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THE U.S. FERTILIZER INDUSTRY:

DEMAND TRENDS AND MARKET STRUCTURE

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This publication has undergone formal review with the University of Minnesota Agricultural Experiment Station.

Table of Contents

Page

List of Figures

List of Tables

PREFACE

This publication summarizes selected aspects of research conducted by the Minnesota Agricultural Experiment Station under contract with the National Agricultural Statistics Services of the U.S. Department of Agriculture. This study, entitled, "The Marketing and Pricing of U.S. Agricultural Inputs," has resulted in two major research reports. The first draft dealt with U.S. animal feed utilization and the supporting industry structure. The second report addressed demand and supply dimensions of the U.S. agricultural chemical industries: fertilizer and pesticides. These underlying research reports are administratively confidential and the property of the U.S. Department of Agriculture.

Permission has been granted by NASS-USDA to issue three staff papers, subject to their review. This is the first in a series dealing with fertilizer, feed, and pesticides.

The authors wish to acknowledge the advice and review efforts of Mr. Fred Thorp and his staff at NASS-USDA, and the suggestions made by the following Minnesota Experiment Station researchers: Jerry Hammond (Ag Econ), Harvey Meredith (Soil Science), and Laddie J. Elling (Agronomy). The authors are also indebted to Carroll Rock and his staff at the Minnesota Statistical Office of NASS-USDA for assistance in the initial study.

THE U.S. FERTILIZER INDUSTRY: DEMAND TRENDS AND MARKET STRUCTURE

INTRODUCTION

Largely within the past three decades, commercial fertilizer use by U.S. farmers shifted from occasional and specialized application to the status of being a major management practice in most cropping operations. Technological advances lowered significantly the production costs of granular and liquid materials in the early 1950s. Aggressive educational and marketing programs not only brought the economic value of fertilizer use to the attention of farmers, but the development of localized bulk-blending facilities throughout the country permitted the custom-mixing of fertilizers to the specific nutrient requirements of crop farmers.

The increases in fertilizer supply and demand at the farm retail level were followed by major changes in wholesaling, chemical formulation, and primary product manufacturing. The fertilizer wholesaling component of the vertically-defined industry nearly went out of existence, leaving a small core of brokers specializing in the sale of imported products. Granulators and primary producers marketed directly through bulk-blenders, or otherwise integrated into retailing as a part of their business activity. Local agricultural cooperatives, through their regional affiliates, formed distribution entities that not only channeled fertilizer to their farmer-members, but also purchased or built granulation plants and primary production operations.

The growth of the fertilizer industry was most dramatic until the mid-to-late 1970s, stimulated by higher farm prices and increased farm land values. With the decline in farm crop prices and land values in the late 1970s and 1980s, fertilizer demand decreased and shifted among products. The fertilizer industry was forced to contract.

This report reviews fertilizer demand trends during the past twenty years, and the changes in market structure.

FERTILIZER PRODUCTS

The fertilizer industry markets a wide range of products. These are broadly classified as (1) raw and intermediate products, and (2) final products.

Raw and Intermediate Products

Fertilizers are any substance applied to soil which improves plant nutrition.[1] Manufactured substances, green cover crop, farm manure, and lime all fit under this definition. The common definition of fertilizer, however, implies manufactured substances which provide plant nutrition.[2]

Macronutrients are six plant nutrients of major importance. They include: nitrogen (N), phosphorous (P), potassium (K), sulfur (S), calcium (Ca), and magnesium (Mg). The first three are primary nutrients. Nitrogen, potassium, and phosphorous, applied in various forms, constitute around 95 percent of gross fertilizer tonnages.[3] Therefore, this paper will focus on those three nutrients. The nutrients phosphorous and potassium are more commonly referred to by their oxides--phosphate (P_2O_5) and potash (K_2O) respectively.

With regards to the other macronutrients, sulfur is usually added as an incidental side ingredient in some multinutrient fertilizers. Calcium and magnesium, on the other hand, usually find their incorporation into soil in the form of lime.

Micronutrients are a group of elements required in extremely small amounts but which are no less essential than macronutrients. A farmer may typically apply a micronutrient at a rate of only 0.5 to 10.0 lbs per acre. Careful use is important since some micronutrients can be toxic if applied in excess or to the wrong crops. Micronutrients are usually applied as secondary nutrients mixed along with primary nutrients.[4]

Fertilizers do not contain nutrients in elemental forms as nitrogen, phosphorous, and potassium but rather in various compound forms which plants can assimilate. In years past, fertilizer materials were obtained from ashes, bone, and by-products from the steel industry and food processing. An increasingly efficient fertilizer manufacturing industry in conjunction with increased demand has rendered such raw materials all but obsolete.

Nitrogen is the dominant primary nutrient, constituting around 50 percent of total nutrient usage. Essentially all manufactured nitrogen used for fertilizers comes from the fixation of atmospheric nitrogen. Large manufacturing plants combine atmospheric nitrogen with hydrogen under high heat and pressure to form ammonia (NH_3). Large quantities of natural gas provide both the feedstock for hydrogen and heat for the process. Anhydrous ammonia (ammonia free from water) is in turn the base material for 99 percent of all commercial nitrogen fertilizers.[5]

Phosphorous comes from phosphate rock. Large ore deposits are located in Florida and North Carolina with lesser deposits in a few Rocky Mountain States. Phosphate ore requires strong chemical treatment to produce nutrient forms usable by plants. When phosphate ore is treated with sulfuric acid, normal (or ordinary) superphosphate (NSP) is produced. This contains around 18-20 percent phosphate. By using a higher ratio of sulfuric acid to phosphate ore, phosphoric acid can be produced. This is used, in turn, to produce many other phosphate fertilizers. When, for example, phosphate ore is treated with phosphoric acid, triple (or concentrated) superphosphate (TSP) results. The process is quite similar to making normal superphosphate but instead has twice the phosphate content (44-52%).[6]

Potassium also comes from mineral ores. Most domestic ore comes from New Mexico potash mines. By the 1960s, new mines in Canada had become the primary source for U.S. potash consumption. Unlike phosphate ore, potash ore requires no chemical conversion. It does, however, require extensive processing to remove impurities such as common salt ($NaCl$). The end result, potassium chloride (KCl), commonly called muriate of potash, can be directly applied to soil. About 95 percent of potassium plant nutrient comes from muriate of potash.

Final Products

Ammonia, superphosphates, phosphoric acid, and potassium chloride are the key intermediate products for the fertilizer industry.[7] These basic materials are used to produce hundreds of different formulations to meet specific crop and soil needs. In producing a formulation, a manufacturer must decide on the desired grade, ratio, and products to be used in such a formulation.

The fertilizer grade is the minimum guaranteed level of plant nutrients. Grade is denoted by a set of three numbers showing, in order, the percent of total nitrogen, available phosphate, and soluble potash. Thus, a 5-10-15 grade contains 5 percent nitrogen, 10 percent phosphate, and 15 percent potash. Similarly, the formulation for ammonium polyphosphate (10-34-0), a liquid fertilizer, shows that the fertilizer contains 10 percent nitrogen, 34 percent phosphate, and no potash. Sometimes a fourth number is used to indicate the amount of sulfur in a mixture.

The fertilizer ratio is the ratio between nutrient percentages. For example, a 5-10-15 grade would have a 1-2-3 ratio and a 6-24-24 grade, a 1-4-4 ratio.

Fertilizers can take on many different forms. Two basic categories are "materials" and "mixtures".

Fertilizer materials are any compound containing not more than two of the three primary nutrients.[8] Thus, a material may be a single nutrient such as urea (containing nitrogen) or ammonium phosphate (containing nitrogen and phosphate). Fertilizer materials may be used as an intermediate product in the production of other formulations or may themselves be directly applied. For example, anhydrous ammonia is used to manufacture other fertilizers but yet is also applied directly to soil. For this reason, the term "direct application" (D.A.) is often used in conjunction with "materials". This helps differentiate between the type of materials which can be directly applied (e.g. ammonium) and a looser usage of the term which includes all forms of plant nutrients under the general rubric of "fertilizer materials". Even when used by a single source, the classification between "materials" and "mixtures" is not always clear-cut. USDA fertilizer consumption data, for example, classes some ammonium phosphates such as 11-48-0 as materials and others such as 11-52-0 as mixtures although both are quite similar in manufacture and usage. Some common fertilizer materials follow.

Anhydrous ammonia--as previously mentioned, the base material for virtually all manufactured nitrogen nutrients. A boiling liquid at room temperature, anhydrous ammonia is stored in pressurized tanks. It contains around 82 percent nitrogen, the highest of any commonly used nitrogen fertilizers.

Ammonium nitrate--a solid nitrogen fertilizer. Its easy manufacture and relatively high nitrogen content (33-34%) made ammonium nitrate long a staple of the fertilizer industry. However, its potential explosiveness (ammonium nitrate is also used in the munitions industry) and problems with caking have resulted in diminished demand, especially when faced with competition from new superior materials.

Urea--yet another solid nitrogen fertilizer. Although it has been produced in the U.S. for over fifty years, there was much initial doubt as to its agronomic suitability. Research over the past decade alleviated that concern with a resulting dramatic rise in consumption. Urea has the highest nitrogen content (45-46%) of any solid nitrogen fertilizer.

Nitrogen solutions--a fluid fertilizer made from a mixture of ammonium nitrate solution and urea solution, thus its other common term, UAN solutions. Since nitrogen solutions are non-pressurized they are both much easier and safer to apply then anhydrous ammonia. They commonly test at between 28-32 percent nitrogen.

Ammonium phosphates--a group of solid fertilizers made from phosphoric acid treated with ammonia in a process known as ammoniation. Features such as high analysis (a high percent of nutrients), good handling properties, and low production costs have pushed them to a leading position in the fertilizer industry. By 1985, ammonium phosphates constituted 80 percent of all phosphate produced in the U.S. The most common type is diammonium phosphate (DAP) sold either as a 16-48-0 grade or a 18-46-0 grade. Monoammonium phosphate (MAP) is made by adding less ammonia. Grades vary from 11-48-0 to 11-55-0.

Potassium chloride--also known as muriate of potash (KCl). Although discussed under intermediate products, muriate finds some usage as a direct application material. Despite the final form it takes, muriate provides about 95 percent of applied potassium plant nutrition. It contains around 60 percent potash (K_2O).

Fertilizer mixtures, on the other hand, contain two or more fertilizer materials.[9] Thus, a mixture may be a NP grade containing different forms of nitrogen and phosphate combined, yet different from the single compound direct application ammonium phosphates. Most commonly, mixtures will contain all three primary nutrients for a complete NPK fertilizer. Mixed fertilizers are essentially produced in one of three processes: through chemical processing called granulation, through physical mixing of dry materials (bulk blending) or fluid materials (fluid mixing).

Granulation has become a complex process with much variation in manufacturing procedure and equipment. Typically, a viscous slurry comprised of different fertilizer salts is made. By proper control of heat and moisture, the slurry "balls-up" and forms granules. The granules are then dried, cooled and screened to obtain a uniform size. Oversized granules are crushed and rescreened while undersized granules are recycled through the granulation process.[10]

Although granulated fertilizers are commonly complete mixed fertilizers such as 10-10-10, several intermediate fertilizer materials are also granulated. Ammonium phosphates, ammonium nitrate, urea, and potash are manufactured into a final granular form. The advent of high-quality, uniform granulated materials helped make bulk-blending possible.

Bulk blends emerged in the 1950s and spread rapidly during the 1960s-70s. In bulk blending, primary fertilizer manufacturers ship solid high analysis materials in bulk to retail blenders each serving about a 25 mile radius.[11] Here the materials are physically blended to form mixtures according to the specifications of individual farmers. Blenders generally use granulated materials of uniform size to avoid segregation during mixing and handling. Bulk blends enjoy advantages of providing farmers with prescription mixtures, ease of application, possible incorporation of micronutrients and pesticides, and low cost. Bulk blending's rise in popularity has shifted the demand for fertilizer products from granulated mixtures to granular materials.[12]

Fluid mixtures are either clear or suspension liquid fertilizers. Clear liquid fertilizers have plant nutrients dissolved completely into a solution. Suspensions, on the other hand, carry part of the fertilizer salts in suspension as finely divided crystals.[13] As such, the average suspension contains almost double the plant nutrient concentration level of clear liquids. Liquid mixtures have outstanding advantages over solids with regard to lower manufacturing plant investment, better homogeneity and less labor in handling and application.

HISTORY

Until the mid-1950s, the predominate form of fertilizer used in the U.S. was granulations based on mixtures of normal superphosphate (20% P_2O_5), nitrogen, and potash materials. The traditional distribution of fertilizer involved basic producers selling intermediate materials to medium-sized production plants producing between 25,000 to 200,000 tons per year of mixed fertilizer.[14] This was distributed to the farmer in a bagged form through many independent retail outlets, often general feed and seed stores.

After the mid-1950s, the increasing demand for high nutrient fertilizers shifted the manufacture of fertilizer to granular materials made from phosphoric acid (54% P_2O_5) and its derivatives. The production of these materials occurred in large-scale facilities located usually in urban areas.[15] Bulk-blending was also introduced in the 1950s. Blenders were able to mix fertilizers according to a consumer's specific needs, thus changing the distribution structure. Large producers now sold intermediate materials directly to bulk-blenders who sold, in turn, custom-mixed formulations to farmers, thus bypassing the middleman. In the early 1960s, the advantages of bulk blending--reduced handling and distribution costs and better customer service--became apparent and blending quickly spread. Many of the major manufacturers developed their own network of bulk blending plants, thus selling directly to the farmer.

CONSUMERS

Farmers consume virtually all of the fertilizer sold in the U.S. Farmers, however, are far from a homogeneous market. Consumption varies according to crop, geography, and income class. Different crops require different rates of fertilizer application. Farmers on the East and West Coast, where land values are high, apply higher rates than elsewhere. And farmers with higher income measured in gross sales allot a greater percent of their overall production expenditures to fertilizer.

A small percent of total tonnage finds its use in nonfarm areas such as lawns, gardens, and golf courses. According to a TVA survey of fertilizer retailers, nonfarm use in 1984 constituted about 3 percent of total tonnage sold by respondents. Most of this occurs as dry bagged granulated fertilizers with fluid mixes being least common amongst nonfarm users. Since the survey did not cover the numerous general hardware and garden retail outlets which would also sell fertilizers, the total tonnage directed towards nonfarm use may be underestimated.

FERTILIZER DEMAND TRENDS

USAGE

Some important fertilizer demand trends include trends in usage, prices, and expenditures. These demand trends vary according to fertilizer nutrient, product, crop, and region.

Consumption by Nutrient

Fertilizer usage changed significantly over the last twenty years--both in form and quantity. A rapidly expanding agriculture in the 1970's provided the impetus for rapid growth in fertilizer consumption. Total fertilizer tonnage rose almost unabated from 32 million tons in 1965 until it peaked at 54 million tons in 1981--or an annual growth rate of 3.3 percent per year.* A dwindling export market for U.S. crops and governmental farm policies (most notably, the PIK program in 1983) significantly reduced fertilizer consumption in subsequent years. The demand for fertilizer suffered along with other inputs in the depressed farm economy. The period 1981-1983 saw quantities demanded drop 23 percent to a twelve year low. Consumption rose again in 1984 to 50 million tons only to fall again in 1985. Future acreage reduction programs may result in a continued diminish demand for fertilizers.

Total nutrient consumption followed the same general trends as for total fertilizer consumption. Nutrient usage, however, rose at an even higher rate--from 11 million tons in 1965 to almost 24 million tons by

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* All fertilizer consumption data is given in terms of crop year ending June 30th.

1981. The higher 4.8 percent annual rate of growth reflects the trend toward higher analyses. Fertilizers in 1985 contained on average a higher percent of nutrients in 1985 (46%) as compared to 1965 (37%).

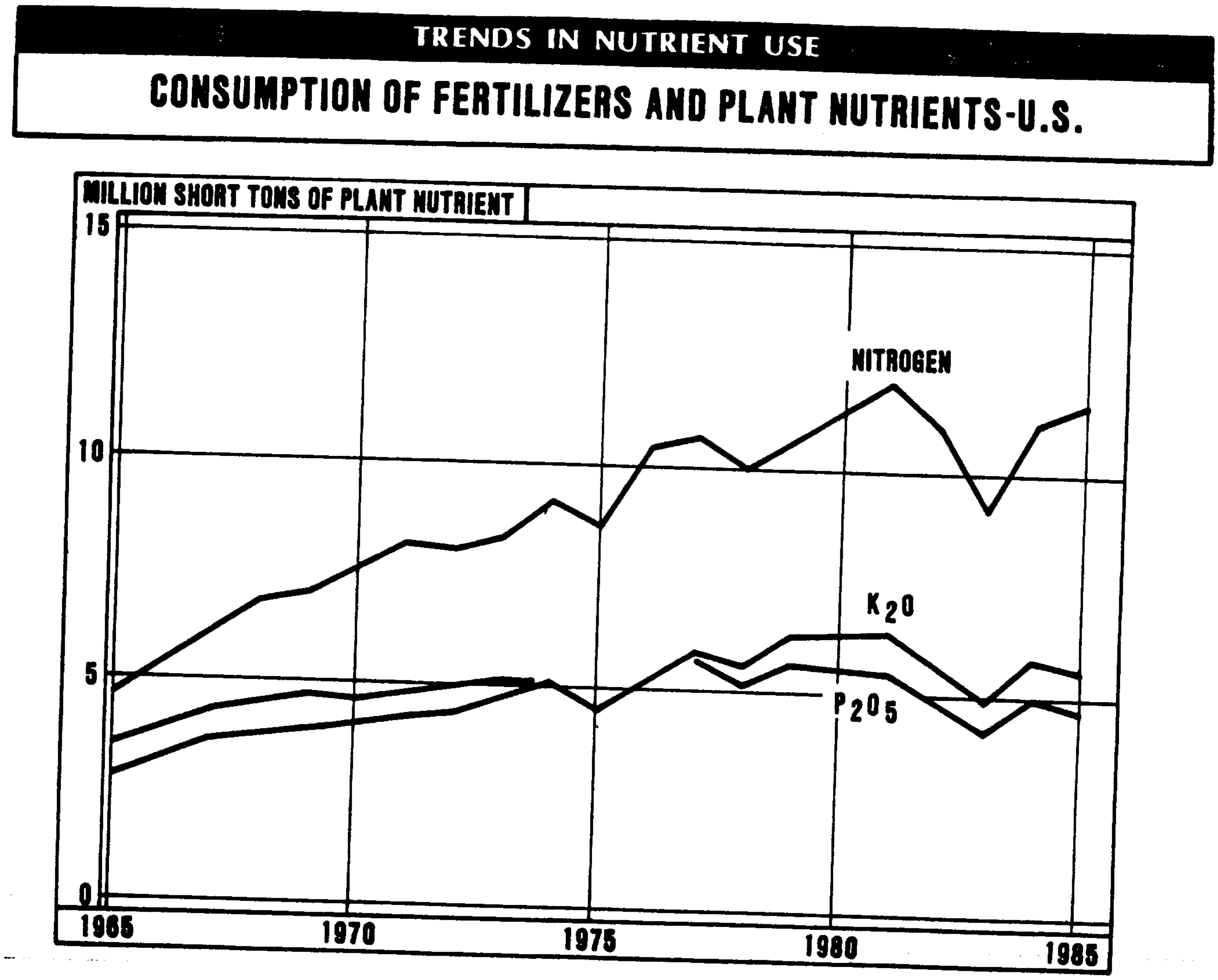
Nitrogen

The three primary nutrients have showed varying consumption trends over the past years. Nitrogen, with its high correlation to increased yields among certain major crops, has exhibited the highest growth in demand. (Figure 1) Total nitrogen use increased from 4.6 million tons in 1965 to a record high of 11.9 million tons in 1981--a growth rate of 5.8 percent per year. After the disastrous 1983 PIK year, consumption rose for the following two years almost reaching previous highs.

While nitrogen consumption increased as a whole, not all commodities gained proportionately. Different nitrogen fertilizers have changed in popularity. (Figure 2) Anhydrous ammonia used for direct application has become the dominant form of nitrogen nutrient application. Usage rose from 15 percent of nitrogen totals to a consistent 35-40 percent market share by the 1980's. By 1985, farmers applied 4.4 million tons of nitrogen nutrients in the form of ammonia.

Nitrogen solutions have exhibited another major upward trend. Nitrogen usage in the form of nitrogen solutions rose four-fold from 1965 to 1985--showing a faster, more consistent rate of growth (7.2% per year) than even ammonia. Unlike most other fertilizers, usage of nitrogen solutions continued to increase throughout recent years reaching a record 2.4 million tons of nitrogen in 1985--almost 21 percent of the nitrogen market. Urea likewise has witnessed a significant rise in popularity.

Figure 1.

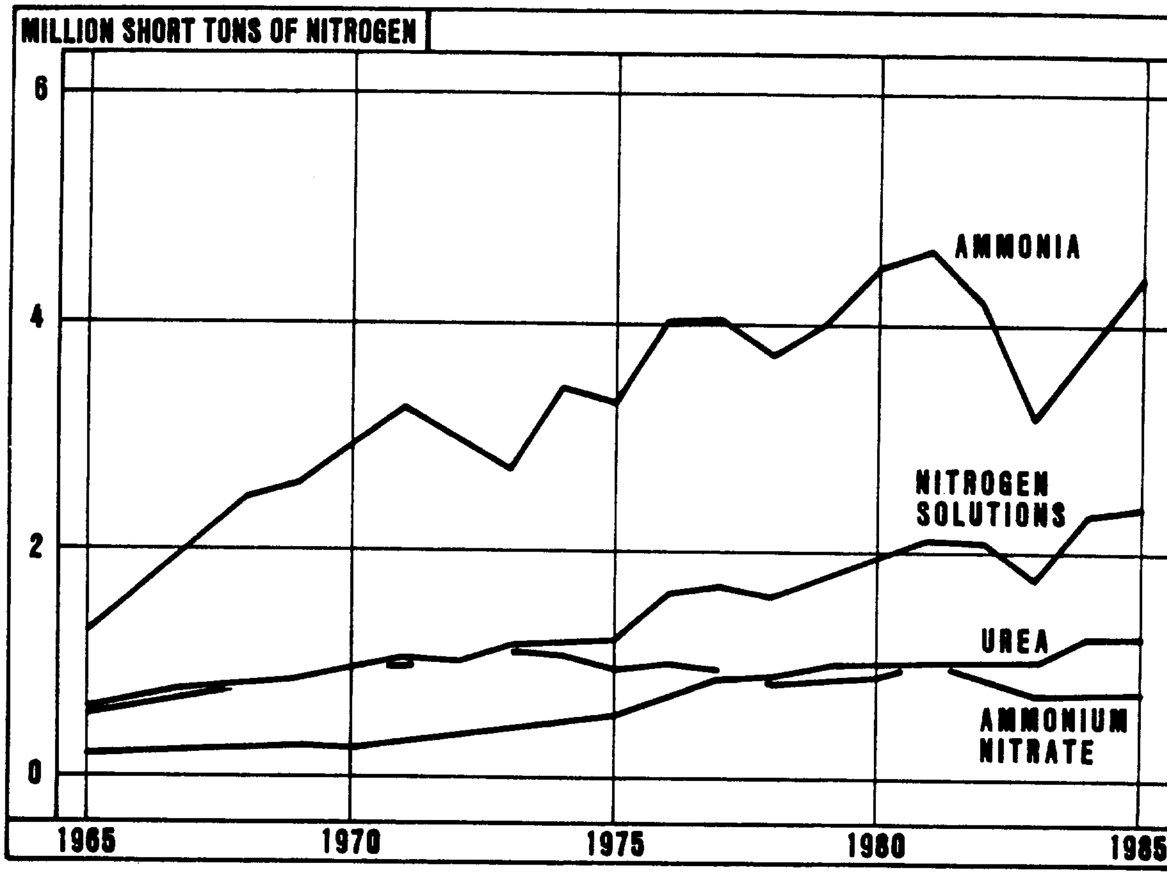


Source: TVA-NFDC, Fertilizer Trends.

Figure 2.

NITROGEN

CONSUMPTION OF SELECTED NITROGEN DIRECT APPLICATION MATERIALS-U.S.



Source: TVA-NFDC, Fertilizer Trends.

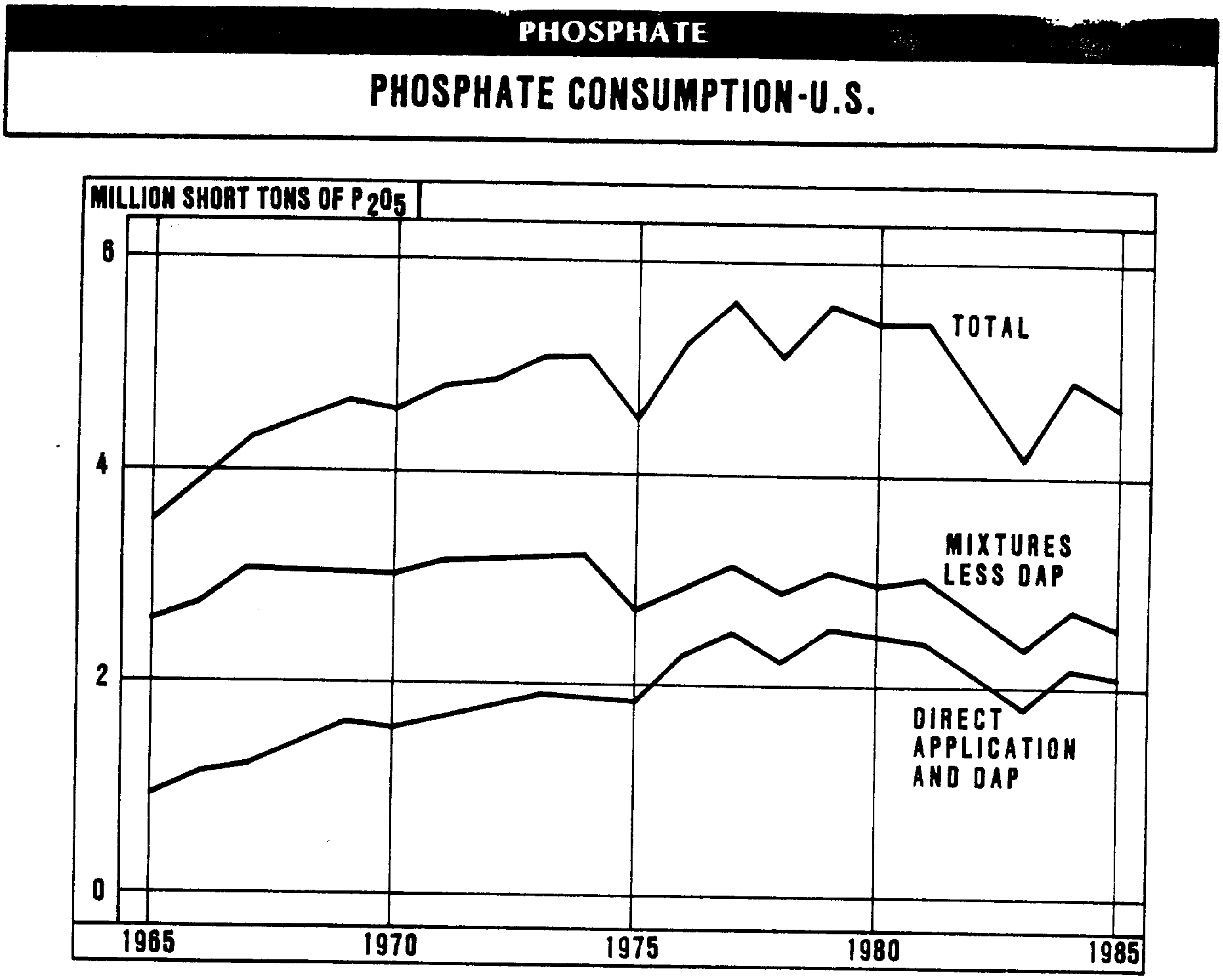
Growth in consumption rose almost unabated until by 1985 urea usage represented 11 percent of nitrogen totals (1.2 million tons). Consumption, however, grew at half the rate in the 1980's as in the sixties and seventies indicating a possible tapering off of growth. In contrast, ammonium nitrate decreased during the same period. In 1965 it held the same market shares as nitrogen solutions but saw this diminish to 4 percent of nitrogen totals by 1985. Similarly, nitrogen as delivered through premixed fertilizers decreased. This was the big tradeoff as farmers turned more to direct application ammonia and nitrogen solutions.

Phosphates

Phosphate is the third most important nutrient in terms of tonnage. Usage peaked in 1977 at 5.6 million tons of phosphate and then declined to 4.6 million tons by 1985. Since P_2O_5 application rates for major crops have changed little over the past years, acreage reductions continue to hold domestic use in check. Currently, phosphates constitute one-fifth of all plant nutrients.

In contrast to nitrogen nutrients, the majority of phosphate is applied in the form of mixtures. (Figure 3) Diammonium phosphate has become a primary P_2O_5 carrier for mixtures. It has found extensive use in bulk blends and suspensions. Consequently, consumption of DAP increased eight-fold from 1965 to 1977 to 1.7 million tons phosphate. Levels have remained fairly stable since then. DAP currently represents about one-third of the total phosphate consumed. Monoammonium phosphate has also made gains in terms of market shares. Usage of MAP has

Figure 3.



Source: TVA-NFDC, Fertilizer Trends.

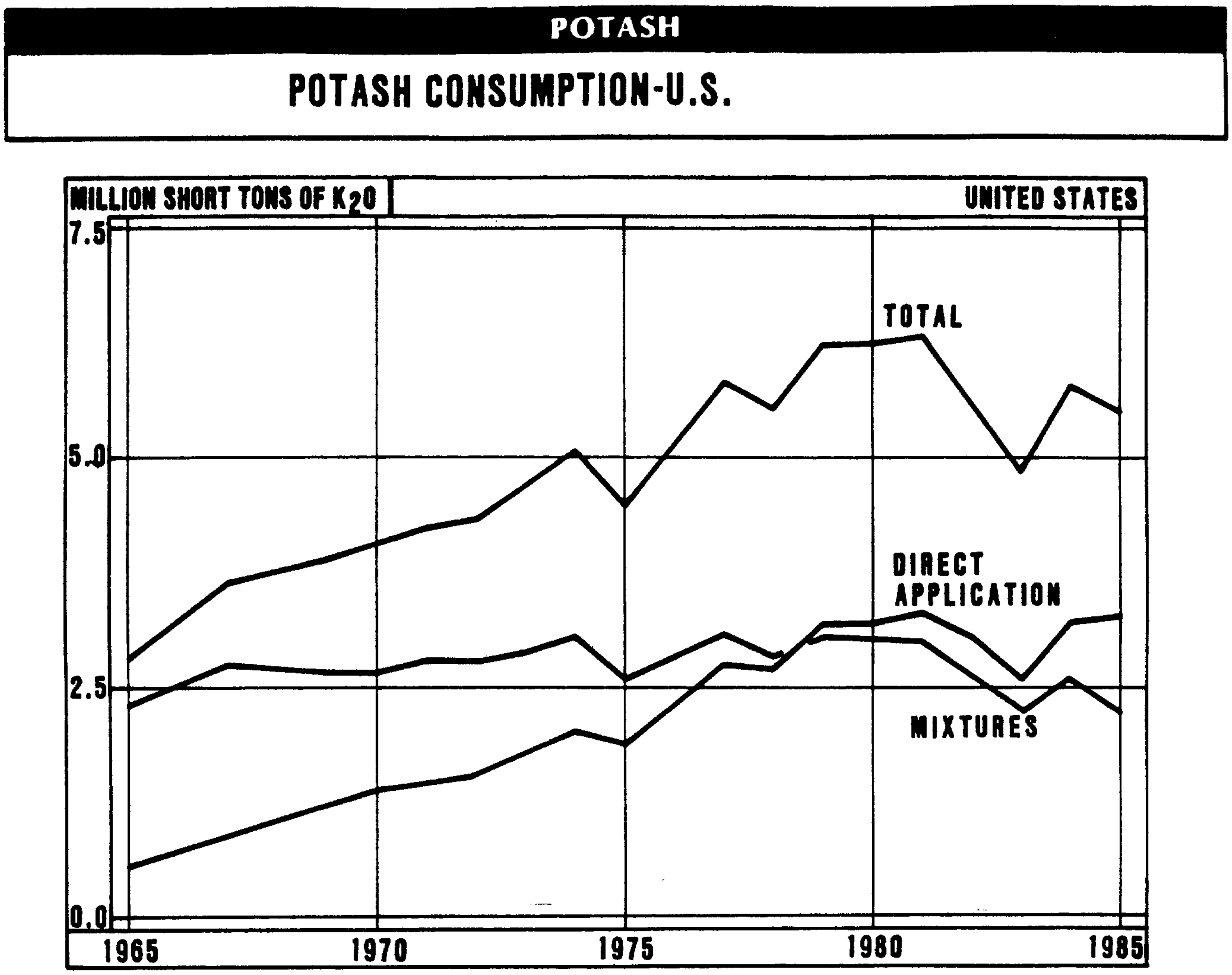
consistently risen each year. Nevertheless, it constituted only 7 percent of total phosphates (0.3 million tons) in 1985. As the quality of phosphate rock declines, lower analysis MAP may continue to gain in importance. In the liquids market, the grade 10-34-0 (ammonium polyphosphate) has found increasing popularity with current consumption also around 0.3 million tons phosphate. The use of superphosphates, meanwhile, continued to decline reaching a twenty year low by 1985 (0.4 million tons phosphate).

Potash

Potash is the second most important nutrient in terms of total tonnage consumed. Usage peaked in 1981 at 6.3 million tons of K_2O reflecting a 5.2 percent annual growth rate since 1965. The depressed farm economy, however, has affected potash in much the same manner as other nutrients. By 1985 potash consumption was a depressed 5.5 million tons. (Figure 4) With improved crop/potash price ratios consumption could regain its previous levels by 1990.[16]

Potassium chloride remains the source of almost all potash. Statistics show an increase in KCl used as a direct application material with a commensurate decrease in potash delivered in the form of mixtures. This is probably more reflective of changes in accounting methods by the individual states. The great majority of direct application KCl is probably used in bulk blends and suspensions, and hence, usage accounted for on the input side rather than the output mixture side. This means that farmers probably continue to use potash primarily through various mixtures.

Figure 4.



Source: TVA-NFDC, Fertilizer Trends.

Consumption by Class

Although statistics concerning total tonnages and nutrients applied are believed to be accurate, variation in state statistical reporting procedures make any attempts to classify fertilizers uncertain. Data concerning total tonnages of DAP or KCl, for example, may be correct; but it is difficult to tell what the final form was before application: whether, for example, a material was applied directly, in a bulk blend, or in a fluid form. The USDA collected consumption data by class using the two broad categories of materials and mixtures.* Both of these are further subdivided into dry bagged, dry bulk, and fluid fertilizers. Since anhydrous ammonia usage has become so prevalent, and since it has unique attributes, we have placed ammonia into its own fourth class.

Even with blurred distinctions, the data still shows clear trends. At one time farmers applied the majority of their plant nutrients in the form of dry bagged fertilizers. By 1974 less than one-fourth of total fertilizer tonnage was delivered in this form. This rapid decline has continued until now less than 10 percent of total fertilizer is sold in a dry bagged form. Half of this was consumed within the East and West coast regions where small specialty farms prevail. Non-farm use throughout the U.S. consumed much of the remainder.

Dry bulk fertilizers have provided much of the competition for bagged fertilizers. Consumption of bulk fertilizers increased from less

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* Note: The National Fertilizer Development Center within the TVA assumed responsibility for the collection of fertilizer data in 1986. Data will be published annually with the same title as the previous USDA publication--Commercial Fertilizers.

than one-third of the total in 1965 to over one-half in 1984. The majority of this market shift occurred by the mid-seventies. Fluid fertilizers, on the other hand, saw a strong consistent growth in popularity throughout the seventies and eighties. Buoyed by the dramatic rise in usage of nitrogen solutions, fluids as a class rose from 13 percent to almost 30 percent of the total market in the last twenty years. As previously noted, Anhydrous ammonia has also risen in popularity doubling its share of the fertilizer market since 1965 to maintain about a 10 percent share throughout the late seventies and eighties.

Verification of the actual form applied fertilizer takes would require surveys of retail outlets. The TVA in conjunction with the American Association of Plant Food Officials (AAPFCO) conducted such surveys in 1974, 1980, and 1984.[17] Variations in survey population prevent clear comparisons across time. Bearing this in mind, some useful insights may still be gleaned from the survey with respect to consumption by class.

The TVA survey grouped consumption into nine different classes. (Table 1) Recombining these classes into the four previously discussed classes, we find that survey results closely corroborate with USDA data--usually within 2 to 3 percentage points. With respect to breakdowns between mixtures and direct application materials, USDA data indicates that mixtures declined steadily in importance from around 54 percent of total tonnage in 1964 to 44 percent in 1984. The TVA survey results, however, appear to contradict this big shift. They seem to indicate that farmers have continued to apply the same amount of fertilizers in the

Table 1. Distribution of Fertilizers by Product Class, for All Firms.

Product Class	Percent of Total Fertilizer Distributed 1974	1980	1984
Dry bulk blends	33.3	35.8	39.0
Dry bagged blends	9.2	5.7	5.5
Bulk granulation	4.9	9.9	8.0
Bagged granulation	6.2	6.3	2.5
Fluid mixtures (liq and sus)	9.7	10.1	11.4
Anhydrous ammonia	7.2	9.2	9.6
Nitrogen solution materials	7.1	10.8	13.1
Dry direct application materials	19.7	10.4	9.1
Liquid direct application materials	2.7	1.8	1.8
Total	100.0	100.0	100.0

Source: Hargett and Berry, 1985.

form of mixtures throughout the past ten years--about two-thirds of total tonnage, in fact. By including USDA figures for dry bulk D.A. materials tonnage along with mixtures, we see a fairly constant two-thirds of total tonnage classed as mixtures. Thus, this indicates that dry bulk materials are being used primarily in mixtures and that the dramatic rise in their usage could be attributed to changes in data reporting methods.

Usage by Region

The economics of factor inputs, differing soil types and moisture regimes will inevitably result in regional variation of fertilizer usage. This is evident in several ways. We will look at consumption patterns according to five major regions.[18] Table A-1 in the appendix lists the states in each of these regions.

New England and Middle Atlantic States. This is the oldest fertilizer use region in the U.S. Changing agriculture has meant changing fertilizer consumption. Land use for agriculture has decreased 40 percent since 1940 leading to reduced fertilizer demand within the past decade. Regional usage of plant nutrients was 0.8 million tons in 1984, or about 4 percent of U.S. totals. Area farmers applied this on harvested crop acreage which also equaled 4 percent of the U.S. total at an average rate of 129 lbs. of nutrients per acre. This comparatively low rate is perhaps attributed to the small amount of cash crops such as corn, soybeans or wheat (34%) in favor of hay (46%).

South Atlantic States. This region also has a long history of fertilizer usage. Many years of cultivation plus relatively infertile soils translates into the highest use rate per acre in the U.S. This region consumed 2.3 million tons of nutrients in 1984, or 10 percent of U.S. totals--down from almost 16 percent in 1965. With only 6 percent of the harvested cropland, this meant an average application rate of 247 lbs. of nutrients per acre. Interestingly enough, even though this region had the highest rate of application in the U.S., it also has the lowest average analysis, around 33 percent. This compares with over 50 percent average analysis in the North Central region.

East North Central and East South Central States. This region includes both the Corn Belt in the North and the Cotton Belt in the South. The higher nutrient requirements of these crops means high levels of fertilizer usage. This region has traditionally used about one-third of U.S. total plant nutrients. Its harvested cropland equalled 25 percent of the total with nutrients applied at a rate of about 180 lbs/acre.

West North Central and West South Central States. Nutrient use in these states has risen significantly. Spurred by increased irrigation and newer fertilizer responsive wheat strains, this region now consumes 40 percent of total nutrient, up from 24 percent in 1965. However, with harvested cropland equalling 53 percent of totals, this region still had one of the lowest application rates - about 96 lbs of nutrients per acre.

Mountain and Pacific States. In this region farmers grow high-value crops under irrigation and special cropping conditions. Relative consumption remained around 10 percent of the nation's totals during the past twenty years. In 1984, usage averaged 124 lbs of nutrients applied per harvested acre. There was significant intra-regional variation, though, with the Mountain States following the trend toward lower nutrient consumption (77 lbs/acre) associated with westward movement while the Pacific States replicated the high consumption rates of the Atlantic east coast (217 lbs/acre).

Usage by Crops

Fertilizer usage by different crops provides yet another perspective on consumption patterns. Different crops have widely divergent nutritional needs which, in turn, account for some of the váriance in usage among regions. Understanding these variations, in conjunction with forecasting future cropping patterns, can give indication of future trends in fertilizer demand.

Corn ranks first among the agronomic crops with respect to nutrient usage. Average rates of total nutrients applied on corn acreage tend to be twice the rate for total U.S. harvested acreage. Average application rates for corn, moreover, almost doubled from 1965 until 1984 when they averaged over 260 lbs per acre. Over half of this in 1984 was in the form of nitrogen (132 lbs per acre) with potash second at 71 lbs/acre.

Cotton usage rates of application were comparable to those for corn in 1965; rates have since, however, declined significantly. Between 1978 and 1981 average rates bottomed out around 87 lbs/acre but more recently climbed to over 100 lbs/acre. Nitrogen has historically accounted for the majority of the nutrients applied.

Wheat nutrient usage increased along with substantial increases in acreage planted. Rates of application also increased. Between 1965 and 1984 average rates rose from 32 lbs/acre to 73 lbs/acre. Most of this was in the form of nitrogen which more than tripled in usage. By 1984, two-thirds of total nutrients applied was nitrogen while another one-fourth went to phosphates.

Soybeans saw the largest relative increase in application rates--from 12 lbs/acre to 40 lbs/acre between 1965 and 1984. As a nitrogen-fixing legume, almost all of soybean nutrient usage occurs as potash (60%) and phosphate (25%).

PRICES

Fertilizer prices have responded to both changes in fertilizer demand and supply. Price fluctuations, though, have been even more pronounced over time than fertilizer demand fluctuations. There is also significant regional price variation.

Prices by Type

Prices of individual fertilizer products have tracked closely together over time. Table 2 compares the Prices Paid Index for agricultural producers, the fertilizer price index, and some selected fertilizer prices over time. As the table indicates, fertilizer prices exhibited extreme price oscillations during the period 1965-85. Large increases in fertilizer production, coupled with technological advances, led to steadily falling prices during the later half of the 1960s. Growth in demand, however, picked up in the early 1970s with increases in total cultivated acreage. Demand eventually outstripped supply with resulting skyrocketing prices during 1975. Increases of two to three-fold were the norm. High fertilizer prices in conjunction with falling farm commodity prices resulted in sharply curtailed demand in 1975 as

Table 2. Fertilizer Prices, 1965-1985.[1/]

	1965	1968	1971	1975	1978	1981	1985
PPI	46	51	58	88	108	151	165
(PITW)				(89)	(109)	(152)	(163)
Fert. Price Index	57	52	51	128	100	147	135
Commodity Prices							
Anhydrous Ammonia	122	91	79	265	171	247	252
	(265)	(178)	(136)	(301)	(158)	(164)	(153)
Nit. Sol. (32%)	--	--	61	168	133	178	160
			(105)	(191)	(123)	(118)	(97)
Amm. Nit.	79	68	63	186	139	192	189
	(172)	(133)	(109)	(211)	(129)	(127)	(115)
Urea	--	92	82	244	170	245	217
		(180)	(141)	(277)	(157)	(162)	(132)
Mur. of Potash	54	49	58	102	98	155	128
	(117)	(96)	(100)	(116)	(91)	(103)	(78)
DAP (18-46-0)	111	101	96	263	186	283	240
	(241)	(198)	(166)	(299)	(172)	(187)	(145)
10-10-10	64	63	62	134	111	166	154
	(139)	(124)	(107)	(152)	(103)	(110)	(93)
6-24-24	86	82	80	186	150	226	192
	(187)	(161)	(138)	(211)	(139)	(150)	(116)
Limestone	5.0	5.3	5.8	9.0	10.5	15.1	16.0
	(10.9)	(10.4)	(10.0)	(10.2)	(9.7)	(10.0)	(9.7)

1/ April prices used for 1965-75, May prices used for 1978-85. Prices in parethesis are in constant 1977 dollars.

Source: NASS-USDA, Agricultural Prices, 1965-1985.

previously noted. Prices dropped to more historic levels during subsequent years as new production facilities came on line. Rising crop prices and cultivated acreage led to the record high levels of fertilizer demand in 1981--and prices again increased.

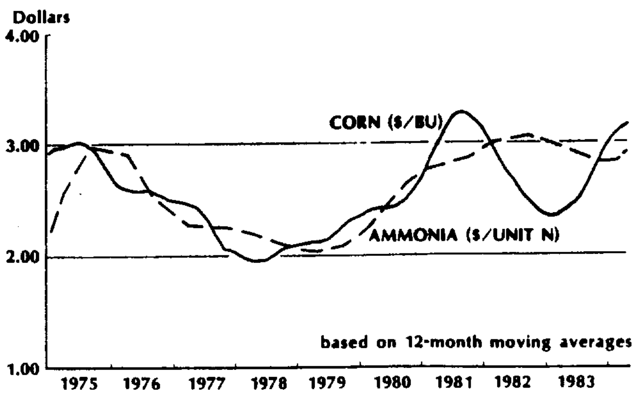
More recently, with the farm economy in recession, demand has declined. Average fertilizer prices have similarly declined. Even with the most recent decreases, fertilizer prices still show a net increase of almost 150 percent since 1965. But while nominal fertilizer prices showed an upward trend, real fertilizer prices decreased by about one-third since 1965. The major proportion of this price decrease occurred by 1971 for most fertilizers. Anhydrous ammonia, for example, dropped almost one-half in real price between 1965 and 1971. Since then, real ammonia prices have risen somewhat. Most other fertilizer materials and mixtures, however, have continued their decline.

Despite the extreme flucuation of fertilizer prices, they follow closely farm commodity price trends. Figure 5, as taken from a TVA report by Douglas and Harre, shows this for the corn-ammonia price cycle.[19] Ammonia prices have historically followed corn prices very closely. Unfavorable price ratios in 1978 and 1982 coincide with the significant decreases in fertilizer consumption during those years while a favorable ratio in 1981 underlies the record levels of consumption during that year.

Prices by Region

There are some distinct regional price differences amongst fertilizers. However, since the USDA does not collect prices for the

Figure 5. Corn-Ammonia Price Cycles.



Source: Douglas and Harre, 1984.

same products in all regions, it is difficult to generate any meaningful summary statistics. The majority of domestic ammonia and phosphate is produced in the Southeast and South Central regions. Prices, correspondingly, average lower in those regions and increase with movement towards the North and West. The Northwest and Southwest regions, in particular, have prices commonly 15-25 percent higher than U.S. averages.

Differences between specific regions can be even more extreme. For example, the May 15th, 1985 price for anhydrous ammonia in the South Central region was $228 per ton. This compared to $362 per ton in the Northwest region--almost 60 percent higher.

EXPENDITURES

Changes in fertilizer usage and prices lead to similar changes in expenditure patterns. An overview of expenditure patterns is provided by Table 3.[20] Total expenditures increased by over two and one-half times between 1971 and 1985. Increased farm sizes, however, meant that average expenditures increased three and one-half times during the same period. Beginning in 1971, fertilizer expenditures averaged $1110 per farm. By 1985 this stood at $3779 per farm. Inflation accounts for much of the rise; average expeditures in terms of real dollars rose only 16 percent during the same period.

Even with larger farms and inflation, increased expenditures also stemmed from the actual increased role of fertilizer in agriculture. Farmers spent a greater proportion of their total production expenditure dollar on fertilizer in 1985 as compared to 1971. Between 1971-73

Table 3. Fertilizer Expenditures.

Year	Total Expenditure[1/]	Average Per Farm	Percent of Total Prod. Exp.
	million dollars	dollars	percent
1971	3,230	1,110	6.1
1972	2,857	997	5.3
1973	4,029	1,419	5.2
1974	5,752	2,036	6.7
1975	6,760	2,411	8.3
1976	7,229	2,606	8.1
1977	6,878	2,545	7.0
1978	7,185	3,037	6.3
1979	8,759	3,763	6.5
1980	10,132	4,182	7.5
1981	9,911	4,077	7.5
1982	9,516	3,972	7.3
1983	8,387	3,546	6.4
1984	8,817	3,788	6.9
1985	8,614	3,779	6.8

1/ Includes total expenditures (operator plus landlord) for fertilizers, and lime and soil conditioners.

Source: NASS-USDA, Farm Production Expenditures, 1971-85.

fertilizer expenditures averaged 5.7 percent of total production expenditures. That proportion leaped to 8.3 percent by 1975 in light of skyrocketing prices that year. Since then, it decreased in a downward cyclical fashion to 6.8 percent by 1985.

Expenditures by Region

Geographic variations in fertilizer expenditures follow the same patterns as geographic variation in consumption.[21] In 1965 the North Central region accounted for 44 percent of fertilizer expenditures followed by the Atlantic region with 24 percent and South Central region with 19 percent of total expenditures. The following years saw significant regional shifts. By 1982 the North Central region accounted for over half of total expenditures with the western North Central region picking up most of the gain. The Mountain region likewise gained in terms of increased fertilizer expenditures. Meanwhile, the Atlantic region declined eight percentage points to 16 percent of the nation's total expenditures. The South Central region remained about the same between 1965 and 1982.

Expenditures by Crop

Fertilizer expenditures among the different crops vary in the same manner as the previously noted variation in crop fertilizer consumption.[22] Corn, in 1984, had the highest average per acre fertilizer expenditures among the major crops - around $53 per acre. Regional expenditure differences followed the previously noted regional consumption differences. Just as application rates were lowest in the

Northern Plains region, expenditures were likewise lowest at $33 per acre. The Southeast, meanwhile, exhibited expenses twice as high at $67 per acre. Cotton had average expenditures of $26 per acre in 1984 while sorghum was a lower $21 per acre. Wheat required expenses of $19 per acre with a significant variation among wheat types. Hard red winter wheat received an average of $14 worth of fertilizer per acre while soft red winter wheat had a three-fold cost at $39 per acre. Soybeans, with their low nitrogen requirements, had an average expenditure of only $9 per acre.

ECONOMIC DEMAND AND USAGE STUDIES

Various economic studies have attempted to analyze the determinants of fertilizer demand and usage with some varying results. Griliches in 1958 studied fertilizer consumption for the period 1911 to 1956.[23] He concluded that plant nutrient consumption was determined by the response of farmers to nutrient prices relative to output prices. The response, however, occurred over time. He estimated the short run price elasticity to be -0.5 and the long run elasticity at approximately -2.0. Griliches attempted to explain the lag as resulting from a lack of education in fertilizer usage among some farmers while others were at a point on their production function where decreasing returns would limit response.

Heady and Yeh (1959) likewise tested the hypothesis that fertilizer demand is a function of relative prices.[24] They concluded that relative crop and fertilizer prices, technological change and an increase in farmers' knowledge had resulted in an increase in fertilizer demand.

They argued, however, that it was capital constraints, not position on a production function, that was responsible for slower rates of response.

Rausser and Moriah (1970) were motivated to ascertain if fertilizer demand coefficients were changing over time.[25] Their answer was affirmative; the elasticity of fertilizer consumption as a function of relative prices had decreased from 1949 through 1964. They computed the short run price elasticity to be -0.22 with a long run elasticity of -1.0, but acknowledged that there could be a downward bias. They proposed the same explanation as their predecessors--that is, increased education resulted in lower sensitivity to price changes as did the diminishing returns from higher attainments on the production function.

Finally, Marhatta (1976) sought to determine the significance of nutrient demand determinants.[26] He used time series data beginning about where Griliches left off and obtained results quite similar. He computed price elasticities for nitrogen, phosphorous and potassium to be -0.55, -0.84, and -0.71 respectively. He concluded, however, that the variable measuring the technical knowledge of farmers was more significant than price for both nitrogen and potassium.

FERTILIZER MARKET STRUCTURE

PRODUCERS

Changes in demand have wrought changes in the supply structure of fertilizer. Unfortunately, the most recent in-depth studies date from the late 1970s. Hence, this portion of the paper will refer primarily to a time period prior to 1977.

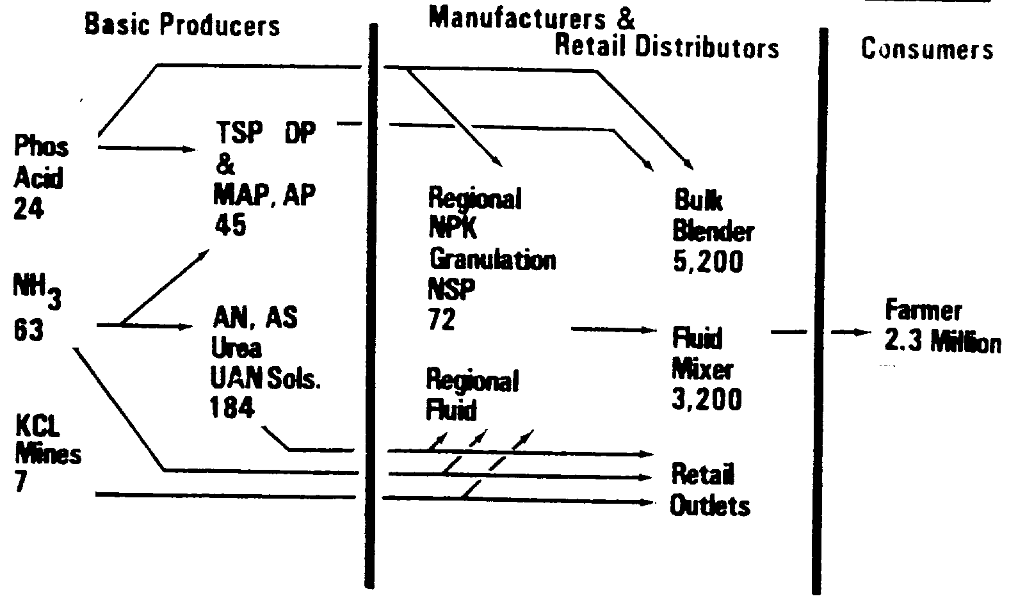
The fertilizer industry has enjoyed almost uninterrupted growth since its inception. It has grown into big business. About 50 million tons of fertilizer worth almost $8 billion move yearly through a network of manufacturers, formulators, blenders and dealers. Dramatic changes in the production and distribution of fertilizers accompanied this growth in demand. Improvements in production processes plus a shift towards higher analysis materials prompted the entry of petroleum and chemical manufacturers in the 1960s. Many of these companies began to integrate forward and sell their products directly at the retail level.[27] Some firms began to integrate horizontally and supply the entire range of nutrients needed by the farmer. Figure 6, based on a 1984 TVA survey, provides a graphic overview of the U.S. fertilizer production and distribution flow.

Nitrogen

Nitrogen, which constitutes over one-half of all plant nutrients, saw the most dramatic fluctuations in market conditions. Since nitrogen fertilizers are derived from ammonia, which in turn is produced from large quantities of natural gas feedstock, energy shortages and skyrocketing costs plagued the sector during the early 1970s. Moreover, the industry tended to expand in cycles which failed to match demand conditions, thereby resulting in successive periods of shortages and overcapacity.[28] The industry responded to record demand levels with a wave of ammonia plant construction. Capacity increased by 30 percent between 1974 and 1977. Overcapacity, however, along with dramatic increases in natural gas prices and competition from imports resulted in

Figure 6.

SIMPLIFIED FLOW OF U.S. FERTILIZER PRODUCTION & DISTRIBUTION



Figures indicate number of operating plants – FY 1984
Total retail outlets: 12,000–14,000
AAPFCO Survey – 1984 MDES TVA

Source: Hargett and Berry, 1985.

29 plants with 4 million tons of capacity closing in the following two years. Currently, more than half of the U.S. ammonia is produced in the Delta and Southern Plains States. These areas provide readily available natural gas as well as access to rail and pipeline transportation.

Efficient ammonia production requires large, capital-intensive plants. Economies of scale are significant. In 1977, the average cost of ammonia production was $55/ton in a 400-ton-per-day plant compared to $41/ton in a 1000 ton-per-day operation.[29] Beyond this size, economies of scale lessen. Nonetheless, a few of the largest plants in the U.S. produce as much as 2,500 tons per day.

In 1976, 93 plants produced ammonia compared to 63 in 1984.[30] The level of concentration among ammonia plants increased until 1984 when the top 4 firms produced a moderate 35 percent of U.S. totals with the top eight firms producing 50 percent of the total.

Ammonia firms are characterized by a high degree of vertical integration. Firms are heavily involved in derivation products such as urea, ammonium nitrate, nitrogen solutions or ammonium phosphates. In 1977, 61 percent of all ammonia firms owned one or more derivative plants. These plants, in turn, produced 88 percent of the total derivative capacity. In addition, there is a fair degree of backward linkages. Many firms were also involved in crude petroleum and crude gas extraction.

<u>Phosphate</u>

The phosphatic fertilizer industry includes the producers and processors of phosphate rock, phosphoric acid, and sulfuric acid. There are three major domestic phosphate rock producing areas: Florida and North Carolina, the Western States, and Tennessee. Of these three, Florida and North Carolina produce over 80 percent of the U.S. total. In addition to supplying domestic needs, U.S. phosphate producers exported about 40 percent of their total production in 1984.

The phosphate sector has become increasingly concentrated. Prior to 1900 there were over 100 rock mining firms in the U.S. By 1984, 21 firms operated 29 mines. Concentration ratios were moderate with the top 4 firms controlling 50 percent of total production and 67 percent controlled by the top eight. Vertical integration among the product subsectors is extensive. Producers of phosphate rock are involved extensively in the production of phosphoric acid, concentrated superphosphate, and ammonium phosphate. In 1976, for example, phosphate rock firms also controlled 50 percent of the phosphoric acid, and 60 percent of the ammonium phosphates and concentrated superphosphates. This integration is probably due to efficiencies resulting from locating the various steps in the production process at a single location, and also as a means for the producers to ensure a market for their product.[31]

Potash

The U.S. potash sector is much smaller than either the nitrogen or phosphate sectors. Domestic sources are found primarily in New Mexico with some additional sources in Utah and California. Saskatchewan with 45 percent of the world's known reserves supplies the bulk of U.S. potash consumption. By 1981, Canadian mines supplied 90 percent of all U.S. potash consumption. Moreover, since potash can be applied directly on farmers' fields with a minimal amount of processing, the potash sector lacks the intermediate derivatives as with the nitrogen or phosphate sector.

Concentration within the potash sector has historically been high. In 1960, prior to the discovery of the Canadian reserves, eight firms operated all of the U.S. mining and processing facilities. Within a few years, U.S. firms were developing the new reserves in Canada. By 1976, 15 potash firms operated within the United States and Canada. Of those, the top 4 controlled about 56 percent of the production capacity of the two countries. However, this picture has most certainly changed over the past years; in 1976, the Canada passed legislation enabling the Saskatchewan government to purchase 50 percent or more of the potash industry in that province. There is a limited amount of economically accessible deposits in the U.S. thus constraining new entry to the industry.[32] The lack of potash derivatives precludes the same type of vertical integration evidenced within the nitrogen and phosphate sectors.

There are also significant linkages among the separate fertilizer sectors. In 1976, thirteen ammonia producers controlling 26 percent of total U.S. ammonia capacity also controlled 59 percent of the domestic phosphate rock capacity. Conversely, only two ammonia firms produced potash. Phosphate rock producers were also interlinked with the nitrogen and potash sectors. In addition to ammonia, several rock producers manufactured ammonia derivatives. For example, eight rock producers controlled 23 percent of the total urea capacity. Linkages between phosphate and potash sectors were not as strong. In 1976, two phosphate rock producers possessed 18 percent of domestic potash capacity.

RETAILING

Fertilizer retailing firms provide the link between producers and farmers. Past surveys have shed light on the structure of fertilizer retailing. The 12,000 to 14,000 retail firms in the U.S. are located mostly in the North Central region, and are engaged in diverse production activities utilizing different material inputs. There is significant variability in firm size, and consequently, forms of business ownership. Finally, retail firms have sought to differentiate an otherwise homogeneous product by placing an increasing emphasis on their services.

The AAPFCO Surveys

The Association of Plant Food Officials (AAPFCO) and the Tennessee Valley Authority cooperated in 1974, 1976, 1980, and 1984 to survey listed fertilizer manufacturers and dealers throughout the United States. The information compiled from these surveys resulted in the TVA publication Directories of Fertilizer Manufacturers in the U.S. for each of the surveyed years.

The TVA made the raw survey data available for the purposes of this study. The 1974 and 1976 data had been previously analyzed at the University of Minnesota under a contract with ERS-USDA.[33] This part of the study is based upon the previous 1974 analysis, and our own analysis of 1980 and 1984 survey data supplemented by insights from TVA analyses.[34]

An estimated 11 to 12 thousand firms sold fertilizer in 1974 and 1976. The 1980 directory listed 12,131 firms with an increased 12,831 listings for 1984.

About half of the firms listed in the TVA directories actually responded to the surveys. In 1980, five states--California, Minnesota, Mississippi, Nebraska, and New York--did not respond to the survey but supplied lists of retail firms. In 1984, California, Mississippi and Nebraska did not respond but again supplied lists. Both 1980 and 1984 surveys supplemented data from respondents with limited data on nonrespondent populations. This combined pool of survey respondents and firms with available data formed the study sample referred to from here on as "All Firms."

It should be stressed here that variable response rates complicate comparisons of firms across time. This is most noticeable for types of firms with small population samples--granulators in particular. Depending upon the year and survey question, the sample for granulators varied from 14 to 72 firms. This, led at times to excessive statistical variability over time. The analysis, however, should still elucidate the more pronounced trends.

Fertilizer Retail Characteristics

Geographic. A majority of retail fertilizer firms are located in the North Central region of the U.S. Table 4 shows the total number of directory listings and "All Firms" by region. In 1980 and 1984 over 60 percent of the directory listings were in the East and West North Central regions. "All Firms" were proportionally the same, averaging around 60 percent for each of the years 1974, 1980 and 1984. The other major region is West South Central with 10 to 15 percent of all firms. Historically high survey response rates, however, resulted in that region

Table 4. Summary of TVA Directory Listings, by Region.

Region	Total Listings[1/] 1980	Total Listings[1/] 1984	All Firms[2/] 1974	All Firms[2/] 1980	All Firms[2/] 1984
New England	86	57	56	46	36
Middle Atlantic	390	419	146	197	209
South Atlantic	856	847	430	563	534
East North Central	2,935	2,933	1,266	1,347	1,529
West North Central	4,502	4,890	2,453	2,609	2,113
East South Central	517	507	274	351	355
West South Central	1,665	1,420	1,494	1,616	1,142
Mountain	519	614	255	337	308
Pacific	661	1,144	198	146	140
Total	12,131	12,831	6,492	7,212	6,366

1/ Total firms listed in 1980 and 1984 TVA directories (1974 not available). Firms compiled through AAPFCO questionnaires and lists of registrants.

2/ Includes firms responding to AAPFCO questionnaires with data for additional firms supplied by registrants lists.

Sources: 1974 - Data derived from AAPFCO survey results by Magnani and Dahl, 1979. 1980, 1984 - All data derived from AAPFCO survey results.

Table 5. Production Activities.

Production Activity	Number of Firms			Percentage of All Firms 1/		
	1974	1980	1984	1974	1980	1984
Blenders, mixers, and granulators	5,015	5,721	5,160	77.2	79.3	81.1
Bulk blenders	3,825	4,002	4,014	58.9	55.5	63.1
Granulators	123	105	72	1.9	1.5	1.1
Fluid mixers	1,734	1,922	1,795	26.7	26.7	28.2
Liquid hot mix	345	295	378	5.3	4.1	5.9
Liquid cold mix	1,447	1,429	1,248	23.3	19.8	19.6
Suspension hot mix	139	312	363	2.1	4.3	5.7
Suspension cold mix	584	442	486	9.0	6.1	7.6
Pipe reactor	73	51	58	1.1	0.7	0.9

1/ Percentage of firms responding to AAPFCO questionnaire with additional firms supplied by registrants lists.

Source: See Table B-1.

accounting for around one-fifth of all responding firms. Low response rates from the Pacific States resulted in that region being underrepresented.

Production Activities. Survey results indicated that over three-fourths of all firms either bulk blend, fluid mix or granulate fertilizer (Table 5). The remaining firms would be classified as "retailers only." This group apparently diminished in relative importance since 1974 as popularity for custom blending and mixing increased over time. Granulator plants also diminished both in real numbers and relatively.

Among fluid mixers several different lines of production activity exist.. Grouped under this heading are both liquid and suspension mixers. Both types of mixer might employ either a hot mix or cold mix process with a small percent using pipe reactors. An increasing percent of firms reported use of the hot mix process while cold mixing appears to be declining in popularity. Fluid mixers, on average, were engaged in only one or two different production activities.

Blends and granulations maintained fairly constant shares of the total retail distribution for the surveyed years. Firms indicated that between 40 and 45 percent of their total tonnage sold was either bulk or bagged blends while granulations comprised another 10 to 15 percent. Both blends and granulations, however, showed the same trend towards a greater proportion of sales in bulk form and a commensurate decrease in sales of bagged fertilizers. Finally, liquid direct application materials (including anhydrous ammonia and nitrogen solutions) increased to almost one-quarter of total distribution by 1984 while dry direct application materials dropped by half to 10 percent of totals.

The percent of firms carrying a given product class likewise varied for each of the surveyed years. In general, and as can be expected, as a product class increased in relative distribution, so did the percent of firms carrying it. For example, firms reporting the distribution of nitrogen solution increased from 41 percent in 1974 to 52 percent in 1984. The opposite, however, cannot be said for product classes declining in popularity. Firms appear to have maintained old product lines while expanding into new ones. The net result has been an increase in the average number of product classes carried by a firm--from 2.9 in 1974 to 3.1 in 1984.

Among bulk blenders, urea, diammonium phosphate (DAP), triple superphosphate, and potassium chloride were the most common materials used in the manufacture of bulk blends (Table 6). Liquid mixers used primarily nitrogen solutions, ammonium phosphate solutions (10-34-0), and potassium chloride solutions. The same was true for firms producing fluid suspensions; however, because suspensions do not require complete solubility of materials, mixers used a wider range of ingredients. Suspension plants also used high amounts of mono-ammonium phosphate (MAP) and anhydrous ammonium, as well as dry clay which acts as a suspending agent.

Finally, granulation plants have undergone changes as reflected by their changing material usage. Many installed pipe-cross reactors that now permit the use of large quantities of phosphoric and sulfuric acid, anhydrous ammonia, and other fluids to produce dry granular NPK fertilizers. Meanwhile, the use of more conventional materials such as triple superphosphate, normal superphosphate and MAP decreased.

Table 6. Types of Materials Used.

Materials	Bulk Blend		Liquid		Suspension		Pipe Reactors		Granulation	
	1980	1984	1980	1984	1980	1984	1980	1984	1980	1984
	- - - - - - - - - - - - - -percent of plants- - - - - - - - - - - - - -									
Ammonium Nitrate	41.4	30.2	—	—	—	—	—	—	—	—
Ammonium Sulfate	21.7	26.6	2.8	5.7	4.3	7.8	8.0	18.4	75.0	96.3
Urea	66.1	79.4	5.7	10.1	2.2	2.9	12.0	22.4	20.0	25.9
Urea (soluble)	—	—	7.4	6.8	14.4	21.6	30.0	18.4	—	—
DAP (18-46-0)	94.5	94.4	1.5	1.5	5.8	6.9	6.0	12.2	85.0	63.0
MAP (11-52-0, etc.)	10.7	15.4	2.3	2.5	31.7	34.3	18.0	28.6	45.0	59.3
Normal Superphosphate	4.1	3.2	—	—	—	—	—	—	60.0	44.4
Triple Superphosphate	78.4	73.0	—	—	—	—	—	—	82.5	74.1
Nitrogen Solutions	—	54.0	83.9	82.9	73.3	76.5	82.0	73.5	—	—
Anhydrous Ammonia	—	50.4	9.3	9.5	37.4	32.4	66.0	73.5	85.0	96.3
10-34-0	—	—	86.0	80.6	69.1	52.9	96.0	85.7	—	—
Phosphoric Acid	—	—	8.9	8.0	7.2	2.9	40.0	32.7	75.0	81.5
Superphosphoric Acid	—	—	3.8	5.7	1.4	1.0	56.0	49.0	—	—
Ammoniating Solutions	—	—	—	—	—	—	—	—	70.0	81.5
Sulfuric Acid	—	—	—	—	—	—	—	—	90.0	92.6
Dry Clay	—	—	3.6	3.6	53.1	42.2	46.0	51.0	—	—
Fluid Clay	—	—	1.9	2.9	18.7	16.7	18.0	30.6	—	—
Potassium Chloride (STD)	93.9	94.5	12.5	8.9	18.0	11.8	24.0	24.5	92.5	100.0
Potassium Chloride (SOL)	—	—	38.8	39.9	59.7	54.9	78.0	77.6	—	—
By-Products	—	—	4.9	6.3	2.2	13.7	—	12.2	—	—
Other	16.9	29.9	—	—	21.6	33.3	8.0	—	22.5	18.5
Number of Plants Reporting	2,727	2,188	472	526	139	102	50	49	40	27

Sources: AAPFCO survey as reported by Hargett and Pay, 1980; Hargett and Berry, 1985 (1974 data unavailable).

Table 7. Average Throughput by Type of Firm.[1/]

	1974	1980	1984
	- - - - - - - - -in tons- - - - - - - -		
All bulk blenders	6,002	6,380	5,642
Bulk blenders only	4,730	5,410	4,903
All fluid mixers	7,191	5,919	5,395
Liquid only	3,433	3,840	3,437
Suspension only	2,573	3,604	2,803
All granulators	107,995	132,980	103,956
Granulators only	70,993	106,453	68,383

1/ For firms reporting total annual distribution.

Sources: AAPFCO survey as reported by Hargett and Wehrman, 1975; Hargett and Pay, 1980; Hargett and Berry, 1985.

Firm Size. The different manufacturing activities exhibit varying characteristics of size. Although we have no data on potential plant production levels, Table 7 shows the average throughput by type of firm. These values would be expected to vary over time with changes in fertilizer demand. In 1979-1980, total fertilizer consumption reached an all-time high. The significantly higher throughputs, as indicated by survey results reflect this. In 1983, consumption hit a 10 year low. If firms based throughput estimates on the previous year's sales, then this would account for the dramatic across the board decreases.

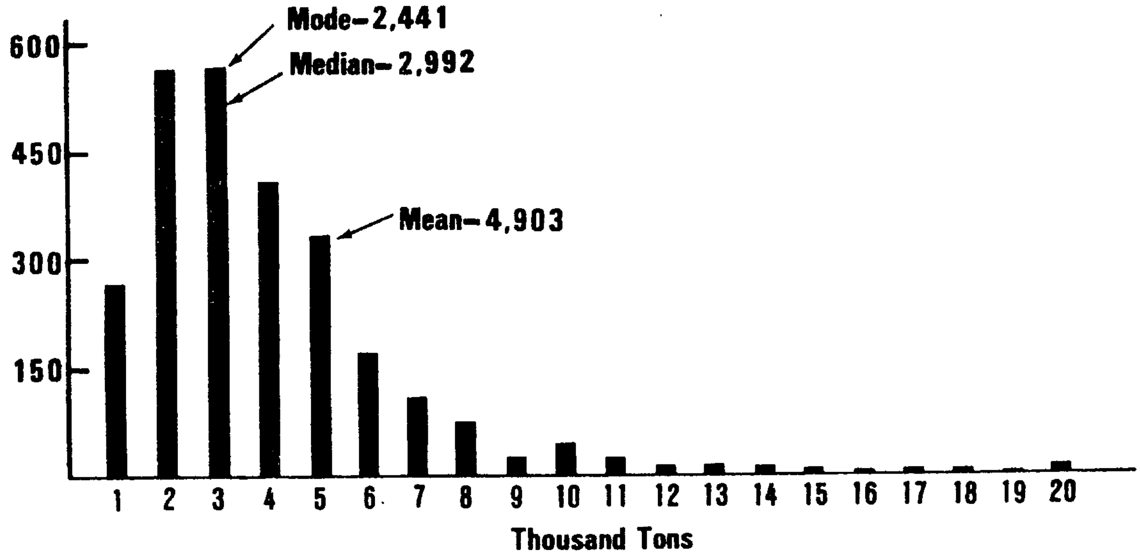
Nonetheless, the figures are still consistent in showing relative plant sizes for each of the surveyed years. Plants that engaged in more than one activity--as indicated by the "All blenders," "All mixers," or "All granulators" categories--exhibited larger average throughputs than the plants engaged in exclusively one activity.

Although the average bulk blend plant had a throughput of 4,900 tons in 1984, a skewed distribution placed the median size at almost 3,000 tons (Fig. 7). Compared with bulk blend plants, fluid mixers tended to be smaller. A frequency distribution for all fluid firms in 1984 showed a mean throughput of around 4,200 tons and a median at 2,130 tons (Fig. 8). Within fluid plants, overall, suspension mixers tended to be smaller than liquid mixers.

Economies of scale become apparent when viewing average throughputs for granulation plants. In 1984, the average size was over 68,000 tons. As firms diversified activities, this apparently gave much greater opportunity for increased throughput with averages increasing to almost 104,000 tons per plant.

Figure 7.

FREQUENCY DISTRIBUTION FOR U.S. BULK BLEND FERTILIZER PLANTS

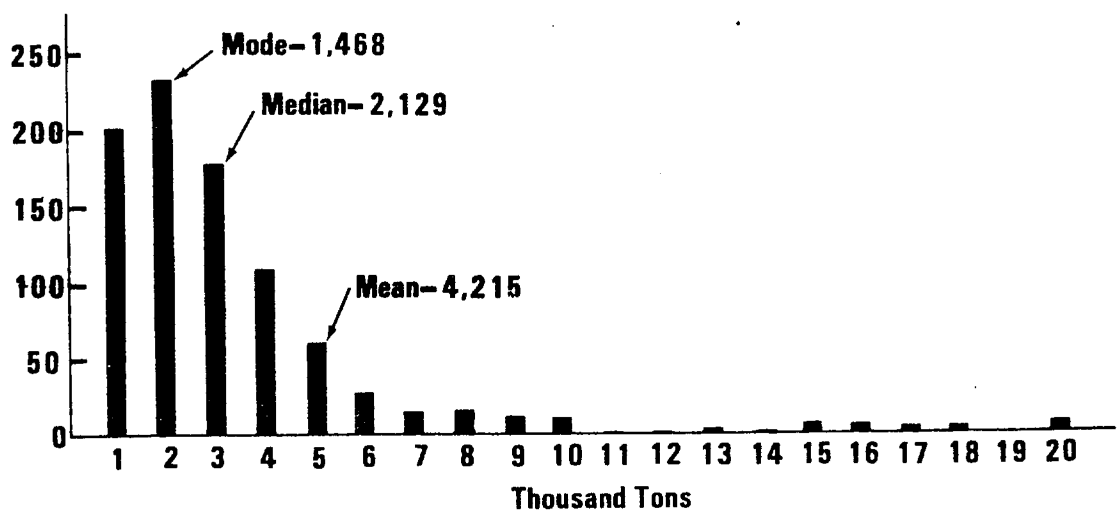


Based on 2,726 Bulk Blend Plants

Source: Hargett and Berry, 1985.

Figure 8.

FREQUENCY DISTRIBUTION FOR U.S. FLUID ONLY FERTILIZER PLANTS



Based on 920 Plants

Source: Hargett and Berry, 1985.

Since fertilizer demand is highly seasonal, the storage capacity of retail firms is very important. Bulk blenders showed the highest average storage capacity in terms of proportion of total fertilizer distributed with capacity equivalent to 45 percent of annual distribution. This compared to 30-35 percent for fluid mixers and granulators. Only granulators, however, show any possible storage capacity trend with increased storage between 1974 and 1984. The distribution of storage capacities is skewed in the same manner as plant throughputs.

Finally, the type of storage possessed by a firm varied significantly. In 1984, 75 percent of all responding firms reported bulk storage while only 14 percent reported storage for finished products.

Services Offered. The range and type of services offered by a firm affect fertilizer pricing. The past 10 years witnessed firms placing a greater emphasis on services offered. An increased proportion of firms which did not bulk blend, mix or granulate (i.e., "Retailers Only") offered a greater array of services, but even more so for bulk blend, liquid mix and granulating firms. Between 1974 and 1984 the average number of services offered by retailer only firms doubled from 1.0 to 2.2. The same occurred among bulk blenders and fluid mixers until those firms offered an average of more than five services per plant.

Table 8 summarizes the types of services offered and the proportion of firms doing so. The types of services offered go hand in hand with the type of production activity undertaken by a firm. Adding seeds to fertilizer mixtures is especially well suited to bulk blends while pesticides are most easily incorporated into fluid mixtures, and hence the variation in services offered between firms. Similarly, application

Table 8. Services Offered.1/

Services	Retailers Only			Bulk Blenders Only			Fluid Mixers Only		
	1974	1980	1984	1974	1980	1984	1974	1980	1984
	- - - - - - - - - - - - - - -in percent- - - - - - - - - - - - - -								
Add seeds	8	28	29	33	46	59	5	19	30
Add micronutrients	7	18	28	40	70	79	55	84	85
Add pesticides	8	2/	2/	25	2/	2/	44	2/	2/
Add herbicides	2/	26	34	2/	45	59	2/	75	81
Add insecticides	2/	17	24	2/	32	35	2/	49	52
Bagging equipment	2	4	3	21	20	18	0.6	0.9	0.6
Spreader rental	37	62	66	76	84	88	42	58	62
Custom application	40	60	53	70	80	80	69	81	85
Soil testing	2/	72	74	2/	90	89	2/	86	86
Consultation on service	2/	71	70	2/	77	73	2/	75	67
Number of firms reporting	3/	799	703	3/	2,476	3,040	3/	905	966

1/ For firms reporting services offered.
2/ Not included on survey.
3/ Not available.

Sources: See Table 4.

of suspension mixtures requires more sophisticated equipment and thus 96 percent of suspension only firms offered custom application in 1984 as opposed to 75 percent of those firms only producing liquid mixes.

In 1984, all firms reported custom applying an average of 39 percent of their total distribution themselves with other applicators custom applying an additional 4 percent. Of the remaining total, farmers applied 32 percent through the use of rental equipment and 21 percent with their own equipment. Variations exist amongst the types of firms. For example, in 1984, suspension firms custom applied almost twice as high a proportion of the total distribution (75%) as the average of all firms (39%). Again, the greater sophistication of suspension mixture application equipment seemed to warrant this.

Business Ownership. The form of business ownership is yet another determinant of fertilizer prices. Table 9 classifies retail firms by type of ownership. Between 1980 and 1984, ownership of retail only firms by sole proprietors slipped from 30 percent to 22 percent with cooperatives picking up the gain. Sole proprietors on the other hand, apparently gained in the ownership of fluid mixing plants. This might have stemmed from the low initial investment required to start a new plant. Cooperatives, as they have sought to establish backward linkages, likewise seem to control a greater proportion of the granulation plants. Nonetheless, corporations were the overall dominant mode of ownership. Over half of all manufacturing plants were organized under corporate ownership in 1984.

Table 9. Form of Business Ownership.

	Sole Proprietor		Partnership		Corporation		Cooperative	
	1980	1984	1980	1984	1980	1984	1980	1984
Retail only	29.6	22.2	8.2	8.0	45.6	48.0	16.6	22.7
Blenders, mixers, and granulators	9.0	10.5	5.0	4.8	51.6	51.4	34.4	34.1
Bulk blenders	7.0	7.6	3.7	4.3	46.1	47.2	43.2	41.6
Liquid mixers	13.0	16.0	7.3	5.6	63.1	61.8	16.6	17.6
Suspension mixers	12.0	16.3	6.7	4.6	71.6	68.7	9.7	11.0
Granulators	1.3	4.2	-	2.8	81.0	67.6	17.7	26.8

Sources: AAPFCO Survey as reported by Hargett and Pay, 1980; Hargett and Berry, 1985; (1974 results not available).

INDUSTRY PERFORMANCE

An examination of the supply structure should close with a look at the performance of the companies in this sector. Unfortunately, there is limited data available from which to draw conclusions. But some insights can be gained by looking at secondary sources.

Capacity

The capacity utilization rate provides one estimate of health for the overall industry. The fertilizer industry has had idled capacity throughout much of the 1980s. Despite pressure from increasing imports, the anhydrous ammonia sector operated at around 90 percent capacity throughout much of the 1980s; but this was possible only through a dramatic contraction of domestic production capabilty stemming from widespread plant shutdowns. Future crop acreage restrictions could lead to reduced domestic consumption and further idled capacity--down to an estimated 75 percent for crop year 1986/87.[35] The ammonium nitrate and urea sectors also possess excess capacity producing at around 85 percent of total capacity for much of the 1980s.

Overcapacity has recently plagued the phosphate industry contributing to declining phosphate prices. Phosphate ore production was down with mines operating at only 85 percent capacity in 1985. Phosphoric acid production remained close to record levels between 1982 and 1985 but with potential output of 12 million tons per year that sector was also operating at only 85 percent capacity.

Declining domestic demand for potash combined with new mines opening in Canada has resulted in an oversupply situation expected to last into the 1990s.[36] Despite some U.S. mines closing, domestic production in 1986 was less than 70 percent of capacity while Canadian mines operated at only 50 percent capacity.

Profitability

The profitability of fertilizer production is difficult to determine since such figures are often buried in annual reports which contain operation figures for non-fertilizer operations. The most recent study that we found was done by the U.S. International Trade Commission in 1979 to investigate whether ammonia imports from the Soviet Union were causing market disruptions.[37] Based on estimates from 35 producers accounting for three-fourths of domestic production, the study noted that profits had dropped dramatically from 1976 to 1979. Net profit margins fell from 28 percent to a net loss in the first half of 1979. But the Commission warned that these figures had questionable reliability due to various accounting procedures employed by producers. Yet another source indicates that persistent low returns underlie the lack of new investments in the ammonia industry.[38]

Attrition and Expansion

Profitability in the fertilizer industry should affect the flow of capital into and out of the industry. As previously noted, the ammonia sector has been hard pressed during the past decade. A high number of ammonia plants closed over the past decade. In 1977, there were 104 plants owned by 63 firms. By 1986, a high attrition rate left 61 plants owned by 43 firms remaining. These plants were the larger, and presumably more cost-effective plants. Average plant capacity increased from 600 tons per day in 1977 to 840 tons per day by 1986; but nonetheless, total domestic production still dropped by 20 percent. With no new capacity scheduled for the next few years, the average age of ammonia plants will be approaching 15-20 years.[39] Prospects of low demand growth and low returns on investments gives little to indicate that producers will replace this capacity as need arises. The ammonium nitrate and urea sectors also saw a significant reduction in the number of operating plants. In these sectors, however, economies of scale enabled fewer larger plants to keep domestic production the same or actually higher.

An export market that was until recently growing has probably lent stability to the phosphate ore sector. In 1986 there were 29 mines, down just one from 1976. The phosphoric acid sector, on the other hand, contracted significantly as plants far removed from centers of mining activity closed leaving remaining plants concentrated around phosphate ore sources. With rising demand, the ammonium phosphate sector received continued investments. Additional plants have been added while other plants have expanded production up to three-fold. The U.S. phosphate industry has nonetheless undergone several ownership changes. Marketing organizations or foreign companies have replaced traditional producers with the long-term effects on the industry uncertain.[40]

With potash imports from Canada providing 90 percent of U.S. consumption, the domestic potash industry has contracted sharply. In 1976, 11 firms operated 11 mines and by 1986, 8 firms operated 8 mines. Total domestic production, however, declined rapidly until by 1986 output was almost half of levels ten years prior. Yet total North American potash capacity continues to expand with the opening of new mines in Canada. Furthermore, because of the extremely long planning horizon for establishing potash production facilities, several new projects are being considered.[41]

Barriers to Entry

A large number of antitrust actions have targeted the fertilizer industry in the past. The industry structure of the primary producers suggests several reasons for concern about anticompetitive behavior. The high degree of vertical integration in the ammonia industry and the high level of concentration in the potash industry would appear to present barriers to entry. Nonetheless, a 1981 Federal Trade Commission study on competition in farm inputs did not perceive restrictive trade practices in the fertilizer industry to pose a problem.[42] The study argued that although costs for entering ammonia or phosphate production are substantial, they are not insurmountable for many companies in the petrochemical industry. Ammonia imports from Mexico and the Soviet Union and potash imports from Canada all effectively compete with local production. Furthermore, cooperatives continue to provide alternative supply outlets for consumers and thus counterbalance oligopolistic tendencies within the industry. The study concluded that "[t]he combination of all these factors tends to reduce the likelihood of anticompetitive behavior in the fertilizer industry."[43]

INTERNATIONAL TRADE

The U.S. domestic market operates in the larger context of international demand and supply. Some sectors in the fertilizer industry, such as ammonia, find themselves under continuing competition from foreign imports. The phosphate sector, on the other hand, exports almost half its P_2O_5 production. As such, the well-being of the U.S. fertilizer industry will continue to be tied to the world market. An examination of the different sectors follows.

Nitrogen

The U.S. was a net exporter of nitrogen nutrient throughout the late 1960s and early 1970s. However, the rising prices in the mid 1970s which prompted heavy investment in new production facilities also led to increased production capacity overseas. This new foreign capacity (primarily ammonia) not only effectively eliminated much of U.S. export demand, it also proved to be a vigorous source of competition for U.S. domestic markets. The influx of low-cost nitrogen from abroad helped hasten the closing of smaller, high-cost U.S. plants throughout the late 1970s and 1980s.

As a result, the U.S. became a net nitrogen importer in 1975 and has remained so for every year, except 1979 and 1980. In 1984 the nitrogen trade deficit was 2.0 million tons. This dropped 65 percent the following year due to favorable prices in the U.S. but regained the former high of 2.0 million in 1986 with forecasts for similar deficits in upcoming years.[44] Ammonia constitutes the bulk of nitrogen imports--over

60 percent in 1985. Urea imports rank second at about a million tons per year, or about 25 percent of totals.

Despite high levels of nitrogen imports, the U.S. still has substantial exports. Nitrogen exports have averaged over 2 million tons per year since 1981 except in 1985 when levels rose to 3 million tons. Even though it is primarily a phosphate, diammonium phosphate is the leading nitrogen export with over 40 percent of the export market.

Phosphates

Although domestic phosphate demand peaked in 1977, a growing export market has led to a continued growth in domestic production. Exports were around 0.4 million tons in 1965. They increased over six-fold by 1977 and doubled yet again by 1985 when low prices that year prompted record high levels of exports at 5.5 million tons. Imports exceeded usage for many countries prompting cutbacks the following year. As a result, exports plummeted to 3.2 million tons in 1986. This seems to characterize export demand of the 1980s: large swings in demand leading to an unstable market and, at times, idled production capacity. Nonetheless, exports still comprise around half of the total demand for U.S. phosphates.

Currently, the U.S. mines about 30 percent of the world's total phosphate rock output. It exports about one-quarter of its production. Increasing governmental regulation and taxes has raised the cost of rock production at home. Meanwhile, phosphate reserves are being developed in other parts of the world. These combined factors have resulted in a decreased demand for phosphate rock.[45]

Concurrently, an increasing preference for high analysis fertilizers has led ammonium phosphates to dominate the export market with over 60 percent of export totals in 1985. Phosphoric acid hit a new record of 1.4 million tons which represented 25 percent of total exports. In addition, more than 60 percent of the U.S. triple superphosphate produced is exported--around 0.7 million tons of P_2O_5.

Potash

The U.S. currently imports about 85 percent of its potash demand. About 95 percent of that comes from Canada with small amounts also imported from Israel. In the 1960s, the U.S. was largely self-sufficient in potash production, importing only 10 percent of its total demand. The discovery and development of Canadian reserves, however, altered that scenario by the early 1970s. By 1985. imports totaled over 5.0 million tons of K_2O nutrient.

Domestic producers see some demand in the form of exports. U.S. potash exports exceeded a half million tons on 1985 and represented 40 percent of producers sales. North American exports combined accounted for one-third of total demand. Most of the world's potash demand lies in areas which already produce potash. Hence, export growth potential is limited. Unlike phosphates, the domestic market will continue to be the dominant factor in potash supply, demand, and price movements.[46]

SUMMARY

TRENDS IN REVIEW

Some distinct past trends stand out within the fertilizer sector. This section summarizes those previously noted and looks at factors which could affect future use. These include:

1. Increased consumption. Total tons of nutrients consumed increased over two-fold between crop years 1965 and 1981. Acreage reduction programs and a stressed farm economy dropped consumption 20 percent by 1986 with further decreases forecasted.
2. Increased average analysis. Farmers are using more high analysis fertilizers. This is reflected in the increased popularity of such products as anhydrous ammonia (82% N) and DAP (16-48-0). Average analysis increased from 37 percent in 1965 to 46 percent by 1980 where it has essentially remained. Future increases will probably be minimal.
3. Changed relative importance of individual nutrients. Nitrogen, potash and phosphates saw differing rates of growth in consumption. Nitrogen usage increased the most between 1965 and 1985 (160%) followed by potash (95%). Phosphates increased only 30 percent during the same period.
4. Changed types of fertilizer consumed. Changes in consumption have been matched by changes in the type of fertilizer used.
    - increased materials consumption. This is most evident in the dramatic rise of anhydrous ammonia and the ammonium phosphates. However, some of the charted rise in materials

consumption, particularly dry bulk materials, is due to changes in accounting practices within state statistical offices. The net change, therefore, remains uncertain.

- changed usage amongst fertilizer classes. Farmers applied different forms of fertilizers in 1985 as opposed to 1965. Usage of bulk blends rose two and a half fold. Demand for granulated mixed fertilizers declined, being replaced by granulated materials used for bulk blending. The increase in bulk blend popularity also affected the packaging of fertilizers. Bagged fertilizers lost a substantial portion of the total market shares. Conversely, consumption of fluid fertilizers increased three and one half fold.

5. Increased rates of application. Farmers applied fertilizers at higher rates of application between 1965 and 1985. This has also contributed to increasing overall fertilizer consumption. There is, however, significant variation amongst crops.
6. Extreme price fluctuations. Fertilizer price fluctuations were more pronounced over time than for most other crop production inputs. Changing demand and OPEC induced supply shocks can account for much of the fluctuation. Nonetheless, prices of similar commodities appear to track closely together. Prices stabilized throughout the 1980s.
7. Decreased real prices. Advancements in fertilizer technology contributed to a decline in the average real price from 1965-85. Within fertilizers, the average price of mixtures declined relative to materials.

8. Increased fertilizer expenditures. Farmers, on average, increased fertilizer expenditures over three-fold during the past 15 years. In 1985 expenditures amounted to an average of $3780 per farm compared to $1110 per farm in 1971. Average expenditures in terms of real dollars, however, rose less dramatically--about 16 percent during the same period. This translates into a rise in relative expenditures as fertilizers occupied a greater proportion of the total production expenditure dollar.

OUTLOOK

According to 1986 FAO/World Bank projections, world demand for fertilizer is expected to grow around 18 percent between 1986 and 1991.[47] Growth in consumption for developed market economies should increase much slower--around 6 percent for nitrogen, 8 percent for phosphate, and 13 percent for potash during the same period. The United States is expected to see continued decline in usage during the early part of 1986-91.

World fertilizer production will be adequate to meet demand through 1990. Production capability for nitrogen is projected to grow slower than demand which could result in higher prices. The world surplus of phosphate fertilizer production capability is expected to continue through the end of the decade. Any increase in U.S. phosphate fertilizer production will depend heavily increases in phosphate exports. Rising potash demand will be met primarily by increases throughout the world in existing production capacity--from 67 percent in 1986 to a forecasted 75 percent in 1991. In addition, Canada and other minor producers are expected to increase production potential about 5 percent.

Numerous variables will continue to affect fertilizer supply and demand in the United States. Acreage planted remains the single most important variable in determining future U.S. fertilizer demand; and in recent years, governmental farm policy has had a heavy intervening hand in farmers' acreage decisions. Relative crop/fertilizer prices is yet another variable.

New technology will most certainly change the face of the U.S. fertilizer market in years to come. Different tillage methods could affect quantities and types of fertilizer used. No-till or ridge-till could result in increased usage of fluid fertilizers matched by decreased dry fertilizers consumptions.[48] On the more distant horizon, researchers foresee possibilities of creating nitrogen fixing crops, such as corn, through bioengineering. This would drastically affect the fertilizer industry through reduced crop nitrogen requirements.[49]

Finally, the fertilizer industry must confront future problems such as continued rising costs natural gas feedstock for the nitrogen sector, diminishing quality of phosphate reserves, increased concerns over pollution, and continued vigorous foreign competition. In the meantime, farm use of fertilizer continues to yield high returns in crop production. This assures an ongoing significant role for the fertilizer industry in agriculture.

APPENDIX

Table A-1. Fertilizer Consumption Regions (TVA-NFDC).

New England States
Maine, New Hampshire, Vermont,
Massachusetts, Rhode Island, Connecticut

Middle Atlantic States
New York, New Jersey, Pennsylvania,
Delaware, Maryland, West Virginia

South Atlantic States
Virginia, No. Carolina, So. Carolina,
Georgia, Florida

East North Central States
Ohio, Indiana, Illinois
Michigan, Wisconsin

West North Central States
Minnesota, Iowa, Missouri, No. Dakota,
So. Dakota, Nebraska, Kansas

East South Central States
Kentucky, Tennessee, Alabama, Mississippi

West South Central States
Arkansas, Louisiana, Oklahoma, Texas

Mountain States
Montana, Idaho, Whyoming, Colorado,
New Mexico, Arizona, Utah, Nevada

Pacific States
Washington, Oregon, California

Note: Data concerning fertilizer consumption, prices and expenditure came from different sources who used different regional groupings.

Table A-2. Fertilizer Prices Paid Regions (NASS-USDA).

Northeast States
Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, West Virginia

Southeast States
Florida, Georgia, North Carolina, South Carolina, Virginia

East South Central States
Alabama, Kentucky, Lousiana, Mississippi, Tennessee

South Central States
Arkansas, Oklahoma, Texas

North Central States
Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, Wisconsin

Northern Plains States
Kansas, Nebraska, North Dakota, South Dakota

Mountain States
Colorado, Montana, New Mexico, Wyoming

Northwest States
Idaho, Oregon, Washington

Southwest States
Arizona, California, Nevada, Utah

Table A-3. Farm Production Expenditure Regions (ERS-USDA)

Northeast
Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont

Appalachia
West Virginia, Virginia, Kentucky, Tennessee, North Carolina

Southeast
South Carolina, Alabama, Georgia, Florida

Corn Belt
Illinois, Indiana, Iowa, Missouri, Ohio

Delta States
Mississippi, Arkansas, Louisiana

Lake States
Michigan, Minnesota, Wisconsin

Northern Plains
North Dakota, South Dakota, Nebraska, Kansas

Southern Plains
Oklahoma, Texas

Mountain
Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada

Pacific
Washington, Oregon, California

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