# Nitrogen's Future: Further Growth

R. P. WESTERHOFF, Ford, Bacon & Davis, Inc., New York

**Nitrogen, second among plant nutrients in tonnage, ranks first on a long-term growth basis. Per-acre use will rise with rising population; to satisfy growing agricultural and industrial demand, nation's nitrogen capacity will have to be expanded 80% by 1975**

FOR THE PAST 40 years, the United States has been feeding a rapidly growing population from a relatively constant area of cropland. In the first half of the 20th century, the nation's population rose from 76 to 152 million. By 1975, according to U. S. Bureau of Census estimates, it is virtually certain to exceed 200 million. It may go as high as 225 or 230 million.

While this growth has been going on, there has been no change in the total land area of the United States—1,904 million acres. And since about 1920, there has been very little change upward or downward in the acreage devoted to crops (Fig. 1). Other uses for land have shifted considerably, as shown in Table I.

To achieve ever-larger production without corresponding increases in cropland acreage, farmers have increased yields through many improved practices. Ranking high among these is their steadily increasing use of fertilizer, consumption of which has gone up very rapidly since 1940.

While the population doubled in 50 years, the total amount of fertilizers consumed increased from 4.4 to 36.0 billion pounds annually. Figure 2 shows how the rate of consumption climbed slowly for the first 40 years, then rapidly to the 1956–57 volume of 45 billion pounds. Of this bulk of 45 billion pounds of total fertilizers, nonfarm consumption accounted for roughly 10%.

By category and by weight per cent, using the values for 1956–57, total fertilizers may be separated into six groups as follows: N-P-K mixtures 64.7%; chemical nitrogen materials 16.3%; phosphates 10.6%; potashes 2.0%; secondary and trace elements 4.2%; natural organic materials 2.1%. This breakdown is of particular interest to the manufacturer but not to the user. The astute farmer wants to know the relative amounts of each available plant nutrient in the fertilizer he purchases. He knows by experience and education that if he correctly proportions these nutrients to suit his particular crop and soil requirements, his yield per acre will increase and quality will improve.

In 1956–57, the three principal plant nutrients accounted for, by weight, 28.1% of the total fertilizer quantity. Their individual percentages were nitrogen (N) 9.4%, phosphorus (available $P_2O_5$) 10.2%, and potash ($K_2O$) 8.5%. Back in 1910 the corresponding breakdown was 2.6, 9.0, and 3.8 for a total of 15.4%. The increase in nitrogen content is significant since it reflects the development and growth of the synthetic ammonia industry. The increase in total nutrients indicates the farmer's preference for highly concentrated fertilizers that result in the reduction of handling and shipping charges per unit of nutrient.

Particularly noticeable is the in-

**Table I. Land Utilization**

| | Acreage (Millions) | |
|---|---|---|
| | *1920* | *1954* |
| Cropland | 402 | 399 |
| Pasture | 328 | 526 |
| Grazing | 661 | 353 |
| Woodland | 328 | 435 |
| Other (including cities, highways) | 185 | 191 |
| Total U. S. Land Area | 1,904 | 1,904 |

creased use of nitrogen. While total fertilizer grew from a volume of 10.90 billion pounds in 1910 to 45.42 billion in 1956–57, for an increase of just over 300%, the volume of available nitrogen grew from 0.283 to 4.27 billion pounds, an increase of over 1400%.

The rate of increase of nitrogen application to the soil was low from 1900 to 1940, leading to a 1940 value of 2 pounds per acre, and then more rapid to the present-day value of approximately 10.7 pounds, an increase of roughly 5 to 1 since 1940.

Figures 2 and 3 show total fertilizer consumption and the amount of nitrogen applied per acre, with reasonable projections of what may be expected to 1975.

Reasons for the early low rate of consumption of nitrogenous fertilizers in the United States were historical. Other than waste products, only imports of nitrates from Chile and Norway were available. These products were later augmented by the expensive nitrous oxides first produced in Norway in 1905 by the arc process, and by cyanamide, also first produced in 1905, but in Italy. The year 1913 should really be designated as the birth date of the synthetic fertilizer industry. It was then that the Germans introduced the Haber process for the direct synthesis of ammonia.

During and following World War I, there were significant technical developments in the fixation of atmospheric nitrogen in the United States, and it is reasonable to assume that the sharp increase in nitrogen use would have begun much earlier than 1940 had it not been for the poor economic conditions of the 1930's.

Even with a 5-to-1 increase in less than 20 years, the application of 10 to 11 pounds per acre is only a fraction of the rates of nitrogen usage in European countries. From data reported in the "Annual Review of World Production and Consumption of Fertilizers—1955," published by the Food and Agriculture Organization of the United Nations, and the 1956 Yearbook of the same group, the amount of nitrogen consumed per acre of arable land has been estimated as follows:

**Table II. Nitrogenous Fertilizer Chemicals**

(Values for 1955, in millions of pounds)

| | Total Weight | % Nitrogen | Nitrogen Weight | % $NH_3$ (1.21 × % N) | Ammonia Weight |
|---|---|---|---|---|---|
| Anhydrous ammonia | 635 | 82.3 | 523 | 100 | 635 |
| Urea | 123 | 46.6 | 57 | 56.6 | 70 |
| Nitrogen solutions | 612 | 25.0 | 153 | 30.3 | 185 |
| Ammonium nitrate | 2,004 | 35.0 | 701 | 42.5 | 852 |
| Ammonium sulfate | 934 | 21.2 | 198 | 25.7 | 240 |
| Calcium cyanamide | 124 | 35.0 | 43 | — | — |
| Calcium nitrate | 101 | 17.0 | 17 | 20.6 | 21 |
| Sodium nitrate | 1,106 | 16.5 | 182 | 20.0 | 221 |
| Potassium nitrate | Neg. | 13.7 | Neg. | — | — |
| Ammonium phosphate | 604 | 12 to 21 | 100 | 20.0 | 121 |
| Mixtures | 26,132 | 5.3 | 1,385 | 6.4 | 1,672 |
| Other | — | — | 153 | — | 186 |
| Total | | | 3,512 | | 4,203 |

**Nitrogen Consumed per Acre of Arable Land**

| | Pounds per Acre |
|---|---|
| Netherlands | 156 |
| Belgium | 84 |
| West Germany | 46 |
| Norway | 38 |
| United Kingdom | 31 |
| Sweden | 20 |
| France | 15 |
| United States | 10 |

Thus nitrogen use in this country can again be increased by 1400% before it reaches the high level per-acre consumption rates now common in the Netherlands.

Among all the plant nutrients applied in the United States, nitrogen ranks first on a long-term growth basis and second on a weight basis. The major nitrogen chemicals are listed in Table II. The data emphasize the importance of ammonia in its role as a key fertilizer building block.

In 1955, the fertilizer industry consumed some 4,200 out of a total of 6,500 million pounds of ammonia produced in the United States. The major portion of this total production was derived from petrochemical sources, the remainder from by-product coke ovens and natural sources. From 1953 through 1956, petrochemical production accounted for the following percentages of all ammonia produced: 75, 85, 90, and 90.

With a natural gas price of approximately 20 to 30 cents per thousand cubic feet, it is generally possible to produce ammonia for $30 to $40 per ton. The farmer would pay approximately 6 cents per pound or 60 cents for the national average of 10 pounds applied per acre. With a farm the size of the national average of 80 acres, he would spend $48 to apply the going rate of ammonia to his cropland. In actual practice, 50 to 100 pounds of anhydrous ammonia is applied per acre by those who use it.

With the exception of anhydrous ammonia, urea contains the greatest concentration of ammonia. For this reason, the recent performance of this compound requires some attention.

Figure 1

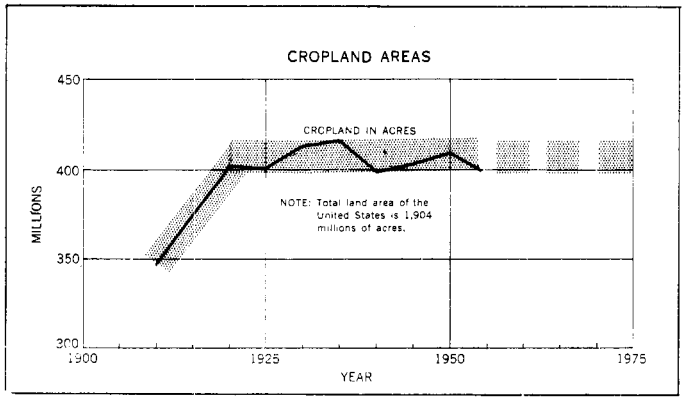



Figure 2

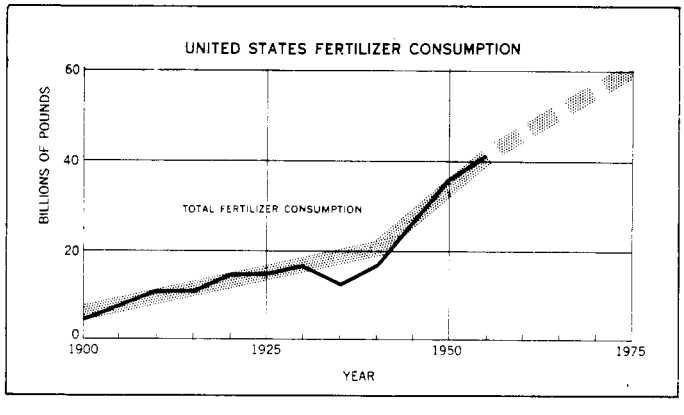


Figure 3

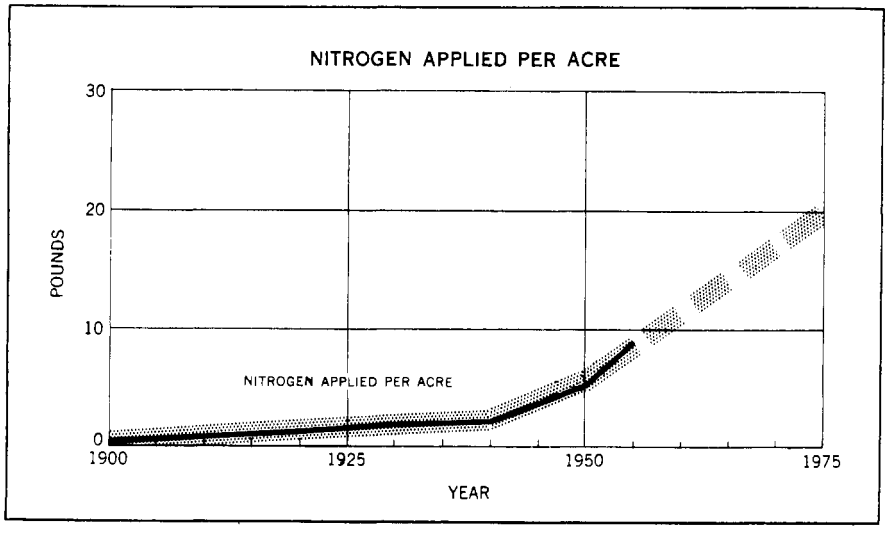



Figure 4

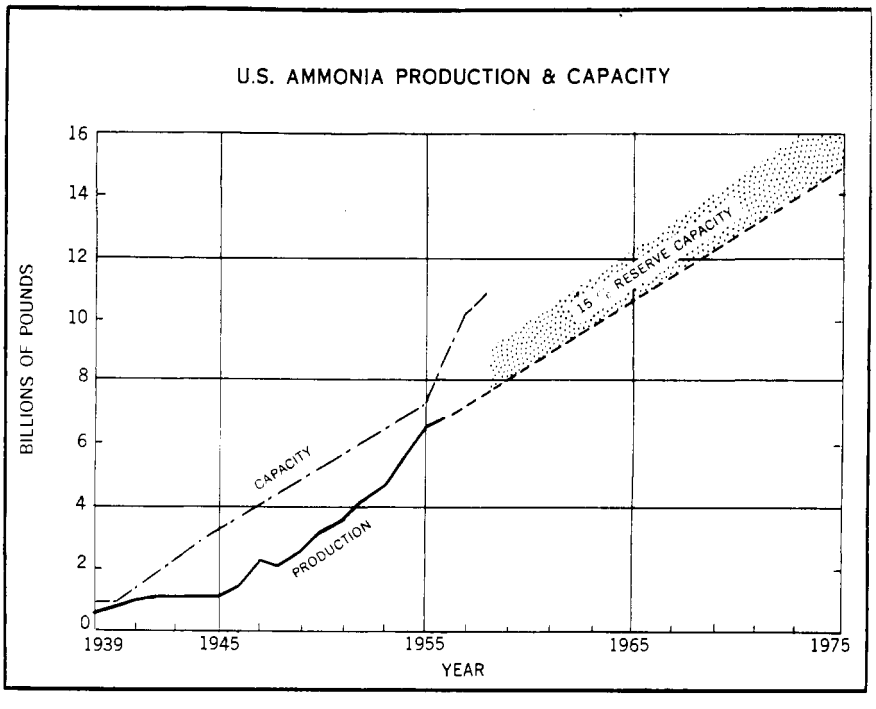
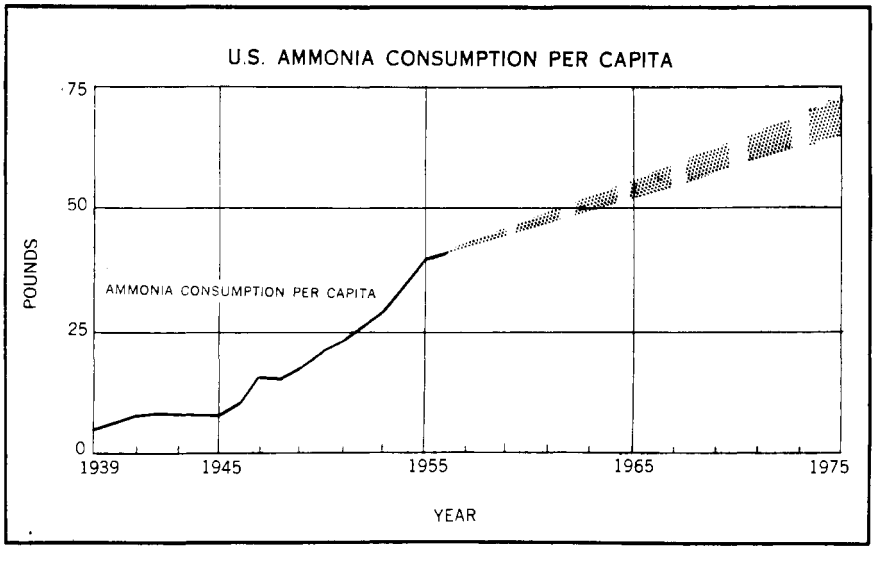



Figure 5




Total urea production in the United States jumped from 350 to 842 million pounds between 1955 and 1956. It rose another 15% in 1957. Total urea capacity stood at 1.25 billion pounds on Jan. 1, 1958, and will have reached 1.6 billion pounds by the end of 1959. In 1956, 494 out of the 842 million pounds, almost 60% of production, was sold as fertilizer. Of the amount sold to the farmers, 70% was applied in solid form and the remainder in solution. Since urea is produced from carbon dioxide and ammonia, further growth in agricultural use of urea points toward further expansion of ammonia capacity.

### *The Growth Outlook*

Indeed, low-cost ammonia may be considered the firm foundation on which the fertilizer industry as a whole may base its future growth. If the projected growth of this industry is to be accommodated, and if sufficient nitrogen chemicals are to be available for other industrial uses, the synthetic ammonia industry will have to increase its total capacity by about 80% before 1975 (Fig. 4). At today's costs, this expansion would call for capital investments of about $400 million. Not included in this estimate is a probable need for some $50 million worth of extra capacity which must be built concurrently to meet growing demands for ammonium nitrate as an explosive. The 300,000 tons of ammonium nitrate used for blasting in 1956 will probably be tripled by 1975.

Existing ammonia capacity, with a value of some $500 million, totals about 10 billion pounds a year. While not all of this capacity is now being used, it is not likely to be very long before consumption (Fig. 5) matches present production capacity. Soil enrichment needs alone could preempt existing ammonia capacity in a few short years. The soil will be called upon to yield greater and greater quantities of food as the years pass, and if the present rate of increase in feeding the soil is maintained, the national average application of nitrogen per acre should at least double to around 20 pounds within the next 17 years.

Exports of nitrogen fertilizers also will contribute to the growth of the industry, by increasing 200% by 1975.

Already at the head of the petrochemical industry in terms of tonnage, ammonia bids well to outdistance its own swift post-war growth. Feeding the American people, coupled with a booming use of ammonium nitrate for blasting, and lower cost production and transportation techniques add up to the promise of a bright future for ammonia.