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The Minnesota Fertilizer Industry trends and prospects

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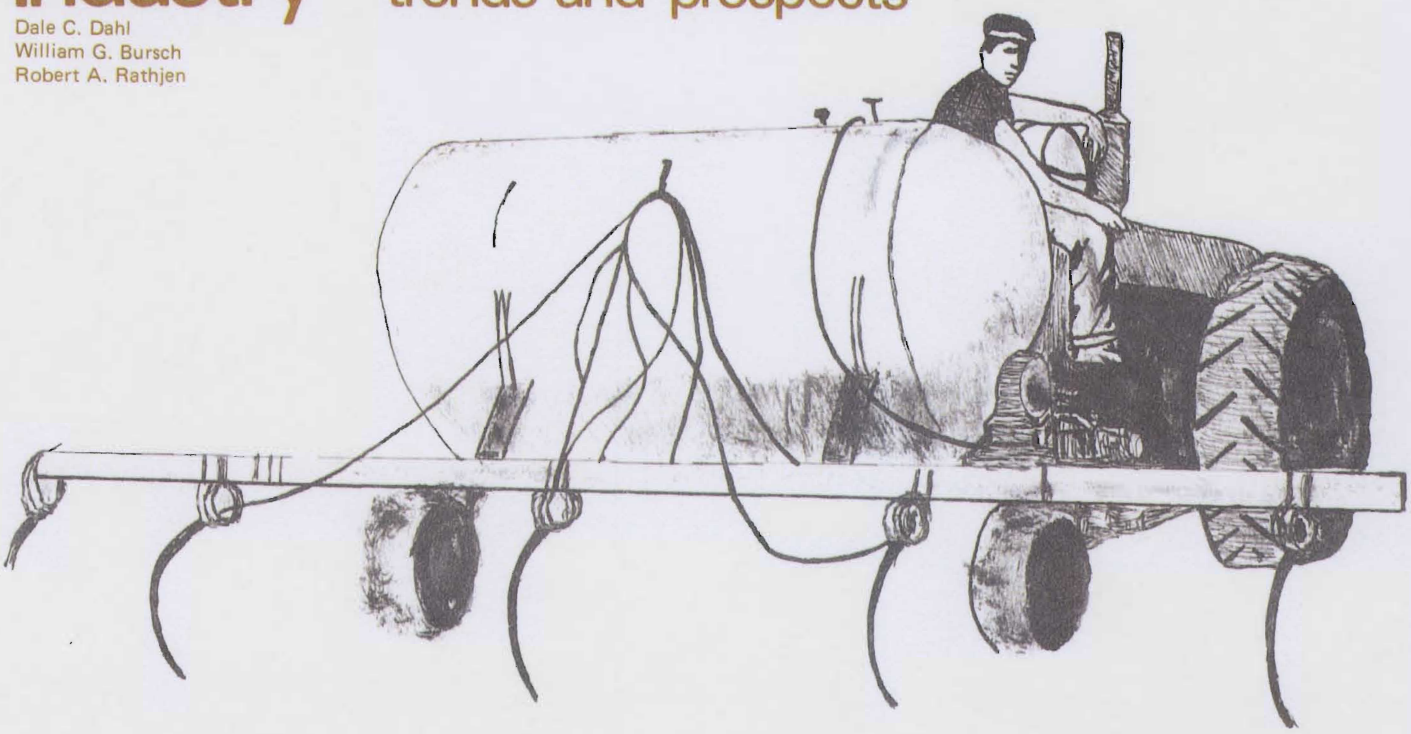

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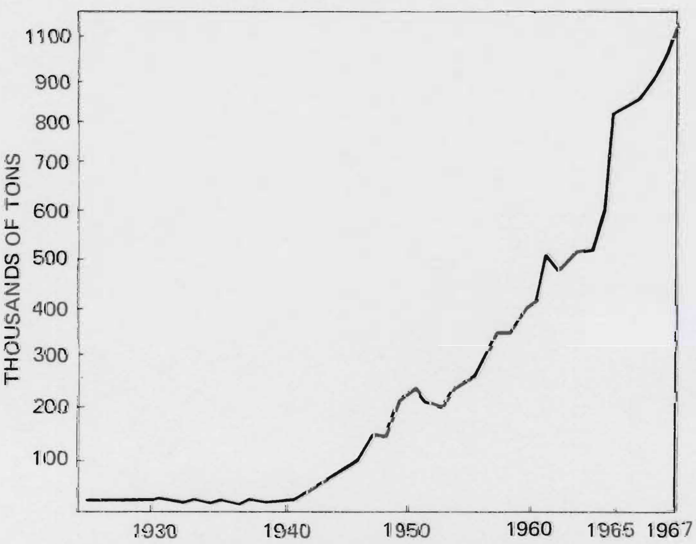
The Minnesota Fertilizer Industry: Trends and Prospects

I. Introduction

Situation

The growth of the Minnesota fertilizer industry may be separated into three historical periods: (1) before 1940, (2) 1940-1955, and (3) 1955 to the present. Before 1940, a low and fairly stable level of fertilizer usage existed in Minnesota (figure 1). From 1940 to 1955, usage increased substantially, but fertilizer distribution channels did not change significantly. After 1955, tonnage consumption of fertilizer increased even more. Unique to this period, however, new channels of fertilizer distribution developed.



Source: Division of Agronomy Services, Minnesota Department of Agriculture.

Figure 1. Thousands of tons of fertilizer sold for usage in Minnesota, 1927-67.

Before 1955, producers of primary nutrients (nitrogen, N; phosphate, P_2O_5; and potash, K_2O) were concentrated in specific areas of the United States. From these locations they supplied primary materials to fertilizer manufacturers in Minnesota and surrounding states. Manufacturers combined the materials into grades of mixed fertilizers and bagged them for retail distribution. Retail outlets, such as country grain elevators, creameries, and farm supply stores distributed fertilizers to the farmer-customer. Some straight (unmixed) fertilizer materials followed the same pattern. Even after 1940, with state fertilizer usage increasing, there was little deviation from these distribution patterns.

After 1955, small blending operations became technically feasible. These plants in areas of heavy fertilizer consumption mixed primary materials according to the farmer's specific soil types and cropping practices. The primary fertilizer producers supplied directly the local blending plants as well as the centralized manufacturers. The successful development of this distribution method reduced the *share* of fertilizer handled through pre-existing distribution channels.

Some of the questions raised after these developments were informational and referred to consumption: What were the fertilizer usage trends in Minnesota? How do they compare with trends in other North Central states and the nation? Which fertilizer grades and ratios increased most in sales? What were the state's geographic patterns of fertilizer consumption? What caused these changes in fertilizer use?

Other questions were concerned with the distribution changes: How many new plants have opened in recent years? How many of these are owned cooperatively and how much fertilizer do cooperatives handle? What are the geographic patterns of plants, and how do they correspond to the geographic patterns of fertilizer use?

Still other questions were raised about the effects of these changes: How much fertilizer can be expected to be consumed in future years? How is this expected to be distributed geographically? How might such usage trends further influence fertilizer distribution methods? How will these developments affect rural industrial and agricultural growth?

Objectives

These questions cannot be answered without extensive research. A descriptive analysis of fertilizer usage and distribution based upon available published and unpublished data provides some answers, however. The general purpose of this report is to provide this analysis. The specific purposes are to:

1. identify fertilizer usage trends in Minnesota by analysis, geographic area, and, where possible, distribution outlet;
2. isolate changes in fertilizer manufacturing and distribution in numbers of firms and plants and their locations and relate these changes to consumption patterns; and
3. project, under various assumptions, future consumption patterns, and assess their probable impact upon the fertilizer distribution channels in the state.

Procedures and Data

This study focuses upon Minnesota's consumption patterns and businesses. Data from other states are presented occasionally for comparison. The study deals primarily with the last 10 years, specifically 1960 and 1964, in certain dimensions.

Within these geographic and temporal limits, numerous government and business data and research reports were reviewed for information about changes in fertilizer consumption and distribution patterns.[1] Much of the data in this report, however, is from unpublished data reports

[1] A cited bibliography is included in this report. A more extensive bibliography is available upon request.

made available for this study by the Division of Agronomy Services of the Minnesota Department of Agriculture. These data summarize annual tonnage and license reports filed by firms and plants selling fertilizer in Minnesota.[2] Other sources are the 1959 and 1964 Censuses of Agriculture, which derive most of the information from a sample of farms.

II. Patterns of Fertilizer Usage

Consumption Trends

A long-term upward trend in fertilizer use in Minnesota began in 1940 with 15 thousand tons, reached 370 thousand tons in 1955, 800 thousand tons in 1965, and over 1.5 million tons by the year ending June 30, 1969 (figure 1). Consumption in 1969 was 314 percent more than in 1955, 187 percent more than in 1960, and 110 percent more than in 1964. Minnesota farmers spent about $78 million on fertilizer in 1967.

[2] The state agency requires tonnage reports from all firms, regardless of location, that sell fertilizer materials or mixtures to manufacturers, distributors, or final consumers in Minnesota (see *Minnesota Statutes*, Chapter 559, as amended 1955, 1959, and 1963).

Fertilizer use since 1955 has grown faster in Minnesota than in the other North Central states or the United States (table 1). In 1955, Minnesota used 5.6 percent of the fertilizer consumed in the North Central states and 1.6 percent of the fertilizer used in the continental United States. By 1969, the figures had increased to 9.7 percent and 4.0 percent, respectively. Minnesota still lags behind the other North Central states in pounds of fertilizer used per harvested acre. Minnesota's more rapid growth rate, however, suggests that the state acre-usage ratio soon may get closer to those of other North Central states.

USAGE TRENDS BY ANALYSIS

"Tonnage" figures underestimate the growth of Minnesota's fertilizer usage. A better estimate is recent growth in the use of plant nutrients (N, P_2O_5, K_2O). The faster growth rate for plant nutrient usage is due to increased use of higher analysis fertilizers (table 2). For example,

Table 1. Tons of mixtures and materials used and percentage change from previous period, Minnesota, North Central states, and United States, 1955, 1960-69.

	Minnesota		North Central states		Continental U.S.	
Year*	Thousand tons	Percent change	Thousand tons	Percent change	Thousand tons	Percent change
1955	373		6,701		22,284	
1960	538	+44.0	7,651	+14.0	24,501	+ 9.9
1961	558	+ 3.7	8,176	+ 6.8	25,163	+ 4.0
1962	560	+ .3	8,428	+ 3.0	26,194	+ 4.0
1963	615	+ 9.8	9,846	+16.8	28,535	+ 8.9
1964	733	+19.2	10,928	+11.0	30,315	+ 6.2
1965	799†	+ 9.0	10,976	+ .4	30,925	+ 2.0
1966	852	+ 6.6	13,554	+23.4	34,158	+10.5
1967	1,111	+30.4	15,314	+12.9	36,718	+ 7.5
1968	1,238	+11.1	16,127	+ 5.3	38,383	+ 4.0
1969	1,545	+24.7	15,916	— 1.3	38,365	0

Source: 1964 *Fertilizer Summary Data by States and Geographic Areas*, National Fertilizer Development Center, Tennessee Valley Authority, Muscle Shoals, Alabama, and Walter Scholl and others, "Consumption of Commercial Fertilizers and Primary Plant Nutrients in the U.S. Year Ended June 30, 1964," *Commercial Fertilizer and Plant Food Industry*, May, 1965.

* Fiscal period, July 1 to June 30.

† Figures for 1965-69 are from *Consumption of Commercial Fertilizers in the United States*, U.S.D.A., Statistical Reporting Service, Report Sp Cr 7 (5-68), and Sp Cr 7 (11-66).

Table 2. Tons of plant nutrients used and percentage change from previous period, Minnesota, North Central states, and United States, 1955, 1960-69.

	Minnesota		North Central states		Continental U.S.	
Year	Tons	Percent change	Tons	Percent change	Tons	Percent change
1955	156,987		2,265,834		5,995,410	
1960	236,685	+50.7	2,882,548	+27.2	7,350,155	+22.6
1961	252,875	+ 6.8	3,106,768	+ 7.8	7,718,870	+ 5.6
1962	256,179	+ 1.3	3,351,094	+ 7.8	8,304,573	+ 7.6
1963	295,123	+15.0	4,046,420	+20.7	9,392,637	+13.1
1964	364,935	+23.7	4,710,764	+16.4	10,354,533	+10.2
1965	402,946	+10.4	4,938,632	+ 4.8	10,830,660	+ 4.6
1966	426,166	+ 5.8	6,160,615	+24.7	12,318,156	+13.8
1967	574,369	+34.8	7,212,962	+17.1	13,850,560	+12.4
1968	662,116	+15.2	7,880,536	+ 9.2	14,911,160	+ 7.6
1969	835,464	+26.2	7,833,132	— .7	15,177,473	+ 1.7

Source: See table 1.

Table 3. Average percentage of plant food content of mixed and total fertilizer, Minnesota and continental United States, selected years.

	1943	1950	1955	1960	1962	1964	1967	1969
Average analysis—all mixtures								
Minnesota	27.5	35.2	41.1	45.0	46.7	50.6	51.6	52.7
United States	21.0	23.1	27.9	31.6	32.9	35.2	37.6	38.8
Average analysis—all fertilizer								
Minnesota	24.3	33.0	42.2	44.0	45.7	49.6	51.8	53.9
United States	20.3	22.5	27.9	31.8	33.4	35.8	39.2	39.5

Source: See table 1.

from 1963 to 1964 in Minnesota, total tonnage (mixtures and materials) increased 19.2 percent and tons of plant nutrients increased 23.7 percent.

The average plant nutrient content of fertilizer mixtures and materials increased steadily during the last 20 years. This trend is explained partly by industry's efforts to reduce freight and handling charges in distribution and application. Minnesota has been a leader in using high analysis fertilizers (table 3).

New fertilizer materials have made this trend possible. High analysis materials such as anhydrous ammonia (82-5-0), concentrated superphosphate (0-46-0), diammonium phosphate (18-46-0, 21-53-0, and others), and muriate of potash (0-0-60), have increased in use both as straight materials and in mixtures.[3]

These general trends in straight and high analysis materials also are seen in usage changes by ratio and materials categories in Minnesota between 1960 and 1964 (table 4).[4] The total number of tons of fertilizer used in the state increased 49 percent during this period. The greatest increases in usage occurred for (1) ratios 1-2-0 and 1-3-0, which include ammonium phosphates and diammonium phosphates, (2) ratio 1-3-1 (predominantly the 10-30-10 grade), (3) anhydrous ammonia, (4) nitrogen solutions, and (5) solid potash. These increases also indicate changes in the distribution methods discussed later.

Table 4. Fertilizer by ratio composition sold for use in Minnesota, 1960 and 1964

Fertilizer	1960	1964	Percent change
	(thousand tons)		
Phosphate and potash only	28.9	36.4	+ 26
Nitrogen and phosphate only			
Ratio 1-1-0	13.5	14.2	+ 6
Ratio 1-2-0 and 1-3-0	16.5	47.5	+188
Ratio 1-4-0	26.4	13.0	− 51
Complete mixed dry fertilizers			
Ratio 1-1-1	22.3	29.3	+ 32
Ratio 1-2-2	16.5	19.9	+ 21
Ratio 1-3-1	8.1	21.4	+163
Ratio 1-4-2	79.4	85.7	+ 8
Ratio 1-4-4	110.8	151.7	+ 37
Other ratios	59.9	80.7	+ 35
Straight materials			
Solid nitrogen materials	20.7	31.0	+ 50
Anhydrous ammonia	6.3	19.4	+206
Nitrogen solutions	16.8	70.1	+319
Solid phosphates	29.1	41.0	+ 41
Solid potash	10.4	36.7	+253
Liquid mixes	15.2	16.3	+ 7
Other	1.8	3.0	+ 69
TOTALS*	482.8	717.7	+ 49

* Totals are derived from unrounded figures. They differ from the data in table 1 because different methods of data collection were used.

USAGE TRENDS BY COUNTY

Fertilizer used on Minnesota farms as reported in the 1964 *Census of Agriculture* accounted for 93 percent of the fertilizers used in 1959 and 87 percent of those used in 1964. County data indicate that the heaviest fertilizer usage on farms in 1959 was primarily in Polk and Marshall counties of the Red River Valley area and in south central counties of the state (figure 2). The same general areas were the heaviest fertilizer users in 1964 also (figure 3).

The greatest increase in fertilizer usage from 1959 to 1964 also came in these areas and in the southwestern and west central areas of the state. The eastern and east central areas changed very little or even decreased in the quantity of fertilizer used during the same period. Twenty of 87 counties reported less fertilizer used on farms in 1964 than in 1959. Many decreases probably were due to a decline in crop agriculture in these counties.

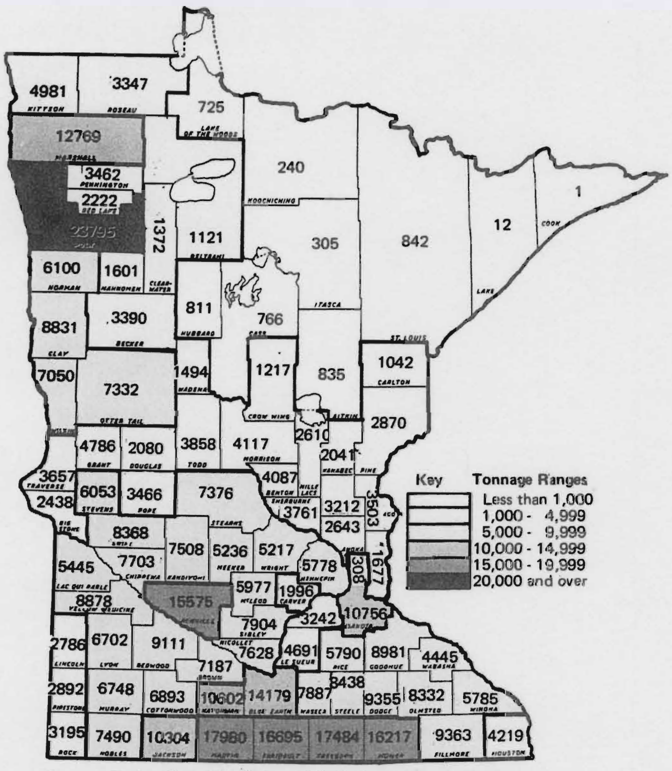
The percentage of producing cropland fertilized also indicates an important geographic trend from 1959 to 1964.[5] Many eastern Minnesota counties used fertilizer on a smaller proportion of their producing cropland in 1964 than in 1959. The western and south central counties fertilized a larger percentage of acres during this period, however (figure 4). The extreme southwestern counties showed the largest group increases. This may be due in part to the extremely low use level in 1959 or may indicate the beginning of a trend.

Nearly every county in the state could expand fertilizer use by following fertilizer practices on *more acres* of cropland.

[3] *The 1963 Fertilizer Summary Data by States and Geographic Areas, op. cit.*, pp. 116, 42, 45, 54, and 56.

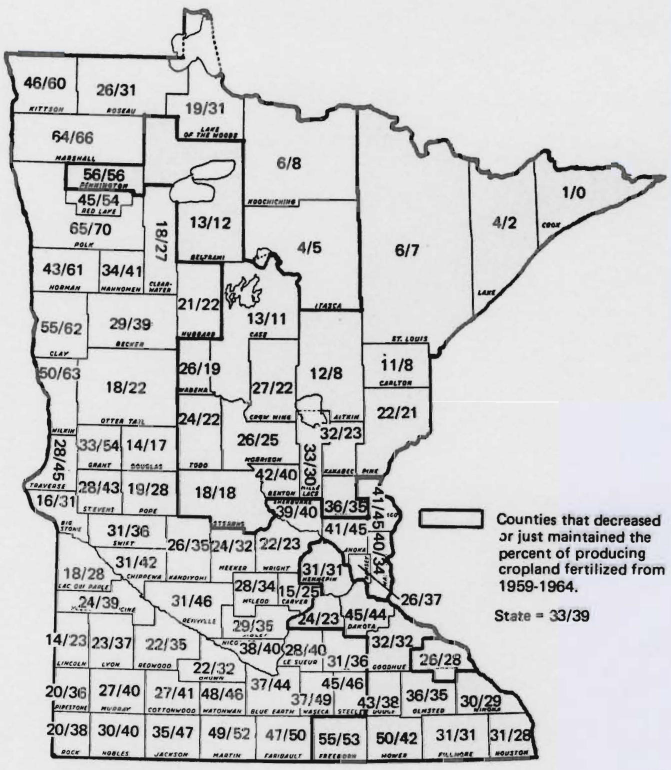
[4] These data were developed from tonnage reports of fertilizer sold for use in Minnesota in 1960 and 1964. The reports were provided for this study by the Minnesota Department of Agriculture.

[5] Producing cropland is cropland harvested and cropland pastured.



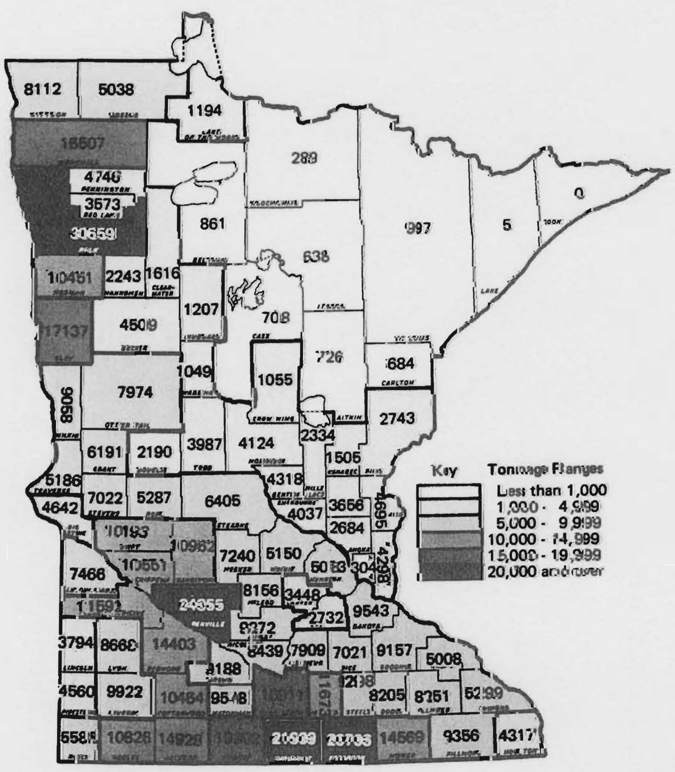
Source: Derived from U.S. Census of Agriculture: 1964 (preliminary report), U.S. Department of Commerce, Washington D.C., March 1966.

Figure 2. Tons of fertilizer used on Minnesota farms by county, 1959.



Source: Same as figure 2.

Figure 4. Percent of producing Minnesota cropland fertilized by county, 1959/1964.



Source: Same as figure 2.

Figure 3. Tons of fertilizer used on Minnesota farms by county, 1964.

Demand Factors

The major reasons for these changes in consumption are: (1) price changes, (2) technical changes, (3) uncertainty and risk, (4) capital availability and use, (5) the "fertility gap," and (6) education and promotion. The fertility gap and education and promotion are discussed here. The other reasons follow in a technical appendix.

FERTILITY GAP

There are at least two concepts of a fertility gap.

(I) It is the difference between the quantity of soil nutrients removed by cropping and the quantity of nutrients returned to the soil with commercial fertilizer. This indicates the extent that the nutrients are being depleted from the soil, taking into account additions to the soil by the way of crop residues, animal excrements, and fixations from the atmosphere.

(II) It is the difference between the quantities of nutrients that should be applied according to fertilizer recommendations and the quantities of plant nutrients that actually are applied. This concept measures the degree that fertilizer is used in farming compared to the degree that is recommended as profitable under most conditions. The first concept of a fertility gap, however, shows the relative amount of soil "mining" or soil "building" in the state or county.

I. Plant nutrients removed by 13 Minnesota crops compared to tonnages sold identify a substantial "fertility gap" for each year from 1955 to 1966 (figure 5). The gap for P_2O_5 in 1955 was eliminated by 1966; the nitrogen gap was reduced during this period; and the gap for K_2O remained nearly unchanged.

The fertility gaps were identified using a procedure used by Munson.[6] The quantity of plant nutrients removed by cropping is far greater than the amount replaced by fertilizer. For the fertilizer year 1961, Minnesota farmers used only 65,102 tons of N, 119,689 tons of P_2O_5, and 73,975 tons of K_2O. During the previous crop year, an estimated 259,234 tons of N, 149,450 tons of P_2O_5, and 268,623 tons of K_2O were removed by the grain, hay, and tubers of eight major crops. Therefore, nutrient mining of Minnesota soils by crops occurred that year. According to the known patterns of fertilizer use and crop production, soil mining has been happening since Minnesota agriculture began. With the increased use of fertilizer in recent years, some progress has been made toward reducing soil mining.

Fertilizer applications in the 1966-67 fertilizer year came somewhat closer to replacing the plant nutrients removed in 1966 by the same eight crops (table 5). The fertility gap is the largest for nitrogen and potash. The gap for phosphate has disappeared considering only the eight crops. The quantities of N, P_2O_5, and K_2O removed were calculated from production figures and plant food removal information from various sources (see appendix table 1).[7]

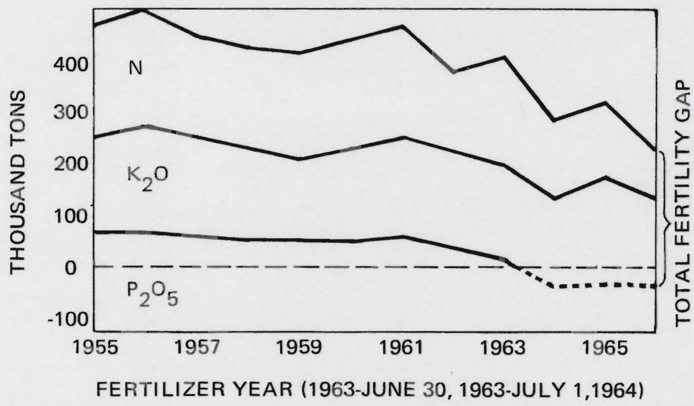
[6] Munson, R. D., "The Fertility Gap in Minnesota," *Minnesota Feed Service*, March, 1962.

[7] Production figures from 1961 and 1964 issues, *Minnesota Agricultural Statistics*, State-Federal Crop and Livestock Reporting Service, Minnesota Department of Agriculture.

Only the grain portion of the grain and oil seed crops was used in calculating nutrient removal because stalks and straw generally are returned to the soil. Nitrogen removed by legumes was not counted because of legumes' ability to utilize nitrogen from the air by symbiotic fixation.

Factors not considered in calculating plant food removal are (1) removal by pasture crops, (2) removal of entire crop plants for silage, and (3) removal by minor crops. Additions to the soil by manures (in excess of straw), free living nitrogen fixing organisms, and other natural sources are not considered either.

The quantity figures of N, P_2O_5, and K_2O applied here are from USDA estimates. (School, Walter, and others, "Consumption of Commercial Fertilizers and Primary Plant Nutrients in the U.S. Year Ended June 30, 1964," *Commercial Fertilizer and Plant Industry*, May, 1965.)



Example: Nutrients sold for consumption in Minnesota between June 30, 1963, and July 1, 1964, were short of replacing the nutrients removed in the 1963 crop year by the amount indicated.

Figure 5. Plant nutrients removed by 13 Minnesota crops not replaced by fertilizer sold, 1955-66.

For a more complete picture of plant food removal and the fertility gap, the above procedure and conditions also were used to measure the plant food removal by 13 major Minnesota crops. Table 6 shows these figures for 1966 and the estimated tons of each plant nutrient applied in Minnesota during the 1966-67 fertilizer year. The fertility gap based on these figures is larger than that based on only eight crops. By 1969 the fertility gap based on the same 13 crops had closed substantially, particularly for nitrogen and P_2O_5 (table 7).

II. Variation in soil type and fertility and in crops grown is important in determining the kind and amount of plant nutrients to use. Fertilizer recommendations consider these and many other variables. To estimate the extent of fertilizer usage in Minnesota with respect to recommended practices, fertilizer recommendations were aggregated for all crops by county. The procedure, using general suggestions for crop fertilization in each county

Table 5. Plant nutrient removal by grain, hay, and tubers of eight major Minnesota crops, 1960, 1963-64, and 1966.

Crop	1960*			1963-64			1966		
	Tons N	Tons P_2O_5	Tons K_2O	Tons N	Tons P_2O_5	Tons K_2O	Tons N	Tons P_2O_5	Tons K_2O
Corn	139,166	54,120	38,657	159,100	61,872	44,195	180,986	58,466	50,274
Wheat	16,589	8,294	4,976	13,561	6,780	4,068	11,448	5,724	3,434
Oats	59,182	23,673	27,754	53,056	21,222	16,129	43,215	17,286	13,137
Barley	13,446	6,350	4,482	11,388	5,176	3,753	9,222	4,192	3,039
Soybeans	†	18,288	28,738	†	25,333	40,183	†	35,036	55,170
All hay	23,507‡	37,840	170,280	21,897	40,005	167,857	21,802	40,470	170,000
Potatoes	2,296	885	3,736	2,335	920	4,457	2,032	800	3,879
TOTALS	254,196	149,450	268,623	261,337	161,308	290,642	268,705	161,974	298,933
Nutrients applied	65,102	119,689	73,975	95,217	168,830	100,888	188,123	211,695	174,551

* These figures are consistent with those of R.D. Munson (see footnote 6).

† Soybeans and other legumes primarily used nitrogen that is fixed by symbiotic organisms.

‡ Adjusted to a level consistent with the more recent calculations with permission of the original author.

considering soil types, is explained in appendix table 3.[8] The information compiled for Minnesota's 1964 crop year suggests that approximately 289 thousand tons of N, 387 thousand tons of P_2O_5, and 384 thousand tons of K_2O are recommended discounting the contribution of manure. However, a part of the animal excrement gets distributed on cropland and contributes significantly to soil fertility. The aggregate recommendations, adjusted for the estimated contributions of manure, are 221 thousand tons of N, 309 thousand tons of P_2O_5, and 293 thousand tons of K_2O.[9]

[8] In general, the level recommended was the average for good management conditions rather than those that would result in the highest yields.

[9] The fertility contribution of manure was estimated from county livestock numbers. It is assumed that 25 percent of the N and 40 percent of the P_2O_5 and K_2O actually became incorporated into the soil (appendix 3).

Table 6. Plant nutrient removal in Minnesota by 13 major crops in 1966.

Crop	Production	Plant food removal—tons		
		N	P_2O_5	K_2O
Corn	402,192,000 bu.	180,986	70,384	50,274
Wheat	18,318,000 bu.	11,448	5,724	3,434
Rye	1,340,000 bu.	938	603	375
Oats	138,291,000 bu.	43,215	17,286	13,138
Barley	20,960,000 bu.	9,222	4,192	3,039
Flax	3,838,000 bu.	4,030	1,285	1,075
Soybeans	80,544,000 bu.	—	35,036	55,171
Alfalfa hay	6,479,000 ton	—	32,395	145,778
Other hay	1,615,000 ton	21,802	8,075	24,226
Sugar beets	1,554,000 ton	2,914	1,166	2,719
Potatoes	12,317,000 cwt.	2,033	800	3,879
Peas	65,310 ton	654	164	327
Sweet corn	493,500 ton	1,975	741	494
TOTALS removed		279,217	177,851	303,929
Sales volume 1966-67 F.Y.		188,123	211,695	174,551
Gap		91,094	−33,844	129,378
Gap assuming a nonfarm use factor of 15 percent		119,312	−2,090	155,560

Table 7. Plant nutrient removal in Minnesota by 13 major crops in 1969.

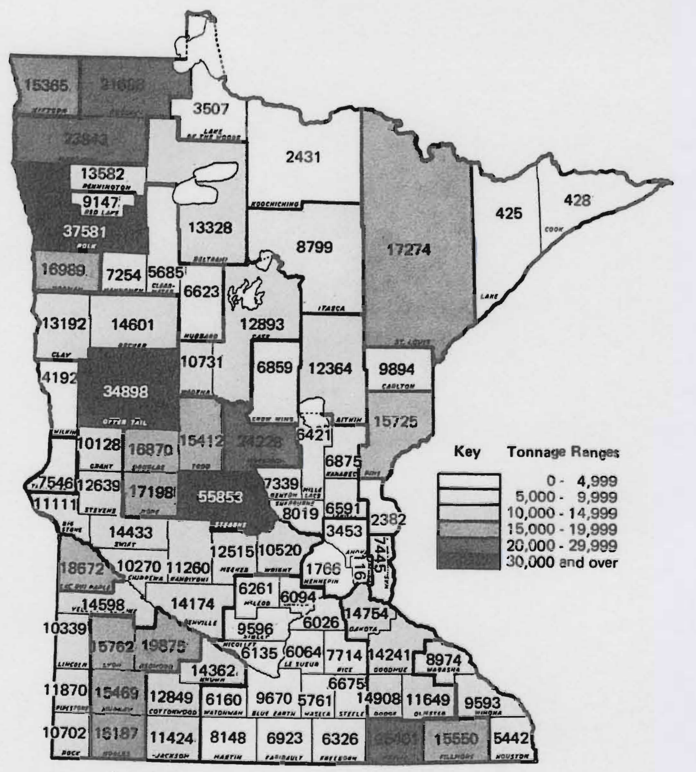
Crop	Production	Plant food removal—tons		
		N	P_2O_5	K_2O
Corn	417,690,000 bu.	187,960	73,096	52,211
Wheat	24,607,000 bu.	15,379	7,689	4,613
Rye	2,142,000 bu.	1,500	964	600
Oats	193,368,000 bu.	60,427	24,171	18,369
Barley	28,842,000 bu.	12,690	5,768	4,182
Flax	6,270,000 bu.	6,538	2,100	1,755
Soybeans	78,008,000 bu.	—	33,063	52,255
Alfalfa hay	6,272,000 tons	—	31,360	141,120
Other hay	1,667,000 tons	22,504	8,335	25,000
Sugar beets	2,366,000 tons	4,436	1,774	4,140
Potatoes	15,475,000 cwt.	2,553	1,005	4,874
Peas	80,280 tons	802	200	401
Sweet corn	608,400 tons	2,433	912	608
TOTALS removed		317,267	190,437	310,128
Sales volume 1968-69		339,789	280,269	213,900
Gap		−22,522	−89,832	96,228
Gap assuming a nonfarm use factor of 15 percent		28,446	−47,792	128,313

The total plant nutrient recommendation is approximately 823 thousand tons for 1964. Compare this to the estimated 311 thousand tons used on Minnesota farms in 1964.[10] This was only 38 percent of the amount recommended and resulted in a fertility gap of about 512 thousand tons of nutrients, or about a 1,024 thousand ton gap of fertilizer mixture and materials.

The quantities used of N, P_2O_5, and K_2O are not easily estimated on a county level. However, the recommended tonnage of total nutrients for each county can be converted to an equivalent tonnage of fertilizer containing an average of 50 percent plant nutrient. This equivalent fertilizer tonnage was compared to the estimated tonnage applied in each county in 1964 to determine the fertility gap for each county. Figure 6 shows the county fertility gap determined by this method and expressed as tons of fertilizer with an average plant nutrient content of 50 percent. The larger counties tend to have larger absolute fertility gaps, as expected. The south central counties have smaller relative fertility gaps than any other major agricultural area.

Table 8 shows the fertility gap for selected crops for the state as a whole in 1959 and 1964.[11] With this, it is impractical to measure manure's contribution to each crop. Thus, the figures give a larger fertility gap than probably exists. The gap has been reduced substantially, but remains large for corn and other crops between 1959 and 1964. Potatoes appear to be receiving the recommended fertilizer. The fertility gap for hay and cropland pasture is large both absolutely and relatively and reveals a major deficiency in crop management and fertilizer use. Potential for increased fertilizer use is substantial for nearly all crops. The exact potential on a crop basis considering the manure contribution is not revealed, however.

The fertility gap approach to analyzing the progress of the fertilizer industry may be limited to comparing fertilizer use in the state or a county with an established norm such as fertilizer recommendations. Fundamental factors influencing the fertilizer industry's potential are the relationships between the price of fertilizer and other production inputs and between the price of fertilizer and the value of additional production from its use. The way the price of other inputs affects the use of fertilizer may be indicated in the high land value and high fertilizer use in the south central Minnesota counties.



Source: See appendix table 3.

Figure 6. Fertility gap by county (value of manure considered), 1964.

EDUCATION AND PROMOTION

Most farmers are practitioners of farming techniques rather than innovators. Converting an innovation into a

[10] Based on tons of fertilizer used on farms as reported in the *1964 Census of Agriculture* and an average nutrient content of 50 percent. The nutrient content of all fertilizer material and mixture was approximately 50 percent in 1964 according to "Consumption of Fertilizer and Primary Plant Nutrient in the U.S. Year Ending June 30, 1964." *Commercial Fertilizer and Plant Food Industry.*

[11] Appendix table 4 shows county gaps by crops.

Table 8. State fertility gap by crop, 1959 and 1964.*

	1959				1964			
	Tons of fertilizer recommended†	Tons of fertilizer used‡	Tonnage gap	Tons used as percent of recom-mended	Tons of fertilizer recom-mended†	Tons of fertilizer used‡	Tonnage gap	Tons used as percent of recom-mended
Hay and cropland pasture	786,824	56,302	730,522	7%	666,685	62,262	604,423	9%
Corn	1,175,010	332,226	842,854	28	802,136	392,699	409,437	49
Soybeans	125,212	6,460	118,752	5	123,826	11,128	112,698	9
Potatoes	20,668	13,421	7,249	64	18,127	17,117	1,010	94
Other crops	747,730	102,620	645,110	14	513,177	138,595	374,582	27
TOTALS	2,855,514	511,029	2,344,485	18%	2,123,951	621,801	1,502,150	29%

* All data are derived from county figures and aggregated for state totals. The nutrient value of manure is not considered.

† Based on nutrient recommendations according to soil type and converted to tons of fertilizer containing 50 percent plant nutrients. The same level of recommendations applies to both years.

‡ From the *1964 U.S. Census of Agriculture*, County Data Preliminary Report, U.S. Department of Commerce, Washington, D.C., March 1966.

practice requires education and learning.[12] This is true with fertilizer also. Presenting the economics of fertilizer use to farmers was begun by public-supported institutions, mainly universities, and the Cooperative Extension Service. They employed numerous tools to demonstrate and project the increased information about fertilizer use. The fertilizer industry recognized the returns of this education and promotion and began to supplement the public programs. Private industry now probably plays the leading role. The knowledge of the fertilizer dealer, who is trained largely by the firm he represents, greatly affects dealer sales and profit.[13] Those who know more about the economics of fertilizer, its use, and associated services also sell more and generally are better prepared and more confident in imparting fertilizer knowledge to their farmer customers.

An Iowa study showed that farmers need additional information about fertilizer and its use.[14] When given a basic test about fertilizer, the average farmer correctly answered only about half of the multiple choice questions. However, data from a random sample of 315 farmers showed a highly significant relationship between the farmer's knowledge about fertilizer use and the knowledge and intensity of fertilizer use per acre of corn. This relationship held for all sizes of farms as measured in crop acres.

In the same study, the importance of knowledge about fertilizer use was shown again. The farmers were asked to rank the three most important from a list of factors that might limit their fertilizer use. The six most frequently listed were:

	Percent checking items as one of three most important limiting factors
1. Purchase cost	59
2. Risk and uncertainty in use	32
3. Lack of necessary application equipment	25
4. Low return per dollar invested	14
5. Problem with handling and applying	12
6. Landlord	12

The report suggested that the largest limiting factor, purchase cost, could be met head on by information about the economics of fertilizer use.[15] If the farmer is receptive to thinking about returns or benefits rather than costs, fertilizer use is favored. This limitation should be one of the easiest to refute.

The farmer, when buying fertilizer according to cost, may save 50¢ to 75¢ per acre. Proper fertilizer use realistically can earn a farmer $10 to $20 per acre.[16] Thus, to encourage fertilizer use, impart information about the economics of fertilizer use to farmers through various service functions. Risk and uncertainty in use, low returns per dollar invested, uncooperative landlords, and some of the facts mentioned less frequently all may spring from a lack of knowledge about fertilizer.

The promotion of fertilizer use through programs to improve knowledge has increased greatly since the Iowa study.[17] It is unlikely that the same farmers would rate so poorly on a fertilizer knowledge test now. Improved knowledge probably played a big part in the 100 percent increase of fertilizer use in Iowa from 1960 to 1964.

Implicit in fertilizer knowledge, and concomitant to fertilizer use, is the recommendation of the most profitable amounts and proportions of plant nutrients. The fertilizer recommendation as a guideline for fertilizer use has become a main educational tool in fertilizer promotion. Using this tool is good because, when executed properly, it supposedly employs both the technical and economic aspects of fertilizer use. These aspects generally are based on the impartial research findings of various public institutions. Yet the precise meaning of a fertilizer recommendation is somewhat vague. What does a fertilizer recommendation mean? What is the technical and economic basis for it? These questions are not easily answered. It appears that the four principal considerations[18] in a fertilizer recommendation are:

1. the relative availability, as determined by chemical analysis, of nutrients in the soil;
2. other sources of nutrients and past cropping history;
3. the likely variation of the production function and an attempt to maintain the marginal return above the marginal cost to allow for the uncertainty involved and for other uses of capital; and
4. the farm operator's yield goal as an indication of his confidence in his farming practices, willingness to accept risk, and opinion of weather variability and suitability for crop production.

The consideration that probably causes the most problems in making a fertilizer recommendation is number 3. The data available on fertilizer response under various conditions and for various soil types are too limited for good estimation of production functions. Despite this limitation, the items considered for a fertilizer recommendation are elements of fertilizer use that are understood better after the recommendations are followed. In this way, fertilizer knowledge increases.

What is the probable role of knowledge in the future? Assuming that farmers are practitioners of techniques, it seems reasonable that promoting or presenting future techniques will continue to be an educational process. However, fertilizer has reached the status of a conventional farm input in many areas. In the future, price variables may be relatively more important than knowledge because farmers are acquainted now with fertilizer.

[12] Griliches, Zvi, "Are Farmers Irrational?" *Journal of Political Economy*, Vol. 68, No. 1, February, 1960, pp. 68-71 (a review of Jesse W. Markham, *The Fertilizer Industry: Study of an Imperfect Market*, Vanderbilt, U.P., 1958).

[13] Beal, G.M., Joe Behlen, and Larry Campbell, "The Critical Role of Fertilizer Knowledge in Fertilizer Sales," *Commercial Fertilizer and Plant Food Industry*, April, 1961, p. 23.

[14] *Ibid.*

[15] *Ibid.*

[16] *Ibid.*

[17] For examples on the use of educational programs as methods of nonprice competition see: Warren J. Sharrat, *op. cit.*; W. L. Ballaw, "Mixed Goods Marketing—Local Area Producers," *Commercial Fertilizer and Plant Food Industry*, February, 1964; and R. G. Walsh, "Impact of Bulk Blending on the Fertilizer Market," *Farm Chemicals*, October, 1964.

[18] This interpretation by the authors draws from the Minnesota Experiment Station Special Report #1 and from consultations with Soil Scientists and Farm Management Specialists.

Or, stated another way, a greater effort must be made to keep the same percentage increase in fertilizer use.[19] However, the trend toward fewer and larger farms reduces the number of individual farmers who must be educated. A farmer adopting a new practice will affect larger acreages and cause more change in fertilizer practice. Thus, arguments could suggest that knowledge could play an even greater role. To some degree the question remains open.

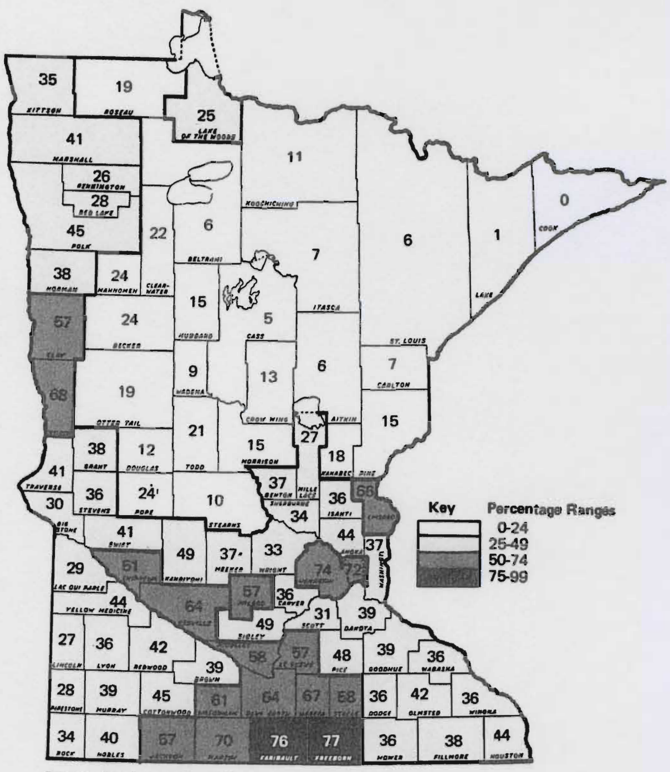
This might suggest a similar trend. With fewer farmers, each more receptive to learning and using innovations, and with extensive promotion and educational programs, agriculture may get closer to a state of "perfect technical knowledge" with respect to fertilizer use.

The determinants of fertilizer demand discussed show existing variables that have either a positive or indeterminant effect. Yet the impact of demand determinants has not been uniform geographically. One would expect many of the technical and price factors to have a relatively uniform impact over a wide geographic area. The direct impact of knowledge on fertilizer use and its indirect effect through uncertainty and capital rationing would be expected to vary and be expressed as geographical variation in fertilizer use practices. An example of this is the variation in fertilizer use in Minnesota counties. The relationship between amounts of fertilizer used to the aggregate fertilizer recommendations for each county may be interpreted as the degree to which fertilizer is regarded as a standard practice (figure 7).

Counties in south central Minnesota seem closer to following conservative fertilizer recommendations than counties in other areas. There is room for substantial improvement in all areas of Minnesota, however. Figure 2 shows the geographical patterns of fertilizer use in Minnesota. The highest concentration of use is in south central Minnesota and, to a lesser degree, the Red River Valley. Use is less concentrated moving away from these areas. It is logical that fertilizer use develops geographically as response to fertilizer use becomes known within a community.

Through service-oriented promotion, competition in fertilizer distribution has contributed to farmers' knowledge of fertilizer use. Leaders in this activity have been fertilizer blenders in Minnesota.[20] Consequently, one would expect fertilizer use to have increased more in those countries first served by blending plants. From 1959 to 1964, the average tonnage increase in counties with one or more blending plants in 1959 was about twice the average increase in the counties with no blending plants. While this seems to support the hypothesis, the results were not statistically significant due to a large variation in the change in fertilizer use from 1959 to 1964 in both categories of counties.

Have there been more incentives to improve knowledge of fertilizer use in some areas than in others? To examine what these incentives might be, four counties in each of five fertilizer use categories were selected ran-



Source: See figures 2 and 6.

Figure 7. Fertilizer applied as a percent of fertilizer recommended, 1964.

domly.[21] Data on land value, farm size, and percentage of harvested acres fertilized in these counties were considered potentially useful and are given in table 9.

The mean land value for each category is progressively lower for lower categories of fertilizer use. This implies two relations: (1) fertilizer is substituted for land more readily where land values are higher and (2) a close correlation probably exists between land value and the land's capacity to absorb profitably more units of fertilizer. This second relationship may imply further that the fertilizer recommendation in figure 2 may be much too low for high land value counties and/or too high for low land value counties.

Somewhat in support of this implication is the comparison of the percentage of harvested acres fertilized with the fertilizer used as the percentage of aggregate recommendations on a county basis. The latter was greater than the former for county groups I, II, and III. This indicates that average usage rates were higher than those used in establishing the recommendations. For categories IV and V, the reverse is true.

[19] Heady, E.O. and Martin H. Yeh, "Factors Relating to U.S. and Regional Demand for Fertilizer," *Commercial Fertilizer and Plant Food Industry*, March, 1960.

[20] Sharrat, Warren J., "Competition is Growing in Minnesota," *Farm Chemicals*, May, 1964.

[21] The use categories based on figure 2 were: I.—60 percent and over; II.—45-60 percent; III.—30-45 percent; IV.—15-30 percent; and V.—less than 15 percent.

Table 9. Relationships of farm size, acres fertilized, and fertility gap by county groups in Minnesota, 1964.

County	Average farm size	Land value	Percent of harvested acres fertilized	Fertilizer used as percent of fertilizer recommended
I. Faribault	234	312	52	76
Blue Earth	209	292	45	64
Freeborn	184	285	55	77
Watonwan	221	255	47	61
Mean	212	286	50	70
II. Chippewa	259	183	43	51
Sibley	187	311	37	49
Steele	170	260	49	58
Nicollet	214	289	42	58
Mean	207	260	43	54
III. Houston	230	116	34	44
Dakota	197	363	47	39
Wright	140	218	24	33
Wabasha	233	138	34	36
Mean	200	209	35	38
IV. Todd	183	98	24	21
Otter Tail	230	94	25	19
Clearwater	253	46	31	22
Kanabec	197	76	27	18
Mean	215	79	27	20
V. Koochiching	233	48	11	11
Cass	244	50	13	5
Wadena	229	55	22	9
Beltrami	251	49	14	6
Mean	239	51	15	8
Minnesota	234	168	42	

Source: *U.S. Census of Agriculture 1964*, Preliminary Report, County data, U.S. Department of Commerce.

Supporting the hypothesis that improved knowledge causes the geographical pattern of fertilizer use is the decreasing percentage of fertilized, harvested acres in counties which use lower percentages of the recommended fertilizer levels. While this conflicts somewhat with the notion in the previous paragraph, the data leave room for both arguments. However, the sample is small and without support of useful statistical tests.

Looking at county averages, farm size explains nothing about the development of a fertilizer use pattern. However, data permitting, it would be important to identifying future fertilizer use trends to learn if larger farms tend to fertilize more of their crop acres and use higher rates than do smaller farms. If this is true, the trend toward larger farms might be a measurable determinant of fertilizer demand.

The increased fertilizer demand is a tribute to the educational programs of industry and universities which promote better farm management. The adoption of soil testing and fertilizer and lime recommendations made from soil tests has been a principal factor in the Minnesota fertilizer industry's growth. A soil test furnishes a farmer with dependable information on the lime and fertilizer needs of crops grown on his fields. In addition, summaries of soil test results indicate the overall fertility status of soils in given areas of the state.[22] These summaries, which are very valuable to farmers, also are useful to the lime and fertilizer industries because they point out the areas where specific products are most needed. These educational programs have proven, through farm experience, that fertilizer is one of the farm inputs yielding the greatest return per dollar invested when its use is based on a soil test. At current fertilizer use levels, the opportunity is great to increase farm productivity and income by increasing fertilizer use.

III. Fertilizer Production and Distribution

Primary Production

Primary production of plant nutrients converts the natural form of the element into a basic material suitable for combination into mixtures or direct application. Four elements — nitrogen, phosphorus, potassium, and sulphur — are basic to the production of the fertilizer forms of

[22] Grava, John, *Fertility Status of Minnesota Soils as Shown by Soil Tests*, University of Minnesota Agricultural Experiment Station Miscellaneous Report No. 56, 1964.

N, P, and K. Sulphur, in the form of sulphuric acid, is necessary to produce soluble phosphates from phosphate rock.

LOCATIONAL PRODUCTION OF PRIMARY NUTRIENTS

Currently, nitrogen production is largely a process of combining atmospheric nitrogen with hydrogen from natural gas or other carbonaceous material to form anhydrous ammonia (NH_3). Natural gas is now the predominate input for NH_3 synthesis. In choosing a location for an ammonia plant, a source of cheap feedstock and the potential market are major considerations.[23]

The basic source of phosphate fertilizer is phosphate rock. The primary rock phosphate mining area is Florida, although deposits exist in Tennessee, North Carolina, and Western States also. The acidulation of phosphate rock by either sulphuric or phosphoric acid produces the normal and concentrated forms of superphosphate. The diammonium phosphates used extensively in blending and mixing are a product of phosphoric acid and ammonia.[24]

In recent years, New Mexico has been the major source of potassium salts for the fertilizer industry. While the Carlsbad, New Mexico area probably will continue to supply the major share of potash for the U. S., deposits in Utah, California, and near Saskatoon, Saskatchewan are likely to become increasingly important.[25]

PLANTS AND CAPACITY

Minnesota is not a phosphorus or potassium source, but primary plant nutrients are produced in the state. Sufficient capacity for ammonia and ammonium nitrate production has made Minnesota a net exporting state in nitrogen for 1964.[26] However, productive capacity in the entire fertilizer business is expanding faster than fertilizer use. This appears to be particularly true for nitrogen.[27]

Phosphoric acid is produced in Minnesota primarily for use in synthesizing diammonium phosphate.[28] Diammonium phosphate capacity is nearly 100,000 tons per year or 40,000 tons of P_2O_5 equivalent. Table 10 compares Minnesota plant capacity with that of the United States. Figure 8 shows the location of primary production in Minnesota.

NEW MATERIALS AND METHODS

The industry consistently has developed new materials and new fertilizers during its growth periods. Notable examples are the high analysis fertilizer and the various granulation techniques that have improved the physical condition for technical combination of fertilizer. The diammonium phosphates are examples of materials that have created considerable impact in their contributions to the blending segment of the industry.

Future items may include polyphosphates capable of a 0-54-0 superphosphate analysis or a 16-60-0 ammonium polyphosphate. Some of these materials appear to be better micronutrient carriers and have other high quality characteristics. A potassium polyphosphate with 56 percent of P_2O_5 and 35 percent of K_2O is being studied also. Urea ammonium phosphates with potential for grades such as 25-35-0 or 33-20-0 may be introduced soon. These TVA developed materials could lower the cost per pound of plant nutrients and affect bulk blending.[29]

[23] "The Nitrogen Picture, 1957 Model," *Journal of Agriculture and Food Chemicals*, August 1957, (a staff report), p. 574.

[24] *Fertilizer Trends 1964*, *op. cit.*, pp. 5-6.

[25] *Ibid.*

[26] From Capacity Data and Nitrogen Used in Minnesota, Minnesota Department of Agriculture.

[27] Fertilizer Trends, 1964, *op. cit.*

[28] Mather, J. W., "Supply Coops Pool Resources and Buying Power," *New Farmer Coops*, January, 1962.

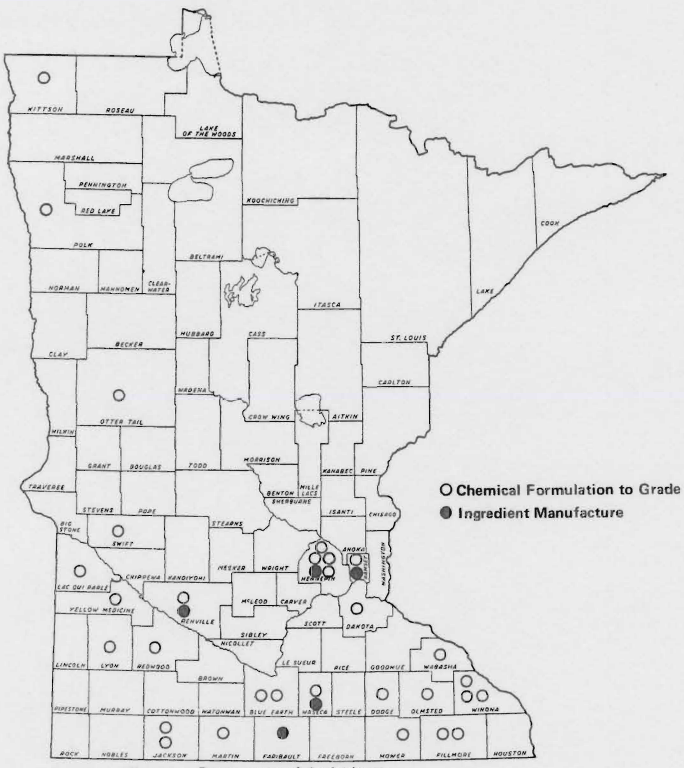
[29] Douglas, John R., Jr., et al. Fertilizer Trends, 1964, including TVA's activities. National Fertilizer Development Center, TVA, Muscles Shoals, Alabama, pp. 9-10.

Table 10. Plant capacity, January 1, 1967, and estimated expansion for major fertilizer materials through 1968.

	1967 capacity				Capacity expansion, U. S.			
	Minnesota		U. S.		Plant expansion		New plants*	
	Number of plants	Thousand tons	Number of plants	Thousand tons	Number of plants	Thousand tons	Number of plants	Thousand tons
Ammonium nitrate	1	88	51	6,689	1	32	7	1,003
Anhydrous ammonia	1	90	95	12,156	6	620	17	5,075
Urea	0	0	35	2,378	1	60	10	1,307
Phosphoric acid (wet process) P_2O_5	1	32	40	4,830	2	288	4	759
Elemental phosphorus	0	0	14	610	2	65		
Concentrated superphosphate	0	0	23	2,478	1	123		
Diammonium phosphate P_2O_5 tons	1	69	50	2,904	0	0	5	363
Potash, U. S. and Canada	0	0	14	6,031	1	1,200	3	2,220

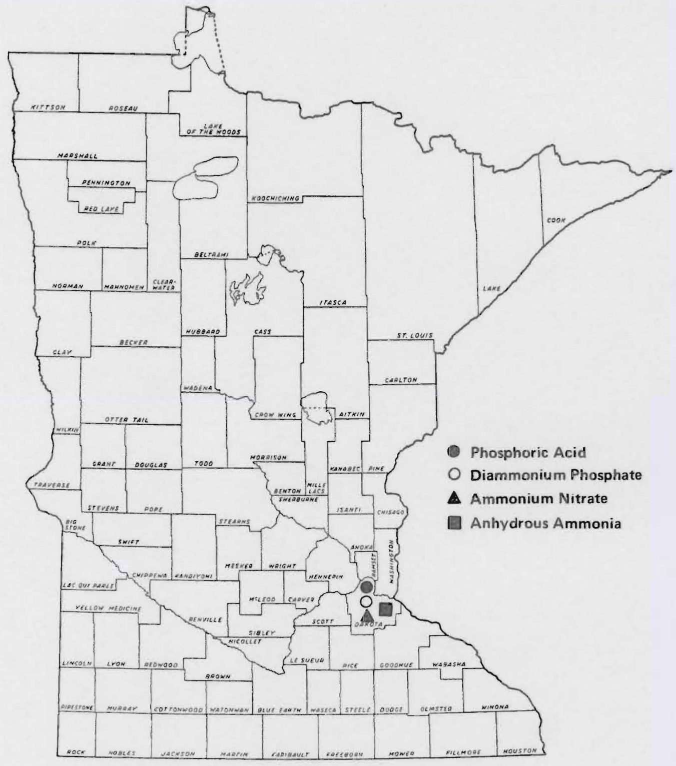
Source: Douglas, John R., Jr., Edwin A. Harre, and E. L. Johnson, "Fertilizer Trends 1967—including TVA's Fertilizer Activities," National Fertilizer Development Center, Tennessee Valley Authority, Muscle Shoals, Alabama.

* New plants under construction or planned.



Source: Minnesota Department of Agriculture

Figure 8. Location of primary fertilizer production activities in Minnesota, 1964.



Source: Minnesota Department of Agriculture

Figure 9. Location of fertilizer manufacturing activities in Minnesota, December 31, 1967.

Other developments applying directly to bulk blending have produced closely sized basic granular materials for use in bulk blending. Compatible particle size of nitrogen, phosphate, and potash materials is essential to accurate mixing and spreading of bulk blended products.

Liquid fertilizer also shows promise of higher analysis through the use of superphosphoric acid in clear solutions. Related to liquid fertilizers are the newly introduced slurry or suspension fertilizers. They offer the advantages of liquid fertilizer without the disadvantage of low analysis. Slurrys can be made from a variety of solid materials held in suspension by a specific process. A wide range of grades is possible.[30]

The industry is working on fertilizers with a higher nutrient content, better physical quality, and lower cost. These fertilizers also may be more effective than those in use today.

Fertilizer Manufacture

The location of fertilizer manufacturing depends much more on consumption than does the primary production of nutrients. Merchandising methods and freight costs may be largely responsible. The distribution of bagged fertilizer and the need for specific grades or ratios for soil and crop needs generally has placed manufacturing plants in areas of high fertilizer use. However, a large operation is necessary for chemical formulation of materials into many different grades.

By December 31, 1967, Minnesota had licensed 35 plants to manufacture dry fertilizers to grade (figure 9). Twenty-seven out-of-state manufacturing plants are licensed to distribute in Minnesota. This represents a decrease in Minnesota plants and a slight increase in licensed out-of-state plants since 1965.[31]

These plants have been formulating an increasing number of grades and ratios to satisfy farm and nonfarm needs and to compete with the versatile bulk blending operations. There also has been a trend toward developing out-of-state bulk handling systems and/or offering bulk spreading service directly from the manufacturing plant. These services and the gradually increasing demand for mixed fertilizers probably have resulted in continued growth.

According to Minnesota data, from 1960 to 1964 dry fertilizer manufacturing firms modestly increased their tonnage sale of dry mixed grades. However, since this increase did not keep pace with the growth of the Minnesota fertilizer industry, their share of the total market declined. Total fertilizer sold by the same firms increased more than the mixed grades increase. This indicates pro-

[30] *Ibid.*

[31] State of Minnesota Department of Agriculture.

portionately larger increases in sales of straight goods. However, the total market share of firms manufacturing dry fertilizer decreased despite absolute increases in tonnage. Table 11 summarizes fertilizer sales as reported by dry fertilizer manufacturing firms.

In Minnesota, liquid mixed grade manufacturing firms have not enjoyed the steady growth of their dry counterparts. Liquid mixed fertilizer sales in Minnesota have been stable at about 17,000 tons per year.[32] However, the number of firms manufacturing liquid fertilizer in the state increased from 19 in 1964 to 26 by mid-1965 and to 37 by mid-1966.[33] The potential market and comparatively low plant investment required are factors attracting producers into the liquid mix fertilizer business.

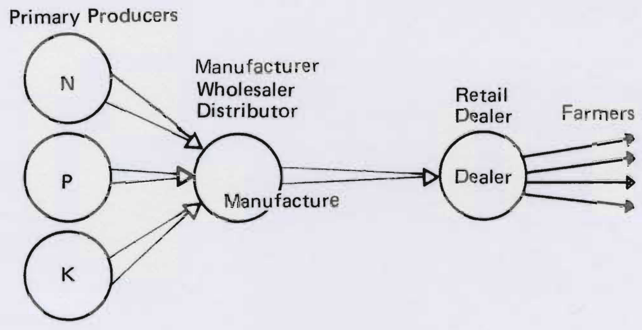
Distribution

The distribution of fertilizer may be described by its marketing process, from the origin in the usual raw state to its ultimate consumption. Marketing includes transportation, processing, handling, packaging, wholesaling, and retailing. Various facets of fertilizer distribution have been changing to some extent recently. Traditionally fertilizer moved from the primary producer to the manufacturer-wholesaler to retail outlets (figure 10).[34] Various storing, processing, handling, and packaging services were performed along the way. The retail outlets were fertilizer dealers, grain elevators, and various farm supply stores. Fertilizers usually were bagged. New methods and modifications of old ones have revolutionized fertilizer distribution.

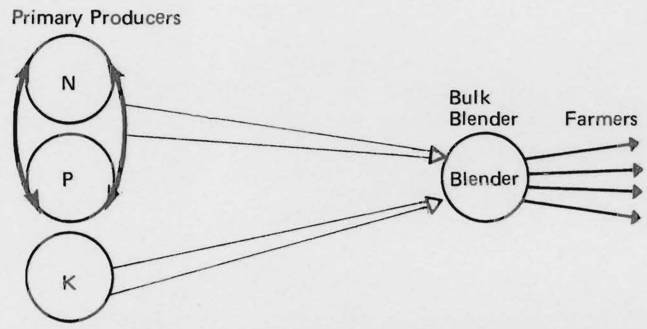
Primary producers now sell sizable quantities of materials in two forms directly to retail outlets, granulated materials to bulk blenders, and liquid nitrogen and anhydrous ammonia to various retail outlets.

Manufacturers-wholesalers continue to distribute much fertilizer traditionally, but also distribute sizable quantities of bulk fertilizer through dealer bulk stations and directly to customers.

Other important changes not seen readily include a large number of mergers, acquisitions, and expansions that integrate the industry vertically.[35] Integration has been both backward to primary production and forward to retail outlets. Primary producers have merged with or acquired manufacturing firms and have developed captive retail outlets, primarily blending plants. Some petrochemical firms recently have become basic in one or more



Hypothetical Production and Distribution Channels for Bulk-Blended Fertilizer



NOTE: Adapted from Eichars, Theodore R., "Cooperative Bulk Fertilizer Blending in the Upper Midwest," USDA Farmers Cooperative Service General Report No. 122, July 1964.

Figure 10. Traditional and newly developing production and distribution channels for mixed and blended fertilizers.

nutrients and quickly have been acquiring old-line, mixed-good manufacturing firms. Some mixed-good manufacturing firms also have become basic in one or more primary nutrients. Within cooperative organizations, integration has occurred from the farmer-customer back through retail outlets to fertilizer manufacture and primary production.

The new activity in nearly all phases of the fertilizer industry affects distribution either directly or indirectly. Table 12 lists seven fertilizer activities carried on for 4 recent years by Minnesota and out-of-state (O.S.) firms selling fertilizer in Minnesota. Most firms and plants engage in more than one activity. Thus, most plants that dry mix to grade also dry blend to customer formula. The rather marked increases in number of activities from mid-1964 to mid-1965 indicate the distribution revolution

[32] Fertilizer Analysis and Registration, State of Minnesota, Department of Agriculture, 1961, and mimeographed supplements for 1962-1965.

[33] Minnesota Department of Agriculture, License Applications.

[34] Douglas, John R., and Robert D. Grisso, "Potential Value of Bulk Blending and Distribution to Southern Agriculture: From an Economic Standpoint," Southern Bulk Blending Conference, Knoxville, Tennessee, January, 1963.

[35] Abbott, John, "Appraising the Market Structure for Fertilizer," Illinois Experiment Station, 1962, AE 3763, pp. 19-22.

Table 11. Fertilizer sales by chemical formulation to grade licensees in Minnesota.

	1960		1964	
	Tonnage	Percent of yearly total	Tonnage	Percent of yearly total
Dry mixed grades	326,817	67.7	362,358	50.5
Total fertilizer	372,420	77.1	461,066	64.2

in the state. The increase in numbers of plants and activities resulted mainly from the entrance of new firms but also from new plants and new activities of established firms (table 13).

The industries responded to increased fertilizer demand since 1955 by developing bulk blending, liquid nitrogen, liquid mixes, and various bulk handling systems.

Consumption Trends through Various Distribution Channels

Concurrent with the trend toward increased total fertilizer use is the trend toward increased bulk retailing. The demand for systems of bulk handling is consistent with the swing toward mechanizing farm operations. Mechanization and an approximate $4 per ton (of dry

Table 12. Fertilizer activities in Minnesota, by plants and firms.

	1963-64				1964-65				1965-66				1966-67			
	Number of plants		Number of firms		Number of plants		Number of firms		Number of plants		Number of firms		Number of plants		Number of firms	
Activity	Minn.	OS	Minn.	OS	Minn.	OS	Minn.	OS	Minn.	OS	Minn.	OS	Minn.	OS	Minn.	OS
Dry blending to customer formula	99	7	66	3	158	12	110	8	204	13	135	13	245	11	151	12
Dry mixing to grade	83	35	54	31	144	21	96	20	182	31	150	31	208	27	161	28
Chemical formulation to grade	20	32	14	28	23	26	15	25	15	27	14	27	18	21	16	26
Ingredients manufacture	6	30	5	28	6	23	5	23	4	31	3	30	2	32	2	33
Liquid grade manufacture	19	23	15	22	26	16	18	16	52	22	19	22	59	18	19	20
Liquid blending to customer request	9	2	7	2	26	3	13	3	37	4	24	4	50	3	25	4
Speciality grade	5	2	5	2	8	26	8	26	6	5	2	5	15	28	8	29

Table 13. New fertilizer activities in Minnesota, July 1, 1966 to July 1, 1967.

	Total 1966-67 increases		Number of new firms in each activity		Amount due to new plants of new firms		Amount due to new plants from previously existing firms		Amount due to expansion of existing plants		Deletion of activity		Net changes	
Activity	Minn.	OS	Minn.	OS	Minn.	OS	Minn.	OS	Minn.	OS	Minn.	OS	Minn.	OS
1. Dry blending to customer formula	57	1	21	1	21	1	24	0	12	0	16	3	+41	— 2
2. Dry mixing to grade	45	2	18	0	20	0	11	0	14	2	19	6	+26	— 4
3. Chemical formulation to grade	3	0	2	0	2	0	1	0	0	0	0	6	+ 3	— 6
4. Ingredients manufacture	0	4	0	3	0	3	0	1	0	0	2	3	— 2	+ 1
5. Liquid grade manufacture	11	1	3	0	4	0	2	1	5	0	4	5	+ 7	— 4
6. Liquid blending to customer request	19	0	5	0	5	0	8	0	6	0	6	1	+13	— 1
7. Specialty grade	9	24	6	24	6	24	1	0	2	0	0	1	+ 9	+23

fertilizer) saving at the farm level probably constitute the basic stimuli for this demand. As recently as 1960, 21 percent of *all* fertilizer sold in Minnesota was sold in bulk (liquid and solid) form, but by 1963 it had risen to 45 percent.[36]

Total fertilizer usage in Minnesota increased by 80,000 tons from 1960 to 1963.[37] During this same period, the use of bulk fertilizer increased by 167,000 tons, indicating an 87,000 ton decrease in the use of bagged fertilizer.

Bulk fertilizer is sold to the customer in three forms: (1) liquid mixtures and materials including anhydrous ammonia, (2) dry bulk-blended, and (3) dry manufactured to grade including straight materials and multinutrient fertilizers.

By nature, liquid mixtures and materials are bulk items. Substantial gains in the use of these fertilizers are partially responsible for the increased bulk use. Dry bulk-blended fertilizers, when combined with fertilizer spreading and other services, are finding expanded markets.

Blending is mixing two or more dry fertilizer materials to meet specified needs. The increased use of solid nitrogen, solid phosphate, solid potash, and some multinutrient nitrogen-phosphate materials is due primarily to fertilizer blending. Ammonium phosphate is the basic ingredient for much blending; straight materials of the three elements are necessary for blending mixtures to specific needs.

Plants producing manufactured-to-grade fertilizer set up bulk-on-grade handling systems to offer some services already extended by the other two types of bulk operations. The total result is the increased use of bulk fertilizer.

Although a small part of total fertilizer consumption, nonfarm fertilizer should not be overlooked. This active segment of the fertilizer business increased 500 percent between 1950 and 1959 while total U.S. fertilizer use rose 39 percent.[38] In 1959, nonfarm fertilizer accounted for 3.3 million tons, or 13.2 percent, of the nearly 25 million tons used that year. Estimates attributed half of this nonfarm use to home lawns and gardens. The other half was used on golf courses, parks, airfields, highway right-of-ways, and lawns of commercial, educational, and governmental properties. With the current and prospective rate of residential, industrial, and highway expansion, growth in this market segment looks promising. The fertilizer industry is cultivating this potential.

Bulk Blending

Bulk blending is the marketing concept that disrupted the traditional marketing pattern of producer-manufacturer-dealer.[39] Blenders bypass the second phase of the pattern by direct purchasing granular forms of basic fertilizer materials from primary producers and, thereby, generally obtaining an economic advantage. Blenders usually sell the exact amount of N, P_2O_5, or K_2O to meet specific soil or crop needs. The correct proportions of materials supplying these plant nutrients are blended mechanically into a single product ready for application. Blenders also sell straight materials to farmers for specific needs. Blending caught on naturally from the spreading of agricultural lime and ground rock phosphate. Some rock phosphate spreaders added muriate of potash on top of their load to apply it on the same trip across the field.[40] Customers were interested in this service. Then ammonium nitrate was added, and mechanical blending of materials in a plant was the next logical step. Although blending probably never will be an entire fertilizer program, potentially it is an important segment of the industry.

ADAPTABILITY

Blending adapts itself to areas of heavy fertilizer use requiring numerous fertilizer ratios. In Minnesota, such areas are the southern half of the state and the Red River Valley (figure 11).

Blending plants which began operations during 1964-1966 did so primarily in counties with substantial fertility gaps. A review of figures 2 and 8 reveals that many of these new plants were reasonably close to some counties with more mature fertilizer use patterns. This situation is shown by total tonnage used and the county's fertility gap.

The location of blending plants also is illustrated in figure 12 which shows the relationship between fertilizer applied as a percentage of fertilizer recommended and blending activity. This approach to the fertility gap is relative, with the highest percentage of fertilizer applied constituting the smallest relative fertility gap.

Soil testing and close adherence to recommendations affect the demand for blended products containing the specified quantities of each plant nutrient. Situations calling for a broadcast treatment, such as fertility programs for forage, small grain, or row crops, are suited particularly to blending operations and their associated services. Blending operators apparently have developed a marketing philosophy based on inherent soil fertility, crop needs, competitive price, and farmer service. The increase in blending activity may indicate the success of this philosophy.

During the infancy of blending, the "market philosophy" and the economic advantage were partially offset by some serious flaws. Segregation of fertilizer materials used in blends resulted in crop responses which were not uniform.[41] Three factors contributed to this segregation: materials of unequal size, shape, and density; blending equipment not specifically adapted for fertilizer; and unperfected spreading equipment. The fertilizer industry now has materials that are better suited to blending than ever before, and better equipment is being built for blending and spreading. If improved materials and equipment are fully employed, blend segregation may become merely an academic problem.

Many people in the fertilizer business believe that blends have a rightful place in the fertilizer market. But, they also believe that they should not be used in some places. Where precise placement and homogeneity are primary concerns, compound manufactured fertilizers are better adapted than blends.[42]

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[36] USDA, ARS Soil and Water Conservation Research Division.

[37] *Ibid.*

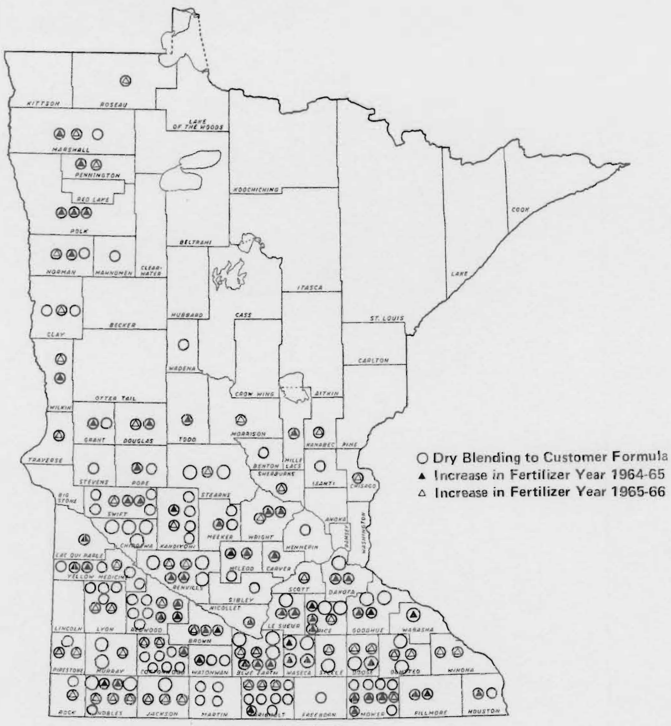
[38] Mehring, A. L., "Brief Look at the Non-Farm Fertilizer Market," *Farm Chemicals*, 125:18, October, 1962.

[39] Ballew, W.L., "Mixed Goods Marketing—Local Area Producers," *Commercial Fertilizer and Plant Food Industry*, February, 1964, pp. 67-69.

[40] Ballew, W.L., "Bulk Blending Revolutionizing the Industry," *Farm Chemicals*, June, 1963.

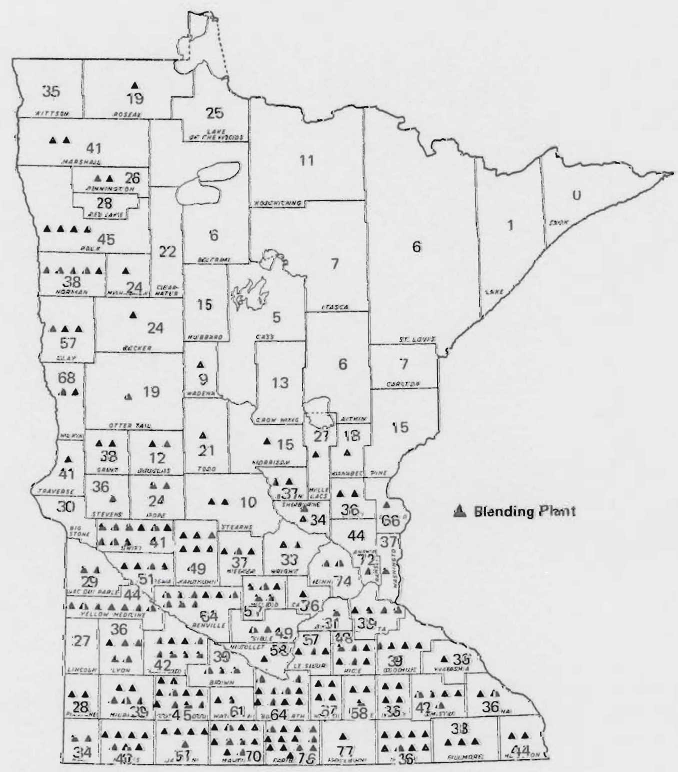
[41] Gaskins, H., "How to Avoid Mistakes in Building Blending Plants," *Ag. Chem.*, 18:60-1, October, 1963.

[42] Hignett, T. P., "What are Comparative Economics of Compound, Blended and Liquid Fertilizer," *Ag. Chem.*, 1944, April, 1960.



Source: Minnesota Department of Agriculture

Figure 11. County distribution of dry blending activities, July 1, 1966, with increases recorded in 1964-5 and 1965-6 identified.



*Fertilizer applied as a percent of fertilizer recommended.

Figure 12. Location of blending plants, December 1967, and percentage fertility gaps, 1964*

GROWTH

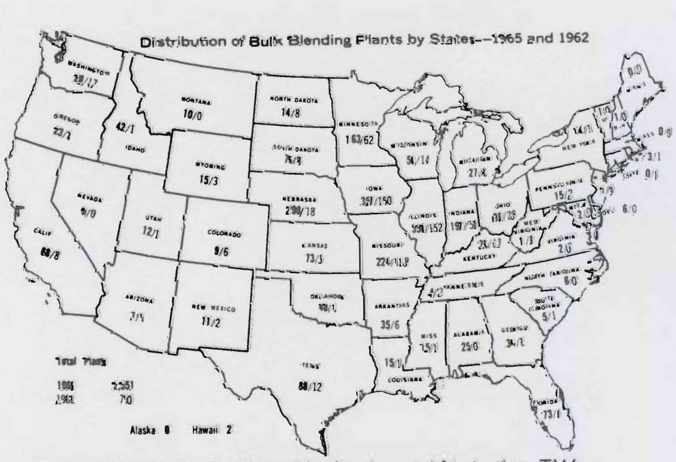
Blending fertilizer at decentralized plants began in Minnesota in 1955. In 1959, 29 bulk blending plants were in the state. By mid-1965, 158 plants were registered to operate in Minnesota. By mid-1966, the number had increased to 204.[43] The actual tonnage sold through bulk blending operations in Minnesota is not known. However, firms licensed with the Minnesota Department of Agriculture to blend to customer formula increased their use of straight materials from 1960 to 1964 (table 14). This increase indicates the trend toward blending but is not conclusive about the trend's actual magnitude.

Table 14. Tonnage of selected materials reported by firms licensed for blending to customer formula.

Materials	Fertilizer year ending June 30	
	1960	1964
1-2-0 and 1-3-0 ratios	4,371	29,508
Solid nitrogen	4,937	18,048
Solid phosphate	5,147	25,604
Solid potash	3,640	28,750
TOTAL	18,095	101,910
Total as percent of yearly total	3.7%	14.2%

Throughout the Midwest, blending developed rapidly while blending plants in other areas appeared more gradually.[44] Iowa and Illinois lead in the number of blending plants. The rapid acceptance and phenomenal growth of bulk blending in the Midwest perhaps resulted in part from a weak link in the old distribution system. The number of fertilizer manufacturer-wholesalers in Midwestern states probably was not sufficient to offer farmers the services desired with the increased use of fertilizer. Growth in bulk blending may well be due to the offering of both fertilizer materials and services (figure 13).

[43] Minnesota Department of Agriculture, License Applications.
[44] "Bulk Blending Revolutionizing the Industry," *op. cit.*



Source: Changes in Fertilizer Distribution and Marketing, TVA, Knoxville, October 1965, p. 72.

Figure 13. Distribution of bulk blending plants by states—1965 and 1962.

PLANT AND MANAGEMENT

A recent study of cooperative bulk fertilizer blending in the upper Midwest describes a "typical" blending plant.[45] According to this report, blending plants generally have frame buildings which cost $10,000 to $50,000 to erect. They are located on a rail siding for convenient receiving of fertilizer materials. Floor space, approximately 5,000 square feet, is used mainly for ingredient storage in separate bins. Minimum equipment includes a front-end loader, scale, mixer, and elevator. Optional equipment might be augers, conveyors, and bagging equipment. Total equipment costs range from $10,000 to $20,000 per plant.

The plant usually is operated by a plant manager with experience in related work; a second full-time man may or may not be required. Due to the highly seasonal nature of the business, seasonal employees are needed. Outside of peak selling months, the manager spends much time on educational programs and farmer services complementing the actual fertilizer blending and distribution of fertilizer.

Undoubtedly, many variations exist in plant size, equipment, layout, and operation. Scale of plant operation throughout the country may vary from something smaller than that described to large plants with capacities of 100 tons per hour.[46]

SERVICES

Blenders usually depend on a service-oriented program to build sales volume.[47] Soil sampling, probably the most important service offered, may be responsible for a significant share of increased fertilizer use. Services such as field mapping, keeping crop records, making fertilizer recommendations, and delivering and spreading fertilizer often are provided by blenders. Charges for services are usually modest or negligible, depending on the cost to the dealer.

Bulk blenders are not the only fertilizer retailers who now offer services. However, the "complete line" of services offered in all phases of fertilizer retailing may be due to the initiative shown by bulk blenders.[48]

Other Distribution Channels

NITROGEN DISTRIBUTION

Over the past 10 years, a time period corresponding to the growth of bulk blending in Minnesota, developments in the distribution of nitrogen products were at least indirectly responsible for nitrogen use increasing at a faster rate than use of all fertilizer.

Although solid nitrogen materials generally are more costly than liquids, per pound of nitrogen, they adapt well to bulk blending. The increased use of solids probably is due to blending activity. Liquid nitrogen materials are well adapted to direct application for high nitrogen using crops such as corn. The three general types are: anhydrous ammonia which is a liquid at a relatively high pressure; low pressure nitrogen solutions; and nonpressure solutions.[49] Since their agronomic benefits are similar, the preference for one type may be due to price, customer usage, or dealer service. Most liquid nitrogen materials are shipped directly to retail outlets from primary producers but purchases may be through cooperative organizations or purchasing agents.

Ease of application and dealers' services partly account for the popularity of various liquid nitrogen products. In most cases, the local dealer applies the nitrogen so the farmer does not have this extra job during a busy season. Charges for this service generally just cover dealer costs. Dealers often show the farmer-customer how to use the applicator. Certainly, educational programs indicating crop responsiveness to nitrogen applications affect nitrogen use. Farmer acceptance of such empirical evidence has been good. A favorable price situation, with the price per pound of nitrogen decreasing in some areas, has also positively contributed to the remarkable growth of nitrogen usage.

Liquid nitrogen is seldom the only fertilizer product distributed by a dealer. His business also may include bulk blends, liquid mixes, or dry manufactured fertilizer. These combinations are logical because they increase the length of the fertilizer season and profitably utilize labor and management. Usually dealers handle only one type of liquid nitrogen material.

LIQUID MIXED FERTILIZERS

Two types of operations in Minnesota include mixed fertilizers: liquid grade manufacturing and liquid blending to customer request. Liquid-mix plants, operating with either one or both operations, are located in the same general areas as blending plants (figure 14).

Typical plants are small, producing an average of a little over 1,100 tons per plant in the United States in 1964.[50] In that year, liquid mixes accounted for 5 percent of all mixed fertilizers produced in the United States. In Minnesota, liquid mixes totaled 16.3 thousand tons, or 3.2 percent of all mixed fertilizers for 1964, and about 16.0 thousand tons, or 2.9 percent, in 1965.[51] Liquid mixes have not grown since 1959 in Minnesota, perhaps because of the alternatives offered by blending plants, the special equipment needed if the customer wants to make application himself, and the low analysis of mixtures.

The future of liquid mixes may improve as high analysis products become available. This development is imminent due to new basic products for solutions and high analysis slurries.

BULK HANDLING

As described earlier, bulk handling includes both liquid and dry fertilizers. It is part of a sales technique begun by bulk blenders and liquid dealers and vigorously pursued by manufactured fertilizer dealers. The technique involves selling a program of simplified application along with fertilizer materials and other services. The

[45] Eichers, Theodore R., "Cooperative Bulk Fertilizer Blending in the Upper Midwest," USDA Farmers Cooperative Service, General Report No. 122, July, 1964.

[46] "Whiteside Service Blends—100 Tons Per Hour," *Farm Chemicals*, 127:38, May 4, 1965.

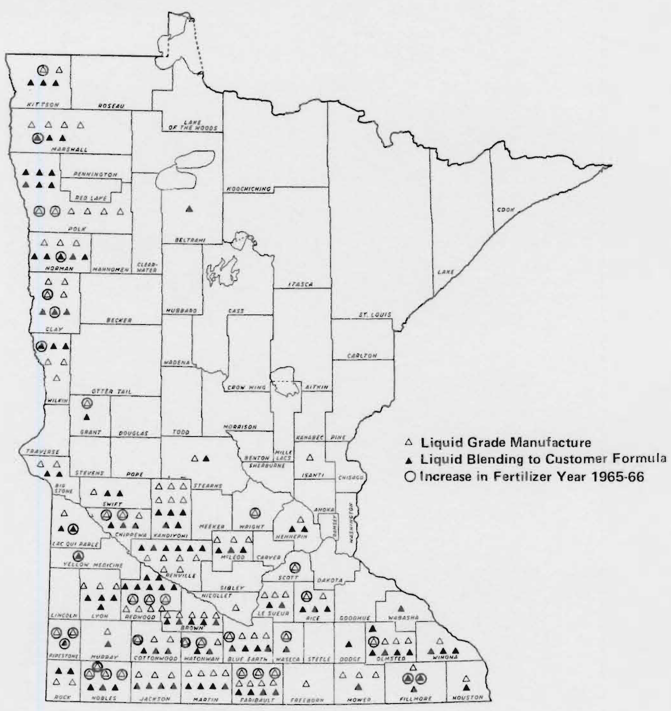
[47] Eichers, Theodore R., *op. cit.*

[48] "Bulk Blends Spark Change in Fertilizer Marketing," *Agricultural Chemicals*, 18:90, February, 1963.

[49] Pentecost, B. H., "Liquid Nitrogen Distribution by Local Cooperatives in Nebraska and Kansas," Farmer Cooperative Service, USDA General Report No. 82, July, 1960.

[50] Slack, A.V., "Liquids '65, How Liquids Capture a Market," *Farm Chemicals*, February, 1965, p. 17.

[51] Minnesota Department of Agriculture, fertilizer tonnage reports.



Source: Minnesota Department of Agriculture

Figure 14. County distribution of liquid-mix fertilizer activities, December 31, 1967, with increases during 1965-66 identified.

gradually increasing interest in bulk handling necessitated equipment changes for the manufacturer, dealer, and farmer.[52]

Several new lines of equipment, including tractor-drawn spreaders with 1- to 4-ton capacity, were developed for bulk handling at all levels. The tractor-drawn spreaders are purchased primarily by bulk fertilizer dealers, including blenders, for rental to farmer-customers. Other lines of equipment were designed for bulk blending plants, miscellaneous bulk handling, and liquid fertilizer spreading and transportation.

[52] "Bulk Handling Builds Sales," *Farm Chemicals*, 125:29, March, 1962.

Handling of bulk goods at the farm level probably is the weakest area of bulk distribution.[53] Using equipment for farm level transportation and mechanical handling of bulk fertilizer probably has not developed as rapidly as other phases of distribution. The availability of bagged fertilizers, custom spreading service, and rental spreaders may be partially responsible.

GEOGRAPHIC OWNERSHIP SOURCE OF MINNESOTA FERTILIZER SALES

Some speculation exists about whether the growth of fertilizer sales in Minnesota accrued to firms outside or within the state. Tonnage reports from firms to the Minnesota Department of Agriculture suggest that the proportion supplied by Minnesota firms did not change significantly from 1960 to 1964 (table 15). Although small discrepancies in these figures are possible, this picture of Minnesota and out-of-state market share trends probably is accurate.

Long prominent in Minnesota's fertilizer industry are the supply cooperatives. These firms include small local cooperatives and several large state and regional organizations located in Minnesota or out-of-state. Table 16 shows that cooperatives had nearly 40 percent of the state's fertilizer business in 1960 but less than 36 percent in 1964. This decline may indicate a general trend or just a temporary market share loss.

Table 16. Fertilizer sold by cooperatives and other firms in Minnesota.

	Cooperatives		Other	
Year	Tonnage	Percent	Tonnage	Percent
1960 . . .	192,027	39.7	290,801	60.2
1964 . . .	257,561	35.8	460,134	64.1

Source: Minnesota Department of Agriculture.

IV. Future Prospects

Projected Usage

Any projection of growth in the fertilizer industry carries with it uncertainties. They include the variable impacts created by weather, government farm programs, costs, prices, buyer attitudes, and improved technology. Yet these uncertainties do not preclude that some projections can be made based on current information accompanied by qualifying assumptions. If reasonably stable

[53] *Ibid.*

Table 15. Fertilizer tonnage reported by Minnesota and out-of-state firms and percentage of yearly total*

	Minnesota		Out-of-state		In-state	
Year	Tonnage	Percent	Tonnage	Percent	Tonnage	Percent
1960	482,818	100	160,861	33.3	321,957	66.7
1964	717,695	100	243,127	33.88	474,568	66.12

* Source: Minnesota Department of Agriculture (Data collected by the authors differ somewhat from State Department of Agriculture data due to a slightly different procedure.)

relationships are assumed between the above-mentioned variables, projections can be based on some existing circumstances all of which indicate dramatic expansion of fertilizer use. Several of these circumstances are discussed here with their corresponding projections.

FERTILIZER TONNAGE GROWTH RATE PROJECTION

The average, annual, compound rate of growth of tons of fertilizer used in Minnesota from 1951 to 1969 was 12 percent.[54] If this remarkable growth rate continues, Minnesota's fertilizer industry will sell 1,730,000 tons of fertilizer in 1970 for about $128 million.[55] Projected to 1975, the tonnage volume would be 2,400,000 – nearly 2 million tons over the 1964 usage. These estimates may be conservative.

CAPACITY PROJECTION

Another approach to viewing the industry's growth in the immediate future is to evaluate potential in terms of increased capacity and aggressive marketing. While this approach does not determine the future fertilizer demand, experience suggests that increased competition and service-oriented marketing help develop the inherent demand. If tonnage figures believed necessary for a blending plant to break even were applied to the additional 46 blending plants registered in Minnesota for the year ending June 30, 1966, the net increase in fertilizer use soon would be 101,000 tons from this one activity alone.[56] If each of the 11 new liquid-mix fertilizer plants sold the average 1,100 tons per year, 12,000 tons increase would result. Numerous increases in other fertilizer activities may cultivate other segments of fertilizer demand for future net increases.

CLOSING THE FERTILITY GAP PROJECTION

If every acre of producing cropland received the recommended fertilizer rate, an additional 1,024,000 tons of fertilizer would need to be applied. A trend exists on many Minnesota farms toward using even greater rates than those used for the aggregate data. There is also a trend toward fertilizing an increased share of the producing cropland. If these trends continue, the fertility gap may be closed and fertilizer use greatly expanded.

FERTILIZER USAGE RATES AND PERCENTAGE OF CROPLAND PROJECTIONS

Minnesota fertilizer use patterns also can be projected on the basis of current trends in rates of fertilizer used on acres fertilized and on the percentage of producing cropland fertilized. Fertilizer rates climbed from 151 pounds per acre in 1954 and 154 pounds per acre in 1959 to 172 pounds per acre in 1964. The projected rate would be about 182 pounds by 1970 and 192 pounds by 1975. Furthermore, the percentage of producing cropland fertilized increased from about 20 percent in 1954 to 33 percent in 1959 and to 39 percent in 1964. Projecting this trend, about 52 percent of the producing cropland will be fertilized in 1970 and 62 percent in 1975. Somewhat offsetting the upward trend of these two factors is the downward trend in productive cropland. The amount of productive cropland decreased from 21.0 million acres in 1954 and 20.2 million acres in 1959 to 18.8 million acres in 1964. If this trend continues during the next 10 years, productive cropland will be 17.6 million acres in 1970 and 16.5 million acres in 1975. When these three projections are combined to yield the projected tonnage of fertilizer used on farms, and the projected tonnage of nonfarm fertilizer use is added, the projection of fertilizer use in Minnesota becomes 972,800 tons for 1970 and 1,167,000 tons for 1975. However, this system of projecting fertilizer use is quite sensitive to deviations from any assumed level. If any factor changed, a substantially different projected fertilizer use could result. For example, if all productive cropland were fertilized in 1975 at 1964 rates, fertilizer use on cropland would be 1,419,000 tons. Adding 180,000 tons of nonfarm fertilizer use, the total projected level of fertilizer use would be 1,599,000 tons.

NUTRIENT GROWTH RATE PROJECTIONS

Previously in this report, tonnages of individual nutrients used in Minnesota for specific years and the recent growth rate of plant nutrients were identified. Of possible significance when considering prospects are the growth rates and projected uses of nitrogen, phosphate, and potash (table 17). These projections may affect the production and distribution of fertilizer materials.

Table 17. Tons of N, P_2O_5, and K_2O used in Minnesota in 1955, 1960-69, and projections for 1970 and 1975 based on average compound growth rate for each nutrient.

Year	N	P_2O_5	K_2O
1955	34,959	78,244	43,784
1960	54,022	114,365	68,298
1961	65,027	115,909	71,939
1962	66,340	115,928	74,711
1963	86,636	123,774	84,813
1964	95,217	168,830	100,888
1965	103,791	189,999	109,161
1966	114,479	196,785	114,902
1967	188,123	211,695	174,551
1968	251,241	214,676	196,199
1969	339,789	280,269	213,900
1970	565,287	310,628	292,389
1975	1,134,400	478,070	525,408
Compound growth rate	19%	9%	12.6%

A continuing compound growth rate of 19.0 percent per year from 1955 to 1969 would have resulted in about the nitrogen use achieved in 1969. Assuming the same growth rate pattern continues during the next decade, nitrogen use by 1975 would be over 1,100,000 tons – more than ten times the 1964 use.

The absolute tonnage of P_2O_5 used in Minnesota has been considerably greater than that of either N or K_2O. Although its average growth rate of 9.0 percent is not as great as that for nitrogen, it is substantial. Based on this rate, the 1975 projected use of phosphate would be 478,070 tons or about 2½ times the 1964 figure.

[54] Based on tonnage reported in Fertilizer Summary Data, 1969, op. cit.

[55] Projected from 1963 tonnage value estimates.

[56] Eichers, Theodore L., op. cit. (2,200 tons volume with $10 per ton markup).

The tonnage of potash used in Minnesota has grown at an average compound rate of 12.6 percent. Using this rate, the estimated 1975 potash use would be 525,408 tons — almost 5 times the 1964 use.

With these various projections, prospects of Minnesota's fertilizer industry can be viewed from several different trends. These trends parallel one another considerably, but do not yield the same absolute projected figures. Table 18 shows four of the discussed methods of projecting Minnesota fertilizer tonnage. Two of the methods result in similar projections for 1975. These projections were independent and are relevant estimates for assumptions and procedures used. Any of the estimates may be considered liberal or conservative depending on how the variable impacts are interpreted. The projections are shown in figure 15.

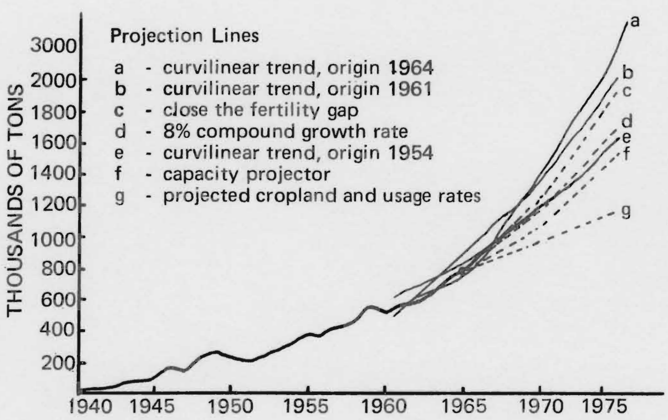


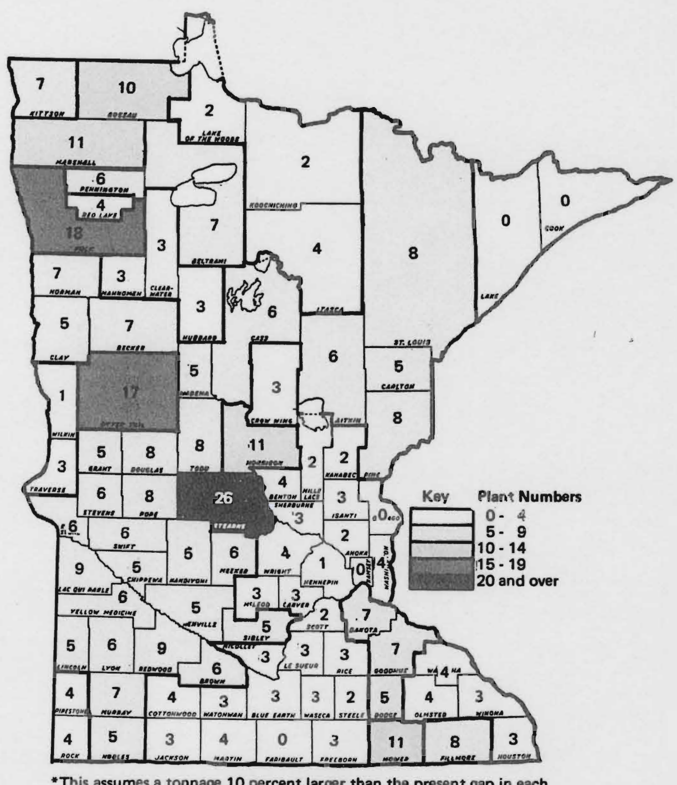
Figure 15. Minnesota fertilizer usage projections, 1970 and 1975.

Implications for Distribution

Projections of current trends indicate an increased fertilizer volume of at least 2½ to 3 times the 1964 usage by 1975. Although the exact nature of the distributive phase of the state's 1975 fertilizer industry is difficult to predict, considerable development is forthcoming. The various aspects of bulk handling undoubtedly will be important, but the relative magnitudes of each may be controlled by factors not yet apparent.

One segment which probably will be prominent is bulk blending. If this one activity would close the fertility gap in each county, several additional blending plants could be established in most counties (figure 16). The counties with the greatest potential for additional blending plants are in the western half of the southern two-thirds of the state. This approach relates to the possibilities in distribution, if each county were to move toward closing its fertility gap, and also could be applied to other types of distribution. This approach assumes that the general cropping pattern existing in 1963 will prevail through the projected period.

The plant nutrient projections discussed earlier affect their respective segments of the industry. The distribution pattern of individual plant nutrients becomes more important as delivery of straight materials to retail increases. Actual quantities of N, P_2O_5, and K_2O used in each county are generally unknown. Of some significance, however,



*This assumes a tonnage 10 percent larger than the present gap in each county to allow for increased recommended levels.

Figure 16. Number of additional blending plants, selling 2,200 tons of fertilizer each, which could be absorbed by each county in closing the fertility gap.* State total: 451.

Table 18. Various projections of tonnage of fertilizer usage.

Method	1970	1975
Continuing 12 percent compound growth rate	1,730,000	2,400,000
Close the fertility gap	—	1,920,000*
Considering projected rate of fertilizer use and increased cropland fertilized	972,800	1,167,000†
Considering current rates of fertilizer use and all cropland fertilized	—	1,599,000

* Considers increased level of recommended use for a net increase in nutrient recommended of 10 percent. Tonnage of fertilizer is assumed to contain 50 percent plant nutrients.
† Fertilizer containing 50 percent plant food.

is the tonnage of each plant nutrient recommended. In figures 17, 18, and 19, each county is allocated its share of the projected tonnage of each plant nutrient on the basis of its fertilizer recommendation. This projected tonnage of nutrients by county is significant for counties that will move approximately with the state average to close the fertility gap. Counties with relatively small fertility gaps may reach their projected tonnage figures earlier than 1975.

Summary and Conclusions

The outlook for Minnesota's fertilizer industry is optimistic. The industry, a positive factor in the Minnesota economy, appears to be in the midst of dynamic growth. An underlying reason for this growth is the nature of soil fertility as a factor of crop production. Unlike weather, disease, and insects, soil fertility is a completely controllable factor in crop production. Fertilizers will be applied to an increasing number of acres to eliminate fertility as a limiting factor of production. Along with dramatic increases in fertilizer use, several trends are expected to continue.

Increased use of still higher analysis fertilizers is possible due to fertilizer industry research. Some tapering off of this trend will result when combining nutrient properties becomes limiting.

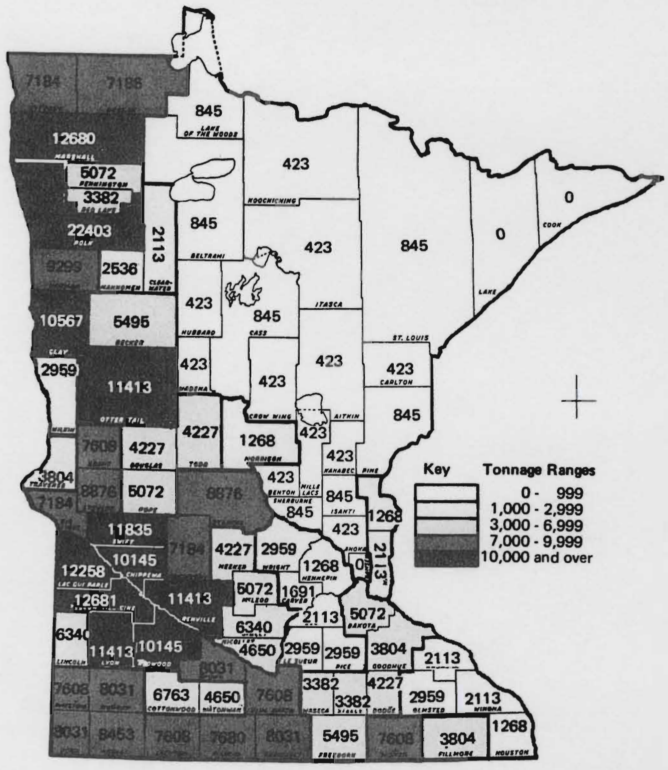


Figure 18. Projected (1975) tonnage of P_2O_5 allocated to counties on the basis of relative P_2O_5 needs in 1964.

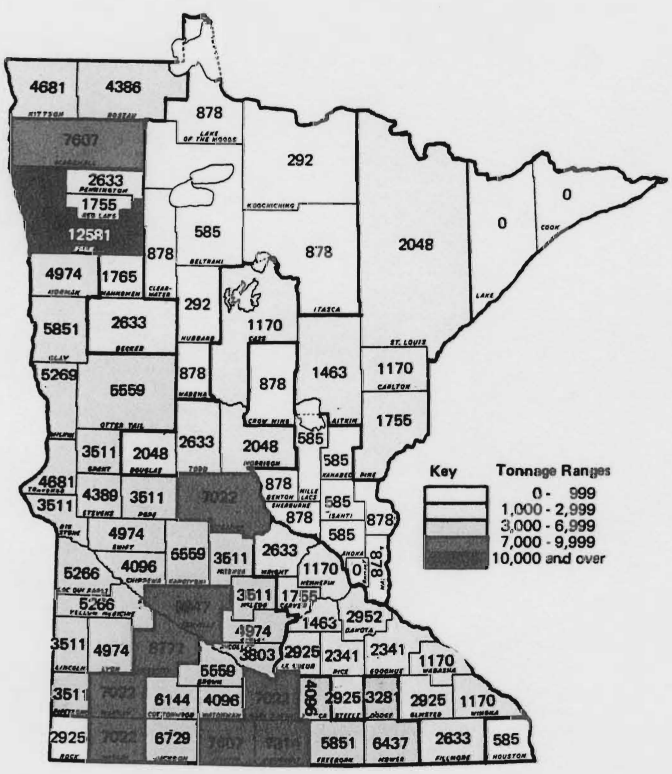
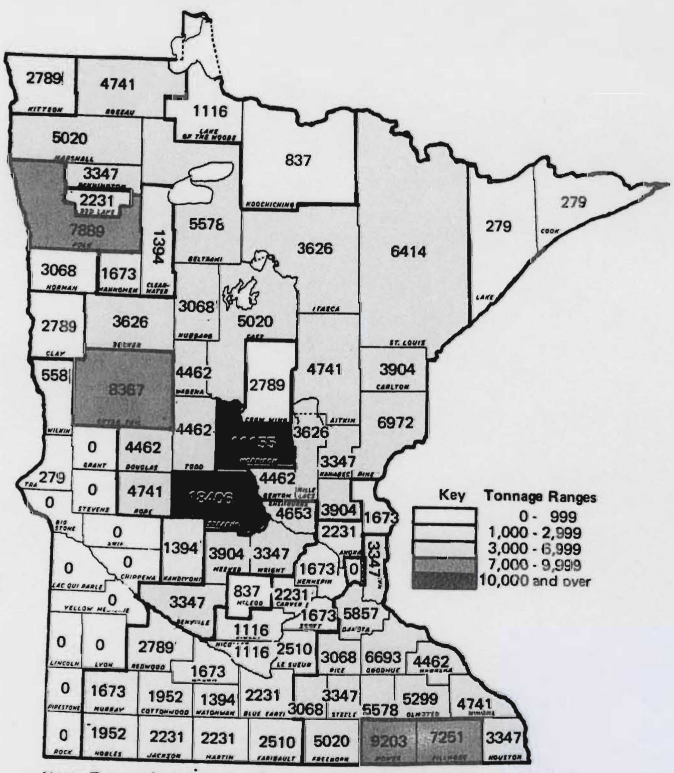


Figure 17. Projected (1975) tonnage of N allocated to counties on the basis of relative N needs in 1964.



Note: Zero projected tonnage for some counties indicates that K_2O needs are quite small rather than no use of K_2O.

Figure 19. Projected (1975) tonnage of K_2O allocated to counties on the basis of relative K_2O_5 needs in 1964.

The nitrogen segment of the industry should grow at an increasing rate and somewhat faster than the phosphate or potash segment. This growth may result partially from the tremendous fertility gap for nitrogen, the slightly downward trend in price, and changes in cropping practices that make nitrogen more economical to purchase than to raise as legume green manure crops.

Bulk blending, and with it the use of straight materials, probably will increase in importance. The three basic reasons for this increase are:

1. Blended fertilizers have an inherent economic advantage due to low production and distribution costs.
2. The demand for services at the local level positively affects blending operations and is consistent with the increasing specialization in agriculture.
3. Materials and equipment used will improve, eliminating most particle segregation problems.

The probable location of future plants is uncertain. However, new plants may be located where relatively large fertility gap counties are near areas with relatively small fertility gaps.

Because of new materials, the role of blending plants in the more distant future could change. Materials from complex chemical combinations, now being developed, could supplant some of the need for physical blending. Replacing some physical blending will be the extended need for bulk handling and spreading. Change in fertilizer recommendations and fertilizing practices may be an accompanying force. While the above changes are speculative, they are being considered in the fertilizer industry.

Bulk-mixed grades will continue to replace bagged fertilizers, conceivably until nearly all farm-used fertilizer is handled in bulk. Two reasons for this movement may be that: (1) definite economies are gained by eliminating bags and the bagging operation and (2) mechanized handling of bulk fertilizer saves labor at all distribution levels.

Growth of mixed liquids is somewhat uncertain although new materials and methods may boost the mixed liquid business.

Underlying current consumption and distribution trends are some aggressive, scientifically based marketing and promotional efforts. These efforts are undertaken generally by large firms, some of them relatively new to the agricultural field. One result is the appearance of complete agriculture service centers which include fertilizer as one of many products and associated services. This activity cannot be projected with any assurance. However, the tendency is strong for marketing and promotion to become increasingly aggressive and have an improved technological base.

The above-mentioned trends assume that federal crop programs will be somewhat consistent with recent ones. Drastic changes could alter the pattern of fertilizer demand. Further increased crop production from increased fertilizer use will be consumed at least partly by population increases and by an increased demand for poultry and meats. Crop production in excess of these demand factors could cause further surplus problems.

The growth of the fertilizer industry is causing some modest rural economic development. This development comes from two basic sources: (1) the rural location of blending plants, liquid mix plants, and other operations providing local employment and additional operational expenditures, which contribute to the overall business volume of a trade center and (2) increased farm production and income resulting from adequate rates of fertilizer also increasing dollar expenditures and business volume in a community.

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Appendices

Fertilizer Demand Analysis

Two major reasons for fertilizer consumption changes, a fertility gap and educational and promotional activities, were discussed in the previous section. Technical discussion of the four other major reasons follows.

PRICE ANALYSIS

Considerable work has been done on fertilizer demand. Research largely attempted to: (1) explain quantitatively the changes in fertilizer demand on a national or regional basis or (2) develop and test a methodological procedure for predicting fertilizer use. Because such analysis employed aggregated time series data, many variables were not included.

Griliches, studying the United States from 1911 to 1956, hypothesized that the increase in fertilizer use could be explained largely by the decline in the "real" price of fertilizer. He defined the "real" price of fertilizer as the price paid per unit of plant nutrient divided by an index of prices received for all crops. According to his regression model, expressed in logs, the log of fertilizer tonnage use was a linear function of the log of real price and the log of "lagged fertilizer" use. Griliches interpreted the results from his analysis to support his hypothesis.[57] In later analysis, Griliches found that disaggregating the fertilizer study by regions and plant nutrients resulted in the same general conclusions.[58]

Another economist drew different inferences from the same data, thereby cautioning against oversimplifying the interpretation of increased fertilizer use as resulting primarily from a decrease in the real price.[59]

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[57] Griliches, Zvi, "The Demand for Fertilizer—An Economic Interpretation of a Technical Change," *Journal of Farm Economics,* Vol. 40, No. 3, August, 1958.

[58] Griliches, Zvi, "Distributed Lags, Disaggregation, and Regional Demand Functions of Fertilizer," *Journal of Farm Economics,* Vol. 41, No. 1, February 1959, pp. 90-102.

[59] Renshaw, Edward F., "Distributed Lags, Technological Change and the Demand for Fertilizer," *Journal of Farm Economics,* Volume 43, No. 4, November, 1961, p. 955.

Heady and Yeh developed national and regional demand functions for fertilizer using time series data for 1926-1956.[60] They developed a regression model using total tons of commercial fertilizer, N, P_2O_5, and K_2O as dependent variables. They intended to provide information on factor demand that could be used for predictive purposes. The variables considered were: (1) a fertilizer price index at planting time, (2) an average crop price index lagged 1 year, (3) cash receipts from farming lagged 1 year, (4) time, and (5) income. For their model, they assumed that the crop price of the previous year served as an expectation for the present year.

Results for the region that included Minnesota indicated that the fertilizer price index, cash receipts from farming, and time were statistically significant variables. The significance of the price index suggested that farmers were price conscious; this finding supported previous studies and theoretical considerations. Substantial decline in the real fertilizer price was a major factor in increased fertilizer use. Cash receipts from farming may be a variable that represents the income effect, the farmer's liquid asset position, and changes in crop prices. The elasticity coefficient of the time variable was significant at the 1 percent level, suggesting a significant upward shift in the demand function associated with time. Heady and Yeh suggested that the time variable was a "catchall" in a regression model based on time series. However, they also believe that it importantly represented increased use of technological knowledge by farmers over time. While this conclusion was difficult to quantify, it was consistent with the increased development and application of technical factors that affected the rapid increase in fertilizer use over the past two decades.

The regression coefficient for cropland acreage was negative, perhaps indicating a substitution of fertilizer for land. While this situation was obviously true in a technical sense, Heady and Yeh suggested that this substitution was related to sporadic government control programs which paid farmers to take land out of production. Therefore, a general hypothesis suggested that farmers made up reduced acreage by applying additional fertilizer and other technological inputs to land in production.

A subsequent study included the years 1926-1960.[61] The variables were the same as those used by Heady and Yeh although others were added. Because of the intercorrelation among important variables, Heady and Tweeten believed that demand functions could not be specified enough to isolate quantitatively the absolute or relative effects of these several variables. Their interpretation of the time variable expressed some of these effects.

Heady and Tweeten found that fertilizer usage increased even when the fertilizer-crop price ratio leveled off somewhat after 1950. The finding indicated the importance of nonprice factors in fertilizer demand. Technological factors apparently were as important as price variables in determining fertilizer demand. Microaspects of fertilizer usage also supported this hypothesis.

In a study similar to that by Heady and Yeh, Brake further recognized the importance of certain "unquantifiable" variables in fertilizer demand:

> "It is the author's impression that effects of technological changes, levels of knowledge and governmental programs have been of much importance and the estimates of the effects of the specifically considered economic variables are over-estimates."[62]

Brake doubted that fertilizer usage would return to levels of some previous period even if previous levels of prices prevailed, allowing for nonincluded variables.

TECHNICAL FACTORS

When determining demand quantitatively, researchers suggested that great technological knowledge came to farmers in a way that was closely correlated to a time variable in regression.[63] For this study, technical knowledge was divided into two separate phenomena: (1) technical factors and closely associated factors and (2) adoption of this technology due to improved knowledge.

Technical factors can be divided into three general categories:[64] (1) *innovations in agricultural production* that interact positively with increased use of fertilizer in increasing crop yields, (2) *changes in the fertilizer resource* product or *its application* that allow it to be transformed into crop yield at an increased rate, and (3) the *depletion of soil nutrients* over time where fertilizer is not applied, resulting in a relatively greater crop yield response to applied nutrients.

Of the innovations, improved crop varieties are probably the most easily recognized. As a crop's inherent capacity to produce increases, increased fertility supplements must be added to the soil if a new variety is to reach its productive potential. High plant population, while depending somewhat on adaptable varieties, and irrigation are other innovations requiring additional fertilizer for successful implementation. In general, these factors cause the marginal value product of fertilizer to increase at higher rates of application; thus, they interact positively with fertilizer to increase yields.

The second category of technical factors includes factors that increased marginal value productivity due to technological improvements in fertilizer itself or its method of use. Several fertilizer production techniques developed over the years make fertilizer more available to crops than it was before. Improvements in the chemical and physical combination of the fertilizer product have been important. With continued effort by the industry, new agronomic materials probably will increase the overall efficiency of fertilizer.[65]

The trends in fertilizer application methods arose from an agronomic need but generally were conductive to increased fertilizer rates. Early equipment for applying row fertilizer had limited application rates which could be applied without causing adverse effects. Equipment for band application improved fertilizer efficiency and allowed use of higher rates. Broadcasting fertilizer, where practical, became more popular as well engineered equipment was employed and uniform application became

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[60] Heady, E. O., and Martin H. Yeh, "National and Regional Demand Function for Fertilizer," *Journal of Farm Economics*, Vol. 41, No. 2, May 1959.

[61] Heady and Tweeten, chapter 7.

[62] Brake, J. R., "Fertilizer Demand in the South Atlantic and East North Central Region," *Journal of Farm Economics*, Vol. 42, No. 3, August, 1960, p. 676.

[63] Heady and Yeh.

[64] Heady, E. O., and Martin Yeh, "Factors Relating to U.S. and Regional Demand for Fertilizer," *Commercial Fertilizer & Plant Food Industry*, March, 1960.

[65] Nelson, L. B., "New Fertilizer on the Horizon," *Crops and Soils*, 16:78, April, 1964.

possible. While this method may not have caused a more efficient conversion of fertilizer into crops, it substantially reduced the labor cost of fertilizer application and probably improved overall efficiency. Broadcasting fertilizer apparently is becoming a partial substitute for band application. This practice generally is used where a high level of soil fertility is desired. The carryover effect for use by succeeding years' crops probably is now well recognized so some cost of a broadcast application can be ascribed to subsequent years. "Pop up" fertilizer, an innovation, makes broadcasting most of the fertilizer even more practical.[66] The use of narrow corn rows also encourages growers to view broadcast with "pop up" fertilizer.

The depletion of nutrients over time no doubt results in a greater response to fertilizer on unfertilized soil the longer it is farmed (or mined). But this factor is relatively less important today than it was during the earlier growth stages of the industry. A related situation – where total nutrients removed from soil by crops are greater than additions from fertilizer and other sources – may be of growing importance. The degree which crops can draw on the soil's fertility stores may gradually diminish. Thus, for maximum profit production and sustained yield, the quantities of nutrients applied must nearly match the quantities removed by cropping.

UNCERTAINTY AND RISK IN FERTILIZER USE

Although the purpose of discussing risk and uncertainty in fertilizer demand analysis may seem obscure, its effect on some obvious determinants of demand warrants consideration.

Some risk and uncertainty is inherent in agricultural production. Therefore, the profitability of using a resource such as fertilizer is clouded somewhat by these elements of risk and uncertainty. To delineate precisely between a risk factor and a situation involving uncertainty is difficult.[67] In general, a certain type of decision may involve risk for which the probability of results is known. However, for a *specific decision*, the situation may be unique and difficult to apply on an a priori probability. Fertilizer use normally involves economic uncertainty.

The source of economic uncertainty probably has two components. The first arises from imperfect knowledge. Because the decisionmaker's experiences do not include the entire body of knowledge available, his decision allows a "margin of safety" to prevent loss. Presumably, knowledge can be improved and this component of uncertainty reduced.

The second component is the uncertainty that arises from exogenous factors beyond the decisionmaker's control. Some of these factors[68] are: (1) unpredictable price variability, (2) weather variability, (3) uncertain responses from new production techniques or methods, (4) government policies (closely associated with price), and (5) actions of other people associated with the farm business such as a banker or landlord. Since price supports for major farm crops generally are established before the decision is made to fertilize, government policy as an uncertainty factor is becoming less important. But weather uncertainty, response uncertainty, and actions of other people remain as sources of uncertainty, with the first two probably of primary importance.

Weather uncertainty and response uncertainty under given weather conditions can be lumped together under the problem of variable fertilizer production functions. Recommended fertilized use levels often are made as if the yield response to the fertilizer input is single valued.[69] Unfortunately, this situation is not true. Undoubtedly, a series of fertilizer response functions are created by variable weather and other, sometimes unknown, conditions.

The effect of this multivalued production function on individual farm demand for fertilizer depends greatly on: (1) management practices, (2) capital availability, and (3) the manager's psychological makeup about risk aversion. A superior manager using optimum agricultural practices has a higher probability of producing on a high response curve than does a poor manager. Therefore, high rates of fertilizer generally are most profitable for the superior manager.[70] Similarly, the operator with unlimited capital can more profitably use high fertilizer levels than can the operator who must divide his limited capital between alternative resources. The tendency to minimize the probability of a capital loss under adverse weather conditions has a dampening effect on fertilizer demand.

Trends in managerial abilities or knowledge, capital availability, and confidence of large rewards from fertilizer use are important aspects of the effect uncertainty has on fertilizer demand. Also important is the rate at which uncertainty arising from imperfect knowledge can be reduced. This latter factor concerns both the farmer's decisionmaking and the impact of extended agronomic-economic research.

CAPITAL AVAILABILITY AND USE

Use of fertilizer requires substantial capital expenditure. Sources of such production capital for purchasing fertilizer (or any input) generally are gross farm income, equity assets, or credit. But what constraints exist on the use of capital from these sources and how do they affect fertilizer demand?

This concept usually is called capital rationing. Two types of capital rationing exist for agriculture: external and internal.[71] As previously implied, the capital limitation results in a deviation from the theoretical behavior of the firm that the necessary amounts of a resource (money) can and will be bought at the going market price. Thus, is it possible that fertilizer is used at a suboptimum level because of capital rationing in one form or another?

[66] "Pop-up Fertilizer Starts Corn Off Fast," *Farm Journal*, March, 1966, pp. 40, 76.

[67] As recognized by F. H. Knight, "risk" involves measurable uncertainty where the distribution of outcome in a group of instances is known. But "uncertainty" is unmeasurable where the situation is unique. *Risk, Uncertainty and Profit*, Houghton Mifflin Co., Boston, Mass., 1921, p. 18.

[68] Heady, E. O., and H. R. Jensen, *Farm Management Economics*, Prentice Hall Incorporated, New York, New York, 1954, p. 516.

[69] Baum, E. L., E. O. Heady, and John Blackmore, *Methodological Procedures in the Economic Analysis of Fertilizer Use Data*, Iowa State College Press, Ames, Iowa, 1956, p. 8.

[70] *Ibid.*, p. 163.

[71] Schultz, T. W., *The Economic Organization of Agriculture*, McGraw Hill, New York, New York, 1953, p. 306.

Internal capital rationing is enforced by the farmer himself. Because of risk and uncertainty, he is unwilling to use his own capital or his borrowing capacity for adequate fertilizer. If part of this uncertainty is due to the farmer's limited knowledge about fertilizer productivity, internal capital rationing probably will decrease as he acquires information.

The concept of external capital rationing is that creditors have limited amounts of capital to lend. Aside from features such as legal requirements and credit rationing traditions, the "tap root" of this capital rationing is grounded chiefly in economic uncertainty by credit agencies.[72] This uncertainty is derived from the uncertainty in agricultural production and the uncertainty surrounding the borrower's management ability and good faith. However, external capital rationing is not a static condition. Creditors also may reduce their uncertainty with increased knowledge and experience. Improved knowledge appears to interact positively with capital rationing, uncertainty, and technical factors.

[72] Schultz, T. W., *Production and Welfare in Agriculture*, The MacMillan Company, New York, 1949, p. 143.

Appendix Tables

Appendix Table 1. — Plant food removal figures used as basis for state plant food removal.*

Crop	lbs. N	lbs. P_2O_5	lbs. K_2O
1 bushel corn	.90	.35	.25
1 bushel wheat	1.25	.625	.375
1 bushel oats	.625	.25	.19
1 bushel barley	.88	.40	.29
1 bushel flax†	2.10	.67	.56
1 bushel rye†	1.40	.90	.56
1 bushel soybeans	—	.87	1.375
1 cwt. potatoes	.33	.13	.63
1 ton sugar beets	3.75	1.50	3.50
1 ton alfalfa hay	—	10.00	45.00
1 ton other hay‡	27.00	10.00	30.00
1 ton peas (shelled) §	20.00	5.00	10.00
1 ton sweet corn ears§	8.00	3.00	2.00

*Source: Romaine, J.D. "Consider Plant Food Content of Your Crops," American Potash Institute, Washington, D.C.

†Source: Morrison, F.B. *Feeds and Feeding.* Morrison Publishing Co., New York, N.Y. 1956.

‡Assumed to have the analysis of timothy hay.

§Source: Knott, James Edward. *Handbook of Vegetable Growers.* Wiley & Sons, New York, N.Y. 1957.

Appendix Table 2. — Estimated state percentage total fertilizer usage by county*

County	1949	1954	1959	1964
Aitkin	.20	.15	.16	.11
Anoka	.81	.75	.52	.48
Becker	1.14	.73	.66	.72
Beltrami	.21	.23	.22	.14
Benton	.95	.82	.80	.67
Big Stone	.32	.42	.48	.73
Blue Earth	1.69	2.56	2.77	2.71
Brown	.94	1.36	1.40	1.44
Carlton	.33	.14	.20	.10
Carver	.57	.35	.39	.54
Cass	.24	.22	.15	.11
Chippewa	1.51	1.38	1.51	1.66
Chisago	.94	.78	.69	.74
Clay	3.10	2.36	2.68	2.69
Clearwater	.30	.12	.27	.25
Cook	—	—	—	—

*Based on fertilizer use report, *U.S. Census of Agriculture* for the years cited.

Appendix Table 2. — (continued)

County	1949	1954	1959	1964
Cottonwood	1.30	1.77	1.35	1.64
Crow Wing	.24	.17	.24	.17
Dakota	1.72	2.29	2.10	1.50
Dodge	1.62	1.79	1.83	1.29
Douglas	.96	.45	.41	.34
Faribault	1.92	3.12	3.27	3.39
Fillmore	3.39	1.68	1.83	1.47
Freeborn	3.28	4.05	3.42	3.25
Goodhue	1.89	1.35	1.76	1.44
Grant	1.22	1.01	.94	.97
Hennepin	1.01	1.55	1.13	.80
Houston	.90	..71	.83	.68
Hubbard	.30	.28	.16	.19
Isanti	.74	.83	.63	.57
Itasca	.19	.09	.06	.10
Jackson	1.99	2.62	2.02	2.34
Kanabec	.53	.42	.40	.24
Kandiyohi	1.51	1.35	1.47	—
Kittson	1.33	1.53	.97	1.27
Koochiching	.13	.08	.05	.04
Lac qui Parle	.83	.91	1.07	1.17
Lake	.07	.03	—	—
Lake of the Woods	.26	.12	.14	.19
Le Sueur	.92	.87	.92	1.24
Lincoln	.69	.67	.55	.60
Lyon	1.60	1.51	1.31	1.36
McLeod	1.25	.99	1.17	1.28
Mahnomen	.50	.19	.31	.35
Marshall	2.17	3.20	2.50	2.58
Martin	2.46	3.87	3.52	3.03
Meeker	1.14	1.01	1.02	1.14
Mille Lacs	.76	.60	.51	.37
Morrison	.93	.86	.81	.65
Mower	4.01	3.70	3.17	2.29
Murray	1.25	1.42	1.32	1.56
Nicollet	1.42	1.38	1.49	1.32
Nobles	1.22	1.60	1.47	1.70
Norman	1.63	1.17	1.19	1.64
Olmsted	2.36	1.62	1.63	1.29
Ottertail	1.91	1.12	1.43	1.25
Pennington	.44	.62	.68	.74
Pine	.78	.59	.56	.43
Pipestone	.68	1.04	.57	.72
Polk	4.76	4.70	5.05	4.81
Pope	1.25	.79	.68	.83

Appendix Table 2. — (continued)

County	1949	1954	1959	1964
Ramsey	.08	.06	.06	.05
Red Lake	.50	.48	.43	.56
Redwood	1.20	1.86	1.78	2.26
Renville	2.20	2.31	3.05	3.90
Rice	1.43	1.17	1.13	1.10
Rock	.57	.87	.63	.88
Roseau	.69	1.67	.65	.79
St. Louis	1.12	.18	.16	.15
Scott	.39	.33	.63	.43
Sherburne	.69	.67	.74	.63
Sibley	1.37	1.23	1.55	1.45
Stearns	1.68	.99	1.44	1.00
Steele	1.32	1.58	1.65	1.46

Appendix Table 2. — (continued)

County	1949	1954	1959	1964
Stevens	.83	1.04	1.18	1.10
Swift	.98	1.29	1.64	1.60
Todd	1.09	.77	.75	.63
Traverse	.63	.55	.72	.81
Wabasha	1.30	.95	.87	.79
Wadena	.34	.24	.29	.16
Waseca	.82	1.19	1.54	1.87
Washington	1.00	.97	.92	.67
Watonwan	1.02	1.70	2.07	1.50
Wilkin	.79	.68	1.38	1.42
Winona	1.52	1.26	1.13	.83
Wright	.83	.81	1.02	.81
Yellow Medicine	.88	1.21	1.74	1.82

Table 3. — Summary of nutrient recommendations, fertilizer tonnage applied, and fertility gap by county, 1964.

Nutrients — (thousand lbs.)	Aitkin	Anoka	Becker	Beltrami	Benton	Big Stone	Blue Earth	Brown	Carlton
Unadjusted nutrients recommended									
N	2,803	1,306	5,610	1,733	2,756	6,163	12,459	10,233	2,310
P_2O_5	1,688	1,040	9,816	2,063	2,369	11,560	13,355	13,820	1,352
K_2O	11,371	5,541	9,947	13,087	11,563	712	7,265	7,130	9,200
Available from applied manure									
N	782	488	1,742	760	1,400	912	1,782	1,914	644
P_2O_5	860	578	1,908	824	1,598	1,058	2,254	2,368	686
K_2O	1,130	684	2,532	1,110	2,032	1,308	2,462	3,350	954
Recommendations adjusted for manure contributions									
N	2,021	818	3,868	973	1,355	5,251	10,677	8,318	1,666
P_2O_5	828	462	7,908	1,239	771	10,502	11,101	11,452	606
K_2O	10,241	4,857	7,415	11,977	9,531	—	4,803	3,780	8,246
Total nutrient required	13,090	6,137	19,191	14,189	11,657	15,753	26,581	23,550	10,578
Tons applied	726	2,684	4,509	861	4,318	4,642	15,911	9,188	684
Fertility gap — tons	12,364	3,453	14,601	13,328	7,339	11,111	9,670	14,362	9,894

Table 3. — (continued)

Nutrients — (thousand lbs.)	Carver	Cass	Chippewa	Chisago	Clay	Clear-water	Cook	Cotton-wood	Crow Wing
Unadjusted nutrients recommended									
N	4,566	2,758	7,421	2,400	9,874	2,039	85	10,999	1,816
P_2O_5	4,947	1,842	15,882	3,315	17,061	4,104	43	12,082	1,180
K_2O	7,373	11,899	1,367	5,218	7,622	4,124	308	6,536	6,852
Available from applied manure									
N	2,042	818	1,118	1,082	1,184	840	2	1,738	544
P_2O_5	2,346	890	1,364	1,196	1,320	904	2	2,140	604
K_2O	2,956	1,190	1,804	1,578	1,724	1,222	4	2,426	786
Recommendations adjusted for manure contributions									
N	2,524	1,940	6,303	1,318	8,690	1,199	83	9,261	1,272
P_2O_5	2,601	952	14,518	2,119	15,741	3,200	41	9,942	576
K_2O	4,417	10,709	—	3,640	5,898	2,902	304	4,110	6,066
Total nutrient required	9,542	13,061	26,821	7,077	30,329	7,301	428	23,313	7,914
Tons applied	3,448	708	10,551	4,695	17,137	1,616	—	10,464	1,055
Fertility gap — tons	6,094	12,893	10,270	2,382	13,192	5,685	428	12,849	6,859

Table 3. — (continued)

Nutrients — (thousand lbs.)	Dakota	Dodge	Douglas	Faribault	Fillmore	Freeborn	Goodhue	Grant	Henne-pin
Unadjusted nutrients recommended									
N	6,097	6,410	5,088	13,169	8,569	11,507	6,544	6,399	2,651
P_2O_5	8,874	8,385	8,600	14,400	10,443	11,052	9,026	11,952	3,100
K_2O	14,590	14,242	12,186	8,036	21,276	13,915	18,216	579	4,968
Available from applied manure									
N	1,466	1,644	1,902	1,932	4,398	2,580	2,902	998	1,082
P_2O_5	1,678	1,920	2,148	2,476	4,952	3,300	3,272	1,034	1,208
K_2O	2,120	2,360	2,764	—	6,032	3,562	4,214	1,294	1,580
Recommendations adjusted for manure contributions									
N	4,631	4,766	3,186	11,232	4,171	8,927	3,642	5,401	1,569
P_2O_5	7,196	6,465	6,452	11,924	5,491	7,752	5,754	10,918	1,892
K_2O	12,470	11,882	9,422	5,376	15,244	10,353	14,002	—	3,388
Total nutrient required	24,297	23,113	19,060	28,532	24,906	27,032	23,398	16,319	6,849
Tons applied	9,543	8,205	2,190	21,609	9,356	20,706	9,157	6,191	5,083
Fertility gap — tons	14,754	14,908	16,870	6,923	15,550	6,326	14,241	10,128	1,766

Table 3. — (continued)

Nutrients — (thousand lbs.)	Houston	Hubbard	Isanti	Itasca	Jackson	Kanabec	Kandi-yohi	Kittson	Koochi-ching
Unadjusted nutrients recommended									
N	2,934	1,020	1,691	1,795	12,429	1,775	10,418	7,645	890
P_2O_5	4,577	1,249	1,779	1,217	13,692	1,501	13,448	10,970	852
K_2O	10,070	7,285	9,509	8,129	7,559	8,804	6,414	6,818	2,008
Available from applied manure									
N	2,170	486	766	482	2,014	1,042	2,204	558	298
P_2O_5	2,532	538	860	518	2,522	1,126	2,624	582	298
K_2O	3,120	700	1,106	704	2,792	1,532	3,230	816	434
Recommendations adjusted for manure contributions									
N	764	534	925	1,313	10,415	733	8,214	7,087	592
P_2O_5	2,045	711	919	699	11,170	375	10,824	10,388	554
K_2O	6,950	6,585	8,403	7,425	4,767	7,272	3,184	6,002	1,574
Total nutrient required	9,759	7,830	10,247	9,437	26,352	8,380	22,222	23,477	2,720
Tons applied	4,317	1,207	3,656	638	14,928	1,505	10,962	8,112	289
Fertility gap — tons	5,442	6,623	6,591	8,799	11,424	6,875	11,260	15,365	2,431

Table 3. — (continued)

Nutrients — (thousand lbs.)	Lac Qui Parle	Lake	Lake of the Woods	Le Sueur	Lincoln	Lyon	McLeod	Mahnomen	Marshall
Unadjusted nutrients recommended									
N	9,580	94	1,347	6,071	6,802	9,515	7,717	2,552	12,505
P_2O_5	19,910	51	1,465	5,969	10,643	19,215	10,249	4,620	19,743
K_2O	1,417	363	2,619	7,461	916	1,570	4,777	4,679	11,776
Available from applied manure									
N	1,532	22	208	1,522	1,622	1,962	2,332	658	1,048
P_2O_5	1,820	24	216	1,858	1,690	2,338	2,696	740	1,108
K_2O	2,184	32	306	2,148	2,808	2,786	3,308	956	1,518
Recommendations adjusted for manure contributions									
N	8,048	72	1,139	4,549	5,180	7,553	5,395	1,894	11,457
P_2O_5	18,090	27	1,249	4,111	8,953	16,877	7,553	3,880	18,635
K_2O	—	331	2,313	5,313	—	—	1,469	3,723	10,258
Total nutrient required	26,138	430	4,701	13,973	14,133	24,430	14,417	9,497	40,350
Tons applied	7,466	5	1,194	7,909	3,794	8,668	8,156	2,243	16,507
Fertility gap — tons	18,672	425	3,507	6,064	10,339	15,762	6,261	7,254	23,843

Table 3. — (continued)

Nutrients (thousand lbs)	Martin	Meeker	Mille Lacs	Morrison	Mower	Murray	Nicollet	Nobles	Norman
Unadjusted nutrients recommended									
N	13,802	7,482	2,043	5,597	12,144	12,705	7,291	13,120	8,468
P_2O_5	14,651	8,609	1,676	4,925	13,886	14,219	8,589	14,977	14,477
K_2O	7,989	11,638	9,124	27,182	22,510	6,661	4,300	7,638	8,491
Available from applied manure									
N	2,264	2,208	1,146	2,604	2,346	2,270	1,546	2,442	1,058
P_2O_5	3,596	2,610	1,254	2,968	2,864	2,708	1,894	2,926	1,168
K_2O	3,132	3,156	1,688	3,780	3,300	3,216	2,176	3,454	1,770
Recommendations adjusted for manure contributions									
N	11,538	5,274	897	2,993	9,798	10,435	5,745	10,678	7,410
P_2O_5	11,055	5,999	422	1,957	11,022	11,511	6,695	12,151	13,309
K_2O	4,857	8,482	7,436	23,402	19,210	3,445	2,124	4,184	6,721
Total nutrient required	27,450	19,755	8,755	28,352	40,030	25,391	14,564	27,013	27,440
Tons applied	19,302	7,240	2,334	4,124	14,569	9,922	8,439	10,826	10,451
Fertility gap — tons	8,148	12,515	6,421	24,228	25,461	15,469	6,135	16,187	16,989

Table 3. — (continued)

Nutrients — (thousand lbs.)	Olmsted	Otter Tail	Pen-nington	Pine	Pipe-stone	Polk	Pope	Ramsey	Red Lake
Unadjusted nutrients recommended									
N	6,949	13,215	4,759	3,971	6,856	20,623	6,958	148	3,363
P_2O_5	7,680	23,445	7,883	2,823	13,194	34,729	9,198	157	5,684
K_2O	14,913	24,522	7,906	17,102	1,002	18,826	12,153	303	5,717
Available from applied manure									
N	2,696	4,722	638	1,524	1,672	1,670	1,688	52	576
P_2O_5	3,122	6,672	652	1,648	1,948	1,822	1,824	66	632
K_2O	3,824	6,916	930	2,256	2,390	2,448	2,312	70	836
Recommendations adjusted for manure contributions									
N	4,253	8,493	4,121	2,447	5,184	18,953	5,270	96	2,787
P_2O_5	4,558	16,773	7,231	1,175	11,246	32,907	7,374	91	5,652
K_2O	11,089	17,606	6,976	14,846	—	16,378	9,841	233	4,881
Total nutrient required	19,900	40,872	18,328	18,468	16,430	68,238	22,485	420	12,720
Tons applied	8,251	7,974	4,746	2,743	4,560	30,657	5,287	304	3,573
Fertility gap — tons	11,649	34,898	13,582	15,725	11,870	37,581	17,198	116	9,147

Table 3. — (continued)

Nutrients — (thousand lbs.)	Redwood	Renville	Rice	Rock	Roseau	St. Louis	Scott	Sherburne	Sibley
Unadjusted nutrients recommended									
N	15,719	17,571	5,782	6,464	7,739	3,858	3,691	2,163	9,917
P_2O_5	17,480	19,755	6,893	14,229	11,430	2,091	4,490	2,005	12,054
K_2O	9,121	10,137	9,530	1,123	11,441	14,506	6,459	10,330	5,685
Available from applied manure									
N	2,246	2,310	2,070	2,022	1,092	616	1,426	680	2,408
P_2O_5	2,724	2,928	2,434	2,384	1,146	656	1,640	794	3,004
K_2O	3,072	3,196	2,966	2,884	1,646	912	2,816	968	3,376
Recommendations adjusted for manure contributions									
N	13,473	15,261	3,712	4,442	6,647	3,242	2,265	1,483	7,509
P_2O_5	14,756	16,827	4,459	11,845	10,284	1,435	2,850	1,211	9,050
K_2O	6,049	6,941	6,564	–	9,795	13,594	3,643	9,362	2,309
Total nutrient required	34,278	39,029	14,735	16,287	26,726	18,271	8,758	12,056	18,868
Tons applied	14,403	24,855	7,021	5,585	5,038	997	2,732	4,037	9,272
Fertility gap — tons	19,875	14,174	7,714	10,702	21,688	17,274	6,026	8,019	9,596

Table 3. — (continued)

Nutrients — (thousand lbs.)	Stearns	Steele	Stevens	Swift	Todd	Traverse	Wabasha	Wadena	Waseca
Unadjusted nutrients recommended									
N	15,757	6,080	7,964	8,842	6,581	7,539	3,886	2,271	7,484
P_2O_5	18,935	6,913	14,331	18,946	9,210	6,021	5,691	1,873	6,920
K_2O	46,120	9,290	1,013	1,379	14,262	1,548	12,499	10,758	8,158
Available from applied manure									
N	5,178	1,746	1,224	1,438	2,792	662	2,256	872	1,414
P_2O_5	6,016	2,084	1,410	1,724	3,180	772	2,586	984	1,718
K_2O	7,360	2,480	1,662	3,048	4,682	942	3,252	1,266	1,996
Recommendations adjusted for manure contributions									
N	10,579	4,334	6,740	7,404	3,789	6,877	1,630	1,399	6,070
P_2O_5	12,919	4,829	12,921	17,222	6,030	5,249	3,105	889	5,202
K_2O	38,760	6,810	–	–	9,580	606	9,247	9,492	6,162
Total nutrient required	62,258	15,973	19,661	24,626	19,399	12,732	13,982	11,780	17,434
Tons applied	6,405	9,298	7,022	10,193	3,987	5,186	5,008	1,049	11,673
Fertility gap — tons	55,853	6,675	12,639	14,433	15,412	7,546	8,974	10,731	5,761

Table 3. — (continued)

Nutrients — (thousand lbs.)	Washington	Watonwan	Wilkin	Winona	Wright	Yellow Medicine	Total	Tons
Unadjusted nutrients recommended								
N	2,555	7,647	8,493	4,023	6,641	9,538	578,238	289,119
P_2O_5	4,330	8,231	4,892	6,088	7,756	20,164	775,931	387,965
K_2O	8,258	4,456	2,393	13,265	11,223	1,564	769,782	384,891
Available from applied manure								
N	1,024	1,270	706	2,358	2,768	1,580	134,902	–
P_2O_5	1,024	1,586	802	2,712	2,166	1,932	158,758	–
K_2O	1,352	1,770	1,020	3,414	4,016	2,216	196,284	–
Recommendations adjusted for manure contributions								
N	1,531	6,377	7,787	1,665	3,873	7,958	443,336	221,668
P_2O_5	3,306	6,645	4,090	3,376	4,590	18,232	617,173	308,586
K_2O	6,906	2,686	1,373	9,851	7,207	–	585,240	292,620
Total nutrient required	11,743	15,708	13,250	14,892	15,670	26,190	1,645,749	822,874
Tons applied	4,298	9,548	9,058	5,299	5,150	11,592	621,801	–
Fertility gap — tons	7,445	6,160	4,192	9,593	10,520	14,598	1,023,948	–

Appendix Table 4. — County fertility gap by crop, 1959-1964.

County and crop	1959 Tons recommended	1959 Actual tons applied	1959 Gap	1964 50 percent nutrient	1964 Actual tons applied	1964 Gap
AITKIN						
Hay & pasture	16,168	294	15,874	14,680	255	14,425
Corn	329	188	141	365	285	80
Soybeans	16	8	8	10	1	9
Potatoes	71	5	66	39	3	36
Other	1,347	340	1,007	768	182	586
TOTAL	17,931	835	17,096	15,862	726	15,136
ANOKA						
Hay & pasture	5,432	247	5,185	4,179	568	3,611
Corn	3,655	1,688	1,967	2,452	1,667	785
Soybeans	641	99	542	494	66	428
Potatoes	181	240	59	162	21	141
Other	932	369	563	600	362	238
TOTAL	10,841	2,643	8,316	7,887	2,684	5,203
BECKER						
Hay & pasture	12,978	1,326	11,652	11,235	1,315	9,920
Corn	2,604	686	1,918	2,139	869	1,270
Soybeans	407	19	1,388	–	40	–40
Potatoes	106	28	78	42	35	7
Other	14,446	1,331	13,115	11,957	2,250	9,707
TOTAL	30,541	3,390	27,151	25,373	4,509	20,864
BELTRAMI						
Hay & pasture	15,510	484	15,026	13,773	227	13,546
Corn	273	150	123	294	129	165
Soybeans	6	–	6	5	1	4
Potatoes	377	137	240	255	128	127
Other	3,353	350	3,003	2,336	376	2,180
TOTAL	19,519	1,121	18,398	16,883	861	16,022

Table 4. – (continued)

County and crop	1959 Tons recommended	1959 Actual tons applied	1959 Gap	1964 50 percent nutrient	1964 Actual tons applied	1964 Gap
BENTON						
Hay & pasture	9,637	322	9,315	9,532	609	8,923
Corn	4,721	3,030	1,691	3,682	2,982	700
Soybeans	514	167	347	395	251	144
Potatoes	20	–	20	6	–	6
Other	4,712	568	4,144	3,072	476	2,596
TOTAL	19,604	4,087	15,517	16,687	4,318	12,369
BIG STONE						
Hay & pasture	4,176	505	3,671	3,763	523	3,240
Corn	10,704	1,566	9,138	8,141	2,916	5,225
Soybeans	1,906	4	1,902	1,085	76	1,009
Potatoes	2	1	1	9	55	−46
Other	5,898	362	5,536	5,437	1,072	4,365
TOTAL	22,686	2,438	20,248	18,435	4,642	13,793
BLUE EARTH						
Hay & pasture	3,923	443	3,480	2,873	852	2,021
Corn	31,650	12,574	19,076	21,339	14,731	6,608
Soybeans	4,911	188	4,723	5,373	429	4,944
Potatoes	41	50	−9	10	–	10
Other	7,086	924	6,162	3,484	899	2,585
TOTAL	47,611	14,179	33,432	33,079	16,911	16,168
BROWN						
Hay & pasture	5,633	876	4,757	4,464	1,095	3,369
Corn	24,605	5,866	18,739	19,509	7,438	12,071
Soybeans	3,409	127	3,282	3,546	241	3,305
Potatoes	7	–	7	4	4	10
Other	6,014	318	5,696	3,660	410	3,250
TOTAL	39,668	7,187	32,481	31,183	9,188	21,995
CARLTON						
Hay & pasture	14,956	511	14,445	11,903	187	11,716
Corn	85	46	39	56	69	−13
Soybeans	178	2	176	–	8	−8
Potatoes	15	21	−6	147	113	34
Other	1,319	462	857	756	307	449
TOTAL	16,553	1,402	15,511	12,862	684	12,178
CARVER						
Hay & pasture	6,580	278	6,302	5,503	619	4,884
Corn	10,756	1,596	9,160	7,977	2,664	5,313
Soybeans	154	3	151	243	44	199
Potatoes	17	1	16	4	–	4
Other	4,992	118	4,874	3,159	121	3,038
TOTAL	22,499	1,996	20,503	16,886	3,448	13,438
CASS						
Hay & pasture	15,881	243	15,638	14,958	243	14,715
Corn	965	391	574	623	344	279
Soybeans	20	4	16	31	20	11
Potatoes	59	5	54	23	7	16
Other	1,783	123	1,660	864	94	770
TOTAL	18,708	766	17,942	16,499	708	15,791
CHIPPEWA						
Hay & pasture	3,398	1,279	2,119	2,871	948	1,923
Corn	21,500	5,150	16,350	14,619	6,957	7,662
Soybeans	3,228	123	3,105	3,200	219	2,981
Potatoes	5	–	5	1	–	1
Other	5,714	1,151	4,563	3,979	2,427	1,552
TOTAL	33,845	7,703	26,142	24,670	10,551	14,119

Table 4. — (continued)

County and crop	1959 Tons recommended	1959 Actual tons applied	1959 Gap	1964 50 percent nutrient	1964 Actual tons applied	1964 Gap
CHISAGO						
Hay & pasture	4,657	341	4,316	4,158	477	3,681
Corn	5,319	2,631	2,688	3,972	3,483	489
Soybeans	704	108	596	567	257	310
Potatoes	60	—	60	62	—	62
Other	3,218	423	2,795	2,174	476	1,696
TOTAL	13,958	3,503	10,455	10,933	4,695	6,238
CLAY						
Hay & pasture	9,602	831	8,771	7,207	1,138	6,069
Corn	3,736	1,673	2,063	2,860	2,486	374
Soybeans	3,409	295	3,114	—	457	−457
Potatoes	3,002	2,062	940	2,179	1,750	429
Other	29,112	8,831	20,281	22,311	11,306	11,005
TOTAL	48,861	13,692	35,169	34,557	17,137	17,420
CLEARWATER						
Hay & pasture	7,036	477	6,559	6,397	473	5,924
Corn	279	54	225	260	163	97
Soybeans	8	—	8	—	—	—
Potatoes	292	272	20	145	97	48
Other	4,752	569	4,183	3,465	883	2,582
TOTAL	12,367	1,372	10,995	10,267	1,616	8,651
COOK						
Hay & pasture	510	—	510	435	—	435
Corn	—	—	—	—	—	—
Soybeans	—	—	—	—	—	—
Potatoes	1	1	—	1	—	1
Other	—	—	—	—	—	—
TOTAL	511	1	510	436	—	436
COTTONWOOD						
Hay & pasture	5,222	763	4,459	3,551	915	2,636
Corn	30,323	5,626	24,697	19,852	9,003	10,849
Soybeans	3,492	116	3,376	4,324	228	4,096
Potatoes	42	—	42	26	—	26
Other	6,017	388	5,629	1,864	318	1,546
TOTAL	45,096	6,893	38,203	29,617	10,464	19,153
CROW WING						
Hay & pasture	9,391	81	9,310	7,762	194	7,568
Corn	1,632	840	792	1,125	719	406
Soybeans	101	17	84	109	19	90
Potatoes	27	1	26	12	4	8
Other	1,527	278	1,249	840	119	721
TOTAL	12,678	1,217	11,461	9,848	1,055	8,793
DAKOTA						
Hay & pasture	8,551	872	7,679	6,212	801	5,411
Corn	22,622	8,006	14,616	14,663	6,495	8,168
Soybeans	1,942	175	1,767	1,701	314	1,387
Potatoes	44	84	−40	120	35	85
Other	9,509	1,619	7,890	6,865	1,898	4,967
TOTAL	42,668	10,756	31,912	29,561	9,543	20,018
DODGE						
Hay & pasture	8,259	458	7,801	6,867	595	6,272
Corn	25,466	8,096	17,370	14,540	6,740	7,800
Soybeans	1,898	129	1,769	1,984	211	1,773
Potatoes	2	—	2	—	—	—
Other	8,075	672	7,403	5,646	659	4,987
TOTAL	43,700	9,355	34,345	29,037	8,205	20,832

Table 4. – (continued)

County and crop	1959 Tons recommended	1959 Actual tons applied	1959 Gap	1964 50 percent nutrient	1964 Actual tons applied	1964 Gap
DOUGLAS						
Hay & pasture	9,119	628	8,491	8,043	380	7,663
Corn	9,585	1,240	8,345	7,272	1,431	5,841
Soybeans	913	8	905	549	64	485
Potatoes	17	–	17	6	–	6
Other	13,629	204	13,425	10,004	315	9,689
TOTAL	33,263	2,080	31,183	25,874	2,190	23,684
FARIBAULT						
Hay & pasture	4,313	1,086	3,227	3,250	1,240	2,010
Corn	34,383	13,500	20,883	22,727	17,388	5,339
Soybeans	4,784	184	4,600	5,476	206	5,270
Potatoes	100	80	20	56	88	–32
Other	4,291	1,845	2,446	4,091	2,687	1,404
TOTAL	47,871	16,695	31,176	35,600	21,609	13,991
FILLMORE						
Hay & pasture	19,726	693	19,033	16,737	670	16,067
Corn	22,362	8,296	14,066	15,743	8,306	7,437
Soybeans	946	25	921	1,350	130	1,220
Potatoes	15	–	15	4	–	4
Other	11,616	349	11,267	6,454	250	6,204
TOTAL	54,665	9,363	45,302	40,288	9,356	30,932
FREEBORN						
Hay & pasture	7,623	1,015	6,608	5,706	1,062	4,644
Corn	35,055	13,886	21,169	20,643	14,673	5,970
Soybeans	2,348	470	1,878	3,010	466	2,544
Potatoes	1,584	1,043	541	1,550	1,981	–431
Other	11,070	1,070	10,000	5,565	2,524	3,041
TOTAL	57,680	17,484	40,196	36,474	20,706	15,768
GOODHUE						
Hay & pasture	14,457	512	13,945	11,979	929	11,050
Corn	15,845	7,244	8,601	11,323	6,870	4,453
Soybeans	1,700	151	1,549	1,791	304	1,487
Potatoes	16	–	16	6	–	6
Other	13,131	1,074	12,057	8,687	1,054	7,633
TOTAL	45,149	8,981	36,168	33,786	9,157	24,629
GRANT						
Hay & pasture	3,792	896	2,896	3,243	758	2,485
Corn	9,665	2,413	7,252	7,219	2,666	4,553
Soybeans	1,653	82	1,751	1,386	196	1,190
Potatoes	5	3	2	2	2	–
Other	10,011	1,392	8,619	7,080	2,596	4,511
TOTAL	25,126	4,786	20,340	18,930	6,191	12,739
HENNEPIN						
Hay & pasture	5,075	278	4,797	3,566	216	3,350
Corn	6,923	3,085	3,838	4,391	2,218	2,173
Soybeans	297	116	181	319	121	198
Potatoes	1,081	1,794	–713	958	2,121	–1,163
Other	3,115	505	2,610	1,485	407	1,078
TOTAL	16,491	5,778	10,713	10,719	5,083	5,636
HOUSTON						
Hay & pasture	11,231	160	11,071	8,891	342	8,549
Corn	7,816	3,710	4,106	5,837	3,845	1,992
Soybeans	28	43	–15	122	36	86
Potatoes	7	–	7	4	–	4
Other	4,466	306	4,160	2,727	94	2,633
TOTAL	23,548	4,219	19,329	17,581	4,317	13,264

Table 4. — (continued)

County and crop	1959 Tons recommended	1959 Actual tons applied	1959 Gap	1964 50 percent nutrient	1964 Actual tons applied	1964 Gap
HUBBARD						
Hay & pasture	9,601	204	9,397	7,625	495	7,130
Corn	905	497	408	784	689	95
Soybeans	20	–	20	52	4	48
Potatoes	43	–	43	13	–	13
Other	1,742	110	1,633	1,080	19	1,061
TOTAL	12,311	811	11,500	9,554	1,207	8,347
ISANTI						
Hay & pasture	8,922	355	8,567	6,723	366	6,357
Corn	4,877	2,150	2,727	3,381	2,497	884
Soybeans	864	190	674	884	284	600
Potatoes	243	150	93	167	193	–26
Other	2,912	367	2,545	1,824	316	1,508
TOTAL	17,818	3,212	14,606	12,979	3,656	9,323
ITASCA						
Hay & pasture	12,733	99	12,634	10,136	169	9,967
Corn	2,169	9	2,160	70	68	2
Soybeans	6	–	6	–	–	–
Potatoes	220	137	83	155	317	–162
Other	2,900	60	2,840	780	84	696
TOTAL	18,028	305	17,723	11,141	638	10,503
JACKSON						
Hay & pasture	5,866	823	5,043	4,439	1,595	2,844
Corn	35,860	9,012	26,847	23,108	12,722	10,386
Soybeans	3,486	59	3,427	4,756	322	4,434
Potatoes	5	–	5	1	–	1
Other	6,058	409	5,649	1,376	289	1,087
TOTAL	51,275	10,304	40,971	33,680	14,928	18,752
KANABEC						
Hay & pasture	9,512	320	9,192	9,484	318	9,166
Corn	2,041	1,387	654	1,184	1,037	147
Soybeans	95	11	84	52	31	21
Potatoes	12	5	7	16	5	11
Other	2,286	318	1,968	1,344	114	1,230
TOTAL	13,946	2,041	11,905	12,080	1,505	10,575
KANDIYOHI						
Hay & pasture	8,164	1,449	6,715	6,183	1,659	4,524
Corn	23,616	5,587	18,029	16,272	7,962	8,310
Soybeans	2,729	28	2,701	3,136	155	2,981
Potatoes	6	–	6	1	–	1
Other	7,573	444	7,129	4,688	1,186	3,502
TOTAL	42,088	7,508	34,580	30,280	10,962	19,318
KITTSON						
Hay & pasture	7,749	116	7,633	6,527	362	6,165
Corn	199	62	137	206	147	61
Soybeans	28	59	–31	–	–	–
Potatoes	1,198	636	562	995	1,086	–91
Other	26,066	4,108	21,958	17,703	6,517	11,186
TOTAL	35,240	4,981	30,259	25,433	8,112	17,321
KOOCHICHING						
Hay & pasture	3,228	44	3,184	3,165	101	3,064
Corn	6	8	–2	7	–	7
Soybeans	6	–	6	–	–	–
Potatoes	74	56	18	17	3	14
Other	1,007	132	875	561	185	376
TOTAL	4,321	240	4,081	3,750	289	3,461

Table 4. – (continued)

County and crop	1959 Tons recommended	1959 Actual tons applied	1959 Gap	1964 50 percent nutrient	1964 Actual tons applied	1964 Gap
LAC QUI PARLE						
Hay & pasture	5,226	904	4,322	4,618	711	3,907
Corn	24,902	4,153	20,749	17,174	6,056	11,118
Soybeans	3,964	8	3,956	3,838	69	3,769
Potatoes	4	–	4	11	–	11
Other	7,676	380	7,296	5,266	630	4,636
TOTAL	41,772	5,445	36,327	30,907	7,466	23,441
LAKE						
Hay & pasture	764	9	755	495	–	495
Corn	–	–	–	–	–	–
Soybeans	–	–	–	–	–	–
Potatoes	1	–	1	1	–	1
Other	15	3	12	12	5	7
TOTAL	780	12	768	508	5	503
LAKE OF THE WOODS						
Hay & pasture	3,614	83	3,531	2,977	120	2,857
Corn	2	3	–1	13	2	11
Soybeans	–	–	–	–	–	–
Potatoes	416	164	252	285	136	149
Other	3,221	475	2,746	2,156	936	1,220
TOTAL	7,253	725	6,528	5,431	1,194	4,237
LE SUEUR						
Hay & pasture	4,744	283	4,461	3,359	419	2,940
Corn	15,030	3,977	11,053	10,583	5,914	4,669
Soybeans	1,326	39	1,207	1,742	141	1,601
Potatoes	12	–	12	3	–	3
Other	7,497	392	7,105	3,814	1,435	2,379
TOTAL	28,609	4,691	23,918	19,501	7,909	11,592
LINCOLN						
Hay & pasture	5,631	603	5,028	4,699	868	3,831
Corn	17,228	1,961	15,267	11,456	2,489	8,967
Soybeans	726	30	696	–	88	–88
Potatoes	4	–	4	1	–	1
Other	6,907	192	6,715	2,205	349	1,856
TOTAL	30,496	2,786	27,710	18,361	3,794	14,567
LYON						
Hay & pasture	5,576	1,059	4,517	4,380	1,433	2,947
Corn	30,657	5,332	25,325	19,930	6,766	13,164
Soybeans	1,898	15	1,883	2,394	78	2,316
Potatoes	4	–	4	2	–	2
Other	6,816	296	6,520	3,594	391	3,203
TOTAL	44,951	6,702	38,249	30,300	8,668	21,632
McLEOD						
Hay & pasture	6,655	1,441	5,214	5,907	1,874	4,033
Corn	15,684	4,127	11,557	11,380	5,428	5,952
Soybeans	1,438	160	1,278	1,660	271	1,389
Potatoes	35	–	35	3	–	3
Other	5,927	249	5,678	3,793	583	3,210
TOTAL	29,739	5,977	23,762	22,743	8,156	14,587
MAHNOMEN						
Hay & pasture	4,098	406	3,692	3,826	528	3,288
Corn	1,049	284	765	940	398	542
Soybeans	110	7	103	–	–	–
Potatoes	67	37	30	34	34	–
Other	8,522	867	7,655	7,051	1,273	5,778
TOTAL	13,846	1,601	12,245	11,851	2,243	9,608

Table 4. — (continued)

County and crop	1959 Tons recommended	1959 Actual tons applied	1959 Gap	1964 50 percent nutrient	1964 Actual tons applied	1964 Gap
MARSHALL						
Hay & pasture	14,248	528	13,720	12,445	629	11,816
Corn	488	181	307	427	231	196
Soybeans	39	2	37	–	4	–4
Potatoes	2,302	1,297	1,005	2,486	1,921	565
Other	36,444	10,761	25,683	28,666	13,722	14,944
TOTAL	53,521	12,769	40,752	44,024	16,507	27,517
MARTIN						
Hay & pasture	5,456	1,694	3,762	3,656	1,840	1,816
Corn	39,253	14,652	24,601	25,694	15,860	9,834
Soybeans	3,481	262	3,219	4,464	376	4,088
Potatoes	20	–	20	1	–	1
Other	7,218	1,372	5,846	2,672	1,226	1,401
TOTAL	55,428	17,980	37,448	36,442	19,302	17,140
MEEKER						
Hay & pasture	8,086	822	7,264	6,604	1,309	5,295
Corn	19,310	4,097	15,213	13,156	5,085	8,071
Soybeans	2,004	82	1,922	2,290	415	1,875
Potatoes	10	1	9	3	–	3
Other	9,576	234	9,342	5,676	431	5,245
TOTAL	38,986	5,236	33,750	27,729	7,240	20,489
MILLE LACS						
Hay & pasture	10,106	291	9,815	9,047	496	8,551
Corn	2,676	1,896	780	1,936	1,626	310
Soybeans	222	13	209	109	22	87
Potatoes	156	80	76	35	45	–10
Other	2,596	330	2,266	1,716	145	1,571
TOTAL	15,756	2,610	13,146	12,843	2,334	10,509
MORRISON						
Hay & pasture	28,418	426	27,992	26,502	720	25,782
Corn	7,103	3,292	3,811	4,974	2,993	1,981
Soybeans	412	28	384	239	68	171
Potatoes	29	–	29	25	–	25
Other	8,763	371	8,392	5,964	343	5,621
TOTAL	44,725	4,117	40,608	37,704	4,124	33,581
MOWER						
Hay & pasture	11,090	464	10,626	8,816	630	8,186
Corn	46,907	14,403	32,584	28,073	12,777	15,296
Soybeans	3,437	120	3,317	3,659	352	3,307
Potatoes	1	–	1	16	–	16
Other	14,500	1,230	13,270	7,976	810	7,166
TOTAL	76,015	16,217	59,798	48,540	14,569	33,971
MURRAY						
Hay & pasture	6,477	1,186	5,291	5,589	1,330	4,259
Corn	31,702	5,289	26,413	20,987	8,117	12,870
Soybeans	1,958	78	1,880	2,758	132	2,626
Potatoes	8	–	8	3	–	3
Other	8,500	195	8,305	4,248	343	3,905
TOTAL	48,645	6,748	41,897	33,565	9,922	23,663
NICOLLET						
Hay & pasture	4,043	912	3,131	2,893	1,216	1,677
Corn	17,176	5,983	11,193	12,134	6,359	5,775
Soybeans	2,151	110	2,041	2,313	195	2,118
Potatoes	29	–	29	6	6	–
Other	4,634	623	4,011	2,834	663	2,171
TOTAL	28,033	7,628	20,405	20,180	8,439	11,741

Table 4. — (continued)

County and crop	1959 Tons recommended	1959 Actual tons applied	1959 Gap	1964 50 percent nutrient	1964 Actual tons applied	1964 Gap
NOBLES						
Hay & pasture	6,957	1,418	5,539	6,142	1,621	4,521
Corn	33,813	5,543	28,720	22,848	8,759	14,089
Soybeans	2,591	62	2,529	3,888	72	3,816
Potatoes	5	–	5	1	–	1
Other	10,421	467	9,954	2,856	374	2,482
TOTAL	53,787	7,490	46,297	35,735	10,826	24,909
NORMAN						
Hay & pasture	8,074	751	7,323	7,190	937	6,253
Corn	3,474	1,102	2,372	2,334	1,249	1,085
Soybeans	1,738	45	1,693	–	126	–126
Potatoes	782	301	481	536	568	–32
Other	26,267	3,901	22,366	21,376	7,571	13,805
TOTAL	40,335	6,100	34,235	31,436	10,451	20,985
OLMSTED						
Hay & pasture	13,646	303	13,343	10,340	604	9,736
Corn	18,635	7,458	11,177	11,987	6,995	4,992
Soybeans	1,144	116	1,020	1,350	133	1,217
Potatoes	12	3	9	6	1	5
Other	9,421	452	8,969	5,859	518	5,341
TOTAL	42,858	8,332	34,526	29,542	8,251	21,292
OTTER TAIL						
Hay & pasture	27,882	2,722	25,160	24,782	1,701	23,081
Corn	13,316	3,379	9,937	11,062	4,012	7,050
Soybeans	591	5	586	906	91	815
Potatoes	55	5	50	23	13	10
Other	33,688	1,221	32,467	24,409	2,157	22,252
TOTAL	75,532	7,332	68,200	61,182	7,974	53,208
PENNINGTON						
Hay & pasture	7,689	430	7,259	7,772	551	7,221
Corn	270	145	125	306	188	118
Soybeans	4	2	2	–	2	–2
Potatoes	71	–	71	150	318	–168
Other	12,864	2,885	9,979	12,320	3,687	8,633
TOTAL	20,898	3,462	17,436	20,548	4,746	15,801
PINE						
Hay & pasture	23,587	405	23,182	19,496	465	19,031
Corn	1,969	1,883	86	1,944	1,780	164
Soybeans	121	33	88	73	19	54
Potatoes	48	5	43	19	18	1
Other	3,991	544	3,447	2,364	461	1,903
TOTAL	29,716	2,870	26,846	23,896	2,743	21,153
PIPESTONE						
Hay & pasture	4,582	544	4,038	4,352	666	3,686
Corn	17,553	1,884	15,669	12,642	3,365	9,277
Soybeans	429	8	421	720	37	683
Potatoes	2	–	2	2	2	–
Other	1,758	456	1,302	3,336	490	2,846
TOTAL	24,324	2,892	21,432	21,052	4,560	16,492
POLK						
Hay & pasture	20,166	1,328	18,838	16,548	971	15,577
Corn	2,542	894	1,648	2,420	1,141	1,279
Soybeans	237	29	208	–	19	–19
Potatoes	6,061	3,497	2,564	5,614	4,263	1,351
Other	60,575	20,047	40,528	49,596	24,263	25,333
TOTAL	89,581	25,795	63,786	74,178	30,657	43,521

Table 4. — (continued)

County and crop	1959 Tons recommended	1959 Actual tons applied	1959 Gap	1964 50 percent nutrient	1964 Actual tons applied	1964 Gap
POPE						
Hay & pasture	7,824	829	6,995	6,651	1,141	5,510
Corn	16,070	2,315	13,755	11,032	3,748	7,284
Soybeans	1,636	35	1,601	1,548	52	1,496
Potatoes	13	–	13	6	–	6
Other	13,299	287	13,012	9,072	346	8,726
TOTAL	38,842	3,466	35,376	28,309	5,287	23,022
RAMSEY						
Hay & pasture	596	73	523	250	8	242
Corn	311	156	155	267	40	227
Soybeans	–	–	–	14	–	14
Potatoes	6	–	6	2	–	2
Other	86	79	7	75	256	–181
TOTAL	999	308	691	608	304	304
RED LAKE						
Hay & pasture	5,765	412	5,353	5,461	357	5,104
Corn	533	243	290	429	383	46
Soybeans	28	8	20	–	3	–3
Potatoes	119	40	79	184	332	–148
Other	9,490	1,519	7,971	8,690	2,498	6,192
TOTAL	15,935	2,222	13,713	14,764	3,573	11,191
REDWOOD						
Hay & pasture	5,800	1,095	4,705	5,077	1,705	3,372
Corn	41,665	7,257	34,408	27,259	11,365	15,894
Soybeans	5,560	68	5,492	5,980	266	5,714
Potatoes	5	–	5	4	–	4
Other	8,793	691	8,102	4,000	1,067	2,933
TOTAL	61,823	9,111	52,712	42,320	14,403	27,919
RENVILLE						
Hay & pasture	6,628	1,560	5,068	4,492	1,682	2,810
Corn	40,260	11,880	28,380	28,031	18,877	9,154
Soybeans	8,732	275	8,457	6,552	540	6,012
Potatoes	29	–	29	34	–	34
Other	12,375	1,860	10,515	8,354	3,756	4,598
TOTAL	68,024	15,575	52,449	47,463	24,855	22,608
RICE						
Hay & pasture	6,958	397	6,561	5,606	500	5,106
Corn	14,782	4,937	9,845	10,450	5,776	4,674
Soybeans	1,194	74	1,120	1,318	177	1,141
Potatoes	15	–	15	6	–	6
Other	7,989	382	7,607	4,825	568	4,257
TOTAL	30,938	5,790	25,148	22,205	7,021	15,184
ROCK						
Hay & pasture	5,292	398	4,894	4,532	618	3,914
Corn	20,516	2,552	17,964	14,175	4,666	9,509
Soybeans	869	10	859	1,494	56	1,438
Potatoes	5	–	5	1	–	1
Other	4,091	235	3,856	1,614	245	1,369
TOTAL	30,773	3,195	27,578	21,816	5,585	16,231
ROSEAU						
Hay & pasture	15,839	883	14,956	14,019	798	13,221
Corn	159	61	98	150	107	43
Soybeans	2	–	2	–	–	–
Potatoes	138	27	111	194	199	–5
Other	17,031	2,376	14,655	16,247	3,934	12,313
TOTAL	33,169	3,347	29,822	30,610	5,038	25,572

Table 4. — (continued)

County and crop	1959 Tons recommended	1959 Actual tons applied	1959 Gap	1964 50 percent nutrient	1964 Actual tons applied	1964 Gap
ST. LOUIS						
Hay & pasture	26,824	476	26,348	19,360	286	19,074
Corn	9	17	−8	14	27	−13
Soybeans	–	–	–	–	–	–
Potatoes	129	69	60	133	138	−5
Other	1,171	280	891	948	546	402
TOTAL	28,133	842	27,291	20,455	997	19,458
SCOTT						
Hay & pasture	4,520	548	3,972	4,253	215	4,038
Corn	9,788	2,424	7,364	6,702	2,420	4,282
Soybeans	423	45	378	590	17	573
Potatoes	6	–	6	33	–	3
Other	4,978	225	4,753	3,092	80	3,012
TOTAL	19,715	3,242	16,473	14,640	2,732	11,908
SHERBURNE						
Hay & pasture	8,007	484	7,523	7,060	340	6,720
Corn	5,997	2,438	3,559	3,739	2,595	1,144
Soybeans	1,338	67	1,271	1,061	91	970
Potatoes	334	305	29	478	524	−46
Other	2,440	467	1,973	2,160	487	1,673
TOTAL	18,116	3,761	14,355	14,498	4,037	10,461
SIBLEY						
Hay & pasture	5,679	1,005	4,674	4,908	1,517	3,391
Corn	21,075	6,021	15,054	14,841	6,284	8,557
Soybeans	2,542	67	2,475	2,592	212	2,380
Potatoes	12	1	11	5	–	5
Other	8,544	810	7,734	5,310	1,259	4,051
TOTAL	37,852	7,904	29,948	27,656	9,272	18,384
STEARNS						
Hay & pasture	39,651	1,264	38,387	39,699	1,448	38,251
Corn	28,408	5,159	23,249	22,722	4,637	18,085
Soybeans	1,263	204	1,059	945	135	810
Potatoes	90	15	75	31	10	21
Other	23,964	734	23,230	17,415	175	17,240
TOTAL	93,376	7,376	86,000	80,812	6,405	74,407
STEELE						
Hay & pasture	6,067	531	5,536	4,901	650	4,251
Corn	17,411	6,512	10,899	11,099	6,917	4,182
Soybeans	1,260	402	858	1,296	423	873
Potatoes	130	278	−148	130	76	54
Other	8,056	715	7,341	4,857	1,232	3,625
TOTAL	32,924	3,438	24,486	22,283	9,298	12,985
STEVENS						
Hay & pasture	4,309	637	3,672	2,890	728	2,162
Corn	15,615	4,152	11,463	12,860	4,996	7,864
Soybeans	2,696	107	2,589	1,678	65	1,612
Potatoes	1	–	1	6	–	6
Other	7,770	1,157	6,613	5,874	1,233	4,641
TOTAL	30,391	6,053	24,338	23,308	7,022	16,286
SWIFT						
Hay & pasture	5,715	1,229	4,486	5,435	1,133	4,302
Corn	21,553	6,256	15,297	15,398	7,494	7,904
Soybeans	3,503	79	3,424	3,406	214	3,192
Potatoes	16	20	−4	33	–	3
Other	6,988	784	6,204	4,925	1,352	3,573
TOTAL	37,775	8,368	29,407	29,167	10,193	18,974

Table 4. — (continued)

County and crop	1959 Tons recommended	1959 Actual tons applied	1959 Gap	1964 50 percent nutrient	1964 Actual tons applied	1964 Gap
TODD						
Hay & pasture	12,194	637	11,557	11,388	461	10,927
Corn	13,875	2,987	10,888	10,315	3,238	7,077
Soybeans	292	25	267	234	24	210
Potatoes	62	–	62	70	–	70
Other	10,796	209	10,587	8,046	264	7,782
TOTAL	37,219	3,858	33,361	30,053	3,987	26,066
TRAVERSE						
Hay & pasture	2,513	369	2,144	3,386	366	3,020
Corn	6,903	1,398	5,305	4,731	1,931	2,800
Soybeans	3,451	78	3,373	2,236	88	2,148
Potatoes	1	1	–	–	–	–
Other	5,955	1,611	4,344	4,755	2,801	1,954
TOTAL	18,823	3,657	15,166	15,108	5,186	9,922
WABASHA						
Hay & pasture	12,165	236	11,929	9,398	258	9,140
Corn	9,863	3,789	6,074	6,974	4,241	2,733
Soybeans	396	35	361	531	57	474
Potatoes	20	–	20	8	1	7
Other	7,742	385	7,357	5,165	451	4,714
TOTAL	30,186	4,445	25,741	22,076	5,008	17,068
WADENA						
Hay & pasture	12,874	479	12,395	11,677	182	11,495
Corn	2,870	872	1,998	1,978	772	1,206
Soybeans	12	2	10	31	–	31
Potatoes	38	–	38	16	–	16
Other	2,409	141	2,268	1,200	95	1,105
TOTAL	18,203	1,494	16,709	14,902	1,049	13,853
WASECA						
Hay & pasture	3,607	297	3,310	2,679	515	2,164
Corn	18,604	6,686	11,918	13,265	9,906	3,359
Soybeans	1,749	43	1,706	1,881	118	1,763
Potatoes	6	–	6	1	–	1
Other	8,230	861	7,369	4,736	1,134	3,602
TOTAL	32,196	7,887	24,309	22,562	11,673	10,889
WASHINGTON						
Hay & pasture	7,565	389	7,176	5,827	532	5,295
Corn	10,293	3,743	6,550	6,312	3,247	3,065
Soybeans	391	22	369	477	53	424
Potatoes	27	2	25	67	–	67
Other	1,895	521	1,374	2,460	466	1,994
TOTAL	20,171	4,677	15,494	15,143	4,298	10,845
WATONWAN						
Hay & pasture	3,220	1,181	2,039	2,304	654	1,650
Corn	22,335	8,783	13,552	14,044	8,323	5,721
Soybeans	2,310	166	2,144	2,736	140	2,596
Potatoes	1	–	1	1	–	1
Other	3,603	472	3,131	1,249	431	818
TOTAL	31,469	10,602	20,867	20,334	9,548	10,786
WILKIN						
Hay & pasture	4,009	742	3,267	2,806	454	2,352
Corn	4,736	1,728	3,008	3,162	1,803	1,359
Soybeans	3,826	155	3,671	3,312	238	3,074
Potatoes	217	153	64	187	86	101
Other	7,935	4,272	3,663	6,311	6,477	–166
TOTAL	20,723	7,050	13,673	15,778	9,058	6,720

Table 4. — (continued)

County and crop	1959 Tons recommended	1959 Actual tons applied	1959 Gap	1964 50 percent nutrient	1964 Actual tons applied	1964 Gap
WINONA						
Hay & pasture	13,548	694	12,854	10,866	380	10,486
Corn	10,073	4,402	5,671	7,529	4,506	3,023
Soybeans	237	48	189	382	83	299
Potatoes	15	–	15	6	3	3
Other	7,536	641	6,895	4,593	327	4,266
TOTAL	31,409	5,785	25,624	23,376	5,299	18,077
WRIGHT						
Hay & pasture	8,913	472	8,411	7,387	347	7,040
Corn	18,877	4,080	14,797	12,380	4,147	8,233
Soybeans	747	54	693	1,120	38	1,082
Potatoes	92	300	−208	74	338	−264
Other	8,732	311	8,421	4,659	280	4,379
TOTAL	37,361	5,217	32,144	25,620	5,150	20,470
YELLOW MEDICINE						
Hay & pasture	5,316	664	4,652	4,028	642	3,386
Corn	29,149	7,316	21,833	19,241	10,004	9,237
Soybeans	3,887	127	3,760	4,059	127	3,932
Potatoes	10	8	2	13	37	−24
Other	6,356	763	5,593	3,925	782	3,143
TOTAL	44,718	8,878	35,840	31,266	11,592	19,674

State and crop	1959 Tons recommended	1959 Actual tons applied	1959 Gap	1959 Used as percent recommended	1964 50 percent nutrient	1964 Actual tons applied	1964 Gap	1964 Used as percent recommended
MINNESOTA								
Hay & pasture	786,824	56,302	730,522	7%	666,685	62,262	604,423	9%
Corn	1,175,080	332,226	842,854	28	802,136	392,699	409,437	49
Soybeans	125,212	6,460	118,752	5	123,826	11,128	112,698	9
Potatoes	20,668	13,421	7,249	64	18,127	17,117	1,010	94
Other	747,730	102,620	645,110	14	513,177	138,595	374,582	27
TOTAL	2,855,514	511,029	2,344,485	18%	2,123,951	621,801	1,502,150	29%

Table 5. Liquid and dry fertilizer 1959-1964*

County	Percent of cropland harvested and fertilized 1964	Percent of cropland harvested and fertilized 1959	Tons: Liquid fertilizer 1964	Tons: Liquid fertilizer 1959	Tons: Dry fertilizer 1964	Tons: Dry fertilizer 1959
Aitkin	8	12	–	–	726	835
Anoka	45	41	262	198	2,431	2,445
Becker	39	29	5	–	6,687	3,390
Beltrami	12	13	–	43	861	1,080
Benton	40	42	171	159	4,147	3,928
Big Stone	31	16	313	511	4,329	1,927
Blue Earth	44	37	4,011	1,793	26,199	12,386
Brown	32	22	1,383	1,324	7,805	5,863
Carlton	8	11	–	110	684	1,032
Carver	25	15	475	265	2,973	1,731
Cass	11	13	–	–	708	766
Chippewa	42	31	698	675	9,853	7,028
Chisago	45	41	634	192	4,061	3,311
Clay	62	55	1,167	238	15,970	13,454
Clearwater	27	18	6	–	1,610	1,372
Cook	–	1	–	–	–	–
Cottonwood	41	27	1,286	426	9,178	6,467
Crow Wing	22	27	45	–	1,010	1,217
Dakota	44	45	967	1,612	8,576	9,144
Dodge	38	43	865	356	7,340	8,999
Douglas	17	14	16	75	2,174	2,005
Faribault	50	47	4,808	4,491	16,801	12,204
Fillmore	31	31	1,460	1,025	7,896	8,338
Freeborn	53	55	3,110	1,430	17,596	16,051
Goodhue	32	32	976	664	8,181	8,317
Grant	54	33	410	302	5,781	4,484
Hennepin	31	31	349	700	4,734	5,078
Houston	28	31	487	274	3,830	3,945
Hubbard	22	21	74	–	1,133	811
Isanti	35	36	599	463	3,057	2,749
Itasca	5	4	–	–	638	305
Jackson	47	35	2,631	2,278	12,297	8,026
Kanabec	23	32	68	–	1,437	2,041
Kandiyohi	35	26	889	729	10,073	6,779
Kittson	60	46	361	46	7,751	4,935
Koochiching	8	6	–	–	298	240
Lac qui Parle	28	18	953	787	6,531	4,658
Lake	2	4	–	–	5	12
Lake of the Woods	31	19	–	–	1,194	725
Le Sueur	40	28	2,246	957	5,663	3,734
Lincoln	23	14	288	385	3,506	2,401
Lyon	37	23	776	1,170	7,892	5,532
McLeod	34	28	719	728	7,437	5,249
Mahnomen	41	34	18	–	2,227	1,601
Marshall	66	64	1,033	452	15,474	12,317
Martin	52	49	3,370	2,961	15,932	15,017
Meeker	32	24	708	416	6,532	4,819
Mille Lacs	30	33	41	41	2,293	2,569
Morrison	25	26	20	65	4,104	4,052
Mower	42	50	1,601	825	12,968	15,392
Murray	40	27	620	433	9,302	6,315
Nicollet	40	38	1,033	776	7,406	6,852
Nobles	40	30	1,324	609	9,502	6,881
Norman	61	43	612	115	9,839	5,985
Olmsted	35	36	1,080	707	7,171	7,625
Otter Tail	22	18	111	188	7,863	7,144
Pennington	56	56	24	141	4,722	3,321
Pine	21	22	31	96	2,712	2,774
Pipestone	36	20	463	207	4,097	2,685
Polk	70	65	2,357	1,249	28,300	24,546
Pope	28	19	291	336	4,996	3,130
Ramsey	37	26	–	8	304	300
Red Lake	54	45	44	–	3,529	2,222
Redwood	35	22	2,191	1,270	12,212	7,841
Renville	46	31	3,930	2,038	20,925	13,537
Rice	36	31	1,062	762	5,959	5,028
Rock	38	20	859	160	4,726	3,035
Roseau	31	26	9	–	5,029	3,317
St. Louis	7	6	–	51	997	791
Scott	23	24	370	768	2,362	2,474
Sherburne	40	39	440	208	3,597	3,553
Sibley	35	29	1,211	1,059	8,061	8,963
Stearns	18	18	220	509	6,185	6,867
Steele	46	45	976	1,307	8,322	7,131
Stevens	43	28	305	1,184	6,717	4,689
Swift	36	31	809	795	9,384	7,573
Todd	22	24	35	175	3,952	3,683
Traverse	45	28	87	161	5,099	3,496
Wabasha	28	26	759	446	4,249	3,999
Wadena	19	26	28	15	1,021	1,479
Waseca	49	37	2,861	841	8,912	7,046
Washington	34	40	547	615	3,751	4,062
Watonwan	46	48	2,120	1,404	7,428	9,198
Wilkin	63	50	111	–	8,947	7,050
Winona	29	30	512	355	4,787	5,430
Wright	23	22	554	538	4,596	4,679
Yellow Medicine	39	24	2,462	1,938	9,130	6,940

*1964 figures may be affected by county total error