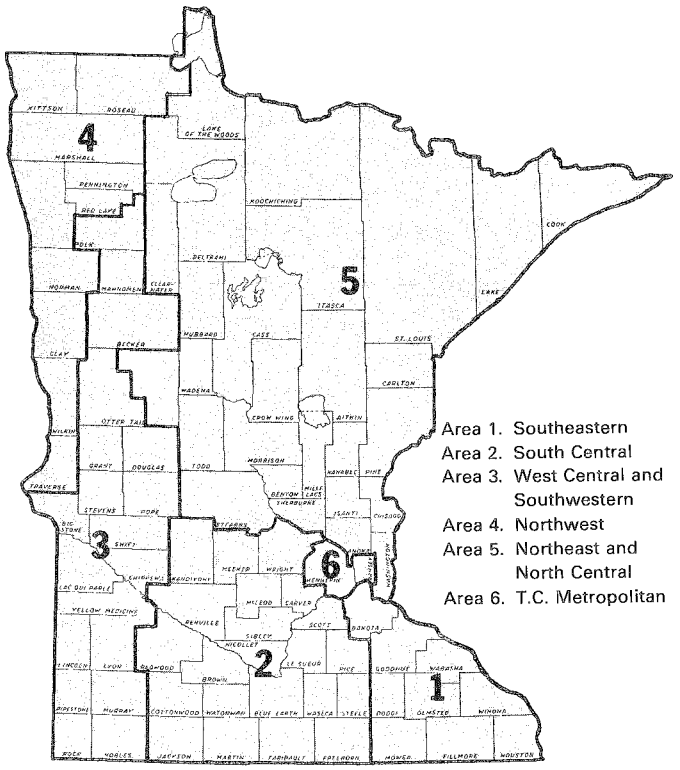


Figure 1. Breakdown of the state into six major areas.

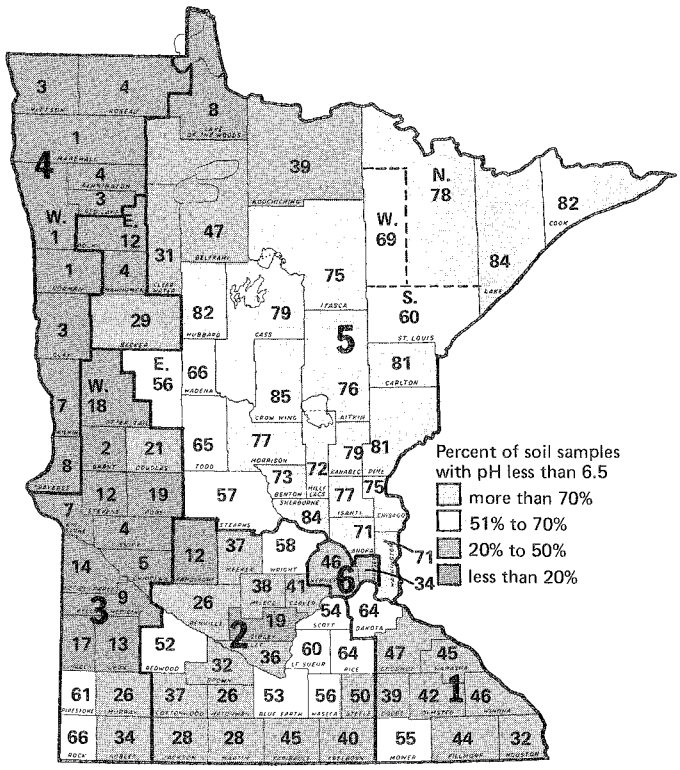


Figure 2. Relative acidity of Minnesota soils.

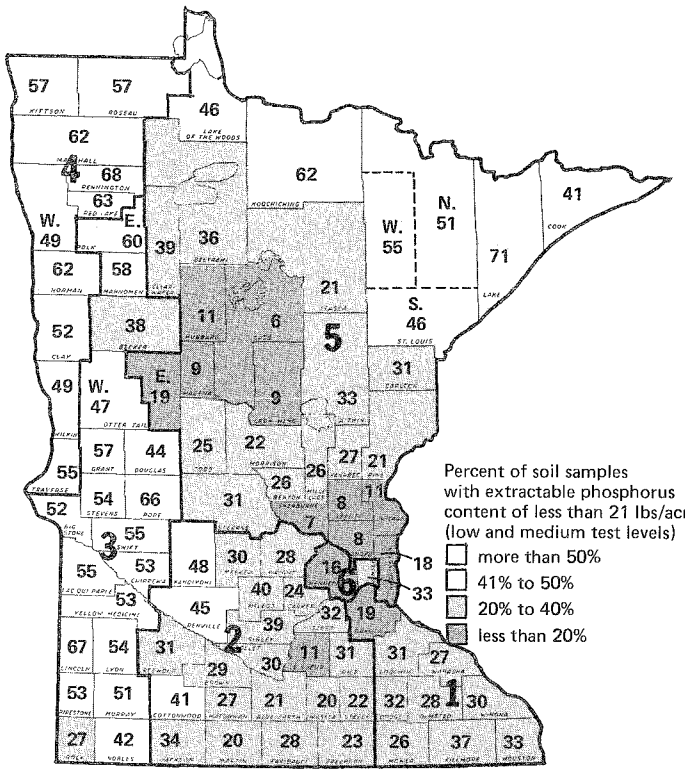


Figure 3. Phosphorus levels of Minnesota soils.

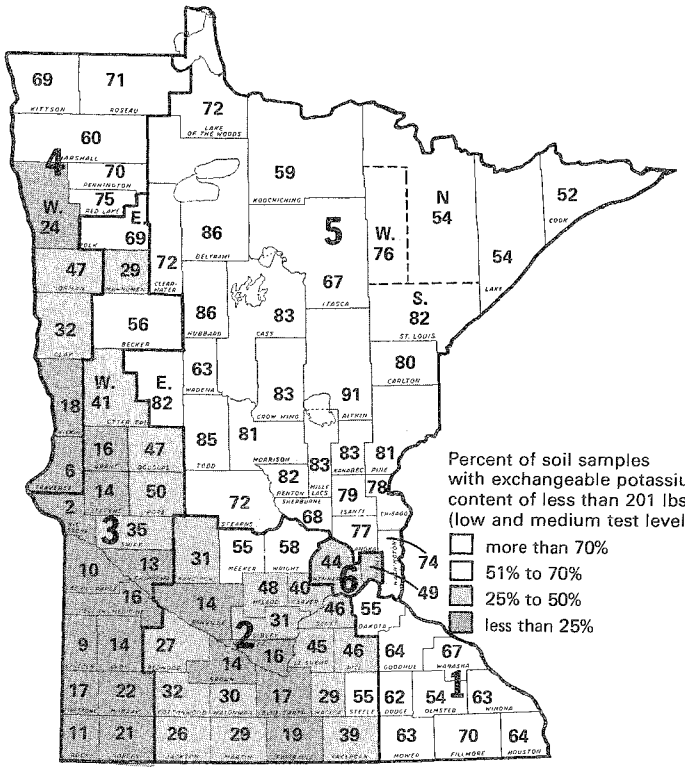


Figure 4. Potassium levels of Minnesota soils.

Texture and Organic Matter

Total number of samples and the distribution of samples in various texture and organic matter categories are shown in table 2. The soils of southeastern Minnesota are predominantly medium textured and low to medium in organic matter. The soils of the south central and western areas contain relatively high organic matter. A large percentage of soils in northeastern and north central Minnesota fall in the medium and coarse texture categories and are relatively low in organic matter.

Relative Acidity (pH)

A definite pattern in relation to soil acidity and geographical location exists in Minnesota (table 3 and figure 2). The pH value of 6.5 is chosen as the dividing point because generally no lime recommendations are made on soils having pH 6.5 or above. Soil pH is a result of the parent material from which it was developed and is affected by leaching, cropping, fertilization, depth of plowing, and liming. Deeper plowing of soils that have alkaline or limy subsoils, as practiced by many farmers in recent years, often results in higher pH values of samples collected from the plow layer. Effects of deeper plowing and the relatively low consumption of liming materials in the state may account for the lack of noticeable shifts in pH levels of soils when compared to previous summaries.

The highest percentage of acid soils are found in eastern Minnesota, with the percentage decreasing gradually toward the west. Soils of the Red River Valley and adjoining areas are predominantly alkaline, as shown by the high percentage of samples with pH of more than 7.4. Such soils may have problems common to calcareous soils, such as phosphorus fixation, iron chlorosis, and zinc deficiency.

Phosphorus

The relative phosphorus availability is indicated in table 4 and figure 3. The phosphorus content of Minnesota soils appears to be related to soil pH. The alkaline soils of western Minnesota (areas 3 and 4) are lowest in phosphorus availability while the acid soils of northeastern and north central Minnesota (area 5) are relatively high.

Relatively high amounts of phosphate fertilizer are used in Minnesota. In 1970, for example, 223,126 tons of P_2O_5 were sold in the state (7). In many instances, farmers have continued to use high rates of this nutrient, even though soil tests have indicated very high levels.

Generous use of phosphorus fertilizer is expected to be reflected in soil test levels. A comparison of phosphorus test results of previous summaries (5) and the current ones, indeed, indicated a noticeable shift, particularly in some

counties of south central and southeastern Minnesota. In 1956, summaries for Faribault, Martin, and Watonwan counties (area 2) showed 63 to 70 percent of samples classed as low and medium in extractable phosphorus. In contrast, current summaries (table 17) show only 20 to 28 percent of samples falling into these categories. Mower and Goodhue counties (area 1) had 55 to 62 percent of samples classed as low and medium in 1956, while in the 1968-1976 summaries (table 16) this percentage had decreased to 26 to 31.

Potassium

The relative potassium availability is indicated in table 4 and figure 4. According to the summary data, roughly 60 percent of Minnesota soils show low to medium potassium levels. These soils are found mainly in the northeastern, north central, and southeastern portions of the state (areas 1 and 5). Most fine textured soils of south central and western Minnesota (areas 2, 3, and 4) contain relatively high amounts of exchangeable potassium.

Current summaries do not show the potassium availability differences between the fine textured soils, with high potassium availability, and the coarse textured soils having low potassium availability of northwestern Minnesota (area 4) shown by previous summaries (5, 6). The area shows 57 percent of samples falling in the low and medium categories.

Two factors may account for this situation. First, the area now includes both the fine and the coarse prairie soils and organic soils of Glacial Lake Plains. In fact, 73 percent of the samples from the area in this summary were medium and coarse textured soils (table 2). A second factor is the large percentage of samples (73 percent) representing fields to be planted to wheat and other small grains. These two factors seem to account for the relatively low potassium availability, as indicated by the current soil test summary, for the northwestern area as a whole and for several counties (Kittson, Marshall, Norman) in particular.

Soil test summaries also indicate certain potassium buildup in soils of some counties of the south central area. In 1956, Faribault, Freeborn, Martin, and Watonwan counties had 52 to 76 percent of samples classed as low and medium, while in the current summary the percentage ranged from 19 to 39. Potassium levels also have increased in soils of some counties of southeastern Minnesota. In the earliest summaries Mower County, for example, had about 90 percent of soils classed as low and medium in potassium, while this summary shows only 63 percent of samples in these categories. This shift in test levels, most likely, resulted from liberal use of potassium fertilizers brought about by field trials, fertilizer demonstrations, and soil test data obtained during the 1950s and 1960s which all pointed out the need for this plant nutrient.

The University of Minnesota Soil Testing Laboratory employs the computer to integrate analytical results with the data derived from research and with the information provided by the farmer.

Sulfur, Zinc and Soluble Salts

The percent distribution of results by area for three special tests which are available to growers upon request is reported in table 5. More than 40 percent of the samples received from north central and northeastern Minnesota (area 5) showed less than 7 ppm of sulfur, which is considered to be a low level. This is in agreement with the generally accepted fact that many soils in this area are sulfur deficient (4, 8). It should be noted that the S test measures only one form of sulfur in the soil, namely, the soil solution and adsorbed sulfate. It does not take into account, however, organic and atmospheric forms which may contribute a considerable amount of sulfur to the total sulfate pool available to the crop during the growing season. The present sulfur test, therefore, is particularly well suited for soils that contain relatively low amounts of organic S (as found in area 5), but it has limitations in measuring S availability in soils having medium and high organic matter contents. Soils of southern and western Minnesota have a relatively high sulfur supplying capacity (8). This apparently large reserve of S is mainly in the organic form and becomes available through the process of mineralization. So the relative need for sulfur in areas 1, 2, and 3, having 16, 12, and 23 percent of samples, respectively, classed as low, must be viewed with the limitations of the soil test in mind.

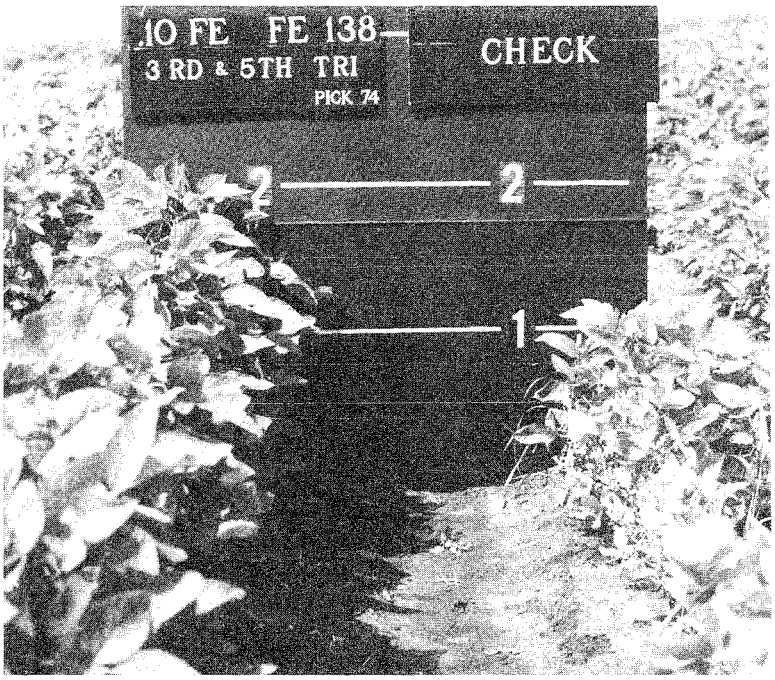
The soils from western Minnesota (areas 4 and 5), which are predominantly alkaline, had slightly higher percentage of samples falling in the low zinc category (less than 1.3 parts per million zinc) than the neutral and acid soils of other areas.

Only 5 percent of the total samples submitted for the soluble salt test showed levels of more than 4 millimhos/cm, which may have a detrimental effect on crop growth. The great majority of samples had readings of less than 2 millimhos/cm, indicating that the soils are "non-saline" and are not affected by salt problems.

Fertilizer Recommendations

Summary data pertaining to recommendations are shown in tables 6 to 15. Percent distribution of samples by crop and area is given in table 6. According to the summary data, half of the samples from southeastern and south central Minnesota and more than a third of the sample from area 3 were collected from fields to be planted to corn. In contrast, wheat and other small grains were the major crops in northwestern Minnesota receiving recommendations. Alfalfa was the third major crop, particularly in the eastern part of the state.

Tables 7 to 15 show percent distribution of samples by area according to the amount of three major plant nutrients recommended for major crops. Included are: corn, soybeans, wheat, other small grains, alfalfa, clovers, grass pastures, and hay.



Research by soil scientists provide information used in soil test analysis and recommendation programs.

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The farmer, when he collects soil samples from his fields, does so in expectation of receiving sound advice on fertilizer and lime use. The recommendations, therefore, culminate the efforts of many persons involved in research and actual testing.

Table 2. Total number of samples received and percent distribution of texture and organic matter test results by area, 1968-1976.

Area	Number of samples	Texture				Organic matter			
		Fine	Medium	Coarse	Organic	Low	Medium	High	Very High
		Percent of samples							
1. Southeast	29,569	2	88	9	1	43	46	11	<1
2. South Central	34,489	30	55	13	2	13	31	55	1
3. West Central and Southwest	23,436	22	54	21	3	7	28	63	2
4. Northwest	25,238	23	53	20	4	5	15	77	3
5. Northeast and North Central	66,409	3	47	41	9	63	27	8	2
6. Twin City metropolitan	8,850	6	50	34	10	25	44	28	3
State	187,991	13	57	25	5	35	30	33	2

Table 3. Percent distribution of pH and SMP buffer test results by area.

Area	Soil pH						SMP buffer index			
	<5.5	5.5-5.9	6.0-6.4	6.5-6.9	7.0-7.4	>7.4	<5.9	5.9-6.2	6.3-6.6	>6.6
	Percent of samples									
1. Southeast	2	13	34	34	13	4	1	16	55	28
2. South Central	2	12	31	24	16	15	<1	10	58	32
3. West Central and Southwest	<1	5	14	17	22	42	1	8	72	19
4. Northwest	<1	<1	3	6	15	76	8	21	36	35
5. Northeast and North Central	7	25	37	20	7	4	2	10	45	43
6. Twin City metropolitan	6	10	22	21	18	23	5	18	47	30
State	4	15	27	21	13	20	2	11	49	38

Table 4. Percent distribution of phosphorus and potassium test results by area.

Area	Extractable phosphorus, lb/acre						Exchangeable potassium, lb/acre				
	<11	11-20	21-30	31-50	51-100	>100	<101	101-200	201-300	301-400	>400
	Percent of samples										
1. Southeast	7	22	21	24	19	7	12	51	24	8	5
2. South Central	8	20	20	25	20	7	6	36	35	14	9
3. West Central and Southwest	23	30	18	16	10	3	7	26	33	19	15
4. Northwest	26	32	17	14	8	3	23	34	16	9	18
5. Northeast and North Central	8	17	15	22	25	13	39	38	14	5	4
6. Twin City metropolitan	13	14	13	17	20	23	17	29	21	13	20
State	12	21	18	21	19	9	22	37	22	10	9

Table 5. Percent distribution of sulfur, zinc, and soluble salt test results by area.

Area	Extractable sulfur ppm			Extractable zinc ppm			Soluble salts mmhos/cm			
	<7	7-12	>12	<1.3	1.3-2.0	>2.0	<2.0	2.0-4.0	4.1-8.0	>8.0
	Percent of samples									
1. Southeast	16	52	32	11	17	72	95	2	1	2
2. South Central	12	47	41	14	18	68	89	10	1	<1
3. West Central and Southwest	23	39	38	21	25	54	71	23	5	1
4. Northwest	8	28	64	25	30	45	75	18	5	2
5. Northeast and North Central	42	47	11	13	17	70	97	2	<1	<1
6. Twin City metropolitan	37	31	32	13	18	69	77	10	7	6
State	33	44	23	16	20	64	81	14	4	1

Table 6. Percent distribution of samples by crop and area.

Next crop	Area					
	SE	SC	WC and SW	NW	NE and NC	State
	Percent of samples					
Corn (grain and silage)	49	50	36	3	26	32
Soybeans	5	8	5	<1	2	4
Wheat	3	3	13	33	3	8
Small grains	14	6	19	34	29	20
Alfalfa	16	9	8	4	19	13
Pasture (grass) and hay (non-leguminous)	3	<1	3	3	4	3

Table 7. Nitrogen recommendations for corn (grain and silage).

Area	Amount of N to apply, lb/acre				
	<21	21-50	51-100	101-150	151-200
	Percent of samples				
1. Southeast	2	6	23	35	34
2. South Central	2	4	28	40	26
3. West Central and Southwest	3	11	65	20	1
4. Northwest	8	17	69	5	<1
5. Northeast and North Central	5	13	45	32	5
6. Twin City metropolitan	3	4	49	27	17
State	3	8	38	33	18

Table 8. Phosphate and potash recommendations for corn (grain and silage).

Area	Amount of P_2O_5 to apply, lb/acre					Amount of K_2O to apply, lb/acre					
	<21	21-40	41-80	81-120	121-140	<21	21-50	51-100	101-150	151-200	>200
	Percent of samples										
1. Southeast	32	56	8	4	0	22	28	18	24	8	0
2. South Central	32	49	8	11	<1	32	29	21	15	3	0
3. West Central and Southwest	35	49	<1	15	1	58	32	8	2	<1	0
4. Northwest	49	45	0	6	<1	56	28	16	<1	0	0
5. Northeast and North Central	72	20	5	3	<1	15	31	24	11	19	<1
6. Twin City metropolitan	53	41	5	1	0	47	24	16	9	4	0
State	45	42	6	7	<1	28	30	19	14	9	<1

Table 9. Phosphate and potash recommendations for soybeans.

Area	Amount of P_2O_5 to apply, lb/acre			Amount of K_2O to apply, lb/acre		
	0	1-20	21-40	0	1-40	41-100
	Percent of samples					
1. Southeast	59	32	9	42	50	8
2. South Central	52	33	15	61	35	4
3. West Central and Southwest	32	43	25	77	20	3
4. Northwest	39	42	19	78	18	4
5. Northeast and North Central	68	23	9	17	43	40
6. Twin City metropolitan	80	17	3	60	34	6
State	53	33	14	52	37	11

Table 10. Nitrogen, phosphate, and potash recommendations for wheat.

Area	Amount of N to apply lb/acre					Amount of P_2O_5 to apply lb/acre			Amount of K_2O to apply lb/acre		
	<21	21-40	41-60	61-80	>80	<21	21-30	31-40	<15	15-20	21-40
	Percent of samples										
1. Southeast	3	30	43	9	15	77	18	5	13	73	14
2. South Central	3	36	36	9	16	72	22	6	21	73	6
3. West Central and Southwest	15	29	33	8	15	55	29	16	34	59	7
4. Northwest	24	22	24	11	19	48	33	19	30	49	21
5. Northeast and North Central	17	32	28	11	12	65	24	11	12	55	33
6. Twin City metropolitan	5	11	6	4	74	56	18	26	57	36	7
State	19	26	28	10	17	55	29	16	27	55	18

Table 11. Nitrogen, phosphate, and potash recommendations for small grain (excluding wheat).

Area	Amount of N to apply lb/acre				Amount of P_2O_5 to apply lb/acre			Amount of K_2O to apply lb/acre		
	<11	11-40	41-60	>60	<21	21-30	31-40	<15	15-20	21-40
	Percent of samples									
1. Southeast	3	86	11	0	83	13	4	20	70	10
2. South Central	3	76	21	0	83	14	3	31	62	7
3. West Central and Southwest	3	66	31	<1	69	19	12	39	51	10
4. Northwest	4	70	25	1	61	22	17	25	48	27
5. Northeast and North Central	7	71	22	0	79	14	7	11	46	43
6. Twin City metropolitan	5	71	24	0	89	10	1	28	57	15
State	5	72	23	<1	75	16	9	19	50	31

Table 12. Phosphate and potash recommendations for alfalfa at seeding time.

Area	Amount of P_2O_5 to apply, lb/acre			Amount of K_2O to apply, lb/acre				
	<41	41-80	81-100	<61	61-120	121-180	181-240	241-360
	Percent of samples							
1. Southeast	89	11	<1	25	45	23	7	<1
2. South Central	78	21	1	42	44	12	2	<1
3. West Central and Southwest	65	20	15	75	13	8	4	<1
4. Northwest	56	24	20	43	28	16	13	0
5. Northeast and North Central	89	10	1	18	18	23	25	16
6. Twin City metropolitan	84	16	0	27	47	18	6	2
State	84	13	3	28	27	20	16	9

Table 13. Phosphate and potash recommendations for alfalfa (established stand).

Area	Amount of P_2O_5 to apply lb/acre		Amount of K_2O to apply lb/acre			
	<31	31-60	<61	61-90	91-120	121-180
	Percent of samples					
1. Southeast	74	26	70	10	16	4
2. South Central	75	25	74	7	15	4
3. West Central and Southwest	65	35	74	3	17	6
4. Northwest	55	45	58	2	21	19
5. Northeast and North Central	86	14	31	1	39	29
6. Twin City metropolitan	81	19	59	3	28	10
State	80	20	50	4	28	18

Table 14. Phosphate and potash recommendations for clovers.

Area	Amount of P_2O_5 to apply lb/acre				Amount of K_2O to apply lb/acre		
	<21	21-30	31-40	>40	0	1-80	81-160
	Percent of samples						
1. Southeast	45	18	25	12	29	47	24
2. South Central	54	15	24	7	52	38	10
3. West Central and Southwest	44	12	26	18	45	36	19
4. Northwest	31	12	32	25	25	38	37
5. Northeast and North Central	59	14	18	9	14	31	55
6. Twin City metropolitan	60	12	15	13	30	43	27
State	55	14	20	11	19	34	47

Table 15. Phosphate and potash recommendations for grass pastures and non-leguminous hay.

Area	Amount of P_2O_5 to apply lb/acre			Amount of K_2O to apply lb/acre		
	<21	21-40	41-60	<21	21-40	41-60
	Percent of samples					
1. Southeast	68	22	10	37	45	18
2. South Central	60	22	18	50	29	21
3. West Central and Southwest	50	17	33	55	26	19
4. Northwest	56	16	28	31	36	33
5. Northeast and North Central	75	15	10	21	35	44
6. Twin City metropolitan	88	10	2	41	32	27
State	68	17	15	31	35	34

Table 16. Percent distribution of pH, phosphorus, and potassium test results by county in SE (1) area.

County	Number of samples	Soil pH						Extractable phosphorus lb/acre						Exchangeable potassium lb/acre				
		<5.5	5.5-5.9	6.0-6.4	6.5-6.9	7.0-7.4	>7.4	<11	11-20	21-30	31-50	51-100	>100	<101	101-200	201-300	301-400	>400
		Percent of samples																
Dakota	6,002	4	22	38	26	7	3	4	15	21	27	24	9	10	45	27	10	8
Dodge	678	3	10	26	35	19	7	8	24	26	26	11	5	7	55	25	7	6
Fillmore	3,286	1	10	33	35	18	3	10	27	22	22	14	5	14	56	19	7	4
Goodhue	3,423	1	11	35	36	14	3	6	25	24	24	17	4	10	54	25	7	4
Houston	5,719	2	10	30	36	16	6	10	23	18	21	18	10	15	49	22	8	6
Mower	3,702	3	17	35	33	11	1	7	19	23	29	18	4	7	56	27	7	3
Olmsted	1,424	1	9	32	37	17	4	6	22	22	26	16	8	7	47	29	10	7
Wabasha	1,264	1	10	34	38	14	3	3	24	24	24	18	7	13	54	22	8	3
Winona	4,071	1	12	33	36	15	3	9	21	21	23	18	8	15	48	23	8	6
SE area	29,569	2	13	34	34	13	4	7	22	21	24	19	7	12	51	24	8	5

Table 17. Percent distribution of pH, phosphorus, and potassium test results by county in SC (2) area.

County	Number of samples	Soil pH						Extractable phosphorus lb/acre						Exchangeable potassium lb/acre				
		<5.5	5.5-5.9	6.0-6.4	6.5-6.9	7.0-7.4	>7.4	<11	11-20	21-30	31-50	51-100	>100	<101	101-200	201-300	301-400	>400
		Percent of samples																
Blue Earth	388	1	14	38	22	17	8	4	17	22	28	21	8	2	15	39	25	19
Brown	299	2	6	24	18	19	31	9	20	18	22	18	13	0	14	38	24	24
Carver	1,119	<1	4	37	33	17	9	7	17	18	25	25	8	6	34	35	15	10
Cottonwood	651	1	13	23	23	24	16	10	31	23	22	10	4	2	30	47	13	8
Faribault	375	0	17	28	21	17	17	6	22	23	24	18	7	<1	19	37	26	18
Freeborn	980	1	12	27	24	17	19	8	15	16	26	23	12	6	33	36	12	13
Jackson	767	1	7	20	25	27	20	7	27	26	22	15	3	2	24	47	20	7
Kandiyohi	920	0	2	10	13	20	55	20	28	16	19	12	5	5	26	37	19	13
LeSueur	3,035	8	18	34	25	12	3	2	9	12	23	35	19	8	37	33	15	7
Martin	1,518	<1	9	19	15	28	29	6	14	14	21	34	11	3	26	33	23	15
McLeod	1,455	0	1	10	27	31	31	14	26	22	24	11	3	4	44	40	8	4
Meeker	1,980	<1	8	29	26	20	17	9	21	20	26	19	5	9	46	28	11	6
Nicollet	263	1	7	28	22	23	19	9	21	17	28	21	4	2	14	47	26	11
Redwood	1,081	4	23	25	16	17	15	13	18	18	27	20	4	<1	27	48	15	10
Renville	1,203	<1	2	9	15	27	47	14	31	19	19	12	5	1	13	39	30	17
Rice	4,528	3	19	42	24	9	3	7	24	24	26	15	4	5	41	35	12	7
Scott	1,395	<1	12	42	26	12	8	9	23	22	23	17	6	9	37	33	13	8
Sibley	535	0	2	17	27	27	27	14	25	18	21	17	5	2	29	48	16	5
Steele	2,698	1	14	35	25	14	11	6	16	21	31	20	6	8	47	31	8	6
Waseca	3,497	2	20	34	18	14	12	8	12	15	31	28	6	1	28	44	18	9
Watonwan	2,027	2	9	15	16	22	36	8	19	22	28	18	5	2	28	35	20	15
Wright	3,775	1	13	44	29	9	4	6	22	21	26	19	6	11	47	27	10	5
SC area	34,489	2	13	31	23	16	15	8	20	19	26	20	7	6	36	35	14	9

Table 18. Percent distribution of pH, phosphorus, and potassium test results by county in WC and SW (3) area.

County	Number of samples	Soil pH						Extractable phosphorus lb/acre						Exchangeable potassium lb/acre				
		<5.5	5.5-5.9	6.0-6.4	6.5-6.9	7.0-7.4	>7.4	<11	11-20	21-30	31-50	51-100	>100	<101	101-200	201-300	301-400	>400
		Percent of samples																
Becker	1,197	1	8	20	24	16	31	13	25	18	21	16	7	23	33	21	13	10
Big Stone	414	<1	1	6	18	28	47	25	27	22	13	10	3	0	2	8	19	71
Chippewa	1,290	0	1	4	7	19	69	24	29	16	20	9	2	1	12	35	35	17
Douglas	1,359	<1	2	19	32	24	23	19	25	17	20	15	4	11	36	28	14	11
Grant	1,034	0	0	2	11	24	63	20	37	20	15	7	1	1	15	31	28	25
LacQuiParle	1,154	0	2	12	19	28	39	20	35	22	17	4	2	<1	10	32	29	29
Lincoln	530	<1	4	13	19	30	34	34	33	17	10	4	2	0	9	35	31	25
Lyon	589	<1	2	11	19	30	38	19	35	23	13	8	2	1	13	36	29	21
Mahnomen	1,236	<1	<1	4	11	23	62	29	29	14	14	9	5	3	26	34	16	21
Murray	766	0	6	20	25	30	19	17	34	23	17	6	3	<1	22	52	18	8
Nobles	1,934	<1	8	26	28	24	14	11	31	25	19	11	3	1	20	49	21	9
Ottertail (west)	1,149	<1	4	14	21	25	36	17	30	19	17	13	4	7	34	30	16	13
Pipestone	820	<1	18	43	18	10	11	17	33	21	20	7	2	<1	17	41	27	15
Polk (east)	3,400	1	1	10	13	22	53	33	27	15	14	9	2	25	44	23	5	3
Pope	2,195	<1	4	15	17	23	41	31	35	15	11	7	1	8	42	33	10	7
Rock	1,004	4	31	35	17	7	6	6	21	23	26	19	5	<1	11	41	26	22
Stevens	1,760	0	<1	4	8	22	66	29	25	16	16	7	7	1	13	32	23	31
Swift	996	0	1	3	7	10	79	29	26	18	16	8	3	3	32	37	18	10
Yellow Medicine	609	<1	1	8	17	27	47	22	31	22	15	8	2	<1	16	27	34	23
WC and SW area	23,436	<1	5	14	17	22	42	23	30	18	17	9	3	7	26	33	19	15

Table 19. Percent distribution of pH, phosphorus, and potassium test results by county in NW (4) area.

County	Number of samples	Soil pH						Extractable phosphorus lb/acre						Exchangeable potassium lb/acre				
		<5.5	5.5-5.9	6.0-6.4	6.5-6.9	7.0-7.4	>7.4	<11	11-20	21-30	31-50	51-100	>100	<101	101-200	201-300	301-400	>400
		Percent of samples																
Clay	1,246	<1	1	2	5	13	79	30	22	18	18	10	2	7	25	23	14	31
Kittson	2,720	0	<1	3	7	10	80	27	30	18	14	9	2	41	28	9	4	18
Marshall	4,506	<1	<1	1	3	15	81	27	35	16	12	7	3	23	37	15	7	18
Norman	974	0	0	1	3	9	87	36	26	15	13	7	3	13	34	15	7	31
Pennington	3,634	<1	1	3	10	26	60	29	39	16	10	4	2	26	44	18	6	6
Polk (west)	3,585	<1	<1	<1	1	3	95	27	22	15	17	15	4	5	19	18	19	39
Red Lake	1,625	<1	1	2	7	20	70	31	32	16	12	7	2	32	43	13	4	8
Roseau	5,336	<1	<1	4	7	12	77	22	35	18	13	9	3	30	41	18	6	5
Traverse	886	0	<1	8	19	27	46	19	36	20	15	8	2	<1	6	20	29	45
Wilkin	926	0	<1	7	9	20	64	21	28	20	18	11	2	2	16	18	17	47
NW area	25,238	<1	<1	3	6	15	76	26	32	17	14	8	3	23	34	16	9	18

Table 20. Percent distribution of pH, phosphorus, and potassium test results by county in NE and NC (5) area.

County	Number of samples	Soil pH						Extractable phosphorus lb/acre						Exchangeable potassium lb/acre				
		<5.5	5.5-5.9	6.0-6.4	6.5-6.9	7.0-7.4	>7.4	<11	11-20	21-30	31-50	51-100	>100	<101	101-200	201-300	301-400	>400
		Percent of samples																
Aitkin	1,832	15	26	35	16	6	2	14	19	14	19	19	15	68	23	5	2	2
Anoka	2,052	10	26	35	19	5	5	3	5	5	13	36	38	37	40	14	5	4
Beltrami	2,679	1	9	37	25	14	14	17	19	10	16	24	14	44	42	9	2	3
Benton	3,270	5	26	42	21	5	1	6	20	22	25	21	6	43	39	12	3	3
Carlton	2,230	20	36	25	16	3	<1	10	21	14	14	20	21	55	25	10	5	5
Cass	1,124	4	37	38	15	4	2	5	9	9	20	37	20	50	33	11	3	3
Chisago	3,380	8	25	42	21	4	<1	2	9	13	24	33	19	33	45	15	4	3
Clearwater	2,649	1	4	26	29	20	20	16	23	15	23	18	5	26	46	21	5	2
Cook	29	10	38	34	14	0	4	10	31	7	28	3	21	10	42	21	10	17
Crow Wing	1,395	11	39	35	12	3	<1	2	7	11	22	37	21	45	38	10	4	3
Hubbard	1,345	6	36	40	14	2	2	2	9	15	31	34	9	52	34	9	3	2
Isanti	3,107	11	27	39	19	4	<1	2	6	8	17	43	24	34	45	15	4	2
Itasca	1,812	7	31	37	18	5	2	10	11	7	12	23	37	36	31	17	8	8
Kanabec	2,482	11	30	38	18	3	<1	5	22	24	26	18	5	45	38	11	4	2
Koochiching	937	3	8	28	29	20	12	32	30	13	10	8	7	24	35	25	10	6
Lake	240	18	44	22	8	2	6	33	38	13	10	3	3	34	20	21	12	13
Lake of the Woods	1,271	1	1	6	10	16	66	19	27	18	23	10	3	38	34	17	7	4
Mille Lacs	4,332	5	26	41	22	5	1	4	22	24	25	19	6	43	40	12	3	2
Morrison	4,111	7	35	35	16	6	1	5	17	17	27	26	8	45	36	12	4	3
Ottertail (east)	1,764	<1	10	46	31	10	3	4	15	19	32	24	6	34	48	13	3	2
Pine	4,491	15	35	31	16	3	<1	4	17	19	25	24	11	47	34	12	4	3
Sherburne	3,311	12	34	38	13	3	<1	2	5	8	17	37	31	28	40	18	8	6
St. Louis (north)	1,220	10	36	32	15	6	1	24	27	12	10	8	19	34	20	19	17	10
St. Louis (south)	1,411	7	25	28	21	14	5	19	27	15	16	13	10	56	26	9	4	5
St. Louis (west)	475	13	32	24	19	9	3	28	27	13	10	11	11	54	22	11	6	7
Stearns	5,950	1	15	41	24	10	9	11	20	18	23	21	7	25	47	19	6	3
Todd	3,448	1	16	48	23	7	5	7	18	19	28	23	5	43	42	10	2	3
Wadena	1,217	3	21	42	20	8	6	3	6	8	26	47	10	28	35	19	6	12
Washington	2,841	5	22	44	24	4	1	3	15	18	26	25	13	29	45	18	5	3
NE and NC area	66,409	7	24	37	20	7	5	8	17	15	22	25	13	39	38	14	5	4

Table 21. Percent distribution of pH, phosphorus, and potassium test results by county in the Twin City metropolitan (6) area.

County	Number of samples	Soil pH						Extractable phosphorus lb/acre						Exchangeable potassium lb/acre				
		<5.5	5.5-5.9	6.0-6.4	6.5-6.9	7.0-7.4	>7.4	<11	11-20	21-30	31-50	51-100	>100	<101	101-200	201-300	301-400	>400
		Percent of samples																
Hennepin	3,045	10	12	24	22	17	15	5	11	13	17	22	32	11	33	26	15	15
Ramsey	5,805	4	10	20	20	18	28	18	15	12	17	20	18	22	27	18	11	22
Metropolitan area	8,850	6	10	22	21	18	23	13	14	13	17	20	23	17	29	21	13	20