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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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DRAFT WORLD-WIDE STUDY OF THE FERTILIZER INDUSTRY: 1975–2000

PREPARED BY THE

INTERNATIONAL CENTRE FOR INDUSTRIAL STUDIES

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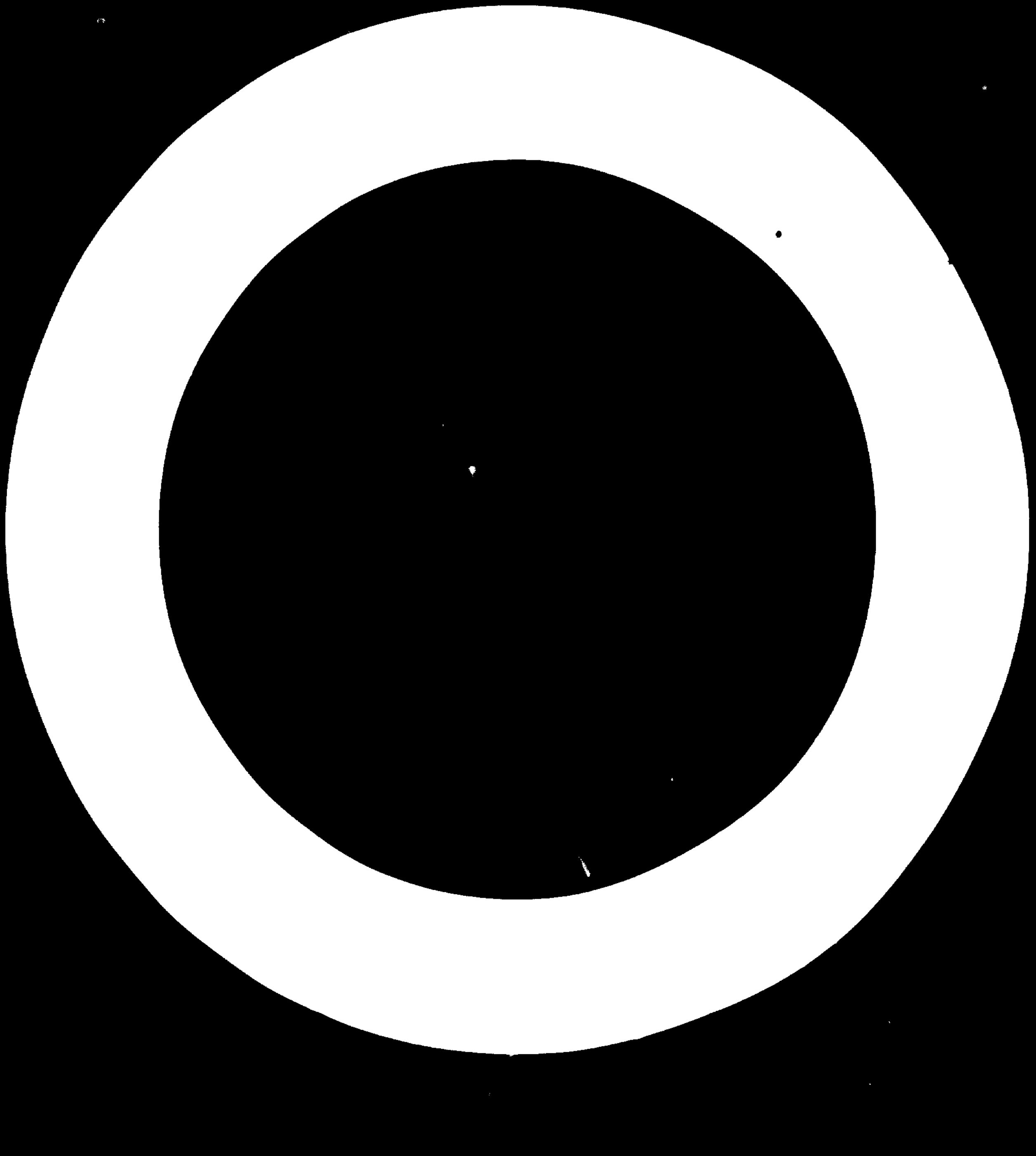


INTRODUCTION

At the Second General Conference of UNIDO held at Lima in March 1975, the Lima Declaration and Plan of Action on Industrial Development and Co-operation was adopted, and subsequently endorsed by the General Assembly at its seventh special session. In the Declaration, the role of industry was re-asserted as a dynamic instrument of growth essential to the rapid economic and social development of the developing countries, and a target was set whereby the developing countries' share of world industrial production should be increased from its present level of 7 per cent to at least 25 per cent by the year 2000.

Of the priority sectors identified in the Lima Declaration, significant emphasis was placed on the promotion of agro-based or agro-related industries which besides arresting rural exodus and stimulating food-production activities, provide an incentive for the establishment of further natural resource-based industries in the developing countries. Of the other basic industries highlighted in the document adopted at the Conference, particular attention was devoted to the development of the petrochemical industry as a means of consolidating the economic independence of the developing countries.

Among the mandates entrusted to UNIDO in the Lima Declaration and Plan of Action was the recommendation that "in order to give concrete content to the process of industrialization in the developing countries, studies must be undertaken and specific measures formulated in different sectors of industry, special attention being given to priority sectors". The fertilizer industry, which is one of the largest manufacturing industries in the world, was selected as a subject for one of the first world-wide studies in view of its vital importance to agricultural production and industrial development in many developing countries. Further reasons for studying this sector were the need for increased food for growing populations and the abundant supply in many developing countries of raw materials for fertilizer manufacture.

The present study represents a concerted attempt to provide an overview of the opportunities for and constraints upon the development of the fertilizer industry: an activity which is linked to both the petro-chemical industry and the agro-industrial sector. Through this study, the newly established International Centre for Industrial Studies in UNIDO is contributing to an understanding of the issues involved in this sector: projections provide an indication of the magnitude of growth in this sector, and in certain instances they relate to the year 2000.

The study takes into consideration the opportunities open to developing countries in their endeavour to increase their share in world industrial production, and duly reflects the implications in terms of structural changes, the resultant international division of labour and appreciable shifts in the relative positions of the various fertilizer production capacities in the world. Moreover, despite the amount of data collected, the study is not intended as a mere compendium of statistics. The data have been gathered, sometimes with difficulty owing to the nature of a predominantly privately owned industry, to serve solely as illustrative background material essential to the clarification of the issues discussed and to an understanding of the multifarious factors involved.

The purpose of the study is to identify the main opportunities for the advancement of the fertilizer industry and to assess the potential contribution this sector could make to the attainment of the over-all industrial production target set in the Lima Declaration. It has been prepared in the light of experience in this sector. Inevitably, the study and its projections, as well as the methodology used to obtain such projections, will be revised periodically in the light of changing circumstances.

The study which is intended as a decision-making tool for persons involved in investing in the fertilizer industry is structured in such a way that the component chapters treat the factors that cannot be ignored in any meaningful discussion of the fertilizer industry and its significance for the future of the developing countries.

Following a summary, the second chapter provides a survey of the past, present and future world fertilizer situation, followed by a chapter on capital and operating costs of fertilizer manufacture. Primary raw materials such as natural gas, naphtha, fuel oil, coal lignite, phosphate rock, sulphur and potash materials, as well as organic materials, are the subject of the fourth chapter.

The subsequent three chapters are devoted to analyses of fertilizer plant location, marketing and distribution of fertilizers, and government fertilizer policies. The final chapter treats certain policy proposals which could be seen to contribute to the achievements of the industrial production target set in the Lima Declaration. An analysis of manpower requirements and personnel training is annexed to the study.

An initial attempt on the part of UNIDO to point up the implications of the Lima Declaration and Plan of Action for the fertilizer industry, this study is also oriented towards the system of continuing consultations called for in the Lima Declaration with a view to facilitating the creation of new industrial facilities in developing countries. The strict schedule established for the initiation of these consultations has necessitated the early completion of this study. It is a reference document presenting basic data on the fertilizer industry, universal in its orientation and applicable to developed and developing countries alike. Its basic objective is the development of efficient fertilizer industries in an increasingly interdependent world.

The International Centre for Industrial Studies was assisted in the preparation of this study by: R. Cook, M. Eid, R. Ewell, C. Middlebrooks, J. Robertson, Davy Pacific Pty. Ltd., International Fertilizer Development Center, and the Tennessee Valley Authority.

Chapter I

WORLD FERTILIZER CONSUMPTION TO THE YEAR 2000: A SUMMARY

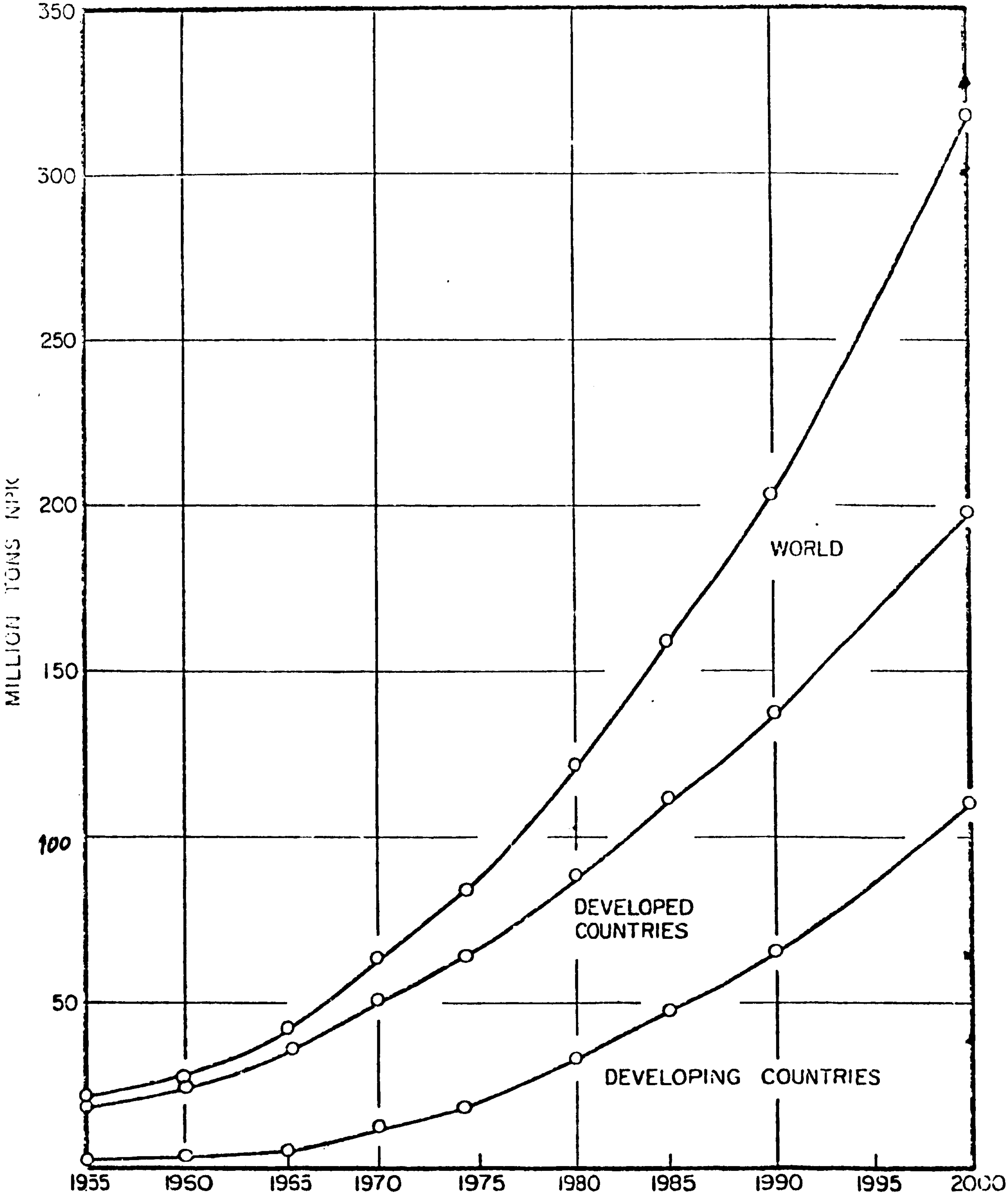
In the study, fertilizer consumption is projected for the period 1980-2000. The method used is a simple mathematical projection of past trends using linear regression equations of the form $\sqrt{F} = A + BT$. The study also presents projections of fertilizer consumption in principal regions of the world, as well as in 40 individual countries in Africa, Asia and Latin America.

Figure 1 shows trends in fertilizer nutrient consumption from 1955 to 1974, with projections to the year 2000, at which time world consumption will be 307 million tons as compared with 83.6 million tons in 1974 - a 3.7-fold increase. Assuming an average nutrient content of 42 per cent ($N+P_2O_5 + K_2O$), the gross weight of fertilizer consumed per annum would be 731 million tons by the year 2000. Nutrient consumption in developing countries is expected to increase from 19.3 million tons in 1974 to 110 million tons in 2000 - a 5.7-fold increase.

The above projections are based on historical patterns of fertilizer consumption, not on estimates of food requirements: estimates based strictly on the nutritional requirements of increasing populations would probably be higher for most developing countries and lower for many developed countries. Any forecast is subject to increasing uncertainties as the forecast period is extended, hence no great accuracy can be claimed for the present projections. They do, however, serve to indicate the potential for expansion in the fertilizer industry up to the end of the century.

The table on page 3 shows past and future consumption for individual nutrients in both developed and developing countries.

Figure 1. World fertilizer consumption



The table shows that developing countries as a whole are expected to maintain a nutrient ratio $N:P_2O_5:K_2O$ of approximately 4:2:1 throughout the 1974-2000 period, whereas the developed countries are expected to increase the nitrogen component from a ratio of 1.4:1.0:1.0 in 1974 to 2.2:1.0:1.1 in 2000. Thus, the greater part of the growth will be in nitrogen fertilizers in both groups. The world-wide nutrient ratios should not be assumed to imply an optimum ratio for any individual country; country ratios should and do vary widely according to the needs of their soils and crops.

Year	Developed countries				Developing countries			
	N	P_2O_5	K_2O	NPK	N	P_2O_5	K_2O	NPK
	(millions of tons)							
1974	27.3	18.9	18.1	64.3	11.4	5.3	2.6	19.3
1985	53.0	29.0	29.0	111.0	28.0	13.0	7.0	48.0
2000	101.0	46.0	50.0	197.0	64.0	30.0	16.0	110.0

Fertilizer production

Fertilizer production in developing countries has always lagged behind actual consumption; in 1974, it was only 64 per cent of consumption. As a result, developing countries as a group are net importers of fertilizers; in 1974 net imports amounted to 7.7 million tons (nutrient basis). This situation, combined with rapidly increasing needs, would seem to provide developing countries with strong incentive to establish and expand fertilizer production facilities. Many developing countries have an abundance of the raw materials needed for nitrogen and phosphate fertilizer manufacture. In this connexion, it should be noted, however, that potash production was not considered since, strictly speaking, it is a mining and beneficiation industry, and very few developing countries have commercially exploitable reserves of potash.

This study presents two alternative plans for world fertilizer production, in which different assumptions are made about the location of the new plants needed between 1980 and 2000. In Alternative A, it is assumed that developing countries as a group would become self-sufficient in the production of nitrogen and fertilizers by the year 2000. To achieve this aim, 40 per cent of world nitrogen and phosphate fertilizer production would take place in these countries. In Alternative B, it is assumed that 50 per cent of world production of those nutrients would take place in the developing countries. Since the developing countries themselves consume only 40 per cent of world production, the latter alternative implies that they would export 20 per cent of this production to developed countries. Neither alternative assumes that each developing country in the group would become a self-sufficient fertilizer producer. It is presumed that factories will be mainly located where economically viable combinations of raw materials and markets (local and foreign) exist.

The production of nitrogen fertilizer is highly capital-intensive. The estimated capital cost of constructing the number of nitrogen and phosphate fertilizer plants required during the period 1980-2000 is summarized below:

	Developing countries	Developed countries	Total
	(Billions of US dollars)		
Alternative A	53	61	114
Alternative B	75	44	119

The difference between the two alternatives reflects the higher capital cost and lower utilization of plants in developing countries. The estimates are based on 1975 prices and make no allowance for interest charges during plant construction or for the cost of connecting the factory to road and rail systems, and to water and power supplies. These items, which were excluded because they vary so much from one project to another, would, on an average, increase the costs given above by about 20 per cent.

Additional capital expenditure would be required for mining and refining raw materials, for transporting and distributing the products and for creating the appropriate physical and technical infrastructure. It is not possible to make a comparable estimate of this additional capital owing to the wide variations in the location and quality of raw material deposits and in the methods of product transport and distribution. However, it is unlikely that it will be less than the manufacturing capital, and it could be appreciably greater.

At this juncture, it should also be pointed out that the manner in which the capital needed to develop the fertilizer industry is to be obtained will be influenced by decisions reached on the allocation of productive capacities, including the location of plants. These factors will have a decisive bearing upon the magnitude of financial assistance. These endeavours to identify an appropriate system of international financing notwithstanding, large-scale investment in the fertilizer industry is being effected at present in a variety of forms. However, it should be emphasized that both the magnitude and form of financial assistance to the development of the fertilizer industry have to be seen in the context of the over-all financial requirements of development in both the agricultural and industrial sectors. In the light of the above, further in-depth study will have to be undertaken at the appropriate time.

For the purposes of estimating the capital requirements, it was assumed that the new plants would produce:

Ammonia
Urea
Diammonium (DAP)
Triple superphosphate (TSP)
Compound or complex fertilizers based on the above materials with potash added as potassium chloride

While in certain cases other products might be more useful or economic, their effect on the total capital required would be negligible. It was assumed that all nitrogen fertilizers would be ammonia derivatives, with only a small percentage (mainly ammonium sulphate) emanating as by-products from other industries. All new ammonia plants were assumed to have a rated capacity of 1,000 tons per day. Whereas larger or smaller plants might be economically preferable in specific situations, the effect on total capital requirements would be comparatively small.

It is estimated that natural gas will be the feedstock used in the majority of new ammonia plants (72 per cent in 1980-85 and 64 per cent in 1990-2000). Naphtha will be used in some 5 per cent of new plants, and heavy fuel oil in about 15 per cent. Coal will find application in 9 per cent in 1980-85 increasing to 17 per cent in 1990-2000. The choice of feedstock greatly affects the capital cost of ammonia plants; at present coal-based plants cost nearly twice as much as those based on natural gas.

It was assumed that in developed countries the amount of anhydrous ammonia used directly as fertilizer would decrease from 15 to 10 per cent and in developing countries it would increase from 2 to 8 per cent. Ammonium sulphate and the nitrogen content of ammonium phosphate would supply about 10 per cent of total nitrogen fertilizer. The remainder was assumed to be urea or ammonium nitrate either straight or in compound fertilizers.1/ The cost calculations are based on urea, but ammonium nitrate costs would not differ significantly. Underutilization of rated capacity sharply increases production costs: the present average utilization is estimated at about 60 per cent in developing countries. For the purposes of the report, however, it is assumed that all plants established after 1980 would on an average operate at 90 per cent of their rated capacity 3 to 4 years after start-up.

All new phosphate plants were assumed to have a daily capacity of at least 600 tons of P_2O_5. Smaller or larger plants may be economically preferable in many cases. It was assumed that the plants established after 1980 would produce DAP (80 per cent) and TSP (20 per cent). Though other products might be more appropriate in certain cases, their effect on overall world-wide costs would not be significant. It is recognized that there will always be a place for single superphosphate and other low-analysis products that have local agronomic application or that lend themselves to the exploitation of local resources. The capital requirement for the production of some of these processes is comparatively low, but the cost

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1/ The term "compound fertilizers" is used here to include all fertilizers containing more than one of the major nutrients, N, P_2O_5, and K_2O.

of transporting low-analysis products is higher per unit of plant nutrient. Since it is not a manufactured product, ground phosphate rock was not considered in this study. However, if its direct application becomes widespread, the need for chemically manufactured phosphates will decrease.

The demand for compound fertilizers will increase in most countries; by the year 2000 it is expected that 65 and 86 per cent of P_2O_5 will be in this form in the developing and developed countries, respectively. The cost of producing compound fertilizers was not taken into account except where it represented a minor addition to the cost of granulating DAP. The preparation of compound fertilizers by mixing, bulk blending, or granulation in local plants was considered part of the distribution and marketing system.

Raw materials

It is unlikely that development of the fertilizer industry from 1980-2000 will be seriously hampered by shortages of raw materials. Phosphate rock, potash, coal, and, in the long term, sulphur are abundant. Natural gas and, especially, crude petroleum are less plentiful. However, if past experience is any guide, further reserves will be discovered in due course. It is estimated that in 1980, the demand for ammonia feedstock will constitute only 3.5 per cent of total gas production and less than 1 per cent of total oil and coal production. This notwithstanding, these premium raw materials can be expected to rise in price, thus leading to a significant shift in some countries to coal as a raw material for ammonia towards the end of the century.

It is difficult to assess the changes which may occur in the supply of sulphur owing to the variety of forms in which it is produced and to the fact that at present the major reserves in coal and gypsum are not economically competitive. Moreover, an increased use of natural gas and petroleum products coupled with improvement in environmental standards will lead to greater elemental sulphur recovery, and to greater recovery of sulphur dioxide produced in fuel combustion or smelting operations. For most of the period under review, elemental sulphur will continue to be the major raw material source, but it is possible that by the end of the period there will be a swing towards other sources.

Reserves of potash are ample, but most of them are located in the developed countries. Therefore, pending the discovery and exploitation of deposits in the developing countries, most of the developing countries will have to import their potash requirements.

Phosphate rock is widely, albeit unevenly, distributed among developed and developing countries, and serious shortages are not anticipated. Indeed, in recent years, the rate of discovery has far exceeded that of consumption. However, given the continuance of the present trend towards lower rock grades, producers and consumers may well have to exercise greater sophistication in their evaluation, specification, grading, and selection of this material.

Water is consumed in large quantities in the manufacture of fertilizers, of N fertilizers in particular. Consumption can be reduced through appropriate plant design, but it will always be large. An adequate supply of water is therefore an important, and maybe decisive, factor in the location of fertilizer plants.

Organic fertilizer materials

Organic materials and chemical fertilizers play complementary roles. Chemical fertilizers stimulate the production of organic materials, and the return of waste organic materials supplements chemical fertilizers. The total amount of organic wastes is very large, and their nutrient content is thus impressive; in 1971, the estimated NPK content of organic wastes in the developing countries was seven times that of chemical fertilizers. Many of these "waste" materials are already being used as fertilizers or for fuel and other purposes. However, those that are not being used involve technical, economic, or social problems owing to their bulk, low concentration of nutrient elements, or to the presence of potentially harmful ingredients.

Organic materials, such as crop residues, help to improve soil texture and moisture-retention capacity. With increased use of chemical fertilizers and the resultant increased crop yields, more crop residues are available for ploughing back into the soil.

More efficient use of organic wastes is desirable. In this connexion, numerous studies are being undertaken, aimed at the recovery of fertilizer and/or energy values, and at the disposal of pollutants. Despite the value of these studies, the amounts of additional fertilizer thus recovered are unlikely to contribute significatly to meeting future fertilizer needs.

Marketing

The objectives of marketing fertilizers are to ensure that the right fertilizer is at the right place at the right time, and to demonstrate to the farmer the benefits to be derived from its use.

In addition to factory storage facilities, regional and village storage centres are essential to ensure prompt distribution in sufficient quantity. Estimates must be made of feritilizer requirements in each area in order that the local centres are adequately stocked in advance. Costs should be minimized through appropriate utilization of available transportation facilities, including waterways. Existing transportation networks will need to be improved and extended in order to cope with the increased flow of fertilizer to the farmers and that of agricultural produce to the markets. Mixing facilities might be provided at regional or district distribution centres in order to ensure the supply of fertilizers appropriate to the regions and their crops. These facilities may range from simple mixing and bulk blending to granulation processes, with the possibility of adding secondary or micronutrients as required.

The capital requirements for marketing may be of a magnitude comparable to those of manufacture. These capital requirements would include the cost of transportation as well as the erection of regional distribution centres to be equipped with bulk blending or granulation, bagging and storage facilities. The requirements also include district distribution centres and working capital to cover the cost of material in storage and loans.

In any study of the fertilizer industry, particular consideration must be given to the socio-economic aspects of fertilizer use and the way in which any constraints these impose can be overcome. Investment in fertilizer production is to no avail as long as the farmer remains unconvinced of the desirability and profitability of its use. Reluctance to use fertilizers might be minimized in several ways: by lowering fertilizer cost; by increasing fertilizer effectiveness; or by obviating socio-cultural inhibitions.

Fertilizer costs should be reduced in the first instance by maximizing the efficiency of the manufacturing and marketing systems. Fertilizer effectiveness may be raised through development of improved fertilizer materials, improved placement and timing of application, more effective water control and plant protection, as well as improvement of plant varieties. Extensive effort will have to be made to convince the farmer of the need for increased and more effective use of fertilizers, while the return that he obtains for his produce can be increased by improving the marketing and processing systems.

Even when farmers have been convinced of the profits to be gained from increased fertilizer use, some form of credit will have to be made available to permit them to buy it. Further encouragement might take the form of fertilizer, credit or crop subsidies, and tax concessions. As comparatively few countries dispose of the resources needed to become entirely self-sufficient, production and marketing on a regional basis may well prove mutually beneficial.

Location of fertilizer plants

The main principles governing plant location as a means of minimizing capital requirements as well as operating and distribution costs are outlined. One of the principal objectives is to minimize the cost of fertilizer delivered to the farmer. Other considerations, which may affect plant location, include national security or self-sufficiency, foreign exchange savings, and assistance to less developed regions; their possible effect on fertilizer cost and, in turn, on food production, should be taken into consideration.

Planning and production within a regional context would permit a more efficient utilization of the individual countries' resources: be they natural gas for ammonia production in one country, sulphur or sulphuric acid in another, phosphate rock in a third, or even potash in a fourth. Regional plant locations are cited and the substantial savings in capital and operating costs to be derived therefrom are briefly examined. Another regional solution might lie in an arrangement whereby a number of countries develop at least enough indigenous production to meet a percentage of their needs, while relying on imports from their regional partners for the remainder. In this way, complementarity in raw material use, fertilizer production and trade within a region would be enhanced.

Environmental considerations

Fertilizer plants can cause pollution because many of the materials they process or produce are harmful to animal and plant life or may adversely affect the quality of the environment. Damage may occur through the gaseous or liquid effluents which are continually discharged, through occasional accidental leakage or through major accidents.

The prevention of leakage or major accidents depends largely on satisfactory equipment design, but it is primarily a matter of technically qualified and alert plant management with particular and painstaking attention to regular and reliable maintenance.

With regard to the control of effluents, stringent environmental standards are mandatory in most developed countries. However, modern fertilizer plants are usually designed to meet these standards under the most unfavourable operating conditions. In normal operation, therefore, effluent quality is better than that legally enforced. The additional capital cost involved in attaining those standards is normally about 10 per cent of the total, and the capital costs cited in the report include this extra capital.

Manpower

The projected development of the fertilizer industry will require increased numbers of engineers, scientists, management personnel, marketing experts, maintenance and operating personnel, and other workers. The estimated total number of additional workers required for the two alternatives discussed earlier is shown below for the period 1980-2000.

	Alternative A	Alternative B
Developing countries	209,000	298,000

The above estimate includes only those workers directly and exclusively concerned with production and distribution. It does not include workers in such areas as mining, beneficiation, and transport of raw materials, nor does it include persons engaged in the sale of fertilizers along with other farm supplies in such ancillary industries as bag production, fertilizer application machinery, equipment manufacture, and construction. In all probability, at least one million workers will need some sort of training in fertilizer production or handling, not to speak of the hundreds of millions of farmers using the fertilizers. Manpower and training requirements will affect investment inputs and the attainment of commonly agreed production goals.

Policies for fertilizer industry development

The successful expansion of the fertilizer industry in developing countries at the rate visualized in either Alternative A or B is clearly contingent upon relevant policies at the national and regional levels. In this respect, the study suggests specific areas in which decision-makers should elaborate policies on fertilizer production and distribution.

The study discusses the implications of government policies with regard to raw materials. Special reference is made to exploration programmes, as well as to research and development programmes directed towards defining optimum use of resources. Attention is also drawn to the importance of pricing policies and price setting. Other raw material policies described relate to the utilization of indigenous raw materials as well as to that of by-products. Policies related to fertilizer production cover the planning of new facilities for maximum efficiency and economy, as well as the need to match production targets with user requirements.

With regard to marketing, transportation and distribution facilities for fertilizer products, the critical relationship between food production and fertilizer inputs may necessitate special policy measures. Policies which have a bearing on marketing infrastructure, on the pattern of fertilizer allocation as well as on research and extension services will have to be co-ordinated in the course of the sector's development.

Emphasis is also placed on policies aimed at increased fertilizer use. In this connexion, the study examines the possibility of employing direct or indirect subsidies, agricultural price support systems and measures to increase agronomic response.

Human resource management will play a substantial role in the development of the fertilizer industry. The study briefly examines the development and acquisition of necessary skills as essential components of national development programmes in the fertilizer industry.

New investment mechanisms and forms will be required to ensure that the necessary capital is available to meet projected outlays. The utilization of capital should be in conformity with national and regional objectives and compatible with their corresponding needs.

Chapter II

THE FERTILIZER INDUSTRY: PAST, PRESENT, FUTURE

In this chapter, an effort is made to project the world-wide growth of fertilizer consumption to the year 2000. To this end, a certain continuity between historical facts and their interrelationships, on the one hand, and future events on the other hand, is assumed. However, as the plausibility of this assumption weakens with the length of the time-range involved and as the present exercise covers nearly a quarter of a century the results obtained must be regarded as being very approximate.

Nevertheless, the figures projected do provide an initial order of magnitude that can be used to draw up a framework of possibilities upon which a plan for the future development of the fertilizer industry can be cast.

With the passage of time, more facts, and a knowledge of their interrelationship, will undoubtedly become available, and predictive capacity will improve accordingly, thus providing firmer grounds for policy- and decision-making.

Growth of the industry

The fertilizer industry has been growing steadily and rapidly since the beginning of the century, as shown by the following table.

	Production (Millions of tons of NPK)[a]	Consumption[b]
1905/06	2.0	1.9
1913/14	4.1	3.9
World War I		
1919/20	3.7	3.5
1938/39	9.7	9.3
World War II		
1945/46	7.9	7.5
1949/50	14.1	13.6
1959/60	29.1	27.8
1969/70	66.2	62.9
1973/74	87.9	83.6
1974/75	91.8	81.7

Sources: Private estimates, and FAO Production Yearbook, various issues.

[a] The conversion rate of NPK (nutrient basis) to finished product is approximately 1:2.5. Which means, for instance, that the 91.8 million tons of NPK produced in 1974/75 correspond roughly to 250 million tons of finished fertiliser.

[b] The difference between production and consumption figures is largely attributable to materials being in process of distribution, and to losses.

Concomitant with the increase in quantity, changes in quality have also taken place. In the early years of the industry - from 1906 to 1939 - much commercially produced fertilizer was organic, largely in the form of meat industry by-products (scrap meat, blood, bones). Since 1945, however, the bulk has come increasingly from mineral and synthetic products, until today, organic materials comprise an extremely small percentage.

Since production in 1946 was less than 10 per cent of today's, it can be concluded that most of the present production capacity has been built since World War II. The distribution of production between developed and developing countries can be seen from Table 1 (page 30). At present, the developing countries produce 15 per cent of the world's fertilizer output (19 per cent nitrogen, 16 per cent phosphate and 4 per cent potash).

Past consumption

Statistical data on fertilizer consumption will be found in the tables and graphs presented in pages 31 to 76 of this chapter. Table 2 gives data on the consumption of each nutrient from 1950 to 1975 in developing and developed countries. In 1974, for example, the respective shares (given as percentages) were:

	N	P_2O_5	K_2O	NPK
Developed countries	70	78	87.5	77
Developing countries	30	22	12.5	23

Table 3 provides information on the consumption of 79 countries.

Again using 1974 as an example, the largest, in terms of total consumption were:

NPK	Millions of tons	N	Millions of tons
USA	17.5	USA	8.3
USSR	12.6	USSR	6.3
France	5.8	China	3.8
China	5.7	India	1.8
Poland	3.3	France	1.8

Table 4 and Figure 2 show per capita consumption in 79 countries in 1973/74. Consumption in Japan was relatively low, at 21 kg per capita, while that in Cuba, at 30 kg, was the highest among the developing countries. China, at 6.8 kg per capita, was a notably higher consumer than India, at 4.7 kg. Table 4 also shows that 28 developing countries used less than 5 kg per capita, which, in most cases, is far too little to fertilize the crops needed to feed their populations adequately. Exceptions to this are Argentina, Thailand and Burma, all of which have low man/land ratios. Figure 4 shows selected countries in bar-chart form. Denmark, at 147 kg, has had the highest per capita consumption in the world for many years.

Table 5 shows fertilizer consumption per hectare of crop land in 79 countries in 1973/74, and Figure 5 shows that for selected countries in bar-chart form. In considering the data given in Table 5, it must be borne in mind that in a number of countries a certain amount of the fertilizer is used on grassland (permanent pastures) for animal feeding, not on crop land. This is the case in, for example, the Netherlands, Belgium, the Federal Republic of Germany, France, Denmark, the United Kingdom, Australia and New Zealand. Japan, at 434 kg, is the highest in actual fertilizer consumption per hectare on crop land. Table 5 also shows that 30 developing countries were below 20 kg in consumption per hectare, and 23 countries were below 10 kg - which is virtually not using fertilizer at all.

Table 6 was compiled in order to show the largest producers, consumers, surpluses and deficits of nitrogen, phosphate and potash fertilizers in the world in 1973/74. The United States wasthe largest producer, as well as consumer, of nitrogen and phosphate, and also the largest consumer of potash. The USSR was the second-largest producer and consumer of nitrogen and phosphate, and the largest producer of potash. Japan had the largest surplus of nitrogen, the United States the largest surplus of phosphate, and Canada the largest surplus of potash. In terms of deficits, China had the largest of nitrogen, France the largest of phosphate, and the United States the largest of potash.

Only a few developing countries are listed among the largest producers, but the number of those listed as largest deficit countries is remarkable.

Figures 1, 2, 3 and 6 illustrate the trend of fertilizer consumption in the period 1955 to 1974. Consumption has been steadily increasing throughout the years, in both developed and developing countries.1/

1/An exception was 1974/75 when, for the first time since 1945, consumption declined. This phenomenon, however, was due to sudden share increase in the prices of nutrients.

As the fertilizer industry is relatively young, in the sense that its rapid post World War II growth has been accompanied by profound qualitative transformations, some epistemological risks are incurred in considering its historical growth as a continuum.[2] Actually, there is reason to believe that a structural break took place in the early 1960's, as a result of the population explosion and resultant increased demand for food.

The rapid growth in world population in the 1950's, compared with the previous decades, is shown by the following data:

	Population increase (millions)
1920-30	200
1930-40	230
1940-50	216
1950-60	485

As a result of this dramatic growth in the 1950's, new pressures on world food supplies and prices emerged at the beginning of the 1960's (although at the time this was recognized only by a small number of economists and demographers). The impact was delayed until the early 1960's because 1958 and 1960 saw the harvesting of an excellent grain crop.

Then, in 1961, the world grain crop was poor, a 2.9 per cent decline from 1960, the largest percentage decline in modern history up to that time. The decline, which was most felt in the United States, Canada, Europe and Oceania, initiated a revolutionary change in the growth rate of world agriculture, including fertilizer use and grain production, beginning first in the developed countries in 1961-1962 and spreading to the developing countries in 1962-1965. New processes and technology for large-scale fertilizer production were successfully introduced, thus laying the foundations for the development of the modern chemical fertilizer industry. The new pattern of growth has continued up to the present time.

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[2] The choice of a starting point or base year for extrapolations such as those developed by the author is a crucial aspect of the projection process. UNIDO hopes to conduct further study into possible underlying structural features of world fertilizer consumption. Such study will shed additional light on the sensitivity of the projections to the choice of the base year and the choice of the time series to which the equations are fitted.

Figure 6 shows that as far as world consumption is concerned, nitrogen has a much higher growth rate than P_2O_5 or K_2O, both of which are running parallel. Prior to 1955, the share of nitrogen was inferior to that of either P_2O_5 or K_2O. In developed countries, the nitrogen percentage has been increasing steadily, from 30 per cent in 1955 to 46 per cent in 1975. The nitrogen percentage in the developing countries has been relatively constant, in the range of 53-63, but has now started to decline slowly. (See Figures 7 and 8.)

The projection model

In order to make a projection it is necessary to rely on an assumption about the mechanism determining the value of the variable to be projected. Formally, this assumption is represented by a model relating the variable to be projected to a set of "explanatory variables".

To be acceptable, a projection model should (a) be based on a theoretically plausible assumption, and (b) this assumption should be in accordance with the observable behaviour of the variables involved.

The assumption

The level of per capita agricultural output is a vital dimension of world welfare. The application of fertilizer may be seen as a mechanism whereby society defends this dimension against population pressure upon arable land. Accordingly, the basic assumption of the model is that society will somehow manage to mobilize enough resources to supply the agricultural sector with the fertilizer needed to maintain at least a constant per capita agricultural output.

The basic assumption may be expressed as follows:

- Agricultural output (Q) is assumed to be a function of two key factors: the area of land under cultivation (A) and the quantity of fertilizer used (F).

- When population (P) increases, the ratio P/A increases also, because A is not significantly extensible. To maintain a constant Q/P, Q must increase in the same proportion as P. An increase in Q requires additional fertilizer per unit of land.

> But successive increases of fertilizer per unit of land are bound to produce decreasing returns, which means that the application of fertilizer in the same proportion as the growth of population would not be enough to secure a constant Q/P. The question then is to determine how much additional fertilizer is necessary to provide the required increase in Q.

As a tentative answer, it has been postulated that the condition to maintain a relatively stable ratio of Q/P is that:

$$\frac{F}{P} \sim \frac{P}{A} \qquad \text{or} \qquad F \sim \frac{P^2}{A}$$

The quantity of fertilizer applied to a constant area of land must increase as the square of population in order to maintain a constant per capita agricultural output.

Assuming that population grows linearly with time (T) (that is, at a steadily decreasing rate) so that P = a + b T, leads to the expression

$$F \sim \frac{(a + b\,T)^2}{A}$$

Admitting that A is a constant, and taking the square root of both sides of the expression, the following approximation is obtained:

$$\sqrt{F} = a + b\,T$$[3]

This expression has been adopted as the projection equation.

Empirical test of the assumption

Before using the model, its analytical validity has to be confirmed. This may be done by testing its performance with historical data inputs.

In such experiments, the coefficient of correlation, R, is a conventional criterion used to judge performance. It should be remembered, however, that R is a necessary, but not sufficient, condition to the determining of "goodness of fit".

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[3] Ideally, of course, it is desirable to take into account demand aspects (e.g. per capita income, amount of arable land or price elasticities). In the author's opinion, the equations utilized here provide accurate indications of future consumption patterns.

Bearing in mind the structural break that may have taken place in the early 1960's (as discussed above), the regression equation has been fitted to the total consumption data available for the period 1965-1974. The following results emerge:

	Time regime: 1965-1974 T = 0 at 1965	Correlation coefficient R
World	$\sqrt{NPK} = 6.49 + 0.292T$	0.999
Developed countries	$\sqrt{NPK} = 6.04 + 0.218T$	0.997
Developing countries	$\sqrt{NPK} = 2.42 + 0.219T$	0.996

In view of the high coefficients of correlation thus obtained, the model may be considered valid. The predictive accuracy of the model has also been assessed by calculating confidence intervals for the predicted values. The results of this exercise are shown in Table 21. From the fact that the confidence limits are found to be quite narrow, it may be concluded that the model is accurate.

Projection results

In all, 123 projection equations, for nitrogen, phosphate and potash, have been drawn for 41 countries and groups of countries (Table 20). These have been used to extrapolate the value of each nutrient consumption for 1979/80, 1984/85, 1989/90 and 1999/2000.

The countries and group of countries have been divided into two categories - developed and developing - and the individual results from each category totalled. Projections for the entire world are in turn obtained by adding the sub-totals for the two categories of countries.[1] In order to obtain figures for fertilizer consumption per hectare and per capita, the total consumption figures have been divided into estimates of areas for future cultivation and estimates of future population. The results are presented in Tables 7 - 18 and Figures 1, 2, 3, and 6. The main findings are summarized in the following table.

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[4] Owing to the non-linearity of the functional form used in the projection model, projections obtained through using global figures differ from those obtained through using national data. The latter figures have been used in this study.

Projected total consumption of N, P_2O_5, K_2O

(Millions of tons)

	Developed countries	Developing countries	World total
Nitrogen			
1974	27.3	11.3	38.6
1980	40.3	19.9	60.2
1985	52.7	28.5	81.2
1990	66.9	38.6	105.5
2000	100.6	63.6	164.2
Phosphate			
1974	18.9	5.3	24.2
1980	23.9	9.1	33.0
1985	28.7	13.3	42.0
1990	34.2	18.1	52.3
2000	46.2	30.4	76.6
Potash			
1974	18.1	2.6	20.7
1980	23.6	4.6	28.2
1985	29.3	6.8	36.1
1990	35.8	9.3	45.0
2000	50.5	15.9	66.4
NPK			
1974	64.3	19.2	83.5
1980	87.8	33.6	121.4
1985	110.7	48.6	159.3
1990	136.9	66.0	202.9
2000	197.3	109.9	307.2

In general, the levels of projected consumption appear to be feasible. However, when attention is focused on the detailed results, some qualification is required. The projections for Western and Eastern Europe may appear high when account is taken of the facts that fertilizer application per hectare is already intensive in these regions and that the area under cultivation is declining. Also, due to lack of information, doubts may arise concerning future consumption in China.

The projection results can be checked in part by comparing them with results obtained elsewhere. The Tennessee Valley Authority (TVA), the World Bank (IBRD) and the UNIDO/FAO/IBRD Working Group have all made projections of expected nitrogen fertilizer consumption in 1979/80.[5] The TVA projections are given as a low-high range. The World Bank and Working Group projections are based largely on the TVA mid-point projections, but with adjustments to reflect changes that have taken place in the fertilizer situation in various regions since early 1974. None of these organizations has made any projections beyond 1980/81. The details of the comparison appear in Table 19. They are summarized below.

Comparison of nitrogen consumption projections, 1979-80

(Millions of tons)

	TVA 1974	IBRD 1975	Working Group 1976	UNIDO Projections 1976
Developed countries	36.60/40.70	37.6	37.36	40.71
Developing countries	16.50/20.06	19.7	18.20	19.52
World	53.10/60.76	57.3	55.56	60.23

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[5] "World Fertilizer Market Review and Outlook", National Fertilizer Development Center, Tennessee Valley Authority, Muscle Shoals, Alabama, March 1974. "Fertilizer Requirements of Developing Countries, Revised Outlook in 1975", Report No. 830, IBRD, Washington, July 1975. Unpublished projections prepared by the Centre d'Etudes de L'Azote (Zurich) for the UNIDO/FAO/World Bank Working Group on Fertilizers, April 1974.

Projected fertilizer consumption per capita

Projected data for the developing countries is summarized as follows:

	Consumption (Millions of tons of NPK)	Population[a] (Millions)	Consumption per capita (kg)
1960	3.31	2,039	1.6
1970	12.42	2,558	4.8
1980	33.67	3,229	10.4
1990	66.1	4,023	16.4
2000	109.8	4,936	22.2

[a] Source: ESA/P/WP/56, 6 October 1975

The low fertilizer consumption per capita in the 1960's and early 1970's is a major reason why food supplies in many developing countries are so low. Even in the year 2000, the projected average fertilizer consumption per capita in the developing countries (22 kg) will only be as high as it was in the developed countries in 1955 (21 kg). Clearly, the developing countries must use much more fertilizer; and, as far as possible, they must manufacture it domestically, using their own raw materials.

Projected fertilizer consumption per hectare

Projected data for the developing countries is summarized as follows:

	Consumption (Millions of tons of NPK)	Crop land[a] (Millions of hectares)	Consumption per hectare (kg)
1960	3.31	800	4.1
1970	12.42	810	15
1980	33.67	830	41
1990	66.1	850	78
2000	109.8	870	126

[a] Sources: Private Estimates, and FAO Production Yearbook, various issues.

The low consumption per hectare in the 1960's and early 1970's is a major reason why most of the developing countries have had low yields of grain and other agricultural products in those decades, compared to the developed countries.

Projected shares of nitrogen, phosphate and potash fertilizers

The projected shares of nitrogen, phosphate and potash in fertilizer consumption are illustrated graphically in Figures 6, 7 and 8.

By 1980, according to the projections, nitrogen will account for 50 per cent of total fertilizer consumed; P_2O_5 for 27 per cent; and K_2O for 23 per cent. In 2000, the figures may be 55 per cent for nitrogen; 24 per cent for P_2O_5; and 21 per cent for K_2O.

Supply/consumption balance

From the above discussion, it will be clear that the methodology applied here does not distinguish between demand and supply functions. The projected quantities should, therefore, be considered as being influenced simultaneously by supply and demand. It is worthwhile, nevertheless, checking the projected consumption figures against supply projections elaborated elsewhere, in order to verify their feasibility.

"Supplies available" figures for 1979/80, by country and region, have been taken from the latest unpublished data compiled by the UNIDO/FAO/World Bank Working Group on Fertilizers, supplemented by estimates of individual countries from the Centre de l'Etude de L'Azote (nitrogen), from ISMA. Ltd. (P_2O_5) and from the International Potash Institute (K_2O).

In the case of nitrogen fertilizer, the following factors were considered:

1. Production in 1973/74;
2. Ammonia production capacity existing in 1973/74;
3. Ammonia capacity existing in 1973/74, but expected to be taken out of production by 1979/80;
4. New ammonia capacity expected to be commissioned between 1973/4 and 1979/80;
5. Assumed operating rates (per cent utilization), plant by plant, in 1979/80, including both old and new capacity;

6. Calculated ammonia production in 1979/80;
7. Deduction of nitrogen used for non-fertilizer purposes;
8. Estimates of ammonia used for direct application as fertilizer;
9. Estimates of process losses in converting ammonia to solid fertilizers;
10. Estimates of apparent losses due to, inter alia, increases in stocks, and transit and storage. (These losses are usually taken as 5 per cent of production of solid fertilizer);
11. Final estimate of available supply of nitrogen fertilizer, including ammonia for direct application.

In the case of phosphate fertilizer, the following factors were considered:

1. Production in 1973/74;
2. Production capacity existing in 1973/74, including all products and processes except ground phosphate rock;
3. Capacity existing in 1973/74, but expected to be taken out of production by 1979/80;
4. New production capacity expected to be commissioned between 1973/74 and 1979/80, including all processes but principally those using phosphoric acid;
5. Assumed operating rates (per cent utilization), plant by plant, in 1979/80, including both old and new capacity;
6. Calculated production of phosphoric acid and other phosphate materials in 1979/80;
7. Deduction of phosphoric acid used for non-fertilizer purposes;
8. Estimates of process losses in converting phosphoric acid to solid fertilizers;
9. Estimates of apparent losses due to, inter alia, increases in stocks, and transit. (These losses are usually taken as 3-5 per cent of production of solid fertilizer);
10. Final estimate of available supply of phosphate fertilizer.

For potash fertilizer, the factors considered include the following:

1. Information on production capacities of old and new potash mines and refineries;
2. Estimate of operating rates (per cent utilization) of mines and refineries;

3. Estimate of potash used for non-fertilizer purposes;
4. Estimate of processing, storage and distribution losses;
5. Final estimate of available supply of potash fertilizer.

A comparison between the supply figures obtained using these factors and procedures and the projected figures for consumption in 1979/80 of N, P_2O_5, K_2O and NPK, is shown below. Except for some discrepancies in the respective share of developed and developing countries in the cases of potash and total fertilizers, the two projections give quite similar results although they were obtained by radically different methods.

	Supply (Working Group)	Consumption UNIDO Projection
	(Millions of tons)	
Developed countries		
Nitrogen	41.67	40.27
Phosphate	26.29	23.92
Potash	30.41	23.63
NPK	98.37	87.82
Developing countries		
Nitrogen	17.19	19.96
Phosphate	9.04	9.13
Potash	1.04	4.58
NPK	27.76	33.67
World		
Nitrogen	58.86	60.23
Phosphate	35.33	33.05
Potash	31.96	28.21
NPK	126.13	121.49

It would thus appear that as far as global supply is concerned no serious imbalance is expected in 1980.

At the regional level the picture is somewhat different. Historically, the developed countries as a group have been surplus producers of fertilizers and therefore exporters, while the developing countries as a group have been importers. Figure 9 illustrates this situation and shows the evolution to the year 1980, according to the projections of UNIDO and of the Working Group. A glance at Figure 9 reveals that although the past situation is not expected to alter fundamentally - at least not within the next 10 or 15 years - the deficit of the developing countries is likely to decrease.

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Notes on tables

The following notes apply to Tables 7 - 21 in the pages that follow:

1. All data for years 1960 - 1974 have been obtained from FAO Production Yearbooks.
2. Demand for N, P_2O_5, K_2O in 1980 - 2000 has been estimated by projection of regression equations of the type
   $\sqrt{N} = A + BT$, $\sqrt{P_2O_5} = A + BT$, $\sqrt{K_2O} = A + BT$
   based on consumption data for 1965 - 1974.
3. "Supplies available" data for 1974 were calculated as production in 1973/74, multiplied by 0.95. Five per cent subtraction from production to obtain "supplies available" represents increases in stocks, losses in transit and storage, and other losses between production at the factory and delivery to the farm. However, the 5 per cent factor does not include process losses in converting ammonia to solid fertilizer: these losses are included in FAO's production data.
4. "Supplies available" estimates for nitrogen fertilizer in 1980 are from unpublished estimates compiled by the UNIDO/FAO/World Bank Working Group on Fertilizer, supplemented by detailed data on individual countries from the Centre d'Etude de l'Azote, Zurich.
5. "Supplies available" for phosphate fertilizer in 1980 are unpublished estimates compiled by the Working Group, supplemented by detailed data on individual countries from ISMA Ltd., Paris.

6. "Supplies available" for potash fertilizer in 1980 are from unpublished estimates compiled by the Working Group, supplemented by detailed data on individual countries from the International Potash Institute, Berne.

Table 1. World fertilizer production - historical data, 1950-75

(Millions of tons)

	Developing countries				Developed countries			
	N	P_2O_5	K_2O	NPK	N	P_2O_5	K_2O	NPK
1950	0.35	0.27	0.01	0.63	3.73	5.59	4.21	13.5
1951	0.43	0.34	0.02	0.79	4.25	5.93	4.94	15.1
1952	0.45	0.36	0.02	0.83	4.49	6.13	5.40	16.0
1953	0.51	0.37	nil	0.88	5.02	6.16	5.87	17.1
1954	0.59	0.41	0.01	1.01	5.59	6.60	6.32	18.5
1955	0.58	0.45	0.02	1.05	6.29	7.34	6.84	20.5
1956	0.59	0.54	0.04	1.17	6.94	7.71	7.14	21.8
1957	0.72	0.56	0.06	1.34	7.49	7.94	7.65	23.1
1958	0.77	0.60	0.09	1.46	8.24	8.20	7.66	24.1
1959	0.86	0.64	0.10	1.60	9.00	8.68	8.17	25.9
1960	0.93	0.72	0.12	1.77	9.43	9.24	8.61	27.3
1961	1.04	0.79	0.14	1.97	10.37	9.56	8.68	28.6
1962	1.14	0.76	0.14	2.04	11.12	9.86	9.25	30.2
1963	1.43	0.85	0.16	2.44	12.2	10.5	9.69	32.4
1964	1.72	1.01	0.19	2.92	13.8	11.7	10.6	36.1
1965	2.02	1.15	0.30	3.47	15.4	12.7	11.8	39.9
1966	2.24	1.30	0.39	3.93	17.7	14.2	13.4	45.3
1967	2.49	1.48	0.38	4.35	19.8	15.3	14.1	49.2
1968	2.79	1.75	0.41	4.95	22.4	16.0	14.8	53.2
1969	3.44	2.01	0.43	5.88	24.9	16.3	15.4	56.6
1970	4.07	2.32	0.59	6.98	26.1	17.0	16.1	59.2
1971	4.59	2.59	1.00	8.18	28.3	18.2	16.9	63.4
1972	5.61	3.11	1.13	9.85	29.3	19.3	18.3	66.9
1973	6.61	3.54	1.22	11.4	31.2	20.1	19.0	70.3
1974	7.24	3.97	1.10	12.3	33.3	21.2	21.1	75.6
1975	7.99	4.22	1.25	13.5	34.3	21.5	22.5	78.3

Source: FAO Production Yearbook, (1950-1974). Data for 1975 from FAO: "Monthly Bulletin of Agricultural Economics and Statistics", April issue.

Table 2. World fertilizer consumption - historical data, 1950-75

(Millions of tons)

	Developing countries				Developed countries			
	N	P_2O_5	K_2O	NPK	N	P_2O_5	K_2O	NPK
1950	0.56	0.36	0.09	1.01	3.19	5.41	4.04	12.6
1951	0.59	0.41	0.11	1.12	3.73	5.81	4.43	14.0
1952	0.68	0.48	0.14	1.30	4.01	5.77	4.86	14.6
1953	0.87	0.51	0.15	1.53	4.60	6.06	5.20	15.9
1954	0.96	0.60	0.19	1.75	5.16	6.51	5.48	17.2
1955	0.94	0.60	0.23	1.78	5.69	7.14	6.11	18.9
1956	1.24	0.66	0.27	2.17	5.82	7.45	6.51	19.8
1957	1.45	0.76	0.31	2.52	6.19	7.68	6.87	20.7
1958	1.58	0.83	0.35	2.76	6.69	7.87	7.08	21.6
1959	1.81	0.86	0.38	3.04	7.47	8.38	7.56	23.4
1960	1.95	0.94	0.42	3.31	7.80	8.90	7.83	24.5
1961	2.45	1.05	0.54	4.04	8.51	9.03	7.96	25.5
1962	2.49	1.10	0.54	4.12	9.15	9.51	8.15	26.8
1963	2.77	1.27	0.58	4.61	10.4	10.1	8.76	29.3
1964	3.33	1.47	0.68	5.48	11.7	11.0	9.36	32.1
1965	3.65	1.58	0.73	5.95	12.8	12.2	10.3	35.3
1966	4.23	1.77	0.84	6.84	14.7	13.0	11.4	39.1
1967	5.33	2.11	1.00	8.44	16.5	13.9	12.0	42.5
1968	5.51	2.34	1.12	8.97	18.5	14.5	12.9	45.9
1969	6.80	2.81	1.34	11.0	19.7	15.2	13.4	48.3
1970	7.70	3.25	1.47	12.4	21.0	15.6	14.0	50.5
1971	8.77	3.51	1.80	14.1	23.0	16.3	14.9	54.2
1972	9.45	4.09	1.93	15.5	23.8	17.0	15.7	56.5
1973	10.6	4.59	2.24	17.4	25.2	18.0	16.6	59.8
1974	11.4	5.34	2.61	19.3	27.3	18.9	18.1	64.3
1975	11.7	5.49	2.85	20.0	27.2	17.4	17.1	61.7

Source: **As for Table 1.**

Table 3. Fertilizer consumption, 1973/74

Includes all countries with population of over 5 million in 1974.
Listing is in order of N P K consumption.

		N	P_2O_5	K_2O	NPK
		(Thousands of tons of nutrients)			
1.	United States	8,277	4,600	4,614	17,491
2.	USSR	6,256	2,699	3,605	12,560
3.	France	1,833	2,147	1,833	5,813
4.	China	3,815	1,390	528	5,733
5.	Poland	1,069	847	1,413	3,329
6.	Germany (Fed.Rep.)	1,101	917	1,163	3,181
7.	India	1,835	634	314	2,783
8.	Japan	821	793	685	2,299
9.	United Kingdom	874	478	498	1,850
10.	Germany (Dem.Rep.)	666	431	658	1,755
11.	Brazil	425	725	523	1,673
12.	Spain	716	481	265	1,462
13.	Australia	176	1,171	104	1,451
14.	Czechoslovakia	448	393	576	1,417
15.	Italy	672	476	268	1,416
16.	Hungary	493	322	387	1,202
17.	Canada	498	480	205	1,183
18.	Romania	420	320	53	793
19.	Korea (Rep.of)	411	196	150	757
20.	Mexico	531	181	36	748
21.	Denmark	365	155	216	736
22.	Yugoslavia	368	193	174	735
23.	Turkey	430	280	13	723
24.	South Africa	231	327	126	684
25.	Bulgaria	328	259	46	633
26.	Netherlands	397	107	114	618
27.	Sweden	263	161	144	568
28.	Belgium	165	166	193	524
29.	Indonesia	350	85	40	475
30.	Egypt	380	75	3	458
31.	Austria	132	116	159	407
32.	Pakistan	342	58	3	403
33.	Korea (DPR)	240	112	45	397
34.	Greece	232	141	22	395
35.	Colombia	154	100	58	312
36.	Iran	177	114	1	292
37.	Cuba	130	50	97	277
38.	Malaysia	113	37	112	262
39.	Portugal	142	78	28	248
40.	Philippines	146	45	45	236
41.	Algeria	94	84	38	216
42.	Chile	59	116	14	189
43.	Bangladesh	122	44	11	177
44.	Vietnam (South)	110	34	18	162
45.	Thailand	70	45	40	155

Table 3. (continued)

	N	P_2O_5	K_2O	NPK
46. Switzerland	42	52	54	148
47. Rhodesia	70	44	32	146
48. Morocco	67	45	25	137
49. Peru	81	9	8	98
50. Argentina	51	28	17	96
51. Sri Lanka	51	12	32	95
52. Venezuela	41	23	21	85
53. Sudan	70	-	-	70
54. Vietnam (DR)	15	50	5	70
55. Burma	42	15	-	57
56. Ecuador	29	15	9	53
57. Guatemala	32	13	4	49
58. Kenya	20	21	3	44
59. Syria	33	8	2	43
60. Tunisia	19	18	6	43
61. Iraq	25	15	1	41
62. Afghanistan	30	7	-	37
63. Angola	12	8	8	28
64. Ethiopia	9	10	-	19
65. Tanzania	11	5.3	3	19
66. Cameroon	9.3	2.3	4.6	16
67. Mozambique	9.0	3.2	1.8	14
68. Nepal	9.0	4.4	0.6	14
69. Madagascar	5.0	3.5	4.6	13
70. Nigeria	4.7	4.1	2.5	11
71. Mali	5.0	3.8	-	8.8
72. Saudi Arabia	4.0	1.2	3.2	8.4
73. Bolivia	4.8	2.0	1.3	8.1
74. Uganda	4.0	2.4	0.8	7.2
75. Zaire	3.2	1.6	1.8	6.6
76. Ghana	1.0	2.6	2.1	5.7
77. Cambodia	1.0	1.0	-	2.0
78. Upper Volta	0.4	0.1	0.1	0.6
79. Yemen (AR)	0.4	-	-	0.4
Developed Countries	27,284	18,907	18,087	64,278
Developing Countries	11,373	5,346	2,613	19,332
World total	38,657	24,253	20,700	83,610

Source: *FAO Production Yearbook*, 1974

Table 4. Fertilizer consumption per capita, 1973/74

Includes all countries with population of over 5 million in 1974

(Kg of NPK/capita)

1.	Denmark	147	41.	Guatemala	8.2
2.	Hungary	114	42.	Morocco	8.1
3.	France	111	43.	Ecuador	7.7
4.	Australia	107	44.	Tunisia	7.7
5.	Germany (Dem.Rep.)	102	45.	Venezuela	7.1
6.	Poland	99	46.	Sri Lanka	6.9
7.	Czechoslovakia	96	47.	China	6.8
8.	United States	82	48.	Peru	6.6
9.	Bulgaria	73	49.	Syria	6.1
10.	Sweden	69	50.	Pakistan	5.9
11.	Austria	54	51.	Philippines	5.5
12.	Belgium	53	52.	India	4.7
13.	Canada	52	53.	Angola	4.5
14.	Germany (Fed.Rep.)	52	54.	Sudan	4.0
15.	USSR	50	55.	Argentina	3.8
16.	Netherlands	46	56.	Iraq	3.8
17.	Greece	44	57.	Thailand	3.8
18.	Spain	42	58.	Indonesia	3.6
19.	Romania	38	59.	Kenya	3.4
20.	Yugoslavia	35	60.	Vietnam (DR)	3.0
21.	United Kingdom	33	61.	Bangladesh	2.5
22.	Cuba	30	62.	Cameroon	2.5
23.	South Africa	29	63.	Afghanistan	2.0
24.	Portugal	28	64.	Burma	1.9
25.	Italy	26	65.	Madagascar	1.7
26.	Korea (DPR)	25	66.	Mali	1.6
27.	Rhodesia	24	67.	Mozambique	1.6
28.	Switzerland	23	68.	Bolivia	1.5
29.	Korea (Rep. of)	22	69.	Tanzania	1.3
30.	Malaysia	22	70.	Nepal	1.1
31.	Japan	21	71.	Saudi Arabia	1.0
32.	Chile	19	72.	Ethiopia	0.7
33.	Turkey	19	73.	Uganda	0.7
34.	Brazil	16	74.	Ghana	0.6
35.	Algeria	13	75.	Cambodia	0.3
36.	Mexico	13	76.	Zaire	0.3
37.	Colombia	12	77.	Nigeria	0.2
38.	Egypt	12	78	Upper Volta	0.1
39.	Iran	9.2	79.	Yemen (AR)	0.1
40.	Vietnam (South)	8.4			

Developed Countries Average	58.3
Developing Countries Average	6.7
World Average	21.5

Source: Fertiliser consumption data from FAO Production Yearbook, 1974. Population data from UN report, ESA/P/WP.56, 6 October 1975.

Table 5. Fertilizer consumption per hectare, 1973/74

Includes all countries with population of over 5 million in 1974
(Kg of NPK/ha[a])

1.	Netherlands	741	41.	Australia	32
2.	Belgium	628	42.	Angola	31
3.	Japan	434	43.	Canada	27
4.	Germany (Fed.Rep.)	394	44.	Mexico	27
5.	Switzerland	385	45.	Indonesia	26
6.	Germany (Dem.Rep.)	361	46.	Kenya	26
7.	Korea (Rep.of)	317	47.	Turkey	26
8.	France	312	48.	Pakistan	21
9.	Denmark	276	49.	Philippines	21
10.	Czechoslovakia	267	50.	Bangladesh	19
11.	United Kingdom	258	51.	Iran	18
12.	Austria	252	52	Morocco	18
13.	Poland	220	53.	India	17
14.	Hungary	216	54.	Venezuela	16
15.	Korea (DPR)	210	55.	Ecuador	14
16.	Sweden	188	56.	Thailand	11
17.	Egypt	161	57.	Sudan	9.8
18.	Bulgaria	141	58.	Saudi Arabia	9.6
19.	Italy	116	59.	Tunisia	9.5
20.	Greece	109	60.	Iraq	8.2
21.	United States	92	61.	Syria	7.3
22.	Yugoslavia	91	62.	Nepal	7.1
23.	Rhodesia	79	63.	Mozambique	4.7
24.	Cuba	77	64.	Afghanistan	4.6
25.	Romania	76	65.	Madagascar	4.6
26.	Malaysia	74	66.	Argentina	3.7
27.	Spain	70	67.	Burma	3.0
28.	Portugal	64	68.	Bolivia	2.8
29.	Colombia	62	69	Cameroon	2.2
30.	USSR	54	70.	Ghana	2.2
31.	South Africa	52	71.	Uganda	1.5
32.	Brazil	49	72.	Ethiopia	1.4
33.	Vietnam (South)	49	73.	Tanzania	1.2
34.	Sri Lanka	48	74.	Cambodia	1.1
35.	China	45	75.	Zaire	0.9
36.	Peru	35	76.	Mali	0.8
37.	Vietnam (DR)	35	77.	Nigeria	0.5
38.	Chile	33	78	Yemen (AR)	0.3
39.	Guatemala	33	79	Upper Volta	0.1
40.	Algeria	32			

Developed Countries average	109
Developing Countries average	22
World average	57

Source: FAO Production Yearbook, 1974.

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[a] Fertilizer consumption/hectare is usually calculated as fertilizer consumption/arable land. Arable land is land used for annual and perennial crops and does not include grasslands (pasture). Therefore, the above data are fictitious in countries where a substantial percentage of fertilizer is used on grassland, such as Netherlands, Belgium, Federal Republic of Germany, Switzerland, United Kingdom, Denmark, Australia and some others. However, in Japan and South Korea almost all the fertilizer is used on crops and very little on grassland, flowergardens, lawns, etc.

Table 6. **Nitrogen fertilizer - Country analyses, 1973/74: largest producers, consumers, surpluses and deficits**

A. Nitrogen fertilizer
(Thousands of tons of N)

	Producers			Consumers			Surpluses			Deficits	
1.	United States	9,152	1.	United States	8,277	1.	Japan	1,341	1.	China	1,084
2.	USSR	7,241	2.	USSR	6,256	2.	USSR	985	2.	India	785
3.	China	2,731	3.	China	3,815	3.	United States	875	3.	Egypt	329
4.	Japan	2,162	4.	India	1,835	4.	Netherlands	816	4.	Turkey	295
5.	France	1,694	5.	France	1,833	5.	Belgium	487	5.	Denmark	282
6.	Germany (FR)	1,473	6.	Germany (FR)	1,101	6.	Italy	439	6.	Brazil	260
7.	Poland	1,366	7.	Poland	1,069	7.	Romania	434	7.	Indonesia	259
8.	Netherland	1,213	8.	United Kingdom	874	8.	Germany (FR)	372	8.	Germany (DR)	255
9.	Italy	1,111	9.	Japan	821	9.	Norway	359	9.	Mexico	155
10.	India	1,050	10.	Spain	716	10.	Poland	296	10.	France	139
11.	Romania	854	11.	Italy	672	11.	Canada	291	11.	United Kingdom	119
12.	Canada	789	12.	Germany (DR)	666	12.	Kuwait	239	12.	Cuba	110
13.	Spain	773	13.	Mexico	531	13.	Bulgaria	191	13.	Vietnam (South)	110
14.	United Kingdom	755	14.	Canada	498	14.	Austria	99	14.	Philippines	93
15.	Belgium	652	15.	Hungary	493	15.	Trinidad	60	15.	Sweden	85
16.	Bulgaria	519	16.	CSSR	448	16.	Spain	57	16.	Sudan	70
17.	Korea (Rep. of)	447	17.	Turkey	430	17.	Saudi Arabia	57	17.	Hungary	69
18.	Norway	445	18.	Brazil	425	18.	Chile	47	18.	Colombia	68
19.	CSSR	424	19.	Romania	420	19.	Korea (Rep. of)	36	19.	Malaysia	67
20.	Hungary	424	20.	Korea (Rep. of)	411	20.	Finland	34	20.	Thailand	62
21.	Germany (DR)	411	21.	Netherlands	397	21.	Greece	24	21.	El Salvador	61
22.	Mexico	376	22.	Egypt	380	22.	Portugal	22	22.	Peru	59
23.	Yugoslavia	350	23.	Yugoslavia	368	23.	Australia	21	23.	Morocco	55
24.	Pakistan	300	24.	Denmark	365	24.	South Africa	16	24.	Sri Lanka	51
25.	Kuwait	289	25.	Indonesia	350	25.	Qatar	14	25.	Pakistan	42

B. Phosphate fertilizer
(Thousands of tons of P_2O_5)

1.	United States	6,013	1.	United States	4,600	1.	United States	1,413	1.	France	454
2.	USSR	3,236	2.	USSR	2,699	2.	USSR	537	2.	Brazil	378
3.	France	1,693	3.	France	2,147	3.	Belgium	463	3.	India	309

4.	**China**	**1,314**	4.	China	1,390	4.	Netherlands	243	4.	Turkey	183
5.	**Australia**	**1,169**	5.	Australia	1,171	5.	Canada	240	5.	Hungary	127
6.	**Germany (FR)**	**962**	6.	Germany (FR)	917	6.	Tunisia	165	6.	Bulgaria	124
7.	**Poland**	814	7.	Poland	847	7.	Luxembourg	132	7.	Indonesia	85
8.	**Japan**	736	8.	Japan	793	8.	Morocco	125	8.	China	75
9.	**Canada**	720	9.	Brazil	725	9.	Norway	76	9.	United Kingdom	61
10.	**Belgium**	629	10.	India	634	10.	Yugoslavia	75	10.	Japan	57
11.	**Spain**	536	11.	Spain	481	11.	Mexico	74	11.	CSSR	57
12.	**Italy**	450	12.	Canada	480	12.	Romania	61	12.	Pakistan	54
13.	**New Zealand**	420	13.	United Kingdom	478	13.	Spain	55	13.	Denmark	52
14.	**United Kingdom**	417	14.	Italy	476	14.	Germany (FR)	45	14.	Switzerland	48
15.	**Germany (DR)**	403	15.	New Zealand	445	15.	Lebanon	41	15.	Thailand	45
16.	**Romania**	381	16.	Germany (DR)	431	16.	Austria	39	16.	Bangladesh	44
17.	**Netherlands**	350	17.	CSSR	393	17.	Greece	21	17.	Iran	40
18.	**Brazil**	347	18.	South Africa	327	18.	South Africa	21	18.	Cuba	40
19.	**South Africa**	346	19.	Hungary	322	19.	Sweden	15	19.	Korea (Rep. of)	37
20.	**CSSR**	336	20.	Romania	320	20.	Senegal	13	20.	Ireland	35
21.	**India**	325	21.	Turkey	280	21.	Portugal	12	21.	Vietnam (South)	34
22.	**Yugoslavia**	268	22.	Bulgaria	259	22.	Egypt	6	22.	Poland	34
23.	**Mexico**	255	23.	Finland	197	23.	Finland	4	23.	Germany (DR)	28
24.	**Finland**	202	24.	Korea (Rep. of)	196	24.	Tanzania	3	24.	El Salvador	28
25.	**Hungary**	195	25.	Yugoslavia	193	25.	Israel	2	25.	Italy	26

C. Potash fertilizer

(Thousands of tons of K_2O)

1.	**USSR**	5,918	1.	United States	4,614	1.	Canada	4,868	1.	United States	2,268
2.	**Canada**	5,073	2.	USSR	3,605	2.	USSR	2,313	2.	Poland	1,413
3.	**Germany (DR)**	2,556	3.	France	1,833	3.	Germany (DR)	1,898	3.	Japan	685
4.	**Germany (FR)**	2,539	4.	Poland	1,413	4.	Germany (FR)	1,376	4.	CSSR	576
5.	**United States**	2,346	5.	Germany (FR)	1,163	5.	Israel	515	5.	Brazil	523
6.	**France**	2,082	6.	Japan	685	6.	Congo	259	6.	United Kingdom	493
7.	**Israel**	515	7.	Germany (DR)	658	7.	France	250	7.	Hungary	387
8.	**Spain**	473	8.	CSSR	576	8.	Spain	208	8.	India	314
9.	**China**	300	9.	China	528	9.	Chile	5	9.	China	228

(Table 6 continued)

Producers			**Consumers**			**Surpluses**			**Deficits**		
10.	Congo	300	10.	Brazil	523				10.	Denmark	216
11.	Italy	137	11.	United Kingdom	498				11.	Belgium	193
12.	Chile	19	12.	Hungary	387				12.	Ireland	181
13.	United Kingdom	5	13.	India	314				13.	New Zealand	180
			14.	Italy	268				14.	Yugoslavia	174
			15.	Spain	265				15.	Austria	159
			16.	Denmark	216				16.	Finland	159
			17.	Canada	205				17.	Korea (Rep. of)	150
			18.	Belgium	193				18.	Sweden	144
			19.	Ireland	181				19.	Italy	130
			20.	New Zealand	180				20.	South Africa	126
			21.	Yugoslavia	173				21.	Netherlands	114
			22.	Finland	159				22.	Malaysia	112
			23.	Austria	159				23.	Australia	104
			24.	Korea (Rep. of)	150				24.	Cuba	97
			25.	Sweden	144				25.	Norway	70

Source: FAO Production Yearbook, 1974

Table 7. Past and expected future consumption of nitrogen fertilizer: a regional summary

(Millions of tons)

	1960	1965	1970	1974	1980	1985	1990	2000
Developing countries								
Asia[a]	1.3	2.4	5.8	8.4	15.3	22.0	29.9	49.5
China	(0.6)	(1.1)	(2.7)	(3.8)	(6.6)	(9.3)	(12.4)	(20.2)
India	(0.2)	(0.5)	(1.4)	(1.8)	(3.6)	(5.2)	(7.2)	(12.0)
Rest of Asia	(0.5	(0.8)	(1.7)	(2.8)	(5.1)	(7.5)	(10.3)	(17.3)
Africa	0.2	0.5	0.7	1.1	1.7	2.4	3.2	5.1
Latin America	0.4	0.7	1.2	1.8	2.9	4.1	5.5	9.0
Total	1.9	3.6	7.7	11.3	19.9	28.5	38.6	63.6
Developed countries								
United States	2.5	4.2	6.8	8.3	11.6	14.6	18.0	25.8
Canada	0.1	0.2	0.3	0.5	0.7	0.9	1.1	1.7
Western Europe	3.0	4.3	6.0	7.4	10.0	12.4	15.0	21.0
Eastern Europe	0.9	1.6	3.0	3.8	6.2	8.3	10.7	16.5
USSR	0.7	1.7	3.8	6.3	10.7	15.3	20.7	34.0
Japan	0.6	0.7	0.9	0.8	0.8	0.8	0.8	0.8
Oceania	0.0	0.1	0.2	0.2	0.3	0.4	0.6	0.8
Total	7.8	12.8	21.0	27.3	40.3	52.7	66.9	100.6
Total, World	9.7	16.4	28.7	38.6	60.2	81.2	105.5	164.2

Table 8. Expected nitrogen fertilizer consumption: countries and regions[a]

(Thousands of tons)

	1980	1985	1990	2000
Developing countries				
Asia[b]				
China	6,580	9,290	12,460	20,190
India	3,600	5,240	7,190	12,020
Indonesia	595	900	1,270	2,190
Pakistan	790	1,190	1,680	2,920
Bangladesh	215	300	410	665
Philippines	230	320	430	685
Thailand	125	180	245	400
Turkey	865	1,360	1,960	3,500
Iran	315	505	735	1,330
Korea (Rep.of)	620	820	1,050	1,580
Vietnam (DR)	150	185	220	300
Vietnam (South)	280	420	595	1,020
Korea (DPR)	400	560	745	1,200
Malaysia	150	215	290	470
Sri Lanka	64	72	80	99
Other countries	320	440	585	925
Total, Asia	15,299	21,997	29,945	49,494
Africa				
Egypt	460	550	650	865
South Africa	405	565	750	1,205
Sudan	125	175	240	395
Algeria	175	280	415	755
Morocco	125	185	225	440
Rhodesia	84	105	125	175
Other countries	385	550	745	1,225
Total, Africa	1,759	2,410	3,180	5,060
Latin America				
Brazil	915	1,470	2,150	3,900
Mexico	835	1,120	1,440	2,210
Colombia	190	270	365	595
Central America[c]	295	405	530	830
Argentina	80	110	140	215

Table 8. (continued)

Latin America (cont'd)

	1980	1985	1990	2000
Peru	97	110	125	155
Venezuela	47	58	71	100
Chile	74	95	120	170
Cuba	200	245	290	400
Dominican Rep.	68	105	145	250
Other countries	100	110	120	150
Total, Latin America	2,901	4,098	5,496	8,975
Total, Developing countries	19,959	28,505	38,621	63,529
Developed countries				
United States	11,570	14,590	17,970	25,770
Canada	655	870	1,120	1,710
Western Europe	10,010	12,380	15,000	21,000
Eastern Europe	6,180	8,290	10,700	16,470
USSR	10,730	15,320	20,740	34,020
Japan	800	800	800	800
Oceania	325	435	560	850
Total, Developed countries	40,270	52,685	66,890	100,620
Total, World	60,229	81,190	105,511	164,149

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[a] Countries listed by order of estimated population in the year 2000.

[b] Excluding Japan

[c] Six countries

Table 9. Supply/consumption balance of nitrogen fertilizer: a regional summary

(Millions of tons of nitrogen)

	Consumption		Supplies available		Surplus (+) Deficit (-)	
	1974	1980	1974	1980	1974	1980
Developing countries						
Asia[a]	8.46	15.30	5.56	13.40	-2.90	-1.90
China	(3.82)	(6.58)	(2.59)	(5.14)	(-1.23)	(-1.44)
India	(1.83)	(3.60)	(1.00)	(3.34)	(-0.83)	(-0.26)
Rest of Asia	(2.81)	(5.12)	(1.97)	(4.92)	(-0.84)	(-0.20)
Africa	1.11	1.76	0.43	1.58	-0.68	-0.18
Latin America	1.80	2.90	0.88	2.21	-0.92	-0.69
Total, developing countries	11.37	19.96	6.87	17.19	-4.50	-2.77
Developed countries						
United States	8.27	11.57	8.69	10.01	+0.42	-1.56
Canada	0.50	0.65	0.75	1.28	+0.25	+0.63
Western Europe	7.38	10.01	8.92	10.69	+1.54	+0.68
Eastern Europe	3.83	6.18	4.17	7.00	+0.34	+0.82
USSR	6.26	10.73	6.88	10.26	+0.62	-0.47
Japan	0.82	0.80	2.05	2.21	+1.23	+1.41
Oceania	0.22	0.33	0.19	0.22	-0.03	-0.11
Total, developed countries	27.28	40.27	31.65	41.67	+4.37	+1.40
Total, world	38.65	60.23	38.52	58.86	-0.13	-1.37

[a] Excluding Japan.

Table 10. Supply/consumption balance of nitrogen fertilizer: countries and regions a/ (Thousands of tons)

	Consumption		Supplies available		Surplus (+) Deficit (-)	
	1974	1980	1974	1980	1974	1980
Asia[b/]						
China	3,815	6,580	2,594	5,143	-1,221	-1,437
India	1,835	3,600	998	3,335	-837	-265
Indonesia	350	595	86	534	-264	-61
Pakistan	342	790	285	714	-57	-76
Bangladesh	122	215	123	213	+1	-2
Philippines	146	230	50	90	-96	-140
Thailand	70	125	8	15	-62	-110
Turkey	430	865	128	360	-302	-505
Iran	177	315	136	431	-41	+116
Korea (Rep. of)	411	620	425	771	+14	+151
Vietnam (D.R.)	15	150	nil	nil	-15	-150
Vietnam (South)	110	280	nil	nil	-110	-280
Korea (DPR)	240	400	228	397	-12	-3
Malaysia	113	150	44	50	-69	-100
Sri Lanka	51	64	nil	39	-51	-25
Other countries	228	320	456	1,304	+228	+984
Total, Asia	8,455	15,299	5,561	13,396	-2,894	-1,903
Africa						
Egypt	380	460	48	525	-332	+65
South Africa	231	405	235	435	+4	+30
Sudan	70	125	nil	nil	-70	-125
Algeria	93	175	49	210	-44	+35
Morocco	67	125	11	100	-56	-25
Rhodesia	70	84	57	70	-13	-14
Other countries	202	385	27	241	-175	-144
Total, Africa	1,113	1,759	427	1,581	-686	-178

Table 10. (continued)

	Consumption		Surplies available		Surplus (+) Deficit (-)	
	1974	1980	1974	1980	1974	1980
Latin America						
Brazil	425	915	157	482	-268	-433
Mexico	531	835	357	924	-174	+91
Colombia	154	190	82	127	-72	-63
Central America[c]	200	295	32	67	-168	-230
Argentina	51	80	36	39	-15	-41
Peru	80	97	20	72	-60	-25
Venezuela	41	47	5	102	-36	+55
Chile	59	74	102	115	+43	+41
Cuba	130	200	19	155	-111	-45
Dominican Republic	41	68	nil	nil	-41	-68
Other countries	92	100	74	130	-18	+30
Total, Latin America	1,804	2,901	884	2,213	-920	-688
Total, developing countries	11,372	19,959	6,872	17,190	-4,500	-2,769
Developed countries						
United States	8,275	11,570	8,692	10,010	+417	-1,560
Canada	500	655	751	1,284	+251	+629
Western Europe	7,385	10,010	8,925	10,686	+1,540	+676
Eastern Europe	3,830	6,180	4,166	7,002	+336	+822
USSR	6,255	10,730	6,878	10,253	+623	-477
Japan	820	800	2,052	2,212	+1,232	+1,412
Oceania	215	325	185	223	-30	-102
Total, developed countries	27,280	40,270	31,649	41,670	+4,369	+1,400
Total, world	38,652	60,229	38,521	58,860	-131	-1,369

a/ Countries listed by order of estimated population in the year 2000.

b/ Excluding Japan.

c/ Six countries.

Table 11. Past and expected consumption of phosphate fertilizer: a regional summary

(Millions of tons of P_2O_5)

	1960	1965	1970	1974	1980	1985	1990	2000
Developing countries								
Asia[a]	0.5	0.9	1.9	3.2	5.5	8.1	11.2	18.9
China	(0.2)	(0.3)	(0.7)	(1.4)	(2.2)	(3.3)	(4.5)	(7.7)
India	(0.1)	(0.2)	(0.4)	(0.6)	(1.3)	(1.9)	(2.6)	(4.5)
Rest of Asia	(0.2)	(0.4)	(0.8)	(1.2)	(2.0)	(2.9)	(4.1)	(7.1)
Africa	0.2	0.2	0.5	0.7	1.1	1.6	2.0	3.2
Latin America	0.2	0.5	0.8	1.4	2.5	3.6	4.9	8.3
Total, developing countries	0.9	1.6	3.2	5.3	9.1	13.3	18.1	30.4
Developed countries								
United States	2.4	3.2	4.2	4.6	5.8	6.7	7.7	9.8
Canada	0.1	0.3	0.3	0.5	0.5	0.6	0.6	0.8
Western Europe	3.5	4.3	5.2	5.9	7.4	8.6	10.0	12.9
Eastern Europe	0.8	1.4	2.1	2.6	4.0	5.2	6.6	9.8
USSR	0.9	1.3	1.9	2.7	3.9	5.1	6.5	9.7
Japan	0.5	0.5	0.7	0.8	0.9	1.1	1.3	1.6
Oceania	0.7	1.2	1.2	1.6	1.4	1.4	1.5	1.6
Total, developed countries	8.9	12.2	15.6	18.9	23.9	28.7	34.2	46.2
Total, world	9.8	13.8	18.8	24.2	33.0	42.0	52.3	76.6

[a] Excluding Japan.

Table 12. Expected future consumption of phosphate fertilizer: countries and regions a/

By regression equations, based on 1965-1974

(Thousands of tons of P_2O_5)

	1980	1985	1990	2000
Asia b/				
China	2,200	3,270	4,540	7,720
India	1,270	1,900	2,640	4,520
Indonesia	150	245	355	640
Pakistan	160	275	415	790
Bangladesh	86	130	180	310
Philippines	77	100	130	190
Thailand	97	140	190	320
Turkey	535	795	1,120	1,910
Iran	185	295	435	790
Korea (Rep. of)	220	260	310	420
Vietnam (DR)	100	120	145	200
Vietnam (South)	42	49	56	71
Korea (DPR)	145	185	225	315
Malaysia	59	91	130	230
Sri Lanka	26	41	60	105
Other countries	150	195	255	385
Total, Asia	5,502	8,091	11,186	18,916
Africa				
Egypt	66	76	87	110
South Africa	525	695	895	1,360
Sudan	5	6	7	10
Algeria	170	265	385	680
Morocco	68	90	115	175
Rhodesia	63	84	110	165
Other countries	250	345	450	715
Total, Africa	1,147	1,561	2,049	3,215

Table 12. (continued)

	1980	1985	1990	2000
Latin America				
Brazil	1,470	2,290	3,280	5,820
Mexico	295	410	545	875
Colombia	92	110	130	170
Central America[c]	94	125	160	240
Argentina	61	86	115	190
Peru	10	12	15	20
Venezuela	36	51	68	110
Chile	130	155	180	240
Cuba	150	185	220	300
Dominican Rep.	40	49	58	80
Other countries	100	125	150	215
Total, Latin America	2,478	3,598	4,921	8,260
Total, developing countries	9,127	13,250	18,156	30,391
Developed countries				
United States	5,780	6,690	7,670	9,820
Canada	490	565	645	815
Western Europe	7,390	8,630	9,970	12,940
Eastern Europe	4,020	5,220	6,590	9,800
USSR	3,940	5,130	6,480	9,650
Japan	940	1,100	1,270	1,640
Oceania	1,360	1,410	1,470	1,600
Total, developed countries	23,920	28,745	34,095	46,265
Total, world	33,047	41,995	52,251	76,656

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a/ Countries listed in order of estimated population in the year 2000.

b/ **Excluding Japan.**

d/ Six countries.

Table 13. Supply/consumption balance of phosphate fertilizer: a regional summary
(Millions of tons of P_2O_5)

	Consumption		Supplies available		Surplus (+) Deficit (-)	
	1974	1980	1974	1980	1974	1980
Developing countries						
Asia[a]	3.24	5.50	2.17	5.02	-1.07	-0.48
China	(1.39)	(2.20)	(1.25)	(1.98)	(-0.14)	(-0.22)
India	(0.64)	(1.27)	(0.31)	(0.70)	(-0.33)	(-0.57)
Rest of Asia	(1.21)	(2.03)	(0.61)	(2.34)	(-0.60)	(+0.31)
Africa	0.72	1.15	0.89	2.71	+0.17	+1.56
Latin America	1.39	2.48	0.71	1.31	-0.68	-1.17
Total, developing countries	5.35	9.13	3.77	9.04	-1.58	-0.09
Developed countries						
United States	4.60	5.78	5.71	7.96	+1.11	+2.18
Canada	0.48	0.49	0.68	0.78	+0.21	+0.29
Western Europe	5.94	7.39	6.04	6.45	+0.10	-0.94
Eastern Europe	2.78	4.02	2.40	3.82	-0.38	-0.20
USSR	2.70	3.94	3.07	4.85	+0.37	+0.91
Japan	0.80	0.94	0.70	0.81	-0.10	-0.13
Oceania	1.61	1.36	1.51	1.62	-0.10	+0.26
Total, developed countries	18.91	23.92	20.12	26.29	+1.21	+2.37
Total, world	24.26	33.05	23.89	35.33	-0.37	+2.28

[a] Excluding Japan.

Table 14. Supply/consumption balance of phosphate fertilizer: countries and regions [a]
(Thousands of tons of P_2O_5)

	Consumption		Supplies available		Surplus (+) Deficit (-)	
	1974	1980	1974	1980	1974	1980
Asia[b]						
China	1,390	2,200	1,249	1,982	-141	-218
India	635	1,270	309	705	-326	-565
Indonesia	85	150	nil	3	-85	-147
Pakistan	58	160	4	208	-54	+48
Bangladesh	44	86	nil	46	-44	-40
Philippines	45	77	38	70	-7	-7
Thailand	45	97	nil	nil	-45	-97
Turkey	280	535	92	587	-188	+52
Iran	114	185	70	249	-44	+64
Korea (Rep. of)	196	220	151	395	-45	+175
Vietnam (DR)	50	100	48	129	-2	+29
Vietnam (South)	34	42	nil	120	-34	+78
Korea (DPR)	112	145	104	142	-8	-3
Malaysia	37	59	23	6	-14	-53
Sri Lanka	12	26	nil	12	-12	-14
Other countries	103	150	78	369	-25	+219
Total, Asia	3,240	5,502	2,166	5,023	-1,074	-479
Africa						
Egypt	75	66	77	91	+2	+25
South Africa	327	525	329	831	+2	+306
Sudan	nil	5	nil	nil	nil	-5
Algeria	84	170	69	354	-15	+184
Morocco	45	68	162	964	+117	+896
Rhodesia	44	63	42	54	-2	-9
Other countries	145	250	214	414	+69	+164
Total, Africa	720	1,147	893	2,708	+173	+1,561

Table 14. (continued)

	Consumption		Supplies available		Surplus (+) Deficit (-)	
	1974	1980	1974	1980	1974	1980
Latin America						
Brazil	725	1,470	330	592	-395	-878
Mexico	180	295	242	490	+62	+195
Colombia	100	92	74	12	-26	-80
Central America c/	76	94	4	7	-72	-87
Argentina	28	61	5	5	-23	-56
Peru	9	10	3	10	-6	nil
Venezuela	23	36	14	78	-9	+42
Chile	115	130	17	64	-98	-66
Cuba	50	150	10	34	-40	-116
Dominican Rep.	16	40	nil	nil	-16	-40
Other countries	65	100	9	18	-56	-82
Total, Latin America	1,387	2,478	708	1,310	-679	-1,168
Total, developing countries	5,347	9,127	3,767	9,041	-1,580	-86
Developed countries						
United States	4,600	5,780	5,714	7,964	+1,114	+2,184
Canada	480	490	684	784	+204	+294
Western Europe	5,935	7,390	6,037	6,448	+102	-942
Eastern Europe	2,785	4,020	2,404	3,825	-381	-195
USSR	2,700	3,940	3,073	4,845	+373	+905
Japan	795	940	698	807	-97	-133
Oceania	1,615	1,360	1,511	1,617	-104	+257
Total, developed countries	18,910	23,920	20,121	26,290	+1,211	+2,370
Total, world	24,257	33,047	23,888	35,331	-369	+2,284

a/ Countries listed by order of estimated population in the year 2000.

b/ Excluding Japan.

c/ Six countries.

Table 15. Past and expected consumption of potash fertilizer: a regional summary

(Millions of tons of K_2O)

	1960	1965	1970	1974	1980	1985	1990	2000
Developing countries								
Asia[a]	0.1	0.3	0.6	1.4	2.5	3.8	5.3	9.3
China	(0.05)	(0.1)	(0.1)	(0.5)	(0.9)	(1.4)	(2.1)	(3.7)
India	(0.03)	(0.06)	(0.21)	(0.31)	(0.7)	(1.0)	(1.4)	(2.4)
Rest of Asia	(0.1)	(0.1)	(0.3)	(0.6)	(0.9)	(1.4)	(1.8)	(3.2)
Africa	0.1	0.1	0.2	0.3	0.5	0.6	0.8	1.1
Latin America	0.2	0.3	0.6	0.9	1.6	2.4	3.2	5.5
Total, developing countries	0.4	0.7	1.4	2.6	4.6	6.8	9.3	15.9
Developed countries								
United States	1.9	2.6	3.6	4.6	5.9	7.2	8.7	11.9
Canada	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.5
Western Europe	3.3	3.9	4.5	5.4	6.4	7.5	8.7	11.2
Eastern Europe	1.1	1.5	2.5	3.3	4.9	6.4	8.2	12.3
USSR	0.8	1.4	2.3	3.6	5.1	6.8	8.6	13.1
Japan	0.5	0.6	0.7	0.7	0.7	0.7	0.7	0.8
Oceania	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.7
Total, developed countries	7.8	10.3	14.0	18.1	23.6	29.3	35.8	50.5
Total, world	8.2	11.0	15.4	20.7	28.2	36.1	45.1	66.4

[a] Excluding Japan.

Table 16. Expected future consumption of potash fertilizer: countries and regions [a]

By regression equations, based on 1965-74

(Thousands of tons of K_2O)

	1980	1985	1990	2000
Asia[b]				
China	915	1,430	2,060	3,670
India	665	1,000	1,400	2,410
Indonesia	56	94	140	260
Pakistan	5	6	7	10
Bangladesh	25	38	53	92
Philippines	74	100	130	205
Thailand	77	125	180	330
Turkey	40	62	88	155
Iran	5	6	7	10
Korea (Rep. of)	215	305	405	660
Vietnam (DR)	30	36	44	60
Vietnam (South)	27	35	44	66
Korea (DPR)	86	140	200	365
Malaysia	220	355	515	925
Sri Lanka	30	30	30	30
Other countries	34	36	39	46
Total, Asia	2,504	3,798	5,342	9,294
Africa				
Egypt	5	6	7	10
South Africa	160	195	235	325
Sudan	5	6	7	10
Algeria	54	76	100	165
Morocco	49	71	96	160
Rhodesia	40	50	60	84
Other countries	145	190	245	365
Total, Africa	458	594	750	1,119

Table 16. (continued)

	1980	1985	1990	2000
Latin America				
Brazil	1,060	1,650	2,370	4,190
Mexico	70	100	140	235
Colombia	60	67	76	94
Central America	73	100	135	210
Argentina	17	22	29	45
Peru	10	12	15	20
Venezuela	30	40	52	79
Chile	15	18	22	30
Cuba	175	215	255	350
Dominican Rep.	40	49	58	80
Other countries	70	85	100	140
Total, Latin America	1,620	2,358	3,252	5,473
Total, developing countries	4,582	6,750	9,344	15,886
Developed countries				
United States	5,900	7,210	8,650	11,930
Canada	265	315	370	500
Western Europe	6,460	7,530	8,680	11,210
Eastern Europe	4,920	6,440	8,175	12,260
USSR	5,090	6,750	8,640	13,130
Japan	665	685	710	750
Oceania	330	410	500	695
Total, developed countries	23,630	29,340	35,725	50,475
Total, world	28,212	36,090	45,069	66,361

a/ Countries listed by order of estimated population in the year 2000.

b/ Excluding Japan.

c/ Six countries.

Table 17. Supply/consumption balance of potash fertilizer: a regional summary

(Millions of tons of K_2O)

	Consumption		Supplies available		Surplus (+) Deficit (-)	
	1974	1980	1974	1980	1974	1980
Developing countries						
Asia[a]	1.39	2.50	0.77	1.14	-0.62	-1.36
China	(0.53)	(0.92)	(0.28)	(0.30)	(-0.25)	(-0.62)
India	(0.31)	(0.66)	nil	nil	(-0.31)	(-0.66)
Rest of Asia	(0.55)	(0.92)	(0.49)	(0.84)	(-0.06)	(-0.08)
Africa	0.32	0.46	0.25	0.39	-0.07	-0.07
Latin America	0.90	1.62	0.02	0.02	-0.88	-1.60
Total, developing countries	2.61	4.58	1.04	1.55	-1.57	-3.03
Developed countries						
United States	4.62	5.90	2.23	2.71	-2.39	-3.19
Canada	0.20	0.27	4.82	7.47	+4.62	+7.20
Western Europe	5.38	6.46	4.97	6.93	-0.41	+0.47
Eastern Europe	3.31	4.92	2.43	3.40	-0.88	-1.52
USSR	3.61	5.09	5.62	9.90	+2.01	+4.81
Japan	0.68	0.66	nil	nil	-0.68	-0.66
Oceania	0.29	0.33	nil	nil	-0.29	-0.33
Total, developed countries	18.09	23.63	20.07	30.41	+1.98	+6.78
Total, world	20.70	28.21	21.11	31.96	+0.41	+3.75

[a] Excluding Japan.

Table 18. Supply/consumption balance of potash fertilizer: countries and regions a/
(Thousands of tons of K_2O)

	Consumption		Supplies available		Surplus (+) Deficit (-)	
	1974	1980	1974	1980	1974	1980
Asia a/						
China	530	915	285	296	-245	-619
India	315	665	-	-	-315	-665
Indonesia	40	56	-	-	-40	-56
Pakistan	3	5	-	-	-3	-5
Bangladesh	11	25	-	-	-11	-25
Philippines	45	74	-	-	-45	-74
Thailand	40	77	-	-	-40	-77
Turkey	13	40	-	-	-13	-40
Iran	1	5	-	-	-1	-5
Korea (Rep. of)	150	215	-	-	-150	-215
Vietnam (DR)	32	30	-	-	-32	-30
Vietnam (South)	18	27	-	-	-18	-27
Korea (DPR)	44	86	-	-	-44	-86
Malaysia	112	220	-	-	-112	-220
Sri Lanka	32	30	-	-	-32	-30
Other countries	5	34	489	838	+484	+804
Total, Asia	1,391	2,504	774	1,134	-617	-1,370
Africa						
Egypt	3	5	-	-	-3	-5
South Africa	126	160	-	-	-126	-160
Sudan	-	5	-	-	-	-5
Algeria	38	54	-	-	-38	-54
Morocco	25	49	-	-	-25	-49
Rhodesia	32	40	-	-	-32	-40
Other countries	98	145	250	394	+152	+249
Total, Africa	322	458	250	394	-72	-64

Table 18. (continued)

			Supplies available		Surplus (+) Deficit (-)	
	1974	1980	1974	1980	1974	1980
Latin America						
Brazil	523	1,060	-	-	-523	-1,060
Mexico	36	70	-	-	-36	-70
Colombia	58	60	-	-	-58	-60
Central America[c]	55	73	-	-	-55	-73
Argentina	17	17	-	-	-17	-17
Peru	8	10	-	-	-8	-10
Venezuela	21	30	-	-	-21	-30
Chile	14	15	18	24	+4	+9
Cuba	97	175	-	-	-97	-175
Dominican Rep.	21	40	-	-	-21	-40
Other countries	52	70	-	-	-52	-70
Total, Latin America	902	1,620	18	24	-884	-1,595
Total, developing countries	2,615	4,582	1,042	1,552	-1,573	-3,030
Developed countries[b]						
United States	4,615	5,900	2,228	2,707	-2,387	-3,193
Canada	205	265	4,817	7,476	+4,612	+7,211
Western Europe	5,380	6,460	4,973	6,930	-407	+470
Eastern Europe	3,310	4,920	2,427	3,400	-883	-1,520
USSR	3,605	5,090	5,624	9,900	+2,019	+4,810
Japan	685	665	-	-	-685	-665
Oceania	290	330	-	-	-290	-330
Total, developed countries	18,090	23,630	20,069	30,413	+1,979	+6,783
Total, world	20,705	28,212	21,111	31,965	+406	+3,753

a/ Countries listed by order of estimated population in the year 2000.

b/ Excluding Japan.

c/ Six countries.

Table 19. Comparison of nitrogen consumption projections for 1979/80 a/

(Millions of tons of nitrogen)

	TVA March 1974	IBRD July 1975	Joint working group April 1976	Table 9 this report
Developed market economies				
North America	11.24-12.54	11.7	11.24	12.22
Western Europe	9.22-9.74	10.0	9.47	10.44
Oceania	0.22-0.39	1.6	0.28	0.32
Japan	0.75-1.09		0.81	0.80
Israel	0.04-0.05		0.04	0.04
South Africa	0.33-0.41		0.42	0.41
Total	21.80-24.22	23.3	22.26	24.23
Developing market economies				
Africa	7.52-9.21	0.8	0.77	0.75
Near East		9.3	8.53	8.74
Far East				
Latin America	2.85-3.29	3.0	2.94	2.90
Total, DGME	10.37-12.50	13.1	12.24	12.39
Centrally planned economies				
Eastern Europe and USSR	14.80-16.48	14.3	15.10	16.48
Asia	6.13-7.56	6.6	5.96	7.13
Total	20.93-24.04	20.9	21.06	23.61
Developed regions	36.60-40.70	37.6	37.36	40.71
Developing regions	16.50-20.06	19.7	18.20	19.52
Total world	53.10-60.76	57.3	55.56	60.23

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a/ **The projections given in table 9 have been re-grouped** below to conform to **the regional grouping by TVA, IBRD and the UNIDO**/FAO/World Bank Working Group **on fertilizers.**

Table 20. Estimated regression equations, 1965-74

Nitrogen

Asia[a]

Bangladesh	$\sqrt{N} = 6.75 + 0.557T$
China	$\sqrt{N} = 35.41 + 3.048T$
India	$\sqrt{N} = 22.79 + 2.481T$
Indonesia	$\sqrt{N} = 7.68 + 1.117T$
Pakistan	$\sqrt{N} = 8.62 + 1.297T$
Philippines	$\sqrt{N} = 6.88 + 0.522T$
Thailand	$\sqrt{N} = 4.64 + 0.439T$
Turkey	$\sqrt{N} = 7.19 + 1.484T$
Iran	$\sqrt{N} = 3.63 + 0.940T$
Korea (Rep.of)	$\sqrt{N} = 13.80 + 0.743T$
Vietnam (DR)	$\sqrt{N} = 8.44 + 0.254T$
Vietnam (South)	$\sqrt{N} = 5.30 + 0.762T$
Korea (DPR)	$\sqrt{N} = 9.06 + 0.731T$
Malaysia	$\sqrt{N} = 5.36 + 0.466T$
Sri Lanka	$\sqrt{N} = 6.50 + 0.098T$
Other countries	$\sqrt{N} = 8.50 + 0.626T$
Total, Asia	(Sum of above)

Africa

Egypt	$\sqrt{N} = 15.55 + 0.397T$
South Africa	$\sqrt{N} = 9.12 + 0.731T$
Sudan	$\sqrt{N} = 4.54 + 0.437T$
Algeria	$\sqrt{N} = 2.52 + 0.713T$
Morocco	$\sqrt{N} = 3.67 + 0.495T$
Rhodesia	$\sqrt{N} = 6.13 + 0.204T$
Other countries	$\sqrt{N} = 8.08 + 0.769T$
Total, Africa	(Sum of above)

Latin America

Brasil	$\sqrt{N} = 6.09 + 1.611T$
Mexico	$\sqrt{N} = 15.23 + 0.909T$
Colombia	$\sqrt{N} = 5.81 + 0.531T$
Central America[b]	$\sqrt{N} = 8.57 + 0.578T$
Argentina	$\sqrt{N} = 4.63 + 0.288T$
Peru	$\sqrt{N} = 7.84 + 0.134T$
Venezuela	$\sqrt{N} = 4.47 + 0.159T$
Chile	$\sqrt{N} = 5.19 + 0.227T$
Cuba	$\sqrt{N} = 9.75 + 0.293T$
Dominican Rep.	$\sqrt{N} = 2.60 + 0.377T$
Other countries	$\sqrt{N} = 8.22 + 0.113T$

Table 20. (continued)

Nitrogen cont'd

Developed countries

United States	$\sqrt{N} = 67.82 + 2.649T$
Canada	$\sqrt{N} = 13.77 + 0.787T$
Western Europe	$\sqrt{N} = 66.41 + 2.243T$
Eastern Europe	$\sqrt{N} = 41.29 + 2.487T$
USSR	$\sqrt{N} = 42.93 + 4.043T$
Japan	$\sqrt{N} = 28.28$ (constant)
Oceania	$\sqrt{N} = 9.74 + 0.555T$

Phosphate

Asia[a]

China	$\sqrt{P_2O_5} = 16.23 + 2.047T$
India	$\sqrt{P_2O_5} = 11.97 + 1.578T$
Indonesia	$\sqrt{P_2O_5} = 2.56 + 0.651T$
Pakistan	$\sqrt{P_2O_5} = 1.12 + 0.771T$
Bangladesh	$\sqrt{P_2O_5} = 3.03 + 0.415T$
Philippines	$\sqrt{P_2O_5} = 5.00 + 0.253T$
Thailand	$\sqrt{P_2O_5} = 3.77 + 0.404T$
Turkey	$\sqrt{P_2O_5} = 7.62 + 1.031T$
Iran	$\sqrt{P_2O_5} = 2.80 + 0.722T$
Korea (Rep. of)	$\sqrt{P_2O_5} = 10.49 + 0.285T$
Vietnam (DR)	$\sqrt{P_2O_5} = 6.89 + 0.207T$
Vietnam (South)	$\sqrt{P_2O_5} = 5.05 + 0.096T$
Korea (DPR)	$\sqrt{P_2O_5} = 7.86 + 0.284T$
Malaysia	$\sqrt{P_2O_5} = 2.06 + 0.373T$
Sri Lanka	$\sqrt{P_2O_5} = 1.25 + 0.259T$
Other countries	$\sqrt{P_2O_5} = 6.54 + 0.375T$

Table 20.(continued)

Phosphate cont'd

Africa

Egypt $\sqrt{P_2O_5} = 6.29 + 0.122T$
South Africa $\sqrt{P_2O_5} = 12.43 + 0.698T$
Sudan $\sqrt{P_2O_5} = 1.55 + 0.046T$
Algeria $\sqrt{P_2O_5} = 3.34 + 0.650T$
Morocco $\sqrt{P_2O_5} = 4.60 + 0.245T$
Rhodesia $\sqrt{P_2O_5} = 4.22 + 0.246T$
Other countries $\sqrt{P_2O_5} = 7.52 + 0.550T$

Latin America

Brazil $\sqrt{P_2O_5} = 9.85 + 1.898T$
Mexico $\sqrt{P_2O_5} = 7.93 + 0.618T$
Colombia $\sqrt{P_2O_5} = 6.96 + 0.175T$
Central America $\sqrt{P_2O_5} = 5.33 + 0.290T$
Argentina $\sqrt{P_2O_5} = 3.28 + 0.301T$
Peru $\sqrt{P_2O_5} = 2.17 + 0.066T$
Venezuela $\sqrt{P_2O_5} = 2.62 + 0.226T$
Chile $\sqrt{P_2O_5} = 8.20 + 0.209T$
Cuba $\sqrt{P_2O_5} = 8.44 + 0.254T$
Dominican Rep. $\sqrt{P_2O_5} = 4.36 + 0.131T$
Other countries $\sqrt{P_2O_5} = 6.48 + 0.234T$

Developed countries

United States of America $\sqrt{P_2O_5} = 58.75 + 1.153T$
Canada $\sqrt{P_2O_5} = 17.28 + 0.323T$
Western Europe $\sqrt{P_2O_5} = 65.09 + 1.391T$
Eastern Europe $\sqrt{P_2O_5} = 36.65 + 1.781T$
USSR $\sqrt{P_2O_5} = 36.18 + 1.773T$
Japan $\sqrt{P_2O_5} = 23.39 + 0.489T$
Oceania $\sqrt{P_2O_5} = 34.48 + 0.156T$

Table 20.(continued)

Potash

Asia [a]

China $\sqrt{K_2O} = 7.50 + 1.516T$

India $\sqrt{K_2O} = 8.35 + 1.164T$

Indonesia $\sqrt{K_2O} = 1.03 + 0.432T$

Pakistan $\sqrt{K_2O} = 1.55 + 0.046T$

Bangladesh $\sqrt{K_2O} = 1.53 + 0.231T$

Philippines $\sqrt{K_2O} = 4.29 + 0.288T$

Thailand $\sqrt{K_2O} = 1.78 + 0.468T$

Turkey $\sqrt{K_2O} = 1.83 + 0.302T$

Iran $\sqrt{K_2O} = 1.55 + 0.046T$

Korea (Rep. of) $\sqrt{K_2O} = 6.30 + 0.555T$

Vietnam (DR) $\sqrt{K_2O} = 3.78 + 0.113T$

Vietnam (South) $\sqrt{K_2O} = 3.07 + 0.144T$

Korea (DPR) $\sqrt{K_2O} = 1.95 + 0.490T$

Malaysia $\sqrt{K_2O} = 3.32 + 0.773T$

Sri Lanka $\sqrt{K_2O} = 5.48$ (constant)

Other countries $\sqrt{K_2O} = 5.06 + 0.049T$

Africa

Egypt $\sqrt{K_2O} = 1.55 + 0.046T$

South Africa $\sqrt{K_2O} = 8.45 + 0.275T$

Sudan $\sqrt{K_2O} = 1.55 + 0.046T$

Algeria $\sqrt{K_2O} = 3.23 + 0.275T$

Morocco $\sqrt{K_2O} = 2.86 + 0.278T$

Rhodesia $\sqrt{K_2O} = 4.22 + 0.142T$

Other countries $\sqrt{K_2O} = 6.75 + 0.354T$

Table 20. (continued)

Potash cont'd

Latin America

Brazil $\sqrt{K_2O} = 8.37 + 1.611T$
Mexico $\sqrt{K_2O} = 3.10 + 0.350T$
Colombia $\sqrt{K_2O} = 6.25 + 0.098T$
Central America[b] $\sqrt{K_2O} = 4.07 + 0.298T$
Argentina $\sqrt{K_2O} = 2.12 + 0.131T$
Peru $\sqrt{K_2O} = 2.17 + 0.066T$
Venezuela $\sqrt{K_2O} = 3.00 + 0.168T$
Chile $\sqrt{K_2O} = 2.65 + 0.081T$
Cuba $\sqrt{K_2O} = 9.12 + 0.274T$
Dominican Rep. $\sqrt{K_2O} = 4.36 + 0.131T$
Other countries $\sqrt{K_2O} = 5.78 + 0.173T$

Developed countries

United States of America $\sqrt{K_2O} = 52.52 + 1.620T$
Canada $\sqrt{K_2O} = 11.63 + 0.306T$
Western Europe $\sqrt{K_2O} = 61.27 + 1.275T$
Eastern Europe $\sqrt{K_2O} = 39.65 + 2.031T$
USSR $\sqrt{K_2O} = 38.90 + 2.162T$
Japan $\sqrt{K_2O} = 24.66 + 0.078T$
Oceania $\sqrt{K_2O} = 12.06 + 0.410T$

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[a] Excluding Japan

[b] Six countries

Note: The coefficient T is a rough indication of the annual increase in nitrogen demand in each country, but the exact calculation is as follows

$$\frac{dN}{dT} = \text{Annual increase in N demand} = 2\ AB + 2\ B^2T$$

Table 21. 99 per cent confidence limits of fertiliser projections
(Millions of tons of N, P_2O_5, K_2O)

	Nitrogen				P_2O_5				K_2O			
	Lower limit	Pro-jection	Upper limit	Variation of limit (per cent)	Lower limit	Pro-jection	Upper limit	Variation of limit (per cent)	Lower limit	Pro-jection	Upper limit	Variation of limit (per cent)
Developing countries												
1980	17.9	19.4	21.0	± 8	8.1	8.8	9.6	± 9	4.1	4.4	4.8	± 9
1990	33.1	36.8	40.8	± 10	15.2	17.0	19.0	± 11	7.6	8.6	9.7	± 12
2000	52.8	59.8	67.3	± 12	24.4	27.9	31.5	± 13	12.3	14.2	16.3	± 14
Developed countries												
1980	36.4	39.7	73.2	± 8	22.8	23.7	24.7	± 4	22.3	23.5	24.7	± 5
1990	56.7	64.6	73.1	± 12	31.2	33.3	35.5	± 7	32.2	35.0	37.9	± 8
2000	81.4	95.6	111.0	± 15	41.0	44.5	48.3	± 9	44.0	48.8	53.9	± 10
World												
1980	55.5	59.1	62.9	± 6	31.1	32.5	33.8	± 4	26.3	27.9	29.3	± 5
1990	92.4	101.4	110.8	± 9	47.2	50.3	53.4	± 6	40.2	43.6	47.2	± 8
2000	139.1	155.4	172.6	± 11	67.0	72.4	78.0	± 8	57.1	63.0	69.3	± 10

Note: When per cent deviation of upper and lower confidence limits were not the same, the average of the two was used.

Figure 1. Past and expected future world fertilizer consumption

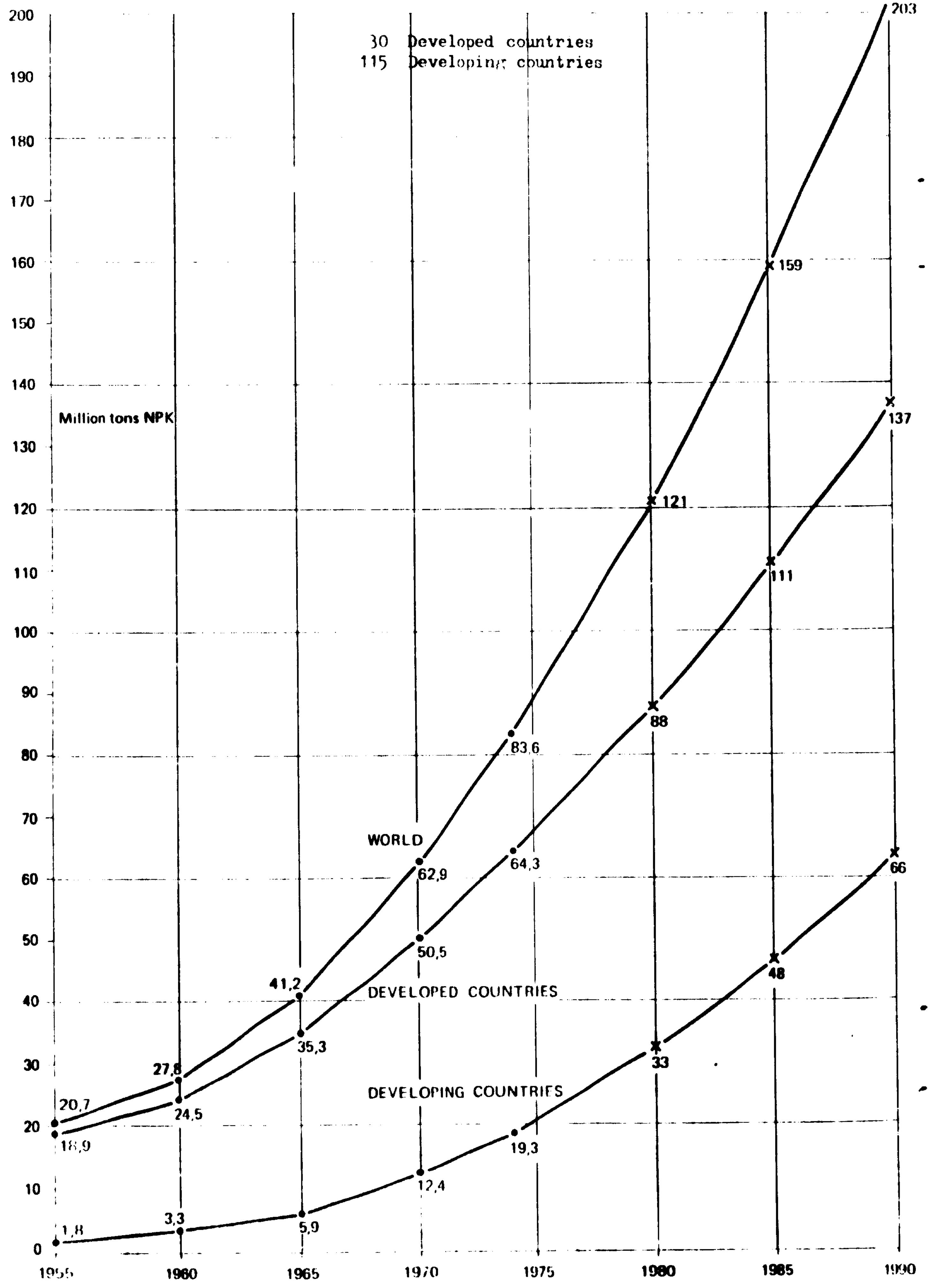


Figure 2. Past and expected future per capita fertiliser consumption

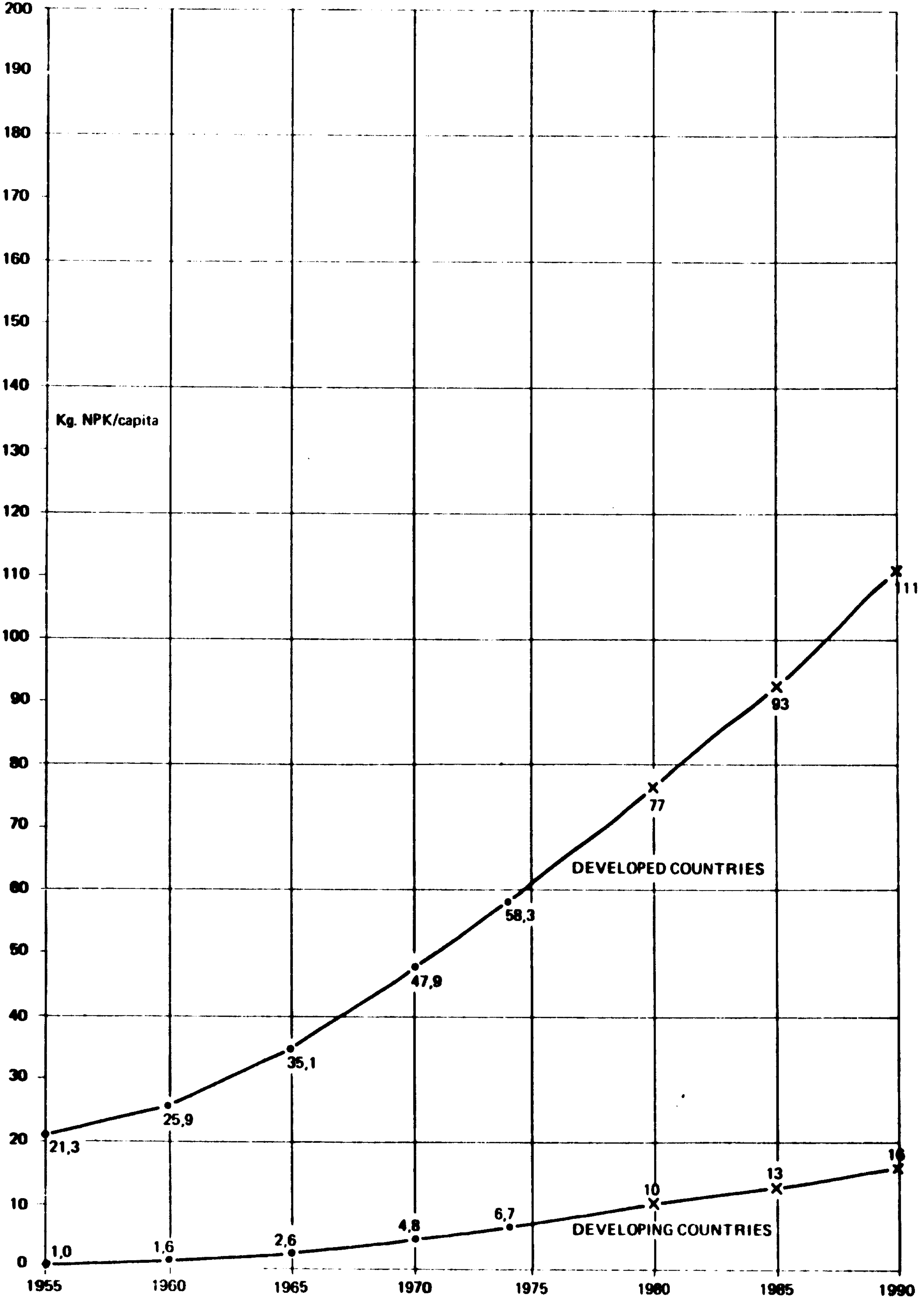


Figure 3. Past and expected future fertilizer consumption per hectare

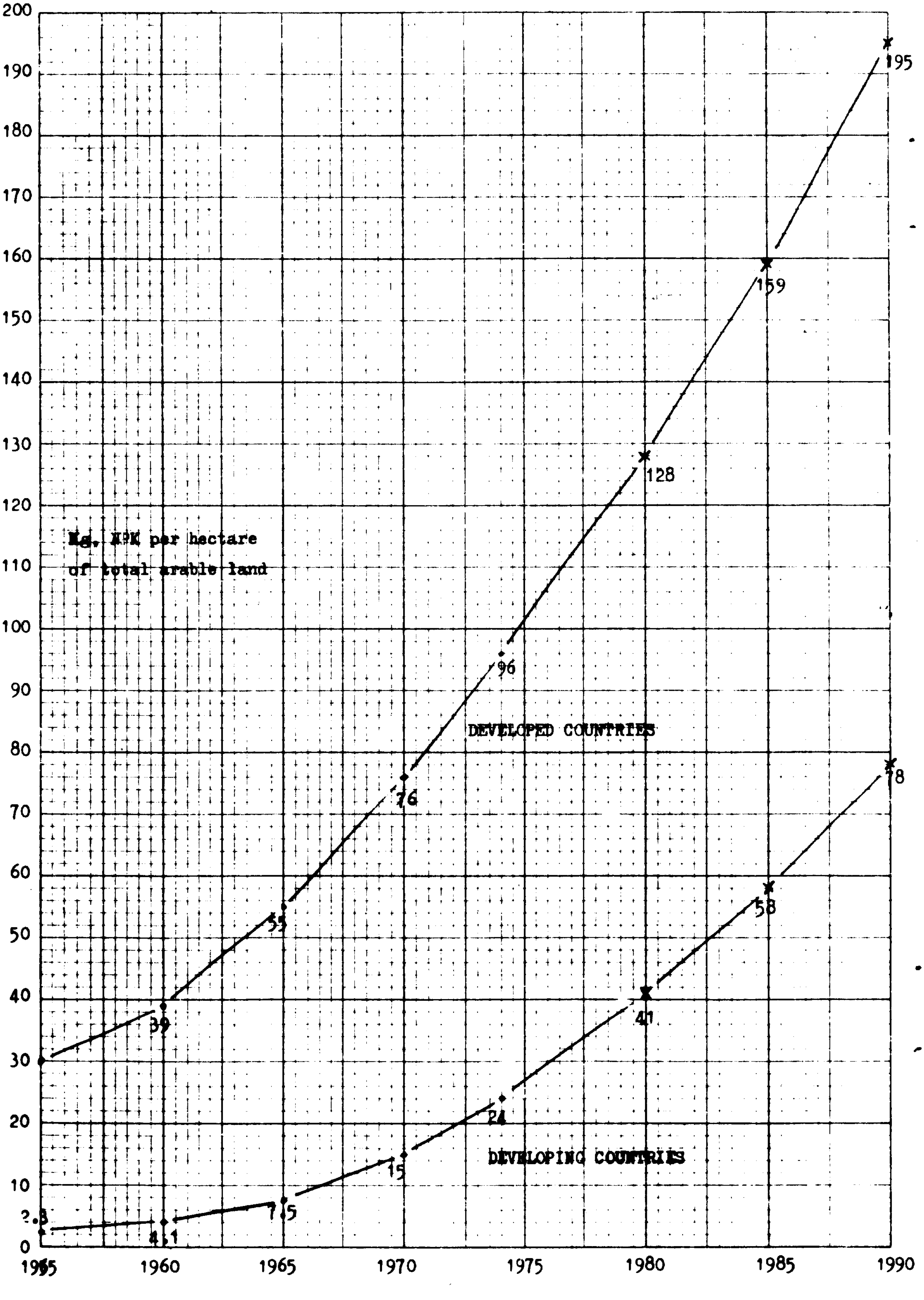


Figure 4. Fertilizer consumption per capita (selected countries), 1973/74

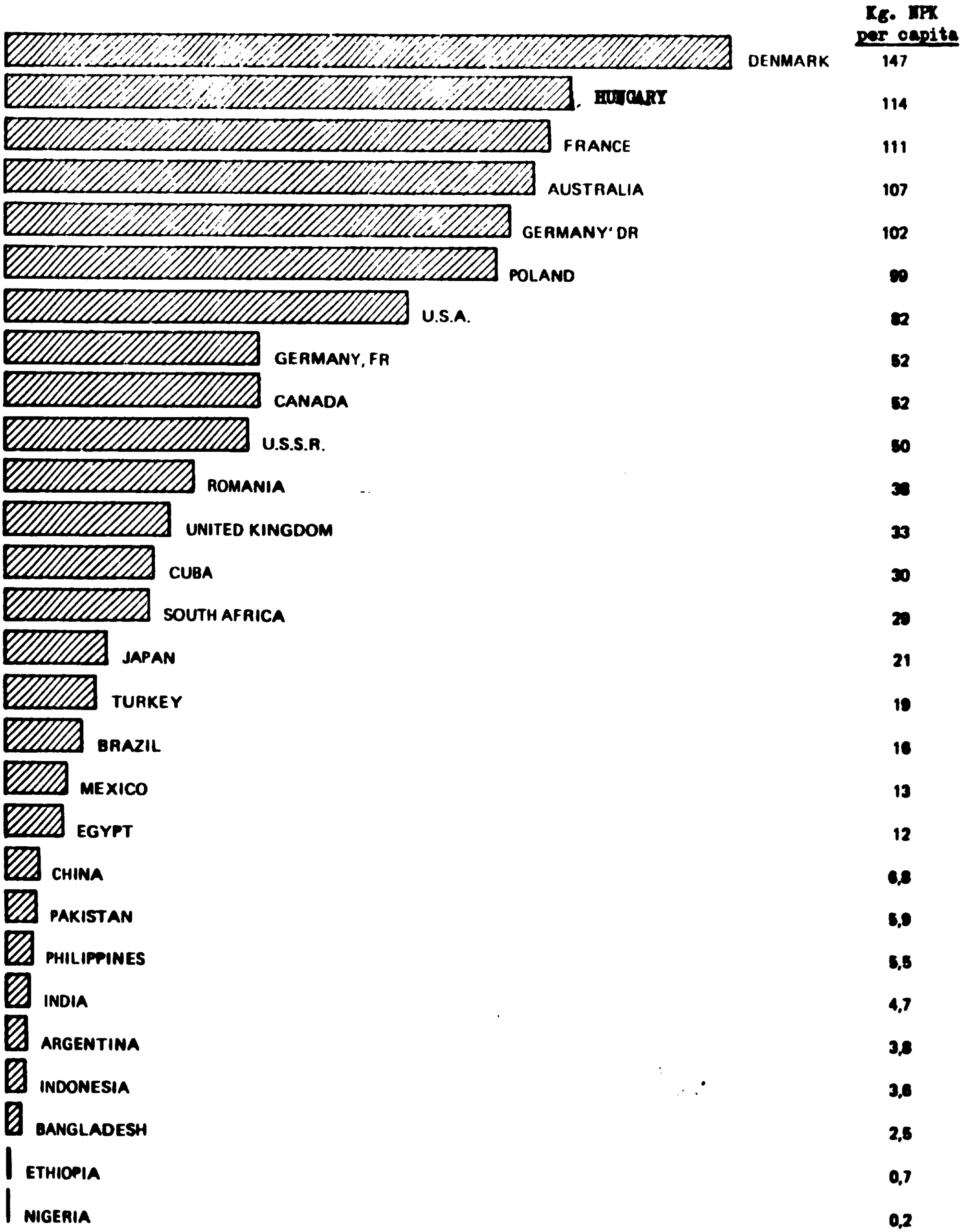


Figure 5. Fertiliser consumption per hectare (selected countries), 1973/74

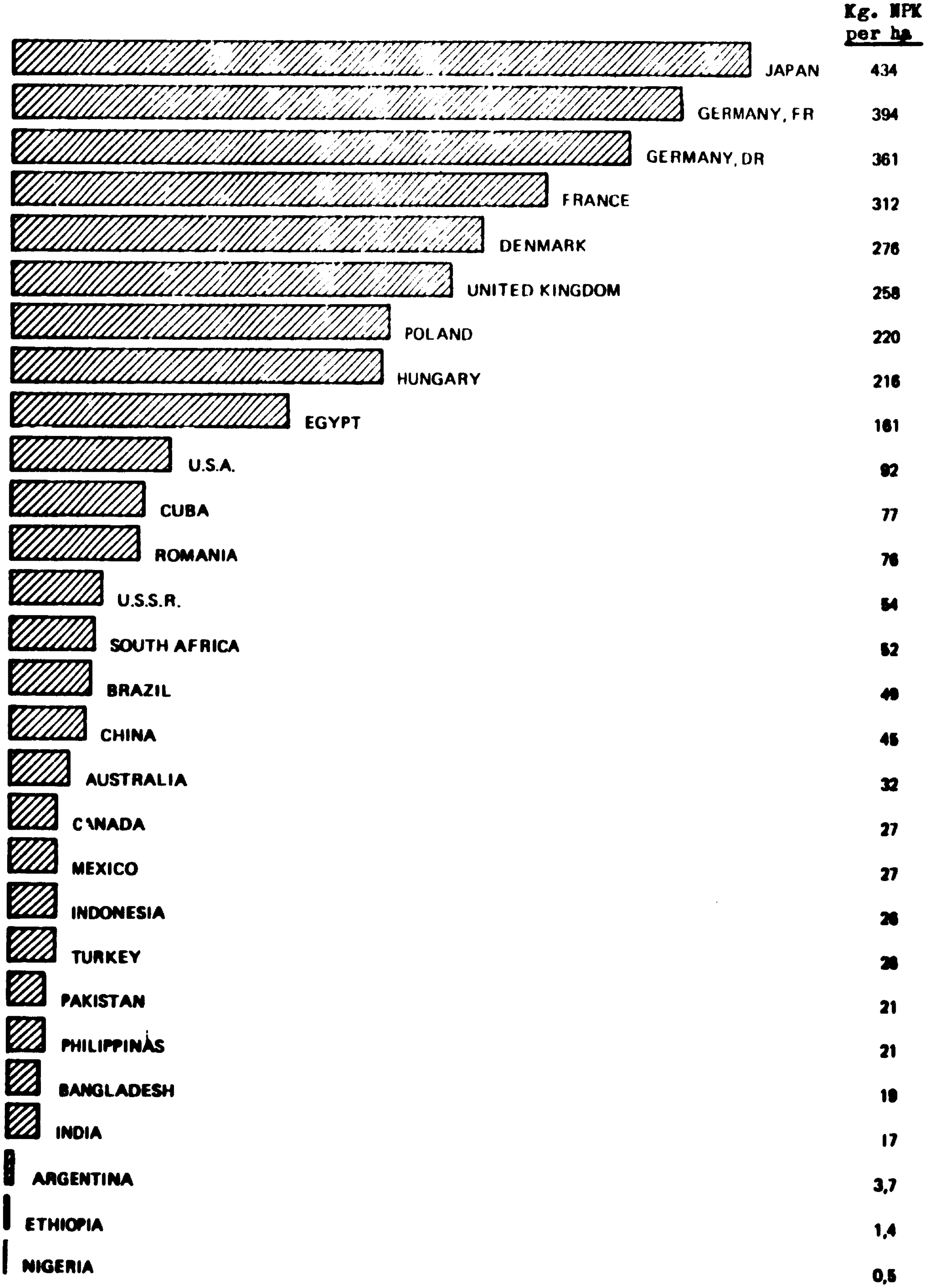


Figure 6. Past and expected future world consumption of N, P_2O_5 and K_2O fertilizer

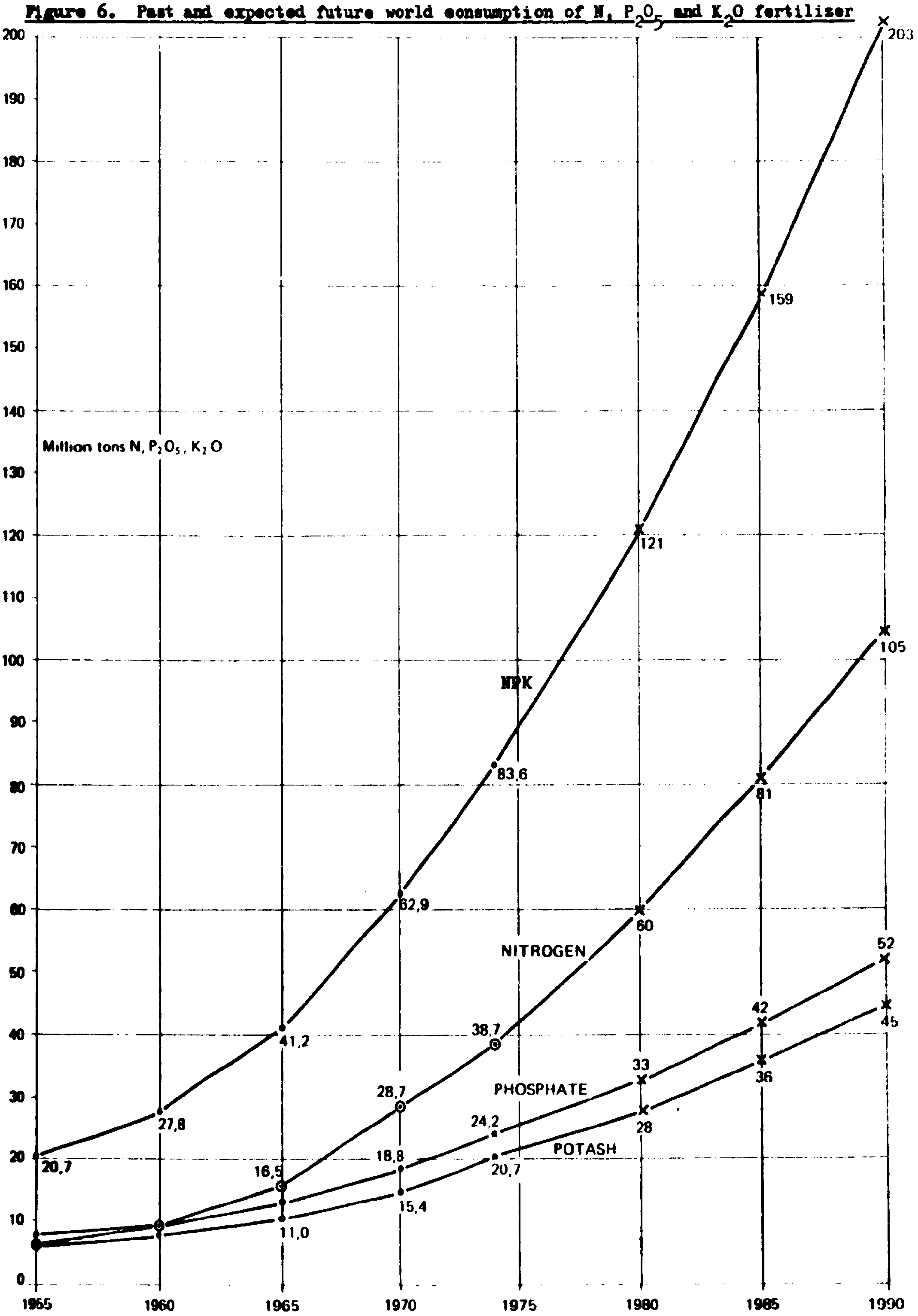


Figure 7. Percentage of N, P_2O_5 and K_2O in fertilizer: past and expected future world consumption

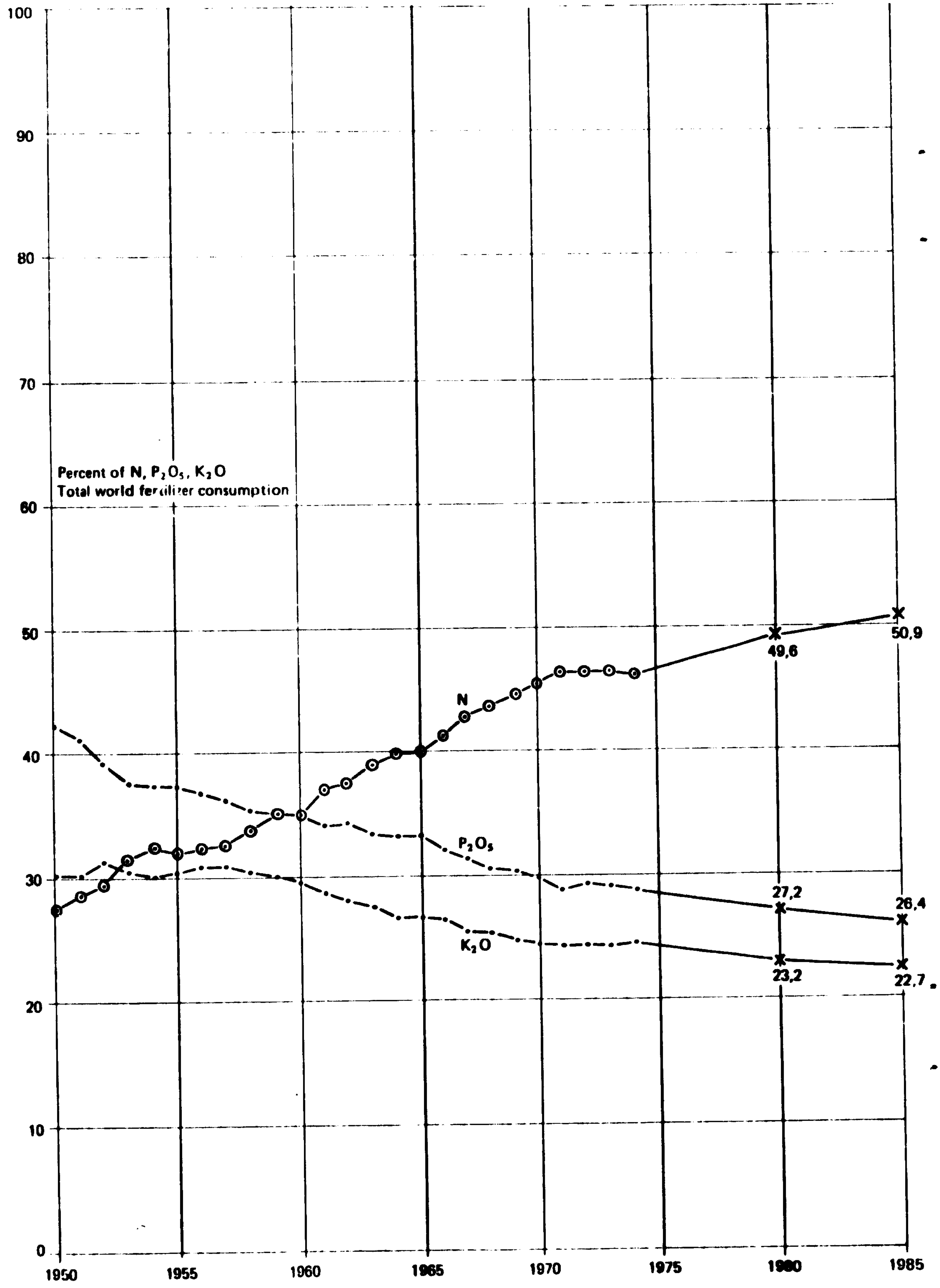


Figure 8. Percentage of nitrogen in fertilizer: past and expected future world consumption

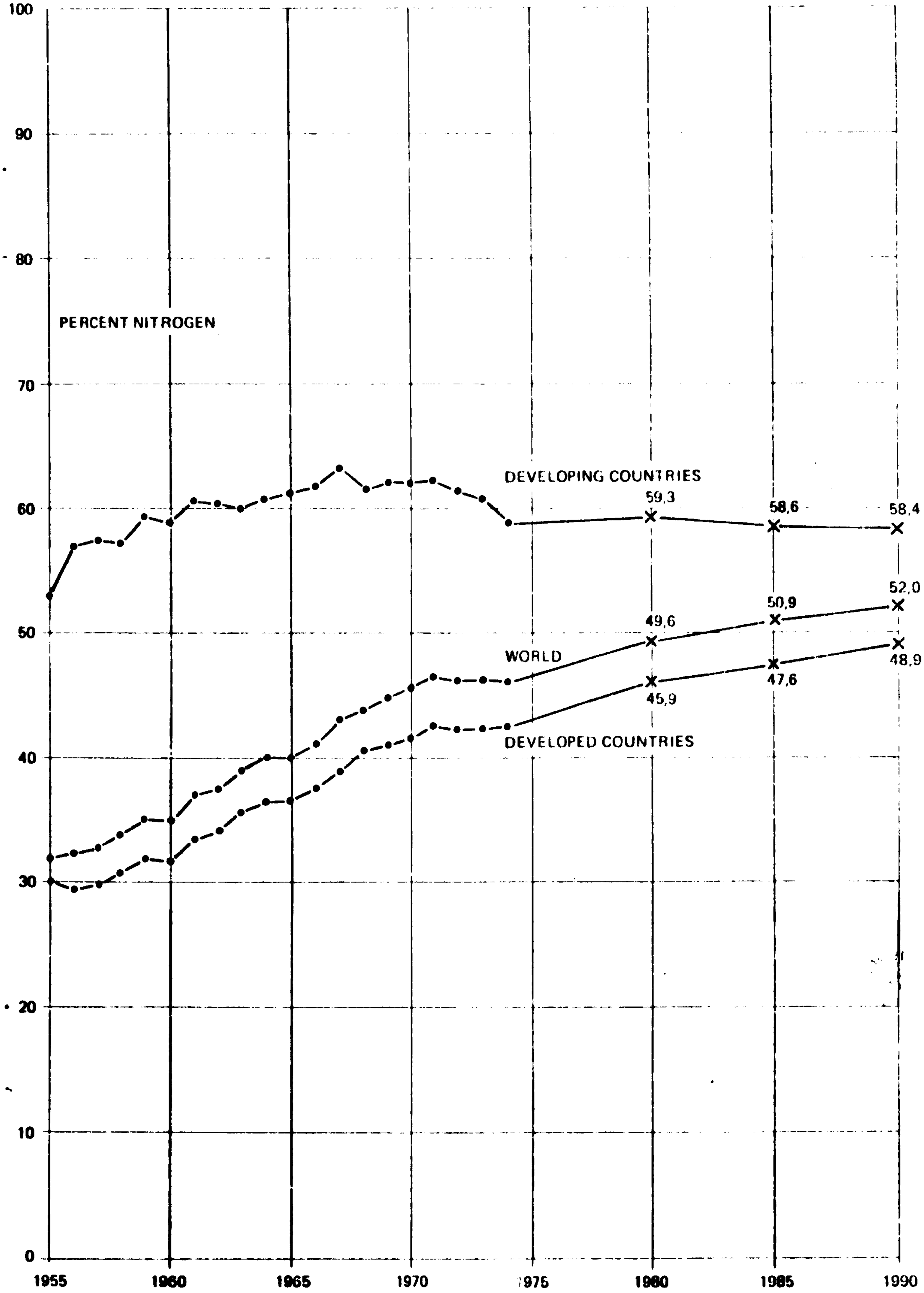
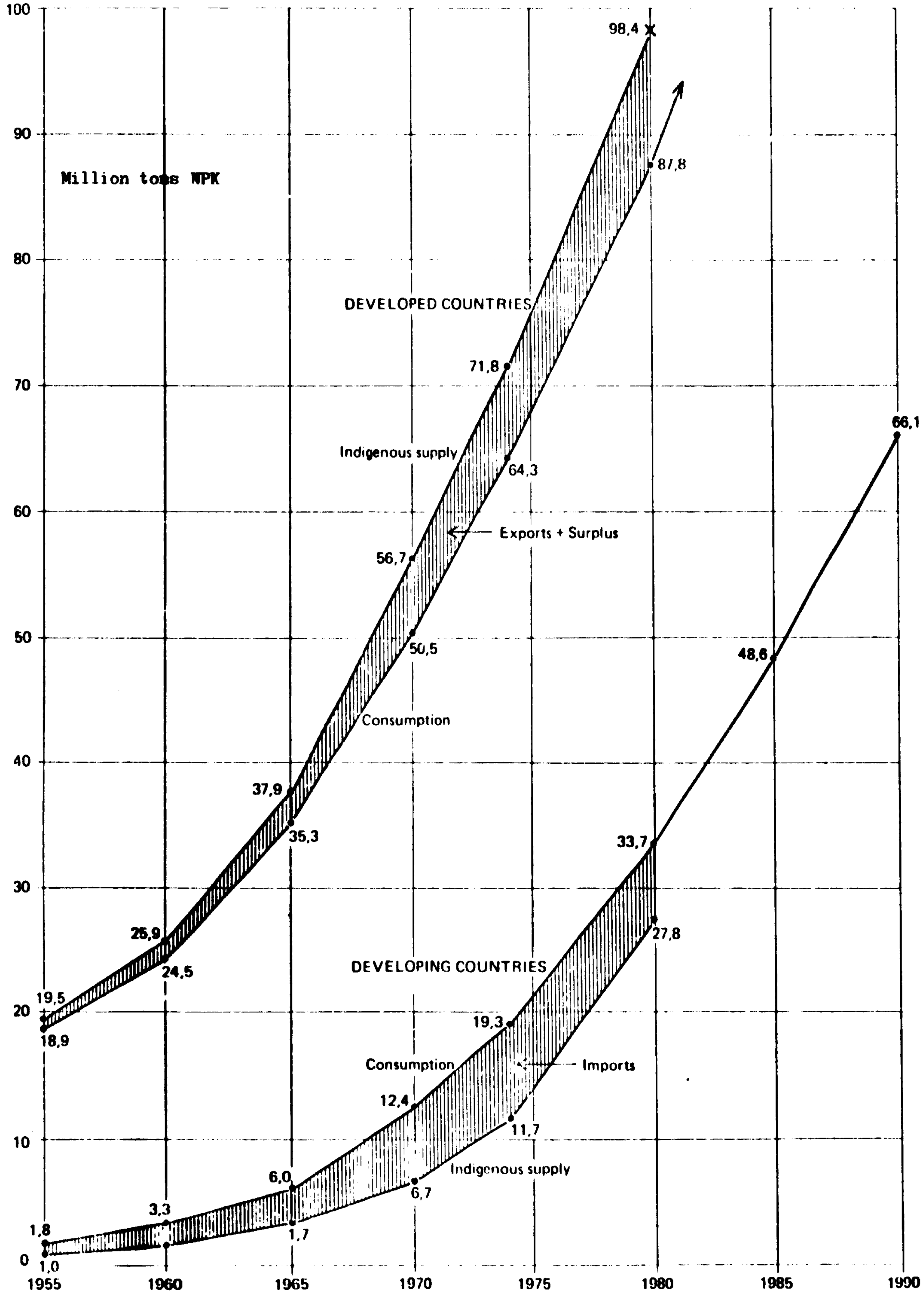


Figure 9. Indigenous supply and consumption of fertiliser



Note: Indigenous supply Indigenous production X 0,95

Figure 10. Square root of past and expected future fertiliser consumption

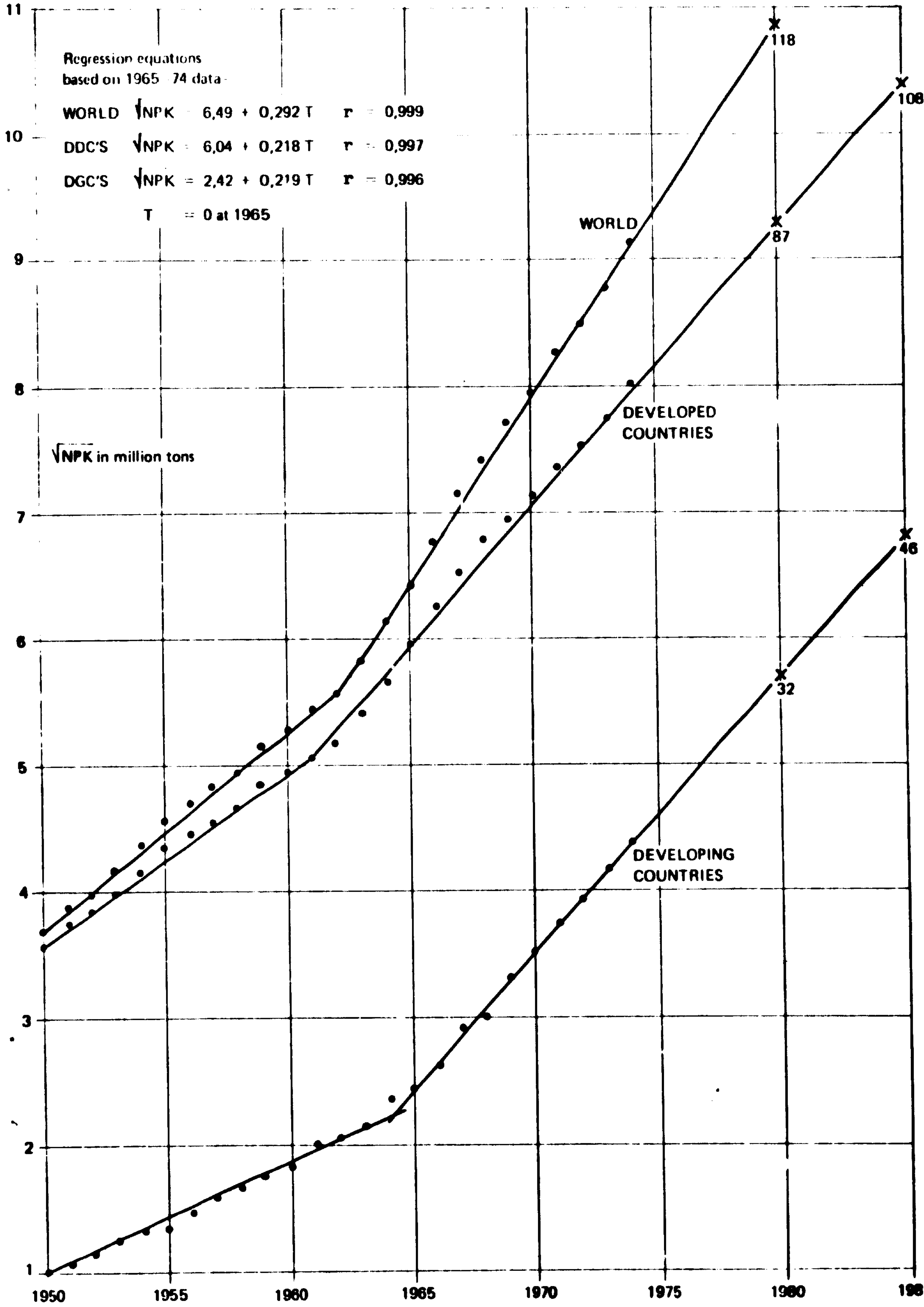


Figure 11. Square root of past and expected future nitrogen consumption

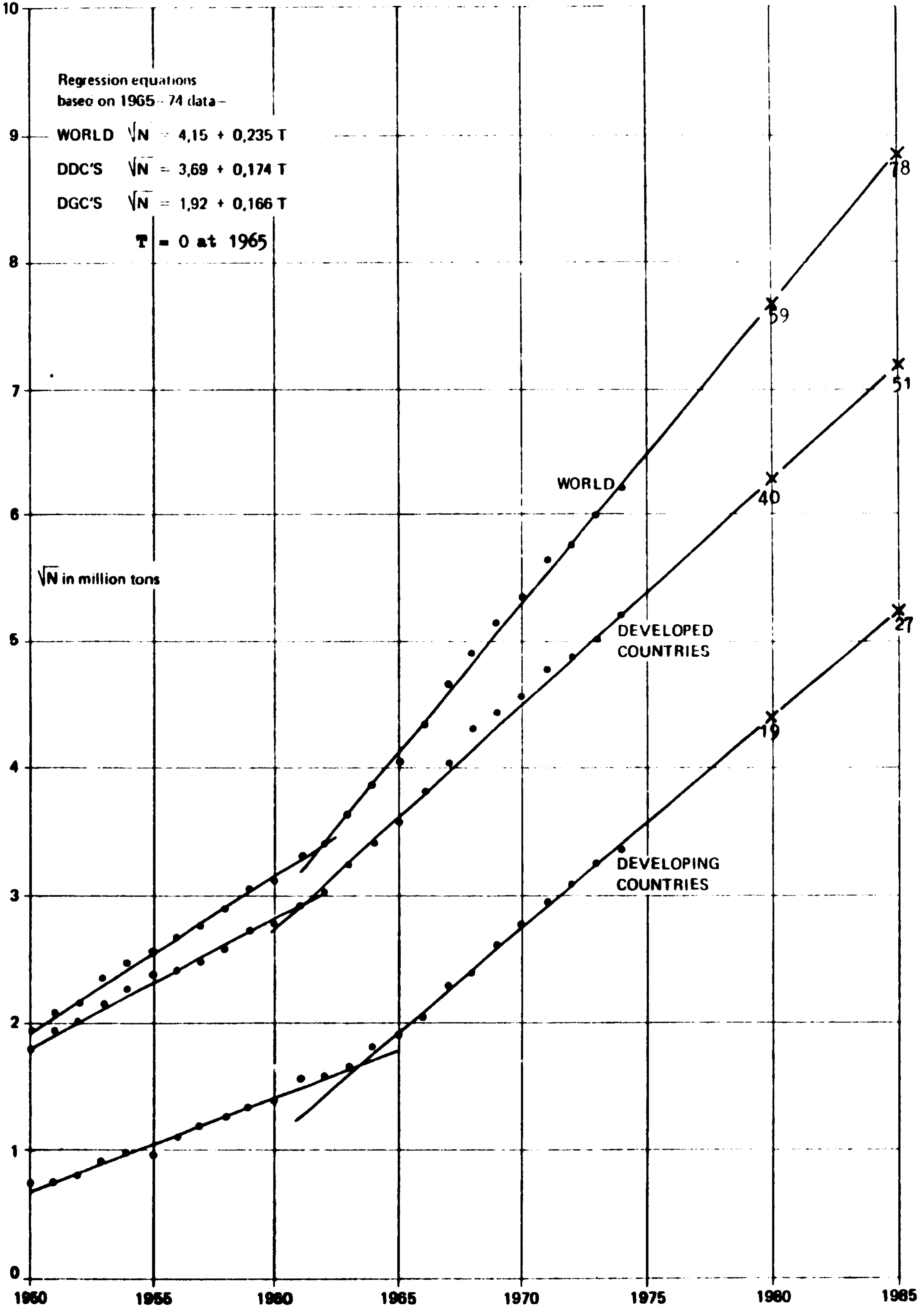


Figure 12. Square root of past and expected future nitrogen consumption: Asian countries

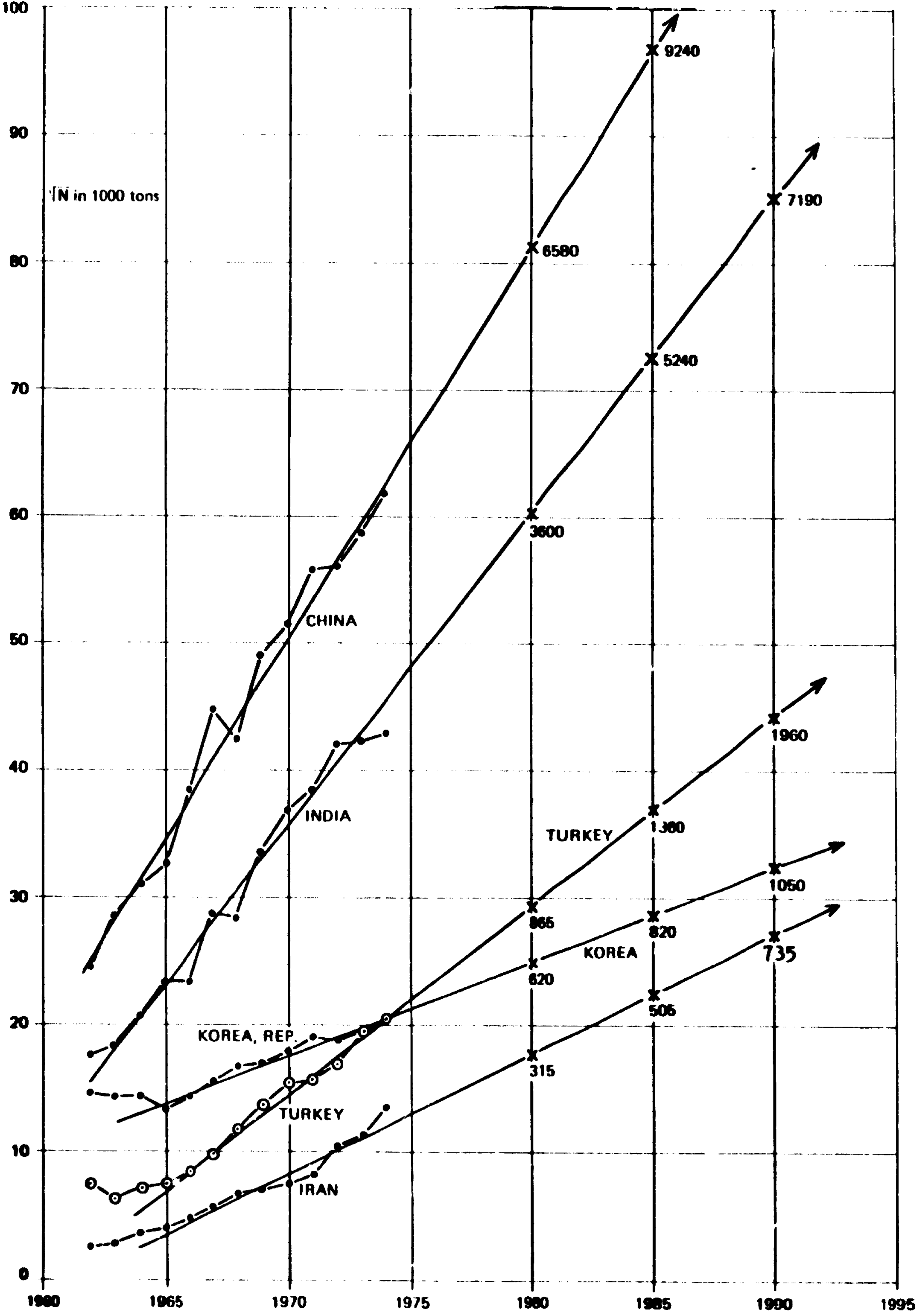
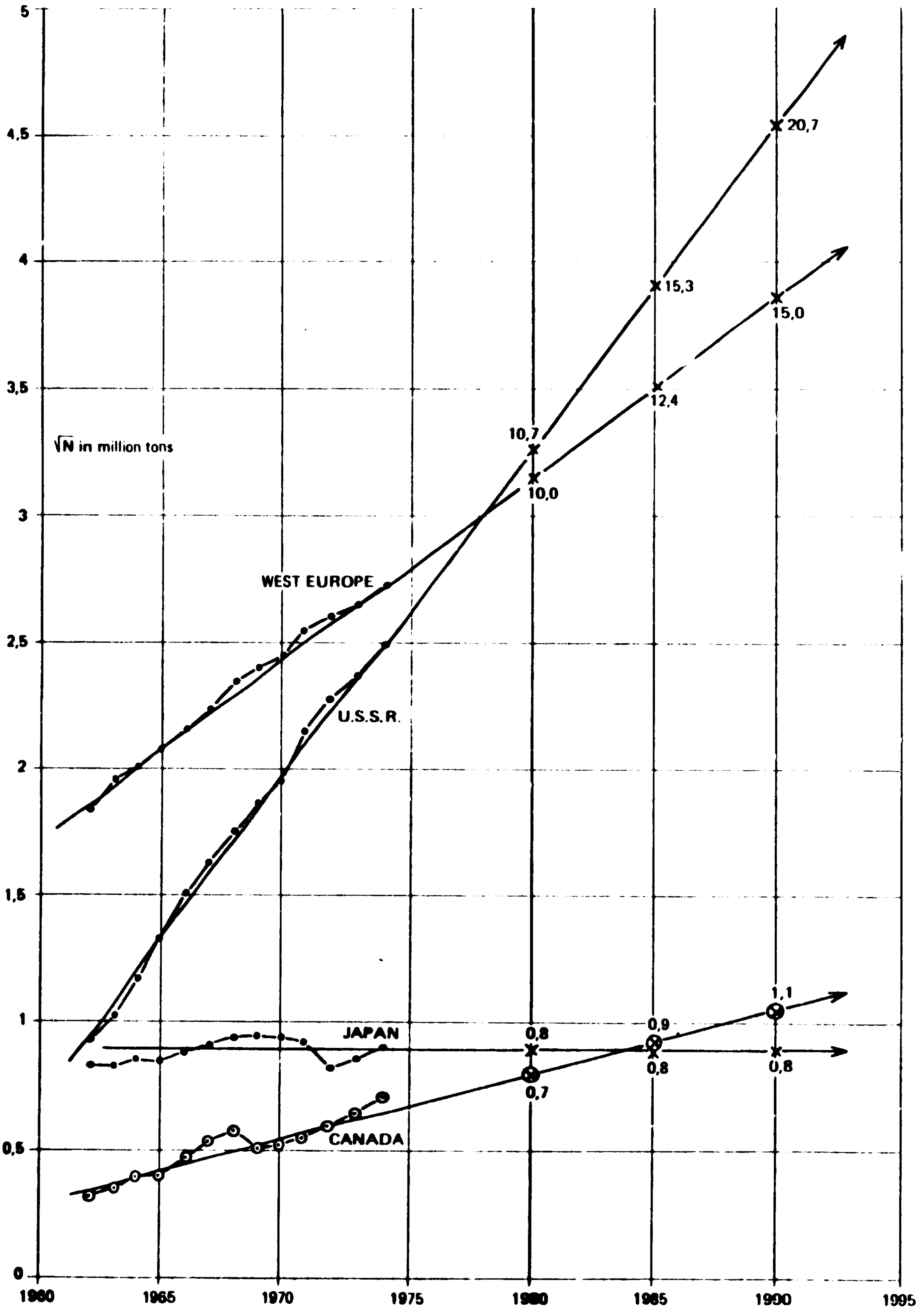


Figure 13. Square root of past and expected future nitrogen consumption: developed countries



Chapter III

FERTILIZER MANUFACTURE: CAPITAL AND OPERATING COSTS

Fertilizer industry

The fertilizer industry is important in itself, and to governments, by virtue of its relationship to food production. The provision of sufficient fertilizers is the most important single factor in improving crop yields. Because of this close relationship, the assurance of an adequate supply of fertilizers at reasonable prices is of major concern to all countries. The desire to have the maximum degree of control over fertilizer supplies and prices naturally leads to efforts to achieve self-sufficiency in fertilizer production. The achievement of this aim is, however, modified or limited by material and economic factors. In order to achieve complete self-sufficiency, a country would have to have in its own territory all the basic raw materials; petroleum or coal, phosphate rock, sulphur and potash. Very few countries are in this fortunate position, and the great majority have to import one or more of these raw materials. Complete self-sufficiency is, therefore, impracticable for most countries.

The attempt to achieve the maximum self-sufficiency within the limitations set by indigenous raw materials will be self-defeating if it leads to excessive fertilizer costs, since these would significantly weaken the incentive to use fertilizer. The most reasonable solution may often arise out of co-operative action between countries in a given region: one country might contribute raw materials and the other markets, thereby leading to an economically sound fertilizer industry, bolstered by a mutually acceptable degree of interdependence in this and other industries. This theme is developed in a later chapter (see Chapter V "The Location of Fertilizer Plants"), and the various possibilities open to countries wishing to establish a fertilizer industry are discussed below.

The fertilizer industry is one of the most rapidly growing major industries. From 1950-1970, the capacity of the industry increased five-fold, and at present its capacity is nearly doubling every ten years. It is a science-based industry whose processes and products are subject to continual technical change and development. It is a capital-intensive industry: a typical modern fertilizer plant entails a capital investment of $0.3 million per person employed, and 50-60 per cent of the cost of production is due to capital charges. Moreover, it requires scientifically educated and professionally trained management as well as a skilled labour force. Economies of scale are very important and the manufacturing units are large. It uses large quantities of raw materials and makes large quantities of solid products, thus calling for a reliable and efficient transport system. A typical modern fertilizer plant produces 0.5 million tons of fertilizer a year and consumes between 0.5-1.0 million tons of raw materials. It uses large amounts of energy and water. A modern nitrogenous fertilizer plant uses 1,000 tons of petroleum products, or more than 2,000 tons of coal and 15,000 tons of water a day.

The fertilizer industry in developing countries

Owing to its high capital requirements, its research and development demands, its need for trained and skilled management and labour, as well as the location of its markets, the fertilizer industry has become established mainly in the developed countries, even though the raw materials required, with the exception of potash, are widely distributed throughout the developing countries. However, this situation is rapidly changing. In 1970, the developing countries imported about 50 per cent of the fertilizer they used; by 1975, this proportion had fallen to 35 per cent and, based on known plans for further factories, it is expected to fall to 15 per cent by 1980, and probably to zero by 1985. By that year, according to the forecasts set out in the previous chapter, the developing countries will have about 34 per cent of the world market, rising to 40 per cent by the year 2000.

Developing countries have some advantages and disadvantages in setting up a fertilizer industry. Their major advantage is that they are better endowed with raw materials than many developed countries, particularly those in Western Europe. These raw materials are, of course, not evenly distributed throughout the developing countries; however, as a group, the developing countries have a large proportion of the world's reserves of natural gas, petroleum and phosphate rock. They also have some supplies of sulphur and potash, but these fall well short of their requirements.[1] Another advantage is that the developing countries have a large and rapidly growing market.

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[1] The raw material situation is reviewed in detail in Chapter IV.

The major disadvantages are those which have held back the development of the developing countries' industrial structure in general: shortage of capital; lack of trained and skilled manpower for the design, erection and operation of factories; and an infrastructure which is often barely adequate to the demands made of it.

It is generally necessary for developing countries to employ contractors from developed countries to design and erect the factories, involving the employment on site of large numbers of expatriate personnel. Furthermore, most of the equipment has to be made in developed countries and transported long distances by sea and rail. Considerable costs may be incurred in supplying the factory with water or electric power, in connecting it with the road and rail systems, and in providing housing, medical and other facilities for employees. All these factors increase capital costs, and some impose heavy demands in terms of foreign exchange. A fertilizer plant erected in a developing country costs 25-35 per cent more than the same plant in a developed country, and the foreign currency required is rarely less that 40 per cent, and may be as high as 80 per cent, of the the total capital cost. During the operation of the plants, interruptions of the water, power or raw material supplies may cause low utilization: this has a severe effect upon costs in an industry where fixed annual costs are often 60-70 per cent of the total production cost.

These disadvantages are decreasing as developing countries acquire greater capital resources, obtain more trained manpower, and strengthen their infrastructures. Moreover these disadvantages have not prevented a rapid increase in fertilizer plant capacity in developing countries, particularly where cheap raw materials are available or the market is large.

Types of fertilizers

The fertilizer industry is concerned primarily with the supply of the three basic plant nutrients - nitrogen (N), phosphorus (P) and potassium (K) - in the form of a range of chemical products containing these elements. The latter two are usually spoken of in terms of their oxides: phosphorus pentoxide (P_2O_5) and potassium oxide (K_2O). In 1975, about 40 million tons N, 25 million tons P_2O_5 and 20 million tons K_2O were supplied, of which the developing countries consumed about 30, 25 and 15 per cent respectively.

The basic nutrients may be supplied singly in fertilizers containing only one nutrient ("straight" fertilizers), or in fertilizers containing two or all three nutrients ("compound" or "complex" fertilizers). In 1975, about 20 per cent N, 50 per cent P_2O_5 and 80 per cent K_2O were supplied in compound fertilizers. Compounds are much more widely used in developed than in developing countries. Their main advantage lies in a reduction of the cost of putting the fertilizer on to the land, since two or more nutrients are supplied in one application of fertilizer.

The supply of potash fertilizers differs from the supply of nitrogen and phosphate fertilizers in that the basic raw material, potassium chloride or sulphate, is applied directly as a fertilizer or, more usually, is incorporated without further chemical processing into compound fertilizers. Thus, there is no separate potash fertilizer industry; the incorporation of potash into other fertilizers is a step in the manufacture of compound fertilizers, in which the basic operation is the production of nitrogen or phosphate fertilizers. For these reasons, the supply of potash is not considered in this chapter. Potash is treated as a raw material and discussed in the following chapter.

Nitrogen fertilizers. Practically all nitrogen fertilizers are made from ammonia: the cost of ammonia manufacture accounts for 60–75 per cent of the cost of the final fertilizer. The nitrogen needed from ammonia manufacture comes from the air; its extraction from air and the provision of the hydrogen needed are achieved by the use of various petroleum products (natural gas, naphtha and fuel oil) or coal. About one ton of petroleum products or two and a half tons of coal are needed to make one ton of ammonia.

The hydrogen can be produced from water by the action of an electric current. This method uses very large amounts of electric power, about 11,000 kWh per ton of ammonia compared with 50 kWh per ton by other processes; it is economic only where large quantities of very cheap electric power are available and cannot be put to better use. It merits consideration in conjunction with large hydro-electric power schemes where the demand for power is otherwise inadequate to justify development. It is not considered further in this chapter.

Ammonia can be used directly in the soil as a fertilizer, and the quantity so used is increasing steadily. At present, the total world consumption of nitrogen fertilizers is about 40 million tons, of which approximately 6 million tons are applied as ammonia, mainly in developed countries. At normal atmospheric temperature, ammonia exists as a gas; when applied as a fertilizer, it is handled as a liquid under pressure in special containers. It's transport, storage and handling call for special techniques and equipment, as well as the stringent observance of safety precautions. It can be applied efficiently only in moist, non-stony soils. Its use is thus limited, even though it is the cheapest form of nitrogen fertilizer available. However, where extensive areas of suitable soils are located reasonably close to a supply of ammonia, its use should be investigated because of its cheapness.

By far the greater part of fertilizer nitrogen is applied as solid fertilizers; about 30 per cent as straight nitrogen fertilizers and 20 per cent in compound fertilizers. The major straight nitrogen fertilizers are ammonium sulphate, ammonium nitrate, and urea, their nitrogen content being 21, 34 and 46 per cent **respectively.**

For many years, ammonium sulphate was the predominant nitrogen fertilizer, but it has since been displaced by the more concentrated ammonium nitrate and urea, and practically no new sulphate plants are being built. Significant quantities are still produced, partly as a by-product of caprolactam manufacture, and partly from gas works and coke ovens.

Ammonium nitrate is widely used in developed countries where, under certain conditions, urea may be less effective. It initially gained ground at the expense of sulphate, but is itself now being displaced to some extent by the more concentrated urea. Ammonium nitrate has the advantage that it can be economically made from imported ammonia alone. Urea, however, whose manufacture also requires carbon dioxide, a by-product of ammonia manufacture, can only be economically made on sites where ammonia is also manufactured. The principal disadvantage of ammonium nitrate is that it requires strict attention to safety precautions during manufacture, storage, handling and transport. It supports combustion and, given the right conditions, can act as an explosive. Many million tons of ammonium nitrate are used annually as fertilizer. However, ammonium nitrate does require more care in handling than other fertilizers, and it may be difficult to arrange its transport by sea.

Because of its high nitrogen concentration and its relative ease of handling, urea is becoming the predominant straight nitrogen fertilizer. It is particularly favoured in developing countries where its use is especially suited to the agricultural and climatic conditions. By 1980, developing countries will be using about six tons of urea to every ton of ammonium nitrate; in developed countries, this ratio will be about 1:1.

The production costs per ton of nitrogen are roughly the same for the different straight nitrogen fertilizers because all are made from ammonia, the production cost of which accounts for two-thirds or more of the fertilizer cost. However, the bagging, transport, storage, handling and application costs per ton of nitrogen fall sharply as the concentration of nitrogen rises, and these costs constitute an important part of the total cost of the fertilizer to the farmer. One ton of urea contains as much nitrogen as 1.3 tons of ammonium nitrate or 2.2 tons of ammonium sulphate, and the costs from factory to farm are roughly in this ratio. It thus becomes apparent why sulphate has been displaced and why the use of urea is continually increasing.

Phosphate fertilizers. The principal phosphate fertilizers are single superphosphate (SSP) containing 16-20 per cent P_2O_5, triple superphosphate (TSP) containing 45-50 per cent, and ammonium phosphate (AP) containing 45-50 per cent P_2O_5 and 10-18 per cent N.

The basic raw material from which all these phosphate fertilizers are made is phosphate rock, containing 30-37 per cent P_2O_5. At present, about 40 per cent of world supplies come from the United States, 25 per cent from North and West Africa, and 20 per cent from the USSR; the remaining 15 per cent comes from a wide range of smaller suppliers. The P_2O_5 in phosphate rock is only slightly soluble,and the rock is subjected to chemical processing to make the P_2O_5 soluble, and therefore more accessible to plants. Some phosphate rock is used directly as a fertilizer, particularly on acid soils, in which the P_2O_5 is more soluble; the amount so used constitutes at present about 8 per cent of total fertilizer P_2O_5. It is by far the cheapest form of P_2O_5 available. Its effect is long-term rather than immediate because of its lower solubility, but its continued application does build up in the soil a reserve of phosphate which is available to plants. The P_2O_5 solubility of different types of rock varies significantly, and the more "reactive" rocks are the most suitable for direct application.

Sulphur is another important raw material used in the manufacture of phosphate fertilizers. It is used to make sulphuric acid, which is reacted with phosphate rock to give SSP or phosphoric acid, from which TSP or AP is made. In recent years, stimulated by shortages and high sulphur prices, processes (nitrophosphate processes) have been developed which do not require sulphur. At present, they do not account for a major part of phosphate fertilizer production, but under certain conditions they can be attractive since they reduce the foreign exchange required for the purchase of raw materials.

Single superphosphate was the original phosphate fertilizer and, for many years, the only phosphate fertilizer. Though it still supplies 25-30 per cent of phosphate fertilizers, it is being rapidly displaced by the more concentrated TSP and AP, and very few new SSP plants are being built.

Its principal advantage is that the process and plant used to make it are relatively simple and do not call for many qualified persons. The economies of scale are much less marked, and comparatively small plants are economically feasible. SSP has the merit of containing sulphur in the form of calcium sulphate (see "Other nutrients" below). Its principal disadvantage is its low concentration which leads to high bagging, storage, transport and application costs. So far the advantages mentioned have not been enough to outweigh these extra costs.

The more concentrated TSP and AP are made by a complex process involving the manufacture of phosphoric acid and its reaction with additional phosphate rock to make TSP, or with ammonia to make AP. Phosphoric acid holds a position in the manufacture of phosphate fertilizers analogous to that of ammonia in the manufacture of nitrogen fertilizers, in that most phosphate fertilizers are made from phosphoric acid, just as most nitrogen fertilizers are made from ammonia. The difference is that 25-30 per cent of current phosphate fertilizers, i.e. SSP, are made without using phosphoric acid, whereas only 1-2 per cent of nitrogen fertilizers are made without prior ammonia manufacture. For new production, however, the positions are closely equivalent; increases in phosphate fertilizer production will come via phosphoric acid, while increases in nitrogen fertilizer come via ammonia.

One important difference between nitrogen and phosphate fertilizers is that a much higher proportion of phosphate fertilizers are used as complex fertilizers, in conjunction with nitrogen or potash, and a much smaller proportion as straight fertilizer. Rather less than 20 per cent of nitrogen fertilizers are used as complex fertilizers as compared with over 50 per cent of phosphate fertilizers. These complex fertilizers can be made simply by mixing the solid fertilizers, such as urea and ammonium phosphates, in any required proportions to produce a fertilizer with a nitrogen/phosphate ratio suited to a particular crop or soil. However, the majority of complex fertilizers are made in the course of phosphate fertilizer manufacture, by means of a granulating process in which ammonia and/or nitrogen fertilizer solids or solutions, and potash are added to phosphoric acid. This process is usually cheaper than simple mixing because the nitrogen can often be added as ammonia, thus avoiding the production of solid nitrogen fertilizer. The mixing process is normally used for small- to medium-scale production, and the granulating process for large-scale production. However, in some developed countries where ammonia, phosphoric acid and fertilizer solutions are readily available, the granulating process is used for medium-scale production.

Other nutrients. While the fertilizer industry is concerned primarily with the supply of nitrogen, phosphorus and potassium, other plant nutrients may assume considerable importance. Chief among these is sulphur, and of lesser importance calcium, magnesium and a wide range of "micro-nutrients", such as zinc, copper and molybdenum: elements required in very small concentrations, but whose absence or gradual removal from the soil may have serious effects upon plant growth. The symptoms of micro-nutrient deficiency are in general well known to agronomists and plant specialists. Where the deficiency of a particular element is established, it is usually practicable to incorporate it into normal fertilizers.

In recent years, much attention has been devoted to sulphur deficiency. The growing importance of sulphur deficiency is partly due to the gradual replacement of the original forms of nitrogen and phosphate fertilizers, ammonium sulphate and single superphosphate, which contain large quantities of sulphur, by more concentrated fertilizers, such as urea and triple superphosphate or ammonium phosphates, which do not contain sulphur. In industrialized countries, significant quantities of sulphur are supplied to the soil when the sulphur dioxide produced by burning coal or fuel oil is washed out of the air; however, this source of supply is generally insignificant in developing countries. As crop yields and the concomitant sulphur removal from the soil increases, sulphur deficiency may arise. In such circumstances, sulphur must be returned to the soil in the form of elementary sulphur or calcium sulphate (a by-product of phosphate fertilizer manufacture), or through the application of such fertilizers as ammonium sulphate and single superphosphate, or of mixtures in which the latter are contained.

Technical developments

It was stated above that the fertilizer industry, being science-based, is subject to continual technical change and development, both in its processes and its products. In the past twenty years, the nitrogen fertilizer section of the industry has experienced major technical and technological change; phosphate fertilizer production has undergone significant, but much less revolutionary changes, while some general trends in the industry have been continued.

Surveying the industry in the mid-1970's, there are no clear indications of a similar extent of change over the next twenty years. However, the research effort devoted to the production and use of fertilisers is so great that even though at present it seems probable that the period will be one of gradual development and not of radical change as in the past, the possibility of major change can never be ruled out. For example, the nitrogen fertilizer industry would be fundamentally affected if it were found possible to produce in the laboratory a variety of nitrogen-fixing symbiotic bacterium which could co-exist in the root area of cereal crops, similar to the genus *Rhizobium* which makes atmospheric nitrogen available to leguminous plants. Short of such revolutionary change, it seems probable that development will continue in directions already broadly mapped out, increasing nutrient concentration, improving the efficiency of fertilizer use, widening the range of raw materials available, improving process efficiency, and reducing costs.

The major changes in nitrogen fertilizer production over the past twenty years have been the development of processes which have made available a much wider range of raw materials, and the increase in typical plant sizes from a few hundred tons a day to a thousand or fifteen hundred tons a day, associated with a major reduction in capital costs.

Twenty years ago, nitrogen fertilizer plants were tied to locations close to their raw materials: natural gas and coal (as coke). The development of the naphtha reforming process aided by the fuel oil-oxygen gasification process brought a new flexibility into the location of plants, since it was now possible to bring the raw materials to the markets and build the plants there. More recently, plants which gasify coal directly with oxygen have been commercially proven. Although the technology has to be developed further, it has greatly increased the possibility of using an indigenous raw material, since coal deposits are large and widely dispersed.

Future developments in process design in coal-based processes are probable, including the ability to predict more reliably the effect of coal and ash types upon performance, the development of pressure gasification processes, and some reduction of the very high capital costs. Over the next two decades, coal-based processes should become more competitive.

Much work has been done on widening the range of hydrocarbons that can be used in the naphtha reforming process, but the results have been meagre. However, the steadily increasing price of naphtha will give an additional impetus to this work because if this trend continues, the naphtha process will soon be priced out of the market. A process permitting the use of heavier hydrocarbons for ammonia manufacture without requiring oxygen would be an important breakthrough.

The large increase in fertilizer plant capacities, with an associate decrease in capital costs per unit of output, has been particularly marked in ammonia plants, but it has also taken place in solid nitrogen fertilizer plants and in phosphate plants. This has been brought about by engineering developments which have made it possible to construct large "single-stream" plants comprising a linked series of large single units instead of a multiplicity of smaller units. The great benefit of this change has been a marked decrease in fertilizer costs which unfortunately has been largely masked by inflation. Though this development has brought significant benefits to all fertilizer users, it has not been without its disadvantages. One disadvantage of particular importance to developing countries has been that the minimum economic plant size has been greatly increased. Prior to this change, countries with a market for 50,000 tons of nitrogen a year could establish a commercially viable plant. Today, a market of about 150,000 tons of nitrogen a year would be about the minimum. Smaller plants are still being built, but they normally require a protected market. The options open to countries with smaller markets are discussed below (see "Manufacturing options") as are the large modern plants (see "Major fertilizer units").

It is improbable that plant sizes will increase further. Plants are now so large that further increases in size bring relatively small gains, and the excessive concentration of production in one factory can lead to serious supply problems if the plant is out of operation for an extended period.

The developments in solid fertilizer production, both nitrogen and phosphate, have been much less spectacular than in ammonia production. Solids are intractable materials to handle and process. Solid fertilizer plants, which of necessity deal with large quantities of solids as raw materials and/or products, are less amenable to increase in unit sizes of equipment than ammonia plants, which deal mainly with gases and liquids. Nevertheless, plant sizes have increased significantly, as has the use of large single-stream plants, though to a lesser extent.

The average nutrient concentration of solid fertilizers has also increased steadily, the incentive being the large savings this brings in bagging, handling and transport costs. Over the past decade, a marked feature has been the very rapid growth in the production and use of urea, particularly in developing countries, as well as a significant increase in the use of ammonia as a fertilizer, mainly in developed countries. The use of concentrated phosphate fertilizers, triple superphosphate and ammonium phosphates has also increased appreciably, and even more concentrated phosphates, ammonium polyphosphates containing 58 per cent P_2O_5, have been introduced into the market.

The increasing use of urea and concentrated phosphates will continue. The major question mark lies over the future of ammonia as a nitrogen fertilizer. It has gained wide popularity in the United States and in a few countries in Western Europe, but it requires a technically complex delivery and application system and is not applicable to all types of soil.

Probably, the most significant development in phosphate fertilizer production has been the commercial exploitation of nitrophosphate processes, which produce an NP or NPK fertilizer by using nitric acid instead of sulphuric acid to dissolve phosphate rock. They therefore differ from all other phosphate processes in not requiring sulphur as a raw material. Established during a period of sulphur shortage and consequently high prices, they have since lost ground once the shortage passed some years ago. The saving of foreign exchange, otherwise used to buy sulphur, may be a deciding factor in some situations; however, it seems improbable that nitrophosphate processes will be widely adopted, unless a long-term sulphur shortage develops.

Another development which may prove highly significant lies in research into the use of ground phosphate rock directly as a fertilizer, without processing. Rock has always been used in this way, particularly in the centrally planned economies in Europe, and at present about 6 million tons, equivalent to about 8 per cent of world phosphate consumption, are used each year. The scientific work being carried out into this use is directed towards demonstrating that, under favourable conditions, the results are comparable with those obtained from superphosphates. It will also provide a basis for predicting what types of rock will do well in what types of soil. A favourable outcome to this research would be of

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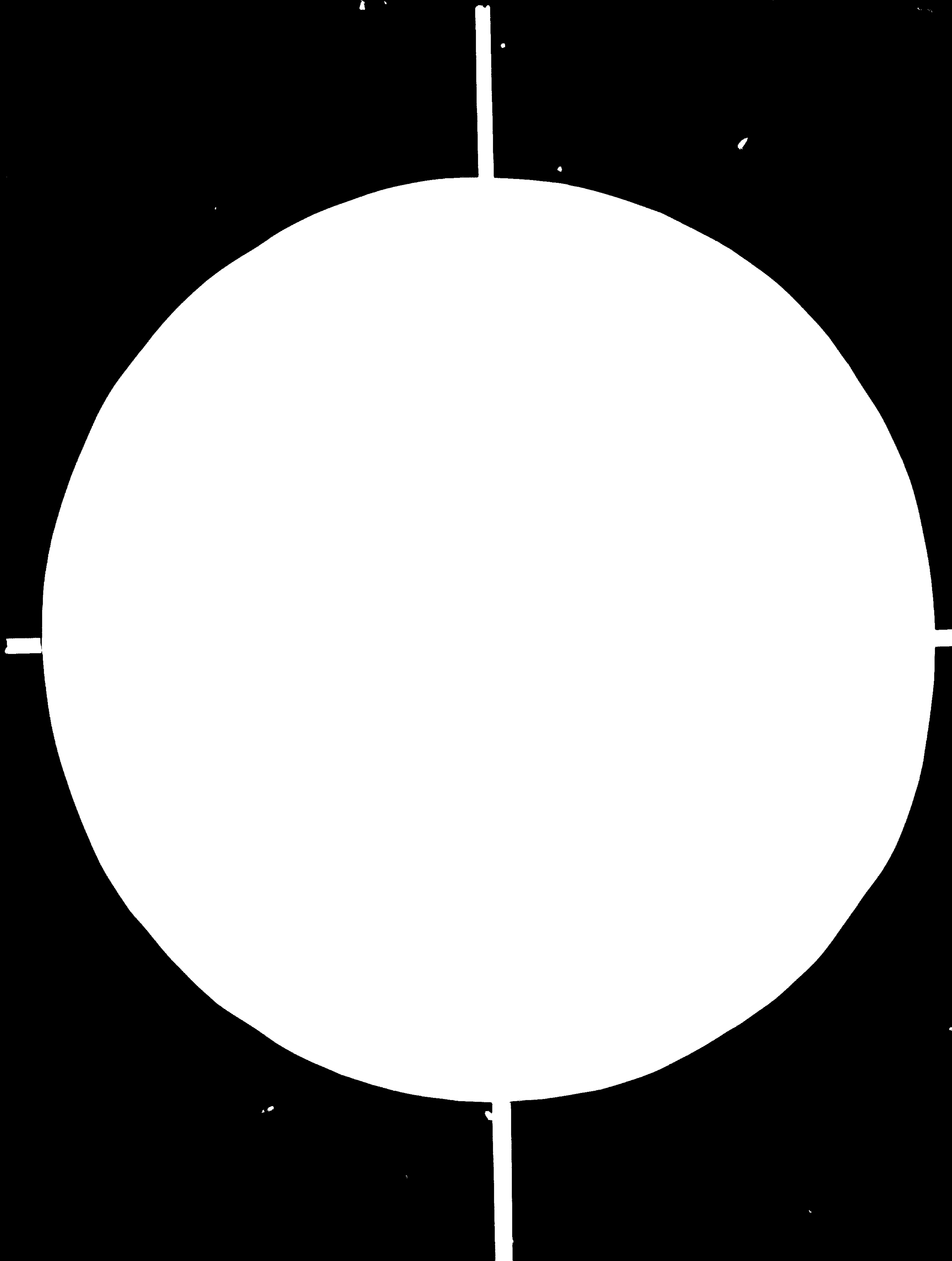

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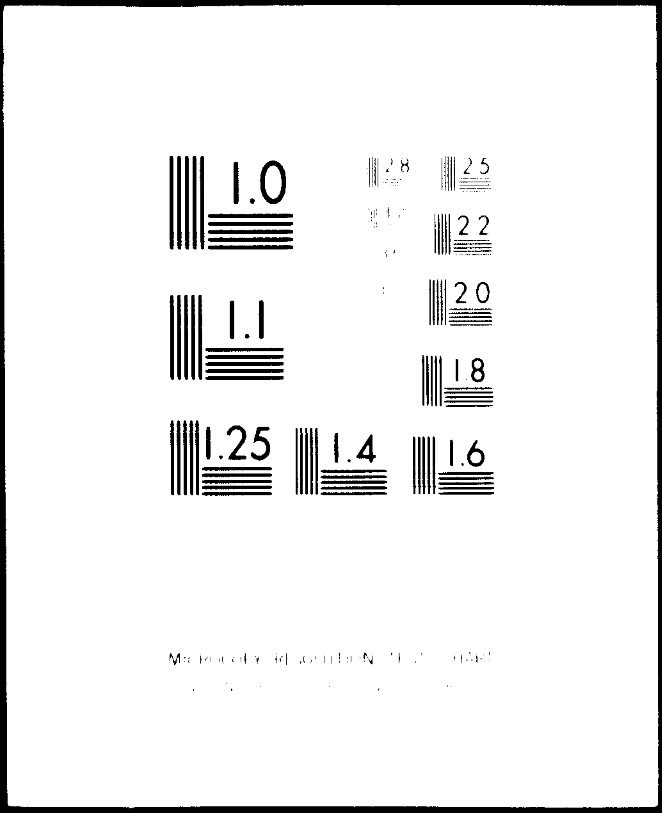

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importance to developing countries because their soils are mostly acid, i.e. those soils in which rock phosphate does best.

Manufacturing options

The estimates of the total capital expenditure required to meet the projected demand from 1980 to 2000 (see "Capital requirements for fertilizer plant: 1980 - 2000" below) are based upon the very large manufacturing units now becoming widespread. These units produce about half a million tons of fertilizer a year and cost hundreds of millions of dollars. These units are the right choice for countries which have the raw materials or markets, the qualified people, and the infrastructure to support them, but they are not the only possible form of fertilizer plant. Countries with smaller markets or without raw materials can enter the fertilizer industry in a number of ways which require much less massive capital expenditure and fewer highly qualified and trained people, but which encourage fertilizer consumption by ensuring local interests a stake in the fertilizer industry.

Bagging and blending plants

When fertilizer demand reaches 50,000-100,000 tons a year, the installation of a simple bagging plant is possible, whereby the fertilizer is imported in bulk and bagged locally. At this scale of operation, bags would have to be imported - unless the demands of local agriculture or industry justify their manufacture - and the value added is small. However, despite the comparatively small scale of operations, it may prove cheaper to bag locally than at the fertilizer manufacturing plant for the following reasons: bulk transport is cheaper than transport in bags, simpler and cheaper bagging equipment can be used, and local labour charges may be lower.

The more usual course is to set up a bagging and blending plant where nitrogen, phosphate and potash fertilizers imported in bulk are mixed to give multi-nutrient NP(K) fertilizers, and subsequently bagged. Imported straight fertilizers would also be bagged at the plant for the local market. A bagging/blending plant costs little more than a bagging plant: the value it adds to the product is higher, the range of services it provides wider. Furthermore, it calls for much greater involvement in the local fertilizer market. The plant is very flexible and can produce a range of products, which would be otherwise difficult or impracticable to import, to suit the needs of particular crops or soils and the preferences of local farmers. It needs a few knowledgeable persons controlling operations and sales and distribution, and unskilled labour can be used for routine plant operation after comparatively little training. At the same time, valuable know-how is acquired in fertilizer handling, bagging, storage, marketing and distribution.

The success of the blending side of the operations depends upon the existence of a market for multi-nutrient fertilizers. If such a market does not exist, it must be developed beforehand by importing NPK fertilizers, demonstrating their advantages and advising farmers on their handling and application. This is the most important single factor, but others need careful consideration. If fertilizer demand is concentrated in a particular period, the capacity of the plant should be so chosen as be able to meet demand during that period, because an increase in capacity entails relatively little expenditure as long as storage capacity is not increased proportionately. Furthermore, if possible, the plant should be located close to the point at which the bulk fertilizers are off-loaded so that they can be transported direct to the plant without intermediate storage. One very important factor which has a decisive effect upon costs is the arrangement of the contracts for bulk supplies. The size of consignment should be as low as is consistent with reasonable prices because it directly determines the working capital required, which can be much larger than the cost of the plant itself. For example, if nitrogen, phosphate and potash fertilizers are imported in 10,000 ton lots, storage facilities must be provided for 30,000 tons of raw materials. If, on an average, these are half-full and if, in addition, the average product stock is 2,500 tons, the working capital for 17[illegible]00 tons would amount to $2.6 million (assuming an average price of $150 a ton) compared with a plant cost of $0.5 to 1.0 million. If 5,000 ton lots could be obtained, the working capital would fall to $1.3 million. Consequently, very careful attention must be paid to the shipping arrangements for the raw materials and a thorough investigation made of the effect on over-all costs of the variation of the delivered prices.

In summary, the costs of a bagging/blending plant must be carefully calculated and a market for multi-nutrient fertilizers established in advance. In many countries, however, its establishment can significantly reduce fertilizer costs, offer better serve to local farmers, create highly desirable local employment and lead to the acquisition of valuable know-how.[2]

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[2] For detailed description and costs of bagging/blending plants, see UNIDO publication Fertilizer Industry Series: Monograph No.8, A Fertilizer Bulk Blending and Bagging Plant (1976).

In addition to forming a starting point for a fertilizer industry with relatively minor capital expenditure, bulk blending plants can also perform a valuable function in a well established fertilizer industry. In this situation they would draw their bulk supplies of single nutrient fertilizers, such as urea and ammonium phosphates, from existing large plants and supplement these with imported potash. With dependence on imports thus greatly reduced, there is much greater freedom in the choice of a location. Bulk blending plants can, and should be, placed close to their markets; they also can develop a close and useful relationship with the local farming community. Because they draw most of their supplies from a local factory, they can operate with much lower stocks, and their working capital, which would otherwise comprise 50-70 per cent of their total capital, is greatly reduced.

The great advantage of a bulk blending plant over a large NPK factory is its flexibility. In order to produce economically, a large factory requires long production runs with the result that it can make only a few grades. A bulk blending plant, however, can produce a wide range of grades to suit local crops and soils.

Single superphosphate plants

It was stated above that, although it still supplies about 25-30 per cent of the phosphate fertilizer market, SSP is being rapidly displaced by more concentrated products, and that very few new plants are being built. However, its role as a provider of sulphur (see "Other nutrients" above) is likely to become increasingly important, and there is still a place for SSP manufacture, mainly in countries where the demand for phosphate fertilizer is fairly small (of the order of 20,000 tons a year or less) or the needs of an area remote from larger plants have to be met.

The process, which involves the manufacture of sulphuric acid from sulphur, the treatment of phosphate rock with that acid, and the granulation and bagging of the SSP thus produced, is more complex than that of a bagging/blending plant. However, the process is still relatively simple and does not require highly skilled people. Its great merit is that the economies of scale are not large: a small plant producing some 50-100 tons a day can be a profitable enterprise and would cost $4-6 million.

The disadvantage of SSP is its low concentration, 16-20 per cent P_2O_5, which makes its transportation over long distances uneconomic. If a plant is under consideration, its size should be carefully determined in terms of the area it can supply in competition with imported concentrated phosphates. The plant should be situated close to its market rather than at the point of supply of phosphate rock and sulphur, since the product weighs twice as much as the raw materials used in its manufacture.

An SSP plant cannot compete with a large plant making TSP or AP and, if demand is large enough, the latter type of plant should be selected. However, many developing countries lack the demand to justify such a plant, and an SSP plant should be seriously considered.

Very large fertilizer plants costing hundreds of millions of dollars are being adopted throughout the world because they produce fertilizers more cheaply than smaller plants. Where adequate raw materials or large enough markets exist, very large plants are the right choice from an economic point of view. However, economics are not everything: such plants make heavy demands upon a country's resources and their establishment may place considerable strains on the social structure of the community in which they are placed. The small unit, such as an SSP plant, can be much more readily integrated into a local community and can be a focus of agricultural co-operation in that community.

Satellite plants

The next possibility after blending/bagging plants and SSP plants is the establishment of medium-sized fertilizer plants based upon the import of one or both of the fertilizer intermediates, ammonia and phosphoric acid. It involves a major step in terms of capital cost and complexity of operations, requires technically qualified people and makes heavier demands of the country's infrastructure. It is a step taken in countries which do not have the basic raw materials, yet have built up a significant fertilizer demand of the order of 30,000-130,000 tons of nitrogen or phosphorous pentoxide a year. Fertilizer demand of this magnitude does not justify the establishment of a large plant based on imported raw materials, but that of a "satellite" plant using imported intermediates may be viable.

Satellite plants have certain limitations. For nitrogen fertilizers, it is desirable to locate the plant within a few kilometres of the point at which the ammonia is off-loaded, so that it can be pumped directly from the ship to plant storage. If the plant is too far away for pumping and the ammonia has to be off-loaded into quayside storage prior to being transported by rail to the plant, the additional costs usually make the project unprofitable. This is also broadly true of the import of phosphoric acid.

A further limitation on nitrogen fertilizer plants is that, if they are to be profitable, ammonium nitrate, and not urea, must be made. The manufacture of urea requires supplies of both carbon dioxide and ammonia. Where ammonia is being produced, this is no disadvantage because carbon dioxide is a by-product of ammonia manufacture. However, if carbon dioxide has to be specially manufactured, the costs of its manufacture would make the urea prohibitively expensive. In developing countries, where urea is often the preferred fertilizer, this may prove a serious handicap. If local farmers have become accustomed to urea, it may be difficult to persuade them to change to ammonium nitrate. This resistance is not agronomically founded because (except for rice grown under flooded conditions) ammonium nitrate is just as good a fertilizer as urea and, in some situations, rather better. Its disadvantages lie solely in its hazardous nature (see "Nitrogen fertilizers" above) and in the greater costs of its storage, transport and application per ton of nitrogen. If a decision is taken to build an ammonium nitrate plant, preliminary market development should be undertaken some years before the plant starts up, unless ammonium nitrate already has a significant share of the market.

Phosphate fertilizer manufacture is subject to no such limitations. A satellite phosphate plant would make TSP or AP and could also make NPK complexes. For TSP, it would be necessary to import some phosphate rock: for AP and NPK, some ammonia, potash and possibly ammonium nitrate or urea would have to be imported. If phosphate and nitrogen fertilizer plants were set up on the same site no imports, other than ammonia, phosphoric acid and potash, would be necessary and the range of products that could be manufactured economically would be greatly increased.

A satellite plant making about 250,000 tons of ammonium nitrate (80-85,000 t N) a year would cost about $35-40 million, and a plant making about 250,000 tons of AP (45,000 t N and 115,000 t P_2O_5) a year would cost about $15-20 million. The considerable difference in cost arises from the fact that the manufacture of AP from phosphoric acid is a relatively simple operation involving the addition of ammonia to the acid, the evaporation of the AP solution and the granulation of the solid. In ammonium nitrate manufacture a similar series of operations is carried out, but it is preceded by the manufacture of nitric acid from imported ammonia.

The establishment of a satellite fertilizer plant represents a major step forward in the fertilizer industry. Its added value is considerable, and it permits significant control of the supply and price of fertilizers for the home market, at a cost much lower than that of establishing a large ammonia/urea plant or a large phosphate plant. As fertilizer demand increases, satellite plants can be readily integrated into complete fertilizer plants using imported raw materials. The economics of these plants need careful investigation in relation to the cost of importing fertilizers, but they offer considerable advantages, not the least of which is a guarantee of an adequate supply at a reasonably stable price.

Major fertilizer units

The major manufacturing units with a daily output of 1,000-1,500 tons of ammonia, 1,700-2,500 tons of urea or 1,000-1,500 tons of AP or TSP, which are now rapidly becoming standard throughout the world, are the outcome of technological changes which have taken place over the last ten to fifteen years (see "Technical developments" above).

These units are not without their disadvantages. Although they are much cheaper than the previous generation of plants, they (particularly ammonia plants) are technologically much more complex and require much greater technical skill and training, in both management and operation. Since single units of equipment are used, these plants are less reliable than the previous generation of multi-stream plants, as many operators have found to their cost. The older plants frequently operated at full output for 340 days a year; in the new plants 300 days is normally regarded as satisfactory. Furthermore, by virtue of its size, one single plant may supply a major part of a country's fertilizer requirements, thus any prolonged failure of the plant may lead to serious fertilizer supply problems. These disadvantages notwithstanding, major plants have gained almost universal favour since they produce fertilizers more cheaply than smaller or multi-stream plants.

A contractor will supply a plant of any capacity required by the client, but the practice of using standard sizes is growing rapidly. For ammonia plants, the most frequent size is 1,000 tons a day, though plants with daily outputs of 1,250 or 1,500 tons are also used; for phosphate plants the most frequent size is 400-600 tons a day. Clients would be well advised to use a standard size of plant wherever possible, because it reduces costs and construction time. Contractors have standard designs for the layout of these plants as well as for the individual items of equipment, thus considerably reducing design charges. Furthermore, since the equipment has already been tested in many plants and any design weaknesses subsequently remedied, the client is in effect purchasing a plant of proven design. These advantages are important and, under normal circumstances, clients would be well advised to select the plant size most closely suited to their requirements.

In the estimates below, it is assumed that the forecast fertilizer demand will be met by these major fertilizer units. As was stated earlier, room still exists for smaller units, ranging from bagging/blending plants to satellite plants, but it remains true that an overwhelming share in fertilizer production will be taken by these very large plants.

Capital and production costs

Capital costs

The most notable fact about capital costs is their very rapid rise in recent years, which is still continuing. From 1972-1976, they have at least doubled. This increase is due partly to general world-wide inflation, and partly to a large fertilizer plant building programme which has led to both shortages of equipment and late deliveries.

This situation has important consequences for capital cost estimates. When considering any estimate, it is essential to bear in mind the date of origin and to make appropriate allowances for subsequent rises in costs. Furthermore, since it takes three to four years to build a plant, inflation may result in actual costs 15-20 per cent higher than the original estimate. (It is for this reason that contractors usually insist on the inclusion of a price escalation clause in their contracts.) Throughout this study, cost figures are based on prices ruling in December 1975, and no allowances have been made for inflation during plant construction. These assumptions have been made because the data cover plants constructed over a twenty year period, i.e. 1980-2000, and it is not possible to predict inflation over so long a period. However, it is important to remember that when any specific plant is built, costs will be significantly higher than the figures given in this chapter.

The major rise in capital costs also has important consequences for the owners of fertilizer plants. Capital charges on new plants account for half to three-quarters of the selling price of nitrogen fertilizers, and efficient use of capital is therefore of primary importance. By choosing a standard size and design of plant and by avoiding delays in construction, the cost of the installed plant is kept to a minimum. Once the plant is in operation, no other factor has as much influence on costs as the loss of production caused by plant shut-downs. In a coal-based ammonia plant, over 80 per cent of the annual operation costs are fixed and do not vary with output. If the plant operates for only 60 per cent of the designed period of time, production costs rise by 50 per cent, and the plant may well be running at a loss (see "Effect of output on production costs" below).

Another important consequence of the rise in capital cost applies to the owners of existing fertilizer plants. In due course when these plants have to be replaced, they will have to be replaced at today's or tomorrow's inflated capital costs. It is important, therefore, that depreciation charges on existing plants should be increased to cope with the higher costs. Depreciation should be based on replacement capital values, and not on historic costs.

Nitrogen fertilizer plants

The capital and production costs of ammonia and urea plants in developing countries are shown in Table 1. The ammonia and urea plants are matched in size, i.e. all the ammonia produced is converted to urea. The production costs have been set out so that adjustments can be made for different feedstock prices or for different rates of depreciation and profit.

It has been assumed that the solid fertilizer produced will be urea since this is by far the most popular solid fertilizer in developing countries. As far as costs are concerned, it makes no difference whether the final product is urea or ammonium nitrate, since the capital and production costs per ton of nitrogen are practically the same.

In Table 1[3] particular attention should be paid to items (i), (ii) and (iii) in footnote [c]. Items (ii) and (iii) were excluded because their cost varies so widely from one project to another. They can increase the fixed capital cost by as much as 40 per cent, but on an average the additional cost is probably 25-30 per cent. These costs must be included in any specific project estimate.

It should be noted that when these costs are included in the plant capital, the depreciation and profit charges shown in the table should also be increased by 25-30 per cent, corresponding to an increase of $15-30 per ton of urea, depending upon the raw material.

Choice of Feedstock. The table clearly shows why natural gas is always used as feedstock when it is available: the capital and the production costs are much lower than for any other feedstock.

At the feedstock prices and capital charges used in Table 1, naphtha, fuel oil, and coal do not differ significantly. Naphtha and fuel oil suffer in comparison with natural gas owing to their high feedstock charges; coal has low feedstock charges, but very high capital charges. Relatively large changes in feedstock prices would have little effect on the cost of urea produced from natural gas or coal, but a major effect on that of urea produced from naphtha or fuel oil.

The choice between naphtha, fuel oil and coal is a difficult one. Coal is by far the most widely distributed feedstock and constitutes about 90 per cent of world fuel resources. In the long term, therefore, coal will doubtless become a major feedstock but at present, processes using coal are much less widespread and consequently less technically developed than processes using naphtha or fuel oil.

Processes using coal also face the inherent difficulty that coal is a much less standard product than naphtha or fuel oil, and therefore have to be designed to suit the particular grade of coal available to each specific project. In Table 1 some allowance has been made for these difficulties by taking 300 days full output for all processes except coal, for which only 280 days have been allowed.

Countries with a market that will support several major nitrogen fertilizer plants and with their own coal resources would be well advised to consider seriously at least one coal-based plant. If the market supports only one major plant, it would, under present circumstances, be safer to use another feedstock.

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[3] Numbered tables are at the end of the chapter.

For those countries which do not have indigenous fuel resources, the choice between naphtha and fuel oil will depend on the view taken of the probable future changes in their prices. Naphtha has important chemical uses for which it cannot be replaced by fuel oil, and its price is becoming increasingly tied to gasoline prices. Fuel oil prices, on the other hand, are more closely related to the prices of alternative fuels, such as natural gas and coal.

Effect of output on production costs. It was stated earlier (see "Capital costs" above) that no other factor has as much influence on costs as the full utilization of the capacity of the plants. No plant can be expected to run continuously for 365 days a year. The plant must be shut down occasionally for routine maintenance and on account of equipment failures. It is customary to rate the capacity of a plant as equal to the designed daily production for 330 days a year. Under favourable circumstances, this output may be achieved: however, most plant operators find it difficult to achieve 90 per cent of this target, i.e. approximately 300 days a year. These levels of production (the "design rate") are assumed in the costs set out in Table 1, except for the costs shown for coal-based plants. The table below shows the serious increase in production costs which occurs when loss of output exceeds this level.

Effect of output on urea costs

Feedstock	Natural gas	Naphtha	Fuel oil	Coal
	($ per ton of urea)			
Design rate[a]	102	168	158	165
80 per cent of design rate	121	190	182	193
60 per cent of design rate	154	225	222	251

[a] Design rate = 300 days a year for natural gas, naphtha and fuel oil, and 280 days for coal.

A 20 per cent drop in output increases production costs by 15-20 per cent. The effect, in absolute terms, is naturally most severe in plants with high capital costs, such as coal-based plants. The figures above illustrate the importance of assessing plant performance realistically when calculating production costs.

Phosphate fertilizer plants

The capital and production costs of a large phosphate fertilizer complex are given in Table 2. The complex comprises a sulphuric acid plant with a daily output of 1,600 tons, a phosphoric acid plant with a daily output of 600 tons P_2O_5, and a matching solid fertilizer plant producing non-ammonium phosphate (MAP: 11 per cent N and 46 per cent P_2O_5) or triple superphosphate (TSP: 46 per cent P_2O_5), only one of which is made at any given time. The solid fertilizer plant may produce DAP for two or three months and then switch to TSP or MAP as required.

Table 2 shows that the P_2O_5 output is greater when making TSP than when making DAP. When DAP is made, ammonia is added to phosphoric acid to produce ammonium phosphate, an NP fertilizer. The P_2O_5 production cannot be greater than the P_2O_5 in the acid. When TSP is made, the acid is added to phosphate rock, which itself contains P_2O_5, so that the total P_2O_5 output is increased; in the case shown in Table 2 this increase is about 200 tons per day. It is for this reason that TSP has a much lower production and capital cost per ton of P_2O_5. The important figure is the cost per ton of nutrient, which is the same for both products.

Nitrogen and phosphate fertilizer costs

Having estimated the capital and operating costs for the production of both nitrogen and phosphate fertilizers, it is interesting, at this stage, to compare them. The relevant data are set out below: the figures have been rounded off.

Comparison of nitrogen and phosphate fertilizer costs in developing countries

	Nitrogen fertilizers				Phosphate fertilizers	
Product	Urea (46% N)				TSP (46% P_2O_5)	DAP (18% N, 46% P_2O_5)
Output (tons nutrient/yr)	220,000-240,000				220,000-240,000	
Raw materials	Natural gas	Naphtha	Fuel oil	Coal	Sulphur and phosphate rock	
Total capital cost ($/ton nutrient/yr)	750	840	930	1,230	DAP 545	TSP 570
Production costs ($/ton nutrient)						
Raw materials	30	160	115	60	210	210
Processing costs	55	66	65	80	65	75
Capital charges	135	150	165	220	95	95
Total	220	370	345	360	370	380

The most striking feature of the above comparison is the low cost of nitrogen fertilizers produced from natural gas; apart from this, the costs of both nitrogen and phosphate fertilizers are comparable. This low cost is primarily due to the current cheapness of natural gas in developing countries and reflects one of their major advantages for nitrogen fertilizer production. Some developing countries have a corresponding advantage in phosphate fertilizer production, i.e. the possession of indigenous supplies of phosphate rock. A country having rock available at $20 a ton, for instance, would have a raw material cost of $110 a ton of nutrient, and DAP and TSP costs of $270 and $280 a ton of nutrient respectively: a very large reduction.

A second striking feature is the very high capital cost of coal-based nitrogen fertilizer plants and the consequently high capital charges. This notwithstanding, coal is able to maintain a competitive position with naphtha and fuel oil because it is so cheap. Experience in the design and operation of coal-based plants is limited, and as design developments occur and operating experience increases, it is probable that costs will drop. However, it is also probable that, in the long term, coal will be used as a raw material only by those countries which lack natural gas and petroleum deposits.

The table above also shows a marked difference in the cost structure for nitrogen and phosphate fertilizers. Raw materials account for rather more than half the cost of phosphate fertilizers, whereas for nitrogen fertilizers the proportion is generally much smaller, ranging from 15-40 per cent. Efficiency in the use of raw materials is, therefore, of major importance in phosphate fertilizer production: plants must be designed and operated with particular attention to the efficient use of raw materials. Conversion costs are similar for both types of fertilizer and account for about 20 per cent of total costs.

The capital charges for phosphates are appreciably lower than those for nitrogen fertilizers, some 25 per cent of total costs as compared with 40-60 per cent. It follows from this that though obviously always undesirable, loss of output does not have so drastic an effect upon phosphate fertilizer costs as it has upon nitrogen fertilizer costs. It also follows that increasing plant sizes contributes less to cost reduction in phosphate fertilizer production than in nitrogen fertilizer production, i.e. the benefits of very large manufacturing units are less marked. In planning a national fertilizer industry, therefore, phosphate fertilizer production can be economically justified at a lower level of demand than would be required for a nitrogen fertilizer plant. In regional or sub-regional planning, the desire for some degree of national self-sufficiency can be met in phosphate fertilizer production with less economic disadvantage than in nitrogen fertilizer production. This difference in the economies of scale is reflected in practice. The overwhelming majority of ammonia plants being built today are large units with a capacity of 1,[illegible] or 1,5[illegible] tons per day. With phosphate plants, the range of sizes is much greater: many new plants are much smaller than the complex (daily output [illegible] tons P_2O_5) costed in this chapter.

Complex fertilizers

The costs given in Table [illegible] cover one straight phosphate fertilizer (TSP) and one complex NP fertilizer (DAP). In practice, about [illegible] per cent of the world phosphate fertilizer consumption is in the form of complex fertilizers containing NP, NK, PK or NPK in a wide variety of nutrient ratios and concentrations. The plant used to make complex fertilizers is similar to a DAP plant, but differs in that the DAP solution is mixed with ammonium nitrate or urea, as solids or in solution, as well as with solid potash, before the solid fertilizer is produced. The nutrient ratios can be readily altered by adjusting the quantities of nitrogen fertilizer or potash added to the DAP solution.

The capital cost (per ton of P_2O_5) of plants producing complex fertilizers is the same as that of DAP plants up to the point at which the nitrogen fertilizer and potash are added. Thereafter the capital cost for complex fertilizers is slightly higher owing to the greater volume of solids to be stored and bagged. This adds about 10-15 per cent to the cost of DAP plant itself. Since the DAP plant cost is only about 20 per cent of the total capital cost of the whole unit, which comprises a sulphuric acid plant, a phosphoric acid plant and the DAP plant, the over-all increase is only 2 to 3 per cent for roughly half the P_2O_5 manufactured. In the calculation of total capital requirements cited below, this slight increase has been neglected.

Capital requirements for fertilizer plants: 1980-2000

Selection of target production for developing countries

In this section, estimates are presented of the total capital cost of the new fertilizer plants needed to meet the fertilizer demand forecast in Chapter II (see pages [illegible] and [illegible]7).

Separate estimates are necessary for developing and developed countries. It costs more to build a plant in a developing country than it does in a developed country: the additional cost varies from country to country, but on an average the cost in a developing country is about 30 per cent greater. Moreover, under present conditions, the annual production of a plant in a developing country is usually less than that of a plant of the same size in a developed country, so that more plants are needed to reach a target production.

These reasons notwithstanding, separate estimates are necessitated by the very nature of this study which arises out of the Lima Declaration adopted at the Second General Conference of UNIDO, in which it is stated that "in view of the low percentage share of the developing countries in total world industrial production....their share should be increased to the maximum possible extend and as far as possible to at least 25 per cent of world industrial production by the year 2000"[2].

In the light of this statement, and given the future consumption estimates set out in Chapter II as well as the nature of the fertilizer industry, a reasonable and practicable target to set for the developing countries' share of production by the year 2000 has to be decided upon. It is obvious that at present, we can do no more than select a target which, on the basis of the information available, does not appear unreasonable. Forecasts extending up to the year 2000 are of necessity very uncertain; they will require revision as time passes, and major unforeseen technical changes may occur in both agriculture and fertilizer use. Furthermore, it is difficult to formulate criteria by which the practicability of a given target can be judged. One obvious guide is the past history of the industry, and data relating to the developing countries' production of nitrogen and phosphate fertilizers are given below:

Fertilizer production in the developing countries
(Millions of tons of N and P_2O_5)

Production	1950	1955	1960	1965	1970	1975	1980	2000
Developing countries	0.62	1.03	1.65	3.17	6.39	12.21	(26.2)	?
World	9.94	14.7	20.3	31.3	49.4	68.0	(94.2)	(260)
Developing countries (per cent)	6.2	7.1	8.1	10.1	12.9	18.0	(27.8)	?

(Production figures based on data in Chapter II: pp. 22 and 27, and Table 1.

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[2] Lima Declaration and Plan of Action on Industrial Development and Co-operation, page 5, paragraph 28 (PI/38)

The developing countries' production and their share of the world fertilizer production have been rising continually over the past twenty-five years, and at an accelerated rate over the last ten or fifteen years. At 18 per cent, their current share in world fertilizer production is already well above their average share of 7 per cent in world industrial production, and it is clear that it should be possible to achieve a target for the fertilizer industry appreciably higher than the global target of 25 per cent. Indeed the 1980 estimates, which are based on expansion programmes already in hand, show that the 25 per cent share should be reached in the next few years. Expansion at the rate envisaged for 1975 to 1980 would result in a production by 2000 of about 90 million tons of nutrients or about 35 per cent of world production. It is too early to be certain that the 1980 estimates will prove correct, but if they are, it would seem that a target of 35 per cent or more should be possible.

A special feature of the fertilizer industry is its direct connection with food supply. If the developing countries themselves do not produce the fertilizers they need, they will have to import them if their nutritional standards are to be maintained. In this context, it is of interest to consider the effect of various shares in nitrogen and phosphate fertilizer production upon the requirements of foreign exchange for fertilizer supply. Shown below is an approximate estimate of the position by the year 2000, assuming the current average price of $300 per ton of nutrient:

Share in fertilizer production and its effect upon foreign exchange requirements for fertilizer imports, 2000

Developing countries' share in production (per cent)	25	30	35	40	45	50
Imports/exports (million tons N and P_2O_5)	33.8	21.7	9.7	-2.3	-14.4	-25.6
Foreign exchange required ($billion)	10	6.5	3	-0.7	-4	-7.5

It is clear that targets of 25 or 30 per cent are unacceptably low, and that even at 35 per cent, import requirements would involve a heavy drain on foreign exchange. A share of about 40 per cent seems to be the lowest reasonable target from the standpoint of foreign exchange savings.

It would thus appear that, in the light of the developing countries' production record and their need to conserve foreign exchange, a target of about 40 per cent, corresponding to approximate over-all self-sufficiency, would be an obvious one to aim at. However, it may be possible to achieve still more, and two targets have been selected for further study: the first (Alternative A) is over-all self-sufficiency of the developing countries, equivalent to approximately 40 per cent of world production; the second (Alternative B) is a 50 per cent share in world production, which would require significant exports (about 20 per cent of production) to the developed countries. It is evident that developed countries will import fertilizers from developing countries only when importation is cheaper than local manufacture. A detailed justification of a 50 per cent target would call for a comparison of manufacturing costs in specific developing and developed countries. Such an analysis, however, would be deviating from the main purpose of this study, and the case for considering a 50 per cent target rests on the fact that it is not self-evidently impracticable, and that there is an <u>a priori</u> case for exports to the developed countries from some developing countries, such as North Africa for phosphates and the Middle East for nitrogen.

Basically, the success of any industrial enterprise depends upon men, money, and materials. As far as the latter are concerned, it is shown in the following chapter that the developing countries as a group have an adequate supply of raw materials for either a 40 or 50 per cent target. The position in respect of money is not so clear. Table 3 of this chapter shows a capital requirement for fertilizer plants in developing countries from 1980-2000 of approximately $55 billion for a 40 per cent target, and $80 billion for a 50 per cent target. When account is taken of raw material development and of the costs of fertilizer distribution, the figures could well be $100 billion and $130 billion. It seems improbable that developing countries could meet these demands from their own resources and some form of co-operative international financing will probably be needed.

The demand for trained and qualified people to operate, maintain and manage the fertilizer plants and to "sell" the fertilizer to the farmer may prove to be the limiting factor. These requirements are the subject of the Annex to this study. The present expansion of the fertilizer industry in developing countries is already placing a heavy strain on current resources: this is shown, in some instances, by delays in plant construction and by troubles in the operation of the plants. In the rush to get plants financed and built, this problem runs the risk of being neglected, partly because the need to build plants is so obvious and so pressing, and partly because investment in people is long term and does not yield easily quantifiable results. Co-operative planned effort in education and training between governments and fertilizer manufacturers on a national and regional scale is essential, if either a 40 or 50 per cent target is to be met.

Capital requirements

The results of the calculations are summarized in Table 3: they are set out in more detail for nitrogen fertilizers in Tables 4 and 5, and for phosphate fertilizers in Table 6. Further details with notes on the method of calculation are given in the Annex to this chapter. However, there are two steps in the calculation which have a major effect upon the results and which require discussion.

The first step concerns the assumptions made about plant utilization. The work that has been done for the UNIDO/FAO/IBRD Working Party on Fertilizers shows that nitrogen fertilizer plants in the developing countries are operating at about 60 per cent of design capacity. By 1980, it is expected that the 30 million tons of nitrogen capacity in these countries will be producing only 18 million tons of nitrogen. If plant utilization could be increased to 85-90 per cent which is normal in developed countries, the same capacity would produce about 26 million tons of nitrogen. Thus, it is obvious that the assumptions made about plant utilization have a major effect upon the estimate of the new plant required to meet the increasing fertilizer demand.

Developing countries get less production from their plants for a number of reasons. First, numerous new plants are being started up and they take some years to settle down to their design capacity. The high proportion of new plant, therefore, reduces the average utilization of existing capacity. Secondly, the infrastructure in developing countries is less reliable; power supplies may fail or be cut off, and raw materials or essential spare parts may not arrive on time. Thirdly, the skilled and experienced people needed to manage, operate and repair the plants are in short supply. It is to be expected that as time passes, these causes of low output will become less pressing and that plant utilization will steadily improve.

The following assumptions were made for the calculation of plant capacity needed to meet the fertilizer demand in developing countries; they lead to the per cent utilization figures given in Tables 4, 5 and 6:

(a) Plant existing in 1980 achieves 60 per cent design output in 1980, 65 per cent in 1985, 70 per cent in 1990 and 75 per cent in 2000. (Lower output is expected from plant existing in 1980, because some units will be old and others will have been built before the technology was fully developed.);

(b) New plant achieves 40 per cent design output in its first year, 60 per cent in its second, 80 per cent in its third, and 90 per cent thereafter;

(c) Designed annual output is 330 days at designed daily output.

The second important step in the calculation refers to the assessment of "replacement capacity". Like motor cars, chemical plants do not last forever. Over the years, and particularly in the closing stages of a plant's life, maintenance costs rise and plant failures, leading to loss of production, increase. Eventually, a point is reached at which the sensible and economic course is to scrap the plant and replace it with a new more modern plant.

The fertilizer industry is in a continual state of change brought about by technical development; breakthroughs may render a plant uneconomic and obsolete long before it has physically deteriorated to the point at which it requires replacement. Although breakthroughs are rare, processes, equipment and control systems are being continually improved, and over the years this has a cumulative effect upon the life of existing plants.

Due allowance has been made in the calculations for the fact that fertilizer plants have a limited life by adding to the estimate of the plant required to meet increasing demand, an estimate of the existing capacity which will have to be replaced. In making this assessment, it has been assumed that the life of a nitrogen fertilizer plant is 30 years, and that of a phosphate fertilizer plant 25 years. (The shorter life cited for phosphate plants reflects the more corrosive conditions in these plants together with the wear and tear involved in pumping and handling slurries.)

FAO fertilizer production statistics show the production of nitrogen and phosphate fertilizers year by year for both developing and developed countries. In calculating the replacement capacity required from 1980-1985 for example, it was assumed that the increase in production in developing countries from 1950-1955 for nitrogen fertilizers and from 1955-1960 for phosphate fertilizers was obtained through a 60 per cent utilization of additional plant. The capacity which requires replacement in 1980-1985 is, therefore, equal to the increase in production for 1950-1955 divided by 0.6.

The estimates set out in Table 3 show a total capital requirement of approximately $120 billion for the period 1980-2000. The costs, from which this total sum has been derived, are based upon December 1975 prices and exclude allowances for both inflation and interest charges incurred during plant construction. If allowance were made for these two items, the total cost would rise by 20-25 per cent to $150-160 billion. If the capital to be invested in plant to supply the additional raw materials as well as the capital required for the marketing and distribution of the additional fertilizers were also to be added, the total capital required would be at least double that needed for the fertilizer plants themselves.

Tables 1 - 6 of Chapter III
begin overleaf

Table 1. Capital and production costs of ammonia-urea plants in developing countries

Feedstock	Natural Gas		Naphtha		Fuel Oil		Coal	
Feedstock price ($)[a]	0.5/1,000scf		140/ton		80/ton		12.5/ton	
Output: ammonia tons/day	1,000	600	1,000	600	1,000	600	1,000	600
urea tons/day	1,720	1,030	1,720	1,030	1,720	1,030	1,720	1,030
urea '000 tons/year[b]	516	310	516	310	516	310	483	290
Capital costs ($m): ammonia[c]	103	72	115	80	140	98	195	130
urea[c]	67	47	67	47	67	47	67	47
Total fixed capital	170	119	182	127	207	145	262	177
Working capital	9	5	17	10	14	8	12	7
Total	179	124	199	137	221	153	274	184
Total: $/ton/N/yr.	754	871	839	962	931	1,075	1,234	1,381
Production costs ($/ton urea):								
Feedstock and fuel[d]	13.7	13.7	73.0	73.0	52.4	52.4	26.3	26.3
Other operating costs[e]	25.9	30.0	27.2	31.8	29.5	34.4	36.5	44.1
	39.6	43.7	100.2	104.8	81.9	87.8	62.8	70.4
Depreciation (8 1/3 per cent)[f]	27.5	32.0	29.5	34.2	33.4	39.0	45.4	50.9
	67.1	75.7	129.7	139.0	115.3	126.8	104.2	121.3
Profit (10 per cent)[g]	34.7	40.0	38.7	44.2	42.8	49.4	56.7	63.4
Total	102	116	168	183	158	176	162	185

a/ **The assumptions underlying the feedstock prices are that** naphtha **and fuel** oil **are** imported: natural **gas** is **in surplus; and the coal-based plant is located near the coalfield.**

b/ The **annual** outputs are calculated assuming 300 days a year at full production for natural gas, naphtha and fuel oil, and 280 days for coal.

c/ The division between ammonia and urea is somewhat arbitrary since the two plants use a common site and facilities. The ammonia plant costs include a 10–15 mW power station to make the plants independent of external power supplies. The capital costs:

- (i) Are based on December 1975 prices;
- (ii) Make no allowance for inflation or for interest charges during plant construction;
- (iii) Exclude road and rail connections to the site, water supply and effluent disposal outside the site boundary, as well as housing and amenities for employees;
- (iv) Include a 10 per cent contingency allowance and pre-operating expenses at 2.5 per cent of fixed capital;
- (v) Refer to plants in developing countries on a "green field" site;
- (vi) Include one month's storage capacity for feedstock/fuel; and for the large plants, storage capacity for 4,000 tons ammonia, 75,000 tons bulk urea and 10,000 tons bagged urea.

d/ Includes feedstock for ammonia production, and fuel for steam and power generation. Where natural gas is available as a feedstock, it is also used as fuel; in the other plants, coal is used as fuel. Where coal is used as feedstock, a relatively low-grade material (a calorific value of 4,500 cal/kg) is assumed. The same material is used as fuel in the naphtha and fuel oil-based plants, but at a cost of $ 17.5 a ton to allow for higher transport costs.

e/ Includes bags (50 kg. polythene) at $ 6.9 a ton, taxes and insurance at 0.5 per cent of fixed capital, selling expenses at $ 1.6 a ton for the larger plant and $ 2.0 a ton for the smaller plant, and maintenance. Maintenance is taken as 2.5 per cent of capital for natural gas and naphtha ammonia plants; 2.75 per cent for fuel oil ammonia plants; 3 per cent for coal ammonia plants; and 3.5 per cent for urea plants.

f/ This gives complete depreciation over twelve years.

g/ This is an arbitrary figure and is low for any normal commercial organization.

Table 2. Capital and production costs of phosphate fertilizers in developing countries

	DAP	TSP
Output		
Product tons/day[a]	1,275	1,715
P_2O_5 tons/day[a]	587	789
Product tons/year[b]	378,750	509,350
P_2O_5 tons/year[b]	174,200	234,330
Capital costs ($m)		
Fixed capital[c]	115	115
Working capital[d]	17	17
Total	132	132
$ per ton P_2O_5	758	568
Production costs ($/ton P_2O_5)		
Raw materials[e]		
Phosphate rock	168.0	171.0
Sulphur	51.5	38.5
Ammonia	75.0	-
	294.5	209.5
Maintenance[f]	39.6	29.5
Other operating costs[g]	49.0	42.3
	383.1	281.3
Depreciation (8 1/3 per cent)	55.0	40.9
Plant cost	438.1	322.2
Profit (10 per cent)	75.8	56.4
Total: $ per ton P_2O_5	514	379
$ per ton nutrient	369	379
$ per ton product	236	174

Table 2. (cont'd)

[a] DAP contains 18 per cent N and 46 per cent P_2O_5.

TSP contains 46 per cent P_2O_5.

[b] Annual output = daily output x 330 x 0.9 = daily output x 297

[c] Costs are for a developing country, on a "greenfield" site; they are based on December 1975 prices and exclude inflation, interest charges during construction, road and rail connections, water supply to the site, effluent disposal outside the site boundary as well as housing and amenities for employees. They include a 7 mW power station and one month's storage capacity for raw materials and 60 days' product storage in bulk

[d] The major item is credit for 45 days' sales at plant cost

[e] This covers 3.365 tons rock (32.1 per cent P_2O_5) at $[illegible] a ton, 0.94 tons of sulphur for DAP and 0.7 tons for TSP at $55 a ton, and 0.5 tons ammonia for DAP at $150 a ton. The assumption underlying these prices is that all these raw materials are imported

[f] Maintenance includes materials and labour and is taken as 6 per cent of fixed capital

[g] This includes utilities, bags at $6.5 a ton of product, labour, management, overheads, taxes and insurance, and sales expenses.

Table 3. Summary of plants required and total capital cost, 1980-2000

(Costs in billion $US)

	Developing countries				Developed countries			
	1980-85	1985-90	1990-2000	1980-2000	1980-85	1985-90	1990-2000	1980-2000
Alternative A								
No. of 1,000 tpd ammonia plants	40	50	126	216	57	66	225	348
No. of 1,720 tpd urea plants	33	36	99	168	51	55	184	290
No. of 600 tpd phosphate complexes	21	28	92	141	14	47	121	182
Ammonia capital	4.4	5.7	14.5	24.6	4.7	5.7	18.9	29.3
Urea capital	2.3	2.4	6.6	11.3	2.6	2.8	9.0	14.4
Phosphate capital	3.0	4.0	12.5	19.5	1.3	4.8	12.0	18.1
Total capital	9.7	12.1	33.6	55.4	8.6	13.3	39.9	61.8
Alternative B								
No. of 1,000 tpd ammonia plants	48	67	186	301	50	46	165	261
No. of 1,720 tpd urea plants	40	49	154	243	43	41	132	216
No. of 600 tpd phosphate complexes	21	56	111	188	14	22	100	135
Ammonia capital	5.4	7.9	22.5	35.8	4.1	3.8	13.4	21.3
Urea capital	2.8	3.4	10.4	16.6	2.2	2.0	6.2	10.4
Phosphate capital	3.0	8.2	15.4	26.6	1.3	1.9	9.7	12.9
Total capital	11.2	19.5	48.3	79.0	7.6	7.7	29.3	44.6

Notes: (1) Capital costs for developing countries are based upon the costs given in Tables 1 and 2. For developed countries, the capital cost is assumed to be 77 per cent of that in a developing country. The cost of a replacement plant is assumed to be 70 per cent of the cost for a new plant, since such plants will usually be built on a developed site.

(2) It is assumed that new phosphate fertilizer production will be 20 per cent TSP and 80 per cent M/DAP.

Table 4. Nitrogen fertilizers - plant required and total capital cost: 1980-2000 (Alternative A)

(Except where otherwise stated, all figures are in million metric tons of nitrogen)

	Developing countries				Developed countries			
	1980	1985	1990	2000	1980	1985	1990	2000
Ammonia								
Forecast demand	20.0	28.5	38.6	63.5	40.3	52.7	66.9	100.6
Production	18.6	29.4	41.8	69.0	43.7	57.2	71.2	108.1
Utilization per cent	60.0	71.0	77.5	83.0	80.0	86.0	88.0	88.0
Production capacity	31.0	41.6	54.1	82.9	54.6	67.1	81.3	123.2
Increase in capacity		10.6	12.5	28.8		12.5	14.2	41.9
Capacity replaced		0.4	0.6	5.5		3.0	3.8	19.4
Total new capacity		11.0	13.1	34.3		15.5	18.0	61.3
Plants (1,000 t/day)		40	50	126		57	66	225
Cost: $ billion		4.4	5.7	14.5		4.7	5.7	18.9
Solid fertilizers								
Production	16.6	24.9	34.1	51.1	31.9	43.1	54.4	84.3
Utilization per cent	60.0	70.0	76.0	82.5	80.0	84.5	86.0	87.5
Production capacity	27.7	35.9	44.7	65.7	39.9	51.0	62.6	96.5
Capacity increase		8.2	8.8	21.0		11.1	11.6	33.9
Capacity replaced		0.3	0.5	4.9		2.2	2.8	14.2
Total new capacity		8.5	9.3	25.9		13.3	14.4	48.1
Urea plants (1,720 t/day)		33	36	99		51	55	184
Cost: $ billion		2.3	2.4	6.6		2.6	2.8	9.0

Notes:
(1) Note 1 to Table 3 also applies to this Table.
(2) N production is higher than demand (in 1980 an allowance is made for imports to developing countries) to cover increases in stocks, and losses in the conversion of ammonia to solid fertilizers.
(3) The N production as urea is lower than it is as ammonia because some ammonia is used directly as a fertilizer; there are losses in converting ammonia to urea; and some ammonia is used in making ammonium phosphates.

Table 5. Nitrogen fertilizers - plant required and total capital cost: 1980-2000 (Alternative B)

(Except where otherwise stated all figures are in million metric tons of nitrogen)

	Developing countries				Developed countries			
	1980	1985	1990	2000	1980	1985	1990	2000
Ammonia								
Forecast demand	20.0	28.5	38.6	63.5	40.3	52.7	66.9	100.6
Exports/imports	-2.8	-	+5.0	+17.8	+1.4	-	-5.0	-17.8
Production	18.6	30.9	47.3	88.6	43.7	55.7	65.7	88.6
Utilization per cent	60.0	71.0	77.5	83.0	80.0	86.0	89.0	89.0
Production capacity	31.0	43.7	61.2	106.3	54.6	65.1	73.7	99.2
Increase in capacity		12.7	17.5	45.1		10.5	8.6	25.5
Capacity replaced		0.4	0.6	5.5		3.0	3.8	19.4
Total new capacity		13.1	18.1	50.6		13.5	12.4	44.9
Plants (1,000 t/day)		48	67	186		50	46	165
Cost: $ billion		5.4	7.9	22.5		4.1	3.8	13.4
Solid fertilizers								
Production	16.6	26.4	38.4	70.6	31.9	41.6	50.3	68.8
Utilization per cent	60.0	69.5	76.5	82.5	80.0	85.0	87.5	89.0
Production capacity	27.7	38.0	50.2	85.5	39.2	49.0	56.8	77.2
Increase in capacity		10.3	12.2	35.3		9.1	7.8	20.4
Capacity replaced		0.3	0.5	4.9		2.2	2.8	14.2
Total new capacity		10.6	12.7	40.2		11.3	10.6	34.6
Urea plants (1,720 t/day)		40	49	154		43	41	132
Cost: $ billion		2.8	3.4	10.4		2.2	2.0	6.2

Notes: See Table 4.

Table 6. Phosphate fertilizers - plants required and total capital cost: 1980-2000

(Except where otherwise stated all figures are in million metric tons of P_2O_5)

	Developing countries				Developed countries			
	1980	1985	1990	2000	1980	1985	1990	2000
Alternative A								
Forecast demand	9.1	13.3	18.2	30.4	23.9	28.7	34.1	46.3
Exports/imports	-0.1				+2.4			
	9.0	13.3	18.2	30.4	26.3	28.7	34.1	46.3
Stock/losses (5%)	0.5	0.7	0.9	1.5	1.3	1.4	1.7	2.3
Production	9.5	14.0	19.1	31.9	27.6	30.1	35.8	48.6
Utilization per cent	60	72	78	83	80	85	87	87
Capacity	15.8	19.6	24.6	38.3	34.5	35.4	41.4	55.8
Increase in capacity		3.8	5.0	13.7		0.9	6.0	14.4
Replacement capacity		0.5	0.7	5.3		2.1	3.8	10.6
Total new capacity		4.3	5.7	19.0		3.0	9.8	25.0
Phosphate complexes (600t/day)		21	28	92		14	47	121
Cost: $ billion		3.0	4.0	12.5		1.3	4.8	12.0
Alternative B								
Forecast demand	9.1	13.3	18.2	30.4	23.9	28.7	34.1	46.3
Exports/imports	-0.1	-	+4.0	+8.0	+0.5	-	-4.0	-8.0
	9.0	13.3	22.2	38.4	26.3	28.7	30.1	38.3
Losses/stocks (5%)	0.5	0.7	1.1	1.9	1.3	1.4	1.5	1.9
Production	9.5	14.0	23.3	40.3	27.6	30.1	31.6	40.2
Utilization per cent	60	71.5	76.5	83.5	80	85	87.5	87
Capacity	15.8	19.6	30.5	48.1	34.5	35.4	36.1	46.2
Increase in capacity		3.8	10.9	17.6		0.9	0.7	10.1
Replacement capacity		0.5	0.7	5.3		2.1	3.8	10.6
Total new capacity		4.3	11.6	22.9		3.0	4.5	20.7
Phosphate complexes (600t/day)		21	56	111		14	22	100
Cost: $ billion		3.0	8.2	15.4		1.3	1.9	9.7

Notes: See Table 3, notes 1 and 2

Annex to Chapter III

ESTIMATION OF TOTAL CAPITAL COSTS FOR FERTILIZER PLANTS

The method used to estimate the total capital costs for nitrogen fertilizer supply (Alternative A) is set out in Annex Table 1 and explained in the notes which follow. The most important assumptions are those made about per cent utilization and replacement capacity, which were discussed under "Capital requirements".

For many of the other adjustments made the data available are inadequate or of uncertain value, and it has been necessary to exercise considerable judgement. Fortunately, in many cases the effect upon the cost estimates is slight.

A1. N demand — Chapter II, pp. 22 and 27.

A2. Exports/imports — The import of 2.8 million tons of nitrogen by developing countries in 1980 is taken from Chapter II, Table 9. It is assumed that between 1985 and 1990 the developing countries as a group will become self-sufficient.

A4. By-product N — The UNIDO/FAO/IBRD Working Group data show 1973-1974 capacities for by-product ammonia and ammonium. sulphate of 6.9 per cent for developed countries and 2.3 per cent for developing countries. For 1980, figures of 5 per cent for developed countries have been assumed with marginal increases thereafter.

A6. Losses — This includes 5 per cent for stock increases and handling losses, and 5 per cent for conversion losses.

A8. Per cent utilization — The 1980 figures are derived from UNIDO/FAO/IBRD Working Group data. Thereafter the following assumptions are made:

		1980	1985	1990	2000
Per cent utilization of 1980 capacity	Developing countries	60	65	70	75
	Developed countries	80	85	87.5	87.5
Year		1	2	3	4 et seq.
Start-up of new plant	Developing countries	40	60	80	90
	Developed countries	60	80	90	90

The over-all per cent utilization figures for 1985, 1990 and 2000 are derived from these assumptions. 100 per cent utilization corresponds to 330 operating days a year.

It would have been more logical to deduct the replacement capacity from the 1980 capacity and add it on to the new capacity, in each period. As this would have complicated the calculation considerably a check was made, using this method, for the 1990-2000 period, in which replacement capacity is large, and it was found that the difference was **insignificant**.

A11. Replacement capacity

Developing countries (increase in production for periods 30 years earlier) ÷ 0.6

Developed countries (increase in production for periods 30 years earlier) ÷ 0.9

A13. Cost

An assessment was made of the probable feedstock supply for new ammonia plants for the three periods concerned. This is set out below.

Period	1980-85	1985-90	1990-2000
Natural gas	72	62	64
Naphtha	5.5	6	4
Fuel Oil	13.5	17	15
Coal	9	15	17
Av. $ per ton N	417	442	445

Percentage of new plants using stated feedstock.

Using these figures and the capital cost data given in Table 1 the weighted average cost per ton of nitrogen was worked out for each period. It was assumed that capital costs for developing countries are 30 per cent greater than for developed countries, i.e. capital cost for developed countries = developing countries ÷ 1.30 = developing countries x 0.77.

Capital costs for replacement plants were assumed to be 70 per cent of the cost of new plants.

B4. **Direct ammonia** In 1971, approximately 18 per cent of the 23 million tons of nitrogen consumed by the developed countries was as ammonia applied directly to the soil, mainly in the United States. It has been assumed that this percentage will fall to 10 per cent by 2000, and that for the developing countries use of direct ammonia will reach 8 per cent by 2000.

B5. **Percentage of solids used as straights** The figures available to the UNIDO/FAO/IBRD Working Group show that about 80 per cent of the developed countries' capacity and 90 per cent of the developing countries' capacity in 1980 is for the manufacture of straight fertilizers. It has been assumed that by 2000 these percentages will decrease to 73 per cent and 80 per cent respectively. The effect of these assumptions upon the proportion of P_2O_5 used as compounds has been checked assuming that the current $N:P_2O_5$ ratio of about 1:1.7 remains unchanged. On this basis the percentage of P_2O_5 in compounds in developing countries increased from 30 per cent in 1980 to 65 per cent by 2000, and in developed countries from 50 per cent in 1980 to 73 per cent by 1990 and 86 per cent by 2000. The latter figure seems high, but it may well be that by 2000 the $N:P_2O_5$ ratio will be greater than 1:1.7.

B8. **N as ammonium phosphates** This figure is derived from the assumptions about new P_2O_5 plants, that new P_2O_5 capacity will be 20 per cent TSP, 30 per cent MAP (11-46-0), and 50 per cent DAP (18-46-0).

B9. **Straight N to compounds** B9 = B5 - B7 - B8

B14. **Replacement capacity**

$$B14 = A11 \times \frac{\text{1980 fertilizer capacity}}{\text{1980 ammonia capacity}} = A11 \times \frac{27.7}{31.0}$$

B16. **Cost**

	New	Replacement	
Developing countries	268	188	$/ton N
Developed countries	206	144	

Replacement = New x 0.7

Developed countries = developing countries ÷ 1.3

Phosphate capital estimates

The same method is used in these estimates. For the calculation of the number of new plants required, a weighted average P_2O_5 capacity per plant has been calculated assuming 20 per cent TSP and 80 per cent M/DAP. Based on the figures for TSP and DAP in Table 2, the average P_2O_5 output per plant is 207,000 tons a year at 330 days operation a year.

Annex Table 1 **N Fertilizer Capital Costs: Alternative A**

	Developing countries				Developed Countries			
	1980	1985	1990	2000	1980	1985	1990	2000
A. **Ammonia capacity**								
1. N demand	20.0	28.5	38.6	63.5	40.3	52.7	66.9	100.6
2. Exports/imports	-2.8	-1.4			+1.4	+1.4		
3. Demand met by own production	17.2	27.1	38.6	63.5	41.7	54.1	66.9	100.6
4. Byproduct N	-0.3	-0.4	-0.6	-0.8	-2.0	-2.1	-2.2	-2.3
5. Synthetic N demand	16.9	26.7	38.0	62.7	39.7	52.0	64.7	98.3
6. Stocks, handling and conversion loss (10 per cent)	1.7	2.7	3.8	6.3	4.0	5.2	6.5	9.8
7. N Production as ammonia	18.6	29.4	41.8	69.0	43.7	57.2	71.2	108.1
8. Per cent utilization	60	71	77.5	83	80	86	88	88
9. Ammonia capacity	31.0	41.6	54.1	82.9	54.6	67.1	81.3	123.2
10. Increase in capacity		10.6	12.5	28.8		12.5	14.2	41.9
11. Replacement capacity		0.4	0.6	5.5		3.0	3.0	19.4
12. Total new capacity		11.0	13.1	34.3		15.5	18.0	61.3
13. Cost: $ billion		4.4	5.7	14.5		4.7	5.7	18.9

Annex Table 1 (contd) N Fertilizer Capital Costs: Alternative A

	Developing Countries				Developed Countries			
	1980	1985	1990	2000	1980	1985	1990	2000
B. Solid fertilizer capacity								
1. Synthetic N demand	16.9	26.7	38.0	62.7	39.7	52.0	64.7	98.3
2. Stock and handling loss (5 per cent)	0.8	1.3	1.9	3.1	2.0	2.6	3.2	4.9
3. Total synthetic N	17.1	28.0	39.9	65.8	41.7	54.6	67.9	103.2
4. Direct ammonia	0.4	1.2	2.5	5.0	7.0	8.0	8.5	9.5
5. N in solids	17.3	26.8	37.4	60.8	34.7	46.6	59.4	92.7
6. Per cent solids used as straights	90	85	80	80	77	75	73	73
7. Solids used as straights	15.6	22.8	29.9	48.6	26.7	35.0	43.4	67.6
8. N as ammonium phosphate	0.7	1.9	3.3	6.7	2.8	3.5	5.0	8.4
9. Straight N to compounds	1.0	2.1	4.2	5.5	5.2	8.1	11.0	16.7
10. Total straight N	16.6	24.9	34.1	54.1	31.9	43.1	54.4	84.3
11. Per cent utilization	60	70	76	82.5	80	84.5	86	87.5
12. Straight N capacity	27.7	35.9	44.7	65.7	39.9	51.0	62.6	96.5
13. Increase in capacity		8.2	8.8	21.0		11.1	11.6	33.9
14. Replacement capacity		0.3	0.5	4.9		2.2	2.8	14.2
15. Total new capacity		8.5	9.3	25.9		13.3	14.4	48.1
16. Cost: $ billion		2.3	2.4	6.6		2.6	2.5	9.0

Chapter IV

RAW MATERIALS

Presented in this Chapter are estimates of the quantities of raw materials required to meet forecast fertilizer consumption estimated in Chapter II and for which capital cost estimates are given in Chapter III. Also discussed is the availability of these raw materials and their sources of supply.

The raw materials are natural gas, naphtha, fuel oil and coal for the manufacture of nitrogen fertilizers; phosphate rock and sulphur for phosphate fertilizers; and potash for potash fertilizers. Natural gas, naphtha, fuel oil, sulphur and potash are chemical substances or mixtures of chemical substances to which a clearly definable specification can be applied and which vary relatively little from place to place. Phosphate rock and coal, on the other hand, are mined products to which a specification can be applied only to a limited degree and which do vary significantly from place to place. They contain constituents, other than phosphate and coal substance respectively, which can have important effects upon the processes in which they are used to manufacture fertilizers. A process may therefore be designed to use a particular phosphate rock or coal. A change in the source of supply may adversely affect the process leading to lower efficiency and/or to loss of output. It is therefore advisable, with these raw materials, to arrange long-term supply contracts which specify the source of supply. If a change in the source of supply becomes necessary, careful and lengthy trials of alternative materials should be made before fresh supply contracts are signed.

On the other hand, it is often desirable when constructing a plant to build in sufficient flexibility to accept phosphate rock from a variety of sources to take advantage of competitive situations or to provide for the possibility that the supply from the intended source may be cut off by hostility, strikes, or other unforeseen events. Also, plant design should, as far as possible, allow for the variations in quality to which both phosphate rock and coal are often subject, even when they are from the same source.

Estimate of raw material requirements

Table 1 sets out an estimate of the raw materials required, divided between developed and developing countries. This estimate is based upon the same assumptions as were made in estimating capital costs in Chapter III and also upon the raw material requirements used in the derivation of the operating costs given in Tables 1 and 2 of Chapter III.

The estimates of ammonia feedstocks, natural gas, naphtha, fuel oil and coal, taken together, give a reasonable estimate of the total amount of energy required for nitrogen fertilizer manufacture, but the estimates of individual feedstock requirements, particularly for naphtha, fuel oil and coal which together account for 30-35 per cent of the energy requirements, are subject to a large margin of error because they depend very much upon an individual assessment of the changes that are likely to take place in the use of these feedstocks up to the year 2000. Because of these uncertainties it has been assumed that the proportion of the total nitrogen fertilizer feedstock supplied by natural gas, naphtha, fuel oil and coal is the same in both developed and developing countries. The assumptions, and the views underlying them, are set out in Note 1 to Table 1.

Availability and sources of raw materials

Information is given in this section on the amount, and geographical distribution, of world reserves of fertilizer raw materials, and their present production. Production rates are known with reasonable accuracy but the same cannot be said of reserves. It is impossible to present more than a rough estimate of the reserves of any mineral deposit, particularly on a global scale, because of the difficulties involved. These fall into two broad categories.

The first difficulty arises from lack of information. Large areas of the globe either have not been surveyed at all or have been surveyed inadequately. Even when deposits are known to exist, information on their quantity and quality varies greatly. Reasonably complete data are available only for deposits being worked or for which concrete development plans exist, and even in such cases the data may cover only the more easily worked and accessible parts of the deposit. For deposits known to exist but not being worked the information may be scanty. For example, deposits of potash salts have recently been discovered in Thailand and reserves are thought to be "very large indeed", but no quantitative data are available. The reason for this lack of data is simply that full exploration and evaluation of a deposit is an expensive process and only undertaken when commercial exploitation is probable. It is a commonplace of reserve estimation that, in spite of high production rates, reserves remain constant, or actually increase over quite long periods of time, because new deposits are being discovered as fast as existing ones are being used up.

Faced with this difficulty, some estimators confine themselves to identified deposits for which reasonably adequate information is available. Others include known but not fully explored deposits, and yet others add a "contingency" for deposits not yet discovered but which may be reasonably, because of known geological factors, presumed to exist (see Note 3 to Table 2).

The second difficulty is that there is no agreed definition of reserves. Some estimators include the total quantity existing in the deposit, whereas others include only that amount which can be extracted by present mining techniques. Others, again, include only the amount which can be economically extracted at the time of writing; this depends upon the cost of mining and beneficiation in relation to market prices for the mineral. On this basis, the proportion of a deposit included in reserves would vary from one deposit to another and would also be affected by changes in market prices or in mining and extraction costs.

With these widely varying concepts of what constitutes a reserve it is not surprising that estimates of total reserves show very large differences, for example, estimated world reserves of phosphate rock vary from 85,000 million tons to 1,300,000 million tons. In comparing various estimates the difficulties are compounded by the fact that the definition of reserves on which the compilation is based is not always clearly stated.

It is clear therefore that the magnitude of national, and global, reserves of fertilizer raw materials is not accurately known. The estimates for crude petroleum and, to a lesser degree, natural gas are the most reliable. Because of their importance much attention has been given to these materials and to the technology required for their estimation. The estimates for the other raw materials are much less reliable, the one for potash being probably the least uncertain of these because the number of known deposits is relatively small and most of them have been carefully surveyed. The estimates for phosphate rock, sulphur and coal have the greatest margin of uncertainty. These materials are widely distributed, many deposits remain to be discovered, and it is difficult to obtain representative samples from which the quality of the deposit can be assessed. Fortunately, the estimates for potash, phosphate rock and coal show that, even when allowance is made for the inevitable inaccuracies, global reserves are more than adequate for the foreseeable future. With sulphur, total reserves are also ample but in time some shift may take place to materials not at present widely used.

Ammonia feedstocks

The feedstocks, natural gas, naphtha, fuel oil and coal, used for ammonia manufacture differ from the other fertilizer raw materials, phosphate rock, sulphur and potash, in that the latter find their major use in the fertilizer industry whilst the use of the former is only a small fraction of the total consumption. The manufacture of fertilizers uses the following proportions of world production of raw materials: 85 per cent of phosphate rock, 40 per cent of sulphur and 95 per cent of potash compared with 3 per cent of natural gas, and about 0.5 per cent of oil products and coal.

The development, structure and economics of the industries supplying phosphate rock, sulphur and potash are therefore closely related to the progress of the fertilizer industry. Indeed, there is at present a marked tendency for major phosphate rock producers to move into the fertilizer industry, converting a part of their production into fertilizers. In the production of ammonia feedstocks no such close relationship exists. In particular, the prices paid by nitrogen fertilizer manufacturers for their ammonia feedstocks are determined by their value for other uses - e.g. as fuels, in the chemical industry, or as constituents of motor fuels - and not by their relative suitability for ammonia manufacture.

Table 2 gives world reserves and annual production of ammonia feedstocks on a regional basis, for developing and developed countries. Table 3 lists the major supplying countries with their reserves and current production.

The figures for reserves are only approximate. The rise in oil prices has caused much more attention to be given to natural gas and the estimate of reserves is increasing every year. The estimate of oil reserves is more stable but even here significant changes are occurring. According to the International Petroleum Encyclopaedia, world reserves of crude oil increased from 81 billion to 96 billion tons during 1974 in spite of a consumption of 2.8 billion tons. Natural gas reserves increased from 56,000 billion m^3 to 72,000 billion m^3 with a consumption of 1,340 billion m^3. Estimate B (see Tables 2 and 3) for coal reserves is speculative; the figure is recorded to illustrate the magnitude of probable reserves as compared with known reserves (estimate A, Tables 2 and 3). Only about half the coal reserves are recoverable by present mining techniques.

A comparison of coal reserves with production shows that reserves are adequate for several hundred years even at much higher production rates. With oil and natural gas the position is different, since current production is a fraction of known reserves, particularly in the developed countries. As far as distribution of reserves and production are concerned, developing countries have about 50 per cent of the reserves of natural gas, 75 per cent of the oil reserves and 33 per cent of the known coal reserves. They produce only 10 per cent of the natural gas and 25 per cent of the coal but 60 per cent of the oil. The estimated consumption of ammonia feedstocks in 1980 will constitute about 3.5 per cent of current gas production, 0.5 per cent of current crude oil production and less than 0.5 per cent of coal production.

The conclusions to be drawn from Tables 2 and 3 are that ammonia feedstocks are widely distributed among both developed and developing countries, that developing countries' reserves are much larger in relation to current production rates than those of developed countries, that supplies of coal are more than adequate, but that during the period 1980-2000 the hydrocarbon feedstocks, though available in adequate quantities, are unlikely to become less expensive.

Phosphate rock

Phosphate rock is, with the possible exception of coal, the most variable of the raw materials used by the fertilizer industry. The deposits from which it is obtained vary widely in their concentration of phosphate and in the types and quantities of other associated materials. The quality of phosphate rock is usually defined in terms of its P_2O_5 content, the concentration normally lying between 28 per cent and 38 per cent. However, apart from the usefulness in determining transport and handling costs per ton of P_2O_5, the P_2O_5 concentration is an inadequate guide to the value, or suitability for fertilizer manufacture, of a particular grade or type of rock.

All phosphate rocks contain a range of impurities which have adverse effects upon their use in the fertilizer industry, particularly in the manufacture of phosphoric acid. The most important impurities are iron, aluminium, magnesium, silica, fluorine, chlorine, carbonates and organic matter. Iron, aluminium and magnesium can cause troublesome sludge formation in phosphoric acid and lower the yield of P_2O_5; fluorine leads to severe liquid and gaseous effluent problems; chlorine to serious corrosion, and carbonates to excessive sulphuric acid consumption and, in conjunction with organic matter, to foaming problems.

In addition to the average chemical composition of a rock, its physical condition, hardness, porosity, particle size and other less tangible factors, have a significant effect upon its suitability for phosphoric acid manufacture and upon the efficiency of the extraction of P_2O_5.

Therefore, while a complete chemical analysis of a representative sample of rock is a useful guide to its suitability for fertilizer manufacture, and to the design of the plant in which it is to be used, it is only a guide. When, in a new plant, it is proposed to use a rock which is extensively used in fertilizer manufacture the experience of other users is invaluable, but if there is little previous experience with the rock concerned, extensive trials should be made before the plant design is decided. For the same reasons, in an existing plant great care should be taken if a change in rock supply is under consideration.

World production of phosphate rock, 85 per cent of which is used in the fertilizer industry, has practically doubled over the past ten years and, according to the estimates of Table 1, will increase a further two and a half times between 1980 and 2000. This trend can be expected to continue as the best quality deposits are gradually depleted and producers turn to lower grade deposits leading to a reduction in the average P_2O_5 content - which thereby becomes increasingly valuable - of the marketed product and to an increase in the impurities it contains.

Plants can be designed to cope with the problems caused by lower grades of rock, but capital costs and also operating costs and problems are increased. It seems probable that as time passes fertilizer producers will find it necessary to exercise greater care and sophistication in their selection of phosphate rock. It may be that rock producers will also become more specialized, producing a "premium" grade for existing plants which cannot satisfactorily handle rocks with impurities above a certain level, and a range of "normal" grades for plants specially designed for rocks of a defined but higher range of impurities.

The production of phosphate rock in terms of its P_2O_5 content is given in Table 4 for individual countries and for regions for the year 1974.[1] This Table shows that though phosphate rock deposits are widely distributed - some 34 countries are producers - Western Europe and the Far East are short of indigenous resources, and three countries, the United States, the USSR and Morocco, account for 75 per cent of current production. This pattern has not changed significantly over the past ten years. From 1964 to 1973 inclusive world production practically doubled, but over the ten years the United States, the USSR and Morocco consistently supplied 75 to 80 per cent of total production. Over this period the USSR doubled its production and the United States and Morocco increased theirs by about two-thirds.[2] Among other producing countries major increases have taken place in South Africa, China, Togo and Senegal.

The three major supplying countries' share of world exports, at 75 per cent, is the same as their share of production, but the division between them is very different. The United States and the USSR, with large domestic markets, are much less dependent on exports than is Morocco. From 1964 to 1973 the United States exported 30 per cent of its production, the USSR 27 per cent and Morocco 95 per cent.[3] The developing countries, as a group, are responsible for over 60 per cent of world exports, half of which come from Morocco.

In 1974, according to FAO statistics, developing countries were responsible for about 15 per cent of P_2O_5 fertilizer production and 20 per cent of

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[1] Data from International Superphosphate Manufacturers Association.

[2] Notholt, A.J.G., Industrial Minerals International Congress, London, July 1974.

[3] Notholt, A.J.G., Ibid.

Notes: See Table 3, notes 1 and 2

consumption compared with 40 per cent of rock production. By the year 2000, according to Alternative A of Chapter III, they will have 40 per cent of production and consumption and according to Alternative B, 40 per cent of consumption and nearly 50 per cent of production. As the subsequent survey of world reserves shows, the developing countries, as a group, should be able to meet these targets from their own resources of phosphate rock. Many developing countries, including Morocco, Tunisia, Algeria, Spanish Sahara, Togo, Jordan, Syria, Egypt, Peru and Brazil are increasing production or have plans for large increases, and less definite plans exist for Angola, Senegal, Iraq, Colombia, Mexico and others.4/ In the developed countries the most significant change is probably the development of the large deposits in Queensland, Australia which reached commercial production in 1974/75. Some of the deposits, for which plans exist or are in the early stages of development, are in remote or inhospitable areas. The exploitation of these deposits will raise formidable problems of transport and infrastructure and costs are bound to be high. The rate of development of such deposits is likely to be slow and will be dependent upon the course of phosphate rock prices.

There is no agreed estimate of world reserves of phosphate rock; different authorities produce widely differing estimates ranging from [illegible]5,000 million tons5/ to 1,300,000 million tons6/. As an illustrative example, to indicate the location and relative magnitude of phosphate rock deposits, in Table 5 is given an estimate of a world total of about 200,000 million tons. The estimate of the requirements for the year 2000 given in Table 1 corresponds to a total demand for all purposes of about 300 million tons a year. It is obvious that ample reserves of rock exist.

The capital required to meet the forecast phosphate rock demands cannot be assessed with any precision. The cost of any project depends upon the depth at which the deposit is located, the quality of deposit, and the location of the site in relation to roads, railways, harbours, water and power supplies, etc. Extensions of deposits already being worked will obviously cost much less than the development of completely new deposits. Lehr7/ gives

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4/ Lehr, J.R., JAPCA Seminar, February 1976.

5/ US Bureau of Mines Bulletin No. 667, p2 (1975).

6/ Emigh, G.D. Eng. and Min., J., April 1972.

7/ Lehr, J.R., Ibid.

illustrative costs in the United States (Florida) of $15-20 per annum per ton of rock compared with $150 per annum per ton for the opening up of the Queensland deposits. At an average capital cost of $80 per annum per ton of rock or $250 per annum per ton of P_2O_5 the total capital required to meet the increased demand for rock from 1980 to 2000 is approximately $10 billion. This is no more than an order of magnitude estimate.

Sulphur

Sulphur is various forms is widely distributed - it constitutes about 0.1 per cent of the earth's crust - but the forms in which it occurs differ greatly in their value as sources. It is found as elementary sulphur, as metal sulphides in coal and mineral ores, as sulphates, as hydrogen sulphide in natural gas, and as complex organic sulphur compounds in crude oil. All these various deposits are used as sources of sulphur but the most important are elementary sulphur, hydrogen sulphide in natural gas, and iron pyrites.

The uses of sulphur are as varied as its sources but about 80-85 per cent is used in the manufacture of sulphuric acid. About half of this acid is used in fertilizer production, so that the consumption of sulphur for fertilizers is about 40 per cent of the total. Sulphur is also used in agriculture as a pesticide and, to a comparatively small extent, as a fertilizer to overcome sulphur deficiency (see Chapter III, "Availability and sources of raw materials" above). In this chapter we are concerned with sulphur solely as a raw material for the manufacture of the sulphuric acid used in the production of phosphate fertilizers. However, if sulphur deficiency were to become widespread, increasingly significant quantities would be used to overcome it, though sulphur-containing materials at present discarded by the fertilizer industry could be used for this purpose.

An unusual and important feature of the sulphur industry is its relation to the control of pollution. Probably the most common industrial pollutant is sulphur dioxide, which is produced whenever coal or oil, and sometimes natural gas, is burned and also in quite large quantities when sulphide ores are "roasted" for metal production. Increasingly strict and widespread regulations limiting discharge to the atmosphere of gases containing sulphur dioxide have led to the development of processes to convert this sulphuric acid or to remove sulphur from fuels, particularly in the metallurgical industries where the effluent gases often have relatively high concentrations of sulphur dioxide. However, by far the most important contribution to sulphur production from these sources comes from the removal of hydrogen sulphide from natural gas and its conversion to elementary sulphur. In 1974 this recovered sulphur amounted to 14 million tons, about half the world production of elementary sulphur and about 30 per cent of the production of all forms of sulphur.

Sulphur is also recovered at refineries by processes which reduce the sulphur content of fuel oils, and in many industrial processes using fuel oil, e.g. in the manufacture of ammonia.

The production of so large a quantity of sulphur as a by-product of other industrial operations, and therefore at a rate which does not respond to the demand for sulphur, requires the production of sulphur from elementary deposits and from pyrites to bear the load of all fluctuations in demand. As shown below, this has led to a marked decrease in the pyrites' share of the sulphur market:

	Production (million tons of sulphur)	Percent of total production			
		Elementary sulphur		Pyrites	Other forms
		Recovered	Other		
1960	22.3	12	34	36	18
1974	51.6	28	34	22	16

There are a number of reasons why pyrites has lost favour as a source of sulphur. Since it contains about 46 per cent sulphur, freight charges are high; the capital costs of sulphuric acid plants using pyrites are much higher than of plants using elementary sulphur; pyrites-burning sulphuric acid plants have more troublesome pollution problems than sulphur-burning plants, and the disposal of the iron oxide residues may also present problems.

Table 4 shows the production of sulphur in all forms, by countries and regions, for 1974.[8/] The developing countries have 12 per cent of world production, totalling 6.3 million tons, as compared with an estimated 1980 demand

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[8/] British Sulphur Corporation, Statistical Supplement No. 12, November/December 1975.

of 6.5 million tons for fertilizer production (Table 1). This comparatively low production reflects the paucity of elementary sulphur deposits in these countries, with the notable exceptions of Mexico and Iraq, and also the lack of demand. As the natural gas reserves of developing countries are exploited (see Table 2) and as increasing industrialization raises demand, their production of sulphur will undoubtedly increase. From 1971 to 1974 production in the Middle East increased from 0.6 million to 1.4 million tons per annum and it is expected to increase still further to about 3 million tons per annum by 1980.[9]

It is difficult to give a significant estimate of total world resources of sulphur because of the wide variety of forms in which it occurs and because of wide differences in the extent and efficiency of extraction from various materials. Total resources are probably about 500 billion to 750 billion tons of which more than 99 per cent is present in coal, oil shales and gypsum, materials which do not make a significant contribution to present production. An estimate is given below of world sulphur reserves[10] compared with the 1974 production:[11]

World sulphur reserves and production

(millions of tons)

		Identified	Probable	Total	Production (1974)
Elementary:	Evaporites	580	100	680	17.6
	Volcanic rocks	130	100	230	
Natural gas		155	885	1,040	15.0
Petroleum		265	1,330	1,595	
Pyrites		640	-	> 640	11.0
Metallic sulphides		260	> 140	> 400	8.2
Subtotal		2,030	> 2,555	> 4,585	51.8
Tar sands		50	> 1,800	> 1,850	
Coal		20,000	200,000	220,000	
Oil shale			-	280,000	
Gypsum				Vast	
Total		22,000	>200,000	>500,000	

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[9] Sulphur 116, 30.

[10] Bixby, D.W., The Role of Phosphorous in Industry - Symposium at Muscle Shoals, Alabama, United States October 1976, in the press.

[11] British Sulphur Corporation, op.cit.

According to Table 1, the consumption of sulphur for fertilizer production will increase from 25 million to 65 million tons from 1980 to 2000, corresponding to a total consumption from 1980 to 2000 of approximately 900 million tons, rather less than one fifth of the reserves at present being used. From the Table it appears that reserves in natural gas and petroleum are larger in relation to present use than for other reserves, although those in pyrites are probably under-estimated. Certainly an increasing demand for natural gas and the spread of pollution control will lead to increasing production of recovered sulphur. Elementary sulphur from evaporites and volcanic rocks will be available for a long time but it is probable that shortages of this form of sulphur may lead to higher prices and a movement to other sources. The fertilizer industry should be able to obtain the sulphur it needs over the next twenty-five years but reserves at present being used would appear to have a limited life.

It is not possible to estimate the capital expenditure needed to supply the 900 million tons of sulphur required by the fertilizer industry from 1980 to 2000 because (a) there is a wide variety of sources of sulphur, (b) nearly 40 per cent of present supplies are a by-product of other industrial operations; and (c) there are uncertainties in the different sources and forms of sulphur over the next twenty five years.

However, there are particular circumstances of the fertilizer industry which insulate it against the possibly serious effects of a long-term world-wide shortage of sulphur. The industry is not a net consumer of sulphur, it merely transforms sulphur into calcium sulphate. Except in the manufacture of single superphosphate, which will be a very small proportion of total output by the year 2000, the sulphur consumed by the phosphate fertilizer industry is discarded at phosphoric acid plants as calcium sulphate in the form of gypsum. This by-product gypsum is not, under present conditions, an economic source of sulphur. However, processes for sulphuric acid manufacture which use naturally occurring calcium sulphate (as gypsum or anhydrite) as a raw material, and which produce cement clinker as a by-product, have been operated for many years and the process is well established. Most of these plants have been shut down and no new ones are being built because their high capital cost makes them uneconomic in comparison with sulphur-burning sulphuric acid plants. By-product gypsum is more difficult to use because it contains P_2O_5, but the difficulties can be overcome. In the unlikely event of a long-term world-wide shortage of sulphur, the fertilizer industry could resort to its gypsum dumps, though at considerable additional cost.

Potash

Workable potash deposits are much more limited in their distribution than the sources of other fertilizer raw materials, phosphate rock and sulphur. Listed below are the twelve countries, nine of them developed countries, in which deposits are now being worked together with an FAO estimate of recoverable reserves of potash:

Recoverable world reserves of potash

	Millions of tons of K_2O	Per cent of Total
USSR	24,000	48.0
Canada	18,000	36.0
GDR	4,000	8.0
FRG	2,000	4.0
Israel/Jordan	500	1.0
USA	300	0.6
France	200	0.4
Spain	80	-
Congo	70	-
Italy/Poland/Denmark	37	-
Developing countries	783	-
	50,000	100.0

This estimate covers deposits with widely varying characteristics and takes rather a broad view of the technical possibilites of exploitation and extraction.

Only a few developing countries have potash deposits. Deposits are being worked in China, the Congo and Chile and plans for exploitation exist in Jordan and Brazil (and also in Poland). Other deposits are known to exist in Thailand/Laos and Ethiopia but neither the extent nor the feasibility of exploitation have yet been determined with any accuracy. Preliminary indications are that the deposits in Thailand/Laos may be very large indeed.

These deposits are very large when compared with the probable demand given in Table 1, which is for about 1,000 million tons of potash from 1980 to 2000 and consumption of 66 million tons in the year 2000. Thus, in twenty years currently-known potash reserves would be reduced from 50,000 million tons to 49,000 million tons. It is clear that the estimated potash requirements can easily be met from known reserves, even if these have been considerably over-estimated, without taking account of possible future developments, e.g. in Thailand.

These reserves are located almost entirely in the developed countries and it will therefore be necessary for developing countries to import most of their potash from developed countries until 1985 or possibly 1990. Thereafter, potash may become available in the developing countries. The exploitation of reserves, known or yet to be discovered, in developing countries will depend upon the comparative costs of working these resources and upon the importance attached to the savings in foreign currency which accrue from the use of indigenous resources.

For the reasons stated in discussing the development of phosphate rock deposits (see "Phosphate Rock" above), it is not possible to estimate at all accurately the costs of bringing new potash deposits into use. In a developed country costs would range from \$ 350 to \$ 500 per annum per ton of K_2O. In a developing country they could be much higher, depending upon the location and quality of the deposit and its distance from an adequate and reliable transport system.

If we assume an average capital cost of \$ 500 per annum per ton of K_2O, the total capital required to supply the additional potash required from 1980 to 2000 is roughly \$ 20 billion. This is no more than an order of magnitude estimate.

Other raw materials

As noted in other chapters of this report, there is often a need for elements other than N, P, and K. The other essential mineral elements are Ca, Mg, and S (sometimes called secondary elements) and the micronutrients Mo, Mn, Fe, B, Cu, Zn, and Cl. In addition, other elements not classified as essential are economically useful in some cases to increase yields or improve the nutritional quality of crops. It is beyond the scope of this chapter to discuss the types, occurrences, and distribution of raw materials for supplying these elements. However, their importance should be recognized for when one of these elements is deficient, the effect on crop production can be as serious as the lack of one of the major elements.

Also, various non-standard processes may require raw materials not mentioned above. For instance, the well-known Rhenania phosphate process requires sodium carbonate which may be obtained from the minerals trona or natron or manufactured from salt. Fused calcium magnesium phosphate utilizes the magnesium minerals such as olivines, serpentine or magnesite. Various secondary sources of hydrocarbons may be used or considered for ammonia feedstock, such as coke oven gas, refinery tail gas, liquefied petroleum gas, by-product hydrogen from electrolytic chlorine production, or products from processing oil shale or oil sands.

Water

The manufacture of fertilizers, particularly nitrogen fertilizers, uses large quantities of water. In the manufacture of ammonia water is a raw material in the strict sense of the word because it is the source of more than half the hydrogen needed to make ammonia. This water is supplied to the process as steam and varies from 1.5 to 3 m^3 per ton of ammonia, depending upon the process used. However, most of the water needed is used as make-up to cooling water systems. The total water requirements for an ammonia/urea plant range from 20 to 35 m^3 per ton of urea. On a 1,000 tons per day ammonia/1720 tons per day urea plant this corresponds to a water supply of 150 to 250 m^3/h.

These large quantities of water are not always readily available, particularly in arid climates. There are a number of ways in which this quantity can be reduced and plant contractors can modify plant designs to give minimum water consumption though this will usually involve some increase in capital cost. Where it is available sea water can be used; air cooling offers a prospect of substantial water savings; more efficient use of water may be possible by pumping water from a "critical" cooler to one where higher temperatures can be tolerated, and so on. However, when all practicable steps have been taken, fertilizer plants will still be large consumers of water. This may affect the decision about their location or may lead to higher costs.

Organic Fertilizers

An organic fertilizer is the product obtained by suitable processing - either singly or more commonly as a mixture - of all kinds of organic waste materials, which is applied to the soil to raise its productivity. The organic waste materials which can be used for this purpose include municipal garbage, consisting of domestic and commercial garbage and wastes from such industries as food-processing, lumber mills, etc; night-soil; animal manure; slaughter-house wastes; sewage sludge; and harvest residues.

Composting is the decomposition or stabilization of organic matter by biological action in a controlled process as applied in sanitary disposal and reclamation of organic waste materials. The final product is compost.

Bio-gas is methane gas produced by the fermentation in the absence of air of organic waste materials, such as farmyard manure, straw, garbage, and night-soil, and recovered for use as fuel for cooking, lighting, refrigeration, and heating, and for other domestic or agricultural purposes, such as providing power for small engines. The spent slurry can be reclaimed for use as organic fertilizer.

Fertilizer potential of organic waste materials

In recent years, emphasis has been placed on the use of mineral fertilizers because they have been found to produce quick and positive results and because of their relative ease of handling and application. Yet it is well known that organic fertilizers, obtained by processing organic waste materials, play a vital role in the improvement of soil fertility.

In addition to the principal nutrients (nitrogen, phosphorus and potash), organic fertilizers contain trace elements (micro-nutrients) essential for optimum plant growth and resistance to plant diseases and parasites. Furthermore, organic fertilizers provide the soil with humus, which enhances the efficiency of mineral fertilizers, improves soil structure, increases water retention and reduces soil erosion. The provision of humus is especially important for intensely cultivated soils, soils in tropical areas, heavy clay soils, loose sandy soils, and saline and alkaline soils.

Recently it has become evident that mineral fertilizers may prove too expensive for a sizable proportion of farmers in developing countries which are in dire need of increasing food production.

Another fact that has emerged clearly is that, owing to population increases and greater urbanization, the disposal of organic waste materials has become an increasingly serious health and pollution hazard. It is therefore important that developing countries should consider launching a vigorous campaign for the reclamation of organic wastes for use in agriculture. Table 6 gives an estimate of the new capital investment needed for a plant, in a developing country, to process 80,000 tons of city refuse a year to produce 50,000 tons of compost. It is assumed that refuse is delivered free of charge to the plant.

The approximate annual availability of crop nutrients from different organic wastes in developing countries has been estimated for 1971.[12] The totals for nitrogen, phosphorus and potash are 48, 16 and 39 million tons respectively, which calculated at 1973 world f.o.b. prices for mineral fertilizers, represent a value of over $ US 16 billion. Comparison may be made with 13.2 million tons, which is the total amount of nutrients in mineral fertilizers used in developing countries in 1970/71.

In estimating the amount of organic wastes available for use as organic fertilizers two facts should be borne in mind: (a) there are very real constraints to the use of organic fertilizers owing to their excessive bulk and high costs of handling, processing and application; and (b) the amount of organic wastes available in practice at a given location may be considerably less than the theoretical figure owing to the high costs of collection and transport, as well as existing practices by farmers of recycling crop residues and using certain wastes, e.g. cow dung, as fuel.

The present status of organic fertilizer usage in developing countries

FAO estimates that the present contribution by organic wastes for fertilizers is probably about 10 per cent of all fertilizers and that there is probably the potential to raise this to about 25 per cent.

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[12] FAO Soil Bulletin No. 27 MI/F.6588/E/2.75/1/1500, page 356

Traditionally, China and India are among the world leaders in the use of organic fertilizers. Along with the rapid expansion of its inorganic fertilizer production, China is increasing the use of organic fertilizers. The importance Chinese agronomists attach to organic fertilizers is illustrated by the following two developments:

(a) Humatic fertilizer is a compound organic fertilizer made from peat, brown coal, lignite and similar materials together with other organic substances and can be mixed with ammonium or potash salts. Technical details are not yet fully available but it is believed that the equipment needed is relatively simple and that the processing cost is reasonably low. An additional advantage is that of using raw materials that are locally available in significant quantities in most provinces of China. China has considerably increased its production of humatic fertilizer in the first half of 1975, which suggests a planned annual production of several million tons;

(b) An increasing emphasis is being given to the utilization of human and animal wastes which remained at the top of the list of organic fertilizers in China's Agricultural Development Programme. Despite her own vast population, it has been reported that China began this year to award large contracts to Hong Kong for night-soil. The increased use of green manure and urban refuse has also been mentioned in Chinese agricultural journals. It has been reported that some half a million bio-gas plants have been installed within the last year and that the economy of these plants depends upon the successful reclamation of the spent slurry for organic fertilizer.

In India, a programme of compost production from both rural and urban wastes was launched in 1945 and has been making good progress. More and more villages have pits for cattle manure, night-soil and domestic refuse, and many farms practice composting of farmyard manure and crop residues. The programme also covers utilization of sewage through sewage irrigation and sludge fertilization. It is estimated that about 40-50 per cent of animal wastes and other farm residues are currently utilized as organic fertilizers. Probably the same proportion of urban refuse is being composted but a considerably smaller fraction (about

5 per cent) of the night-soil is being used to produce organic fertilizers. It is estimated that the use of sewage irrigation has led to increases in crop yields ranging from 30-50 per cent or more, as compared with irrigation by ordinary water.

There has recently been a revival of interest in urban refuse composting by mechanized plants in both developed and developing countries. The general opinion is that the shut-down of plants in countries such as the United States and Japan is largely attributable to the unnecessarily sophisticated equipment and processes used, and to the lack of attention to market development for the compost.

Many developing countries are finding an economic solution to rapidly increasing urban refuse problems through the establishment of compost plants. With careful planning and organization, and the use of simple processing techniques and equipment, municipal refuse can be transformed into a source of valuable fertilizer to market gardeners in the vicinity. Although urban refuse composting can meet only a small portion of a country's fertilizer needs, in many cases it may provide the only fertilizer readily available since developing countries have lower labour costs, and their urban refuse contains a far higher percentage of organic matter than is the case in industrialized countries, the urban refuse compost plant can, for certain cities, provide the most profitable method of urban waste disposal and utilization. The costs for the nutrient value of the compost gained can be one half of the equivalent foreign exchange value of imported chemical fertilizers. Burundi, Guinea, Morocco, and the People's Republic of Yemen are planning and developing urban compost programmes.

Conclusions, possibilities and constraints

Despite the obvious value of organic fertilizers, only certain developing countries have utilized their potential to some degree. Among the reasons are:

(a) Lack of extension work on the proper utilization of organic wastes as fertilizers;

(b) Lack of appreciation of the value of organic fertilizers to soil fertility and undue emphasis on short-term economic gains realizable through the use of mineral fertilizers;

(c) Lack of interest by municipal authorities to make the extra capital outlay needed for the reclamation of refuse and sewage;

(d) Lack of adequate infrastructure for the collection, distribution and sale of such high bulk, low unit value materials as organic fertilizers;

(e) Lack of interest by agricultural research institutions in the promotion of organic fertilizers.

It is believed that the reclamation of rural and urban wastes for use in agriculture can be done in an economic and sanitary manner through proper planning and choice of process and equipment.

Bio-gas production from suitable organic wastes can also be economically viable, provided the spent slurry is reclaimed for use as organic fertilizer, preferably in an integrated farming system.

Table 1. Raw Material Requirements

	Developing countries				Developed countries			
	1980	1985	1990	2000	1980	1985	1990	2000
Alternative A								
Natural gas (10^9 m^3)	14.1	25.3	36.5	61.3	33.0	47.5	60.0	94.5
Naphtha (million tons)	2.4	3.0	3.7	4.7	5.9	6.6	7.3	8.6
Fuel oil (million tons)	1.3	2.7	4.8	8.8	3.0	4.8	7.1	12.5
Coal (million tons)	2.8	8.6	18.3	40.3	6.5	13.9	25.0	57.6
Phosphate rock (million tons P_2O_5)	9.3	14.1	19.1	31.5	27.4	32.2	37.9	50.7
Sulphur (million tons)	6.5	10.5	14.6	24.9	19.2	23.1	27.8	38.3
Potash (million tons K_2O)	4.5	6.5	8.9	14.8	24.6	30.4	36.7	51.2
Alternative B								
Natural gas (10^9 m^3)	14.1	27.2	45.8	81.3	33.0	45.8	51.1	74.2
Naphtha (million tons)	2.4	3.0	4.2	5.6	5.9	6.5	6.8	7.7
Fuel oil (million tons)	1.3	2.9	6.3	12.0	3.0	4.6	5.6	9.2
Coal (million tons)	2.8	9.4	25.4	57.1	6.5	12.9	17.0	37.4
Phosphate rock (million tons P_2O_5)	9.3	14.1	22.6	39.7	27.4	32.2	34.5	42.6
Sulphur (million tons)	6.5	10.5	17.5	31.7	14.2	23.1	25.0	31.7
Potash (million tons K_2O)	4.5	6.5	8.9	14.8	24.6	30.4	36.7	51.2

Notes

1. **Ammonia feedstocks.** The table below gives the assumed percentage of ammonia production from the different feedstocks.

	Natural gas	Naphtha	Fuel oil	Coal
1980	71.5	15	7	5.5
1985	71	13	8.5	6.5
1990	69.5	12	10	7.5
2000	68	9.5	12	10.5

The table reflects the view that naphtha will become too expensive a material for ammonia production, that first fuel oil will replace naphtha, and from 1990 coal will begin to take an increasing share.

From 1980 onwards, it has been assumed that new nitrogen fertilizer plants will have their own power generation plant fueled by natural gas in plants using this feedstock but by coal in other plants. The use of coal in naphtha and fuel oil plants accounts for about 20 per cent of the total coal consumption. The quality of coal assumed for both power and ammonia production is relatively low grade, with a calorific value of 3500 k cal/kg.

2. **Phosphate rock.** This is equal to P_2O_5 production plus an allowance of 8 per cent for conversion losses. It should be noted that in Chapter II, forecasts of P_2O_5 demand are based on the FAO consumption data. These data exclude ground phosphate rock which has, for a number of years, accounted for about 7 per cent of total P_2O_5 consumption. If consumption continues at this rate the estimates of rock consumption would therefore be about 7 per cent low.

3. **Sulphur.** The consumption for M/DAP is taken as 0.94 tons/ton P_2O_5 and for SSP and TSP 0.70 tons/ton P_2O_5, and zero for nitrophosphate (NTP). For 1980 it is assumed that production is 46 per cent M/DAP, 46 per cent SSP/TSP and 8 per cent NTP. From 1980 onwards it is assumed that production is 80 per cent M/DAP and 20 per cent TSP.

4. This is equal to the potash demand plus an allowance of 5 per cent for stock increase and handling losses.

Table 2. Reserves and production of ammonia feedstocks, by regions

	Natural gas		Crude petroleum		Coal		
	Reserves (billion m^3)	Production (billion m^3)	Reserves (million tons)	Production (million tons)	Reserves(A) (billion tons)	Reserves(B) (billion tons)	Production (million tons)
Developing countries							
Africa	8,070	5	5,140	180	6	15	5
Latin America	2,840	87	5,490	240	9	36	12
Near East	19,960	35	58,550	1,170	1	2	6
Far East	1,920	11	2,510	90	23	86	95
Centrally planned Asia	710	2	3,380	60	300	1,011	458
Total	33,500	140	75,080	1,740	340	1,150	580
Developed countries							
North America	8,320	728	5,600	520	326	2,383	547
Western Europe	5,740	163	3,490	20	150	401	283
Centrally planned Europe	23,250	301	11,690	470	205	4,052	657
Oceania	1,220	5	320	20	26	113	57
Others	50	3	-	-	32	52	85
Total	38,580	1,200	21,100	1,030	740	7,000	1,630
World total	72,100	1,340	96,200	2,770	1,080	8,150	2,210
% of World total Developing	47	10	78	62	32	14	26
Developed	53	90	22	38	68	86	74

Notes

1. Sources. Data for natural gas and crude petroleum are from the International Petroleum Encyclopaedia 1975 pp. 296-7. Reserves are as at 1 January 1975 and production is for 1974. Data for coal are from the United Nations Statistical Yearbook for 1974. Production is for 1973.

2. It should be noted that for natural gas and crude petroleum the reserves and production are in the same units. For coal, the reserves are in billion tons and production in million tons.

3. The figures for coal are for "black" coal only. Reserves A refer to measured and explored deposits and Reserves B to Reserves A plus known but not fully explored deposits, plus estimated probable deposits. About half of Reserves A, and presumably also of Reserves B, are extractable by current mining techniques.

   For brown coal and lignite world Reserves A are 340 billion tons, Reserves B 2,630 billion tons and 1973 production was 825 million tons. The USSR, the United States, FRG and GDR account for 70 per cent of Reserves A, 90 per cent of Reserves B and 65 per cent of production.

4. Country classification: the FAO regional classification is used.

Africa:	All countries on the continent of Africa except South Africa, Egypt, Libya and Sudan, but including the off-shore island countries
Latin America:	All countries in Central and South America including the West Indies
Near East:	Middle East states plus Afghanistan, Cyprus, Egypt, Lebanon, Sudan and Turkey
Far East:	Other Asiatic states but excluding centrally pla[illegible]d economies
Centrally planned Asia:	China, DPR Korea, Mongolia, DR Vietnam
Western Europe:	Includes Yugoslavia
Other developed countries:	Israel, Japan, South Africa

Table 3. Reserves and production of ammonia feedstocks, by countries

	Natural gas		Crude petroleum		Coal		
	Production (million m^3)	Reserves (billion m^3)	Production (million tons)	Reserves (million tons)	Production (million tons)	(A)	Reserves (B) (billion tons
Developing countries							
Venezuela	41,200	1,220	150	2,030			
Iran	25,600	9,350	300	8,930			
Mexico	19,400	430	30	1,840	4	5	12
Argentina	7,900	210	20	320			
Chile	6,000	80					
China	5,300	710	60	3,380	430	300	1,010
Indonesia	4,600	430	70	2,030			
Bolivia	4,300	310					
Pakistan	4,000	450					
Iraq	3,700	780	90	4,740			
Colombia	3,000	110			3		4
Afghanistan	2,600	100					
Peru	2,100	140					
Nigeria	1,700	1,270	110	2,830			
Kuwait	1,400	910	130	9,850			
Libya	1,200	750	70	3,600			
Algeria	600	6,500	50	1,040			
Abu Dhabi	-	5,660	70	4,060			
Saudi Arabia	-	1,560	420	22,260			
Malaysia	140	620	15	340			
Bangladesh	-	280					
Qatar	50	230	25	810			
Neutral Zone			20	2,340			
Oman			15	810			
India					80	20	80
Korea (D.P.R.)					30		
South Korea, Rep. of					14	1	2
Developed countries							
United States	633,000	6,700	430	4,600	530	320	2,280
USSR	261,000	23,000	450	11,300	460	170	3,400
Canada	95,000	1,600	80	960	17	9	100
Netherlands	81,000	2,700					
United Kingdom	34,200	1,400		2,130	130	100	130
Romania	26,500	60	15	230	7	1	7
F. R. Germany	19,100	330			100	44	230
Italy	16,200	340					
France	8,600	160			26	1	1
Poland	5,000	60			160	32	46
Hungary	4,600	85					
Australia	4,500	1,080	19	390	55	26	110
Japan	2,700	50			22	7	7
Austria	2,500	30					
Norway	-	700	-	1,000			
S. Africa					60	24	44
Czechoslovakia					28	6	12
Spain					10	1	2

Table 4. Phosphate rock, sulphur and potash production

Phosphate rock (1974) (thousands of tons)	P_2O_5	% of total	Sulphur (1974) (thousands of tons)		% of total	Potash (1975) (thousands of tons)	K_2O	% of total
United States	12,500	35	United States	12.200	24	USSR	7,700	32
USSR	7,830	22	USSR	8,500	16	Canada	5,450	23
Morocco	6,350	18	Canada	7,800	15	German D.R.	3,000	12.5
Tunisia	1,140	3	Poland	4,300	8	United States	2,300	9
Togo	910	2.5	Japan	2,800	5.5	F.R. Germany	2,200	9
China	900	2.5	Mexico	2,400	4.5	France	1,900	8
Nauru	890	2.5	France	2,100	4	Israel	600	2.5
Spanish Sahara	860	2.5	F.R. Germany	1,400	2.5	Spain	450	2
Senegal	670	2	Spain	1,300	2.5	China	300	1.25
Christouis Is.	640	2	Italy	800	1.5	Congo	290	1.25
Jordan	520	1.5	Iraq	700	1.5	Italy	150	0.5
South Africa	460	1.3	Iran	600	1	Chile	20	
Vietnam D.R.	420	1.2	Finland	500	1			
			Germany D.R.	400	0.8			
			Norway	300	0.5			
			South Africa	300	0.5			
			Australia	300	0.5			
Others	1,610	4.6	Others	5,000	10			
TOTAL	35,700			51,800			24,360	

Regions	Phosphate rock		Sulphur		Potash	
Africa	10,200		300		290	
Latin America	210		2,910		20	
Near East	860		1,440			
Far East	100		270			
CP Asia	1,440		1,390		300	
Others	1,750		-			
Total developing	14,600	41%	6,300	12%	610	(2.5%)
North America	12,500		20,000		7,750	
Western Europe	20		7,600		4,700	
CP Europe	7,830		14,500		10,700	
Oceania	-		300		-	
Others	760		3,100		600	
Total developed	21,100	59%	45,500	88%	23,750	(97.5%)

Table 5. World phosphate rock reserves

(Millions of metric tons)

	Identified[a]		Hypothetical[b]		Total	
	Rock	P_2O_5	Rock	P_2O_5	Rock	P_2O_5
United States	11,640	3,490	37,500	9,520	49,140	13,010
Latin America	730	220	2,670	710	3,400	930
Africa	26,800	8,050	81,900	21,800	108,700	29,850
West Asia	1,000	300	6,500	1,670	7,500	1,970
Asia (other)	3,060	920	9,460	2,500	12,520	3,420
Australia	1,530	460	10,700	2,750	12,230	3,210
Pacific Islands	45	14	80	23	130	40
	44,810	13,450	148,810	38,970	193,620	52,420

[a] Identified - Specific identified deposits

[b] Hypothetical - Undiscovered deposits, geologically predictable as existing within known districts.

Source: Chemical Economics Handbook (Dec. 1975) based upon U.S. Geological Survey Professional Paper 820, U.S. Dept. of Interior 1973 pp.515-525.

Table 6. Cost estimate of a compost plant to produce 50,000 tons/annum of compost from 80,000 tons of city refuse

(Thousands of US dollars)

	1975 costs
Capital costs	
Machinery	250.0
Transportation, installation, fabrication of ancillary equipment and purchase of spares	125.0
Total machinery	375.0
Civil construction	250.0
Internal transport	40.0
Total capital costs	665.0
Fixed costs	
Capital debt service (principal and interest)	
Machinery	77.0[a]
Civil construction	29.4[b]
Internal transport	10.6[c]
Total capital service	117.0
Maintenance and repairs	
Machinery	56.3[d]
Civil construction	2.5[e]
Internal transport	8.0[f]
Total maintenance and repairs	66.8
Salaries and wages	60.0
Total fixed costs	243.8
Annual average variable costs	
Utilities	10.0
Fuel and lubricants	75.0
Administration	5.0
Total variable costs	90.0[g]
Total fixed and variable costs	333.8
Total production cost per ton of compost	6.68[h]

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[a] Amortized at 10 per cent annual interest over 7 years

[b] Amortized at 10 per cent annual interest over 20 years

[c] Amortized at 10 per cent annual interest over 5 years

[d] Estimated at 15 per cent annually of machinery capital cost installed

[e] Estimated at 1 per cent annually of civil construction capital cost

[f] Estimated at 20 per cent annually of transport capital cost

[g] Based on 80,000 metric tons/annum of refuse processed and 1975 unit costs for electricity, petroleum products, and other supplies

[h] Based on 50,000 metric tons/annum of compost production with N, P_2O_5 and K_2O content of 1.12, 1.02 and 0.81 per cent.

Annex to Chapter IV

WORLD TRADE IN FERTILIZERS AND THEIR RAW MATERIALS[1]

The pattern of trade in fertilizer raw materials, intermediates and products is changing. When single superphosphate (SSP), containing 16-20 per cent P_2O_5, was the principal phosphate fertilizer it was cheaper to transport phosphate rock, containing 28-38 per cent P_2O_5, than SSP. Now that SSP is being displaced by more concentrated products, containing about 50 per cent P_2O_5, this is no longer true and there is an increasing tendency for phosphate rock producers to convert the rock to finished products. There is also a steadily developing trade in intermediate products such as ammonia and phosphoric acid.

From 1950 to 1971 most developing countries increased fertilizer consumption rapidly, the small ones mainly through imports, the large ones partly through increased domestic production and partly through imports. But there also emerged net fertilizer-exporting developing countries.

At present (data relate to 1973/74), about 20 per cent of world production of nitrogen fertilizers enters international trade; for phosphatic fertilizers the proportion is about 17 per cent, but for potash fertilizers it is as much as about 55 per cent. These differences largely reflect various technical and economic conditions.

Pattern of world trade in fertilizers and fertilizer materials

In 1973/74, developing countries (the UNCTAD definition excludes centrally planned economies (CPE) in addition to Asia, Turkey and South Africa, but includes Israel and Yugoslavia) accounted for about 8.5 per cent of world fertilizer production while their consumption reached

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[1] Summary of a preliminary report prepared by the secretariat of UNCTAD on the trade implications of a restructuring of the world fertilizer industry, in compliance with resolutions adopted at the UNIDO Lima Conference in March 1975 and at the fourth session of the UNCTAD conference in May 1976.

about 15 per cent of that total. Taken together the developing countries imported about 5.5 million tons (nutrient content) corresponding to an import value of perhaps $800 million at 1973 prices.[2] The developing countries are, on the other hand, not exporters of phosphate rock. In Table 1 the 1974 world pattern is shown in Annex Table 1.

Annex Table 1. World exports of phosphate rock, 1974

(Millions of tons)

Exports from / to	Australia Canada Japan	Western Europe	Eastern Europe	Developing countries	China	World
United States	5.8	3.5	0.3	3.0	0.1	12.7
USSR	-	3.0*	3.0*	-	-	6.0
Developing countries						
Pacific Islands	4.4	-	-	0.1	-	4.5
North Africa	1.0	14.8	4.6	3.0	0.3	23.7
Others	0.4	4.6	0.1	1.4	0.1	6.6
World	11.6	25.9	8.0	7.5	1.4[a]	55.2[b]

Source: Phosphorous and potassium, No. 82, March-April 1976.

* No direct information used.

[a] Including 0.9 million tons exported from North Vietnam.

[b] Including 0.8 million tons from other exporters not listed and with unknown destinations.

Hence, developing countries (including the Pacific Islands) accounted in 1974 for 64 per cent of world exports of phosphate rock and for 14 per cent of world imports. Intra-trade accounted for about 50 per cent of their total imports, a proportion which should increase with the opening of the Suez Canal. For example, a fertilizer plant in Iran, originally scheduled to operate on North African rock, switched to Florida rock after the closure of the Canal.

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[2] Prices of internationally traded fertilizers more than doubled between 1973 and 1974.

The international trade classifications (SITC and BTN) attempt to show trade in fertilizers according to their chemical composition, but irrespective of the nutrient content and also of the degree of processing. However, internationally traded manufactured fertilizers are either "pure" (containing only one of the three major nutrients, for example, urea, superphosphates or muriate of potash), or complex (produced by a process of chemical reaction), or mixed (from a mechanical mixing procedure). Hence, the ordinary trade statistics cannot show fertilizer trade for the three nutrients separately. The FAO statistics show total exports and imports of individual countries in terms of N, P_2O_5 and K_2O. As the production and consumption projections are expressed in nutrient content it is desirable to show the geographical pattern of world fertilizer trade also in terms of nutrients. Such trade data are not available to UNCTAD. Using the FAO data (in terms of nutrient content) on total exports and imports and available trade statistics expressed in values, the very crude geographical pattern of world trade in manufactured nitrogen and phosphate fertilizers, shown in Annex Table 2, can be established for 1973.

Although, unavoidably, many of the entries in this Table are inaccurate, it does indicate the broad geographical pattern of world trade in nitrogen and phosphate fertilizers (nutrient content) in 1973. The rough estimates in the Table indicate that in developing countries, in Western Europe and in Eastern Europe (groupings consisting of a large number of, or economically integrated, countries) intra-trade accounts for more than 50 per cent of total exports of nitrogen and phosphate fertilizers. In the other three groupings (consisting of a small number of countries) intra-trade obviously plays a much smaller role. In relation to total imports, intra-trade accounted for 67 per cent or more in North America, Western Europe and Eastern Europe but only about 15 per cent in developing countries.

In 1973, OECD countries' exports of fertilizers amounted to about $2.1 billion, of which $0.8 billion, or 38 per cent was to developing countries (excluding China). A fairly large proportion of fertilizer exports to developing countries occurred under various aid schemes.

Annex Table 2. Geographical pattern of world trade in nitrogen and phosphate fertilizers, 1973

(Thousands of tons of nutrient content)

Export from / to	Developing countries a/	North America	Western Europe	Other developed countries	Eastern Europe	Asian CPE	World
Developing countries	710	60	190	20	230*	120*	1,330
North America	2,090	700	240	120	-	30	3,180
Western Europe	1,300	180	2,900	20	70	180	4,650
Other DMEC	800	20	-	50	-	710	1,580
Eastern Europe	60*	-	210	-	520*	200*	990 b/
Asian CPE	50*	-	-	-	-	100*	150 c/
World	5,010	960 d/	3,540 e/	210	820	1,340	11,880

Sources: FAO Monthly Bulletin of Agricultural Economics and Statistics, March 1976, for the world totals (average of 1972/73 and 1973/74 data expressed in nutrient content); trade statistics for 1973 of developed market economy countries and of 50 developing countries for the geographical trade pattern (value data used).

* No direct information used.

a/ UNCTAD definition

b/ The source gives 1,530,000 tons exported. This figure cannot be reconciled with other data in the table, unless the intra-trade of Eastern Europe is increased, as it would raise the total imports into Eastern Europe above the figure given in the table which agrees with the FAO data.

c/ According to FAO, only about 30,000 tons.

d/ According to FAO, about 1,250,000 tons.

e/ According to FAO, about 3,290,000 tons.

Only about 7 per cent of the developed countries' total imports of fertilizers in 1973 originated in developing countries. North America took small amounts from Mexico, Trinidad, Chile and Israel; Japan took even less (from Israel and Chile); while imports into Western Europe were fairly significant, and were supplied largely by Israel (potash), Tunisia (phosphate), Yugoslavia (nitrogen and mixed), Lebanon (mixed), Congo (potash) and Senegal (phosphate).

Intra-trade among developing countries. Trade statistics for 1973 are available in full commodity and geographical breakdown for 50 developing countries and are summarized in Annex Table 3. These countries accounted in 1973/74 for about 90 per cent of total fertilizer exports from all developing countries (UNCTAD definition) in terms of nutrient content and for about 75 per cent of total fertilizer imports of developing countries.

Annex Table 3. Trade of 50 developing countries in manufactured fertilizers (SITC 561), 1973

(Millions of dollars: imports c.i.f. exports f.o.b.)

Countries of origin for imports and of destination for exports	Imports	Exports
50 developing countries[a]	83.1	92.7
Other developing countries	14.1	36.6
Developed market economy countries	685.8	77.2
Centrally planned economies	77.2	57.8
Unspecified	8.5	2.6
Total	868.7	266.9

[a] Trade flows reported by both importer and exporter totalled $42.4 million when the smaller of the two values was used.

The statistics clearly demonstrate the limitations of using ordinary trade statistics for only one year to arrive at a trade network. There are major discrepancies between Kuwait's export figures and the recorded imports from Kuwait, and Singapore appears as a major importer and exporter of fertilizers when the figures represent mainly trans-shipments.

The intra-trade in fertilizers (SITC 561) among the 50 countries in 1973 is shown in aggregate form in Table 4. The major individual flows in the intra-trade of 50 developing countries in 1973 were:

Annex Table 4. Intra-trade in fertilizers (SITC 561) among 50 developing countries, 1973

(Millions of dollars)

A = Exporter's data

B = Importer's data

Exports to from	North Africa		Other Africa		Latin America		Middle East		Other Asia		Yugoslavia		Total	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
North Africa	0.5	-	0.2	0.1	9.0	7.9	-	0.1	10.0	4.2	2.3	1.4	22.0	14.7
Other Africa	-	-	5.1	1.8	1.2	2.0	-	-	2.2	3.6	-	-	8.5	7.4
Latin America	-	-	-	-	15.5	20.5	-	-	-	-	-	0.6	15.5	21.1
Middle East	9.3	10.4	2.7	3.1	3.7	3.8	4.3	3.1	27.6	18.7	1.0	-	48.6	39.1
Other Asia	-	-	-	0.1	-	-	-	-	33.2	10.5	-	-	33.2	10.6
Yugoslavia	-	4.1	-	-	1.5	-	-	-	-	-	-	-	1.5	4.2
Total	9.8	14.6	8.0	5.2	31.0	34.1	4.3	3.1	73.0	37.1	3.3	3.0	129.3	97.2

Source: Special tabulations by the UNCTAD secretariat

Kuwait exports to India, Sudan, Pakistan and Indonesia; Venezuela and Tunisia exports to Brazil, Pakistan and Yugoslavia; Singapore exports (re-exports) to Malaysia; Malaysia exports to Thailand.

In 1973/74 there were 61 developing countries without any form of chemical fertilizer production, 25 countries exported nitrogen fertilizers, 17 exported phosphates and 3 exported potash. Kuwait accounted for almost 45 per cent of the total nitrogen exports of 680,000 tons and five other countries for a further 40 per cent. Of phosphates, Tunisia and Morocco accounted for 50 per cent of the total of 600,000 tons of P_2O_5 and a further 40 countries for an additional 50 per cent.

Of the 25 nitrogen exporters only 12 had a net export, and for phosphates, 10 out of 17 had a net export.

Fertilizer prices

The prices of internationally traded fertilizers and fertilizer materials had been relatively stable for many years up to 1973. During this period of ample supplies, spot prices were frequently lower than prices quoted under long-term arrangements. However, in the course of 1973, fertilizer prices tended to increase as a result of general boom conditions and strong inflationary pressures. The increases in the posted price of crude petroleum imposed by OPEC in October and December 1973 - directly affecting the cost of nitrogen fertilizer production - were accompanied by a trebling of the export price of Moroccan phosphate rock on 1 January 1974 (announced in November 1973), followed by a further 50 per cent rise on 1 July 1974; but on 1 January 1976 export prices were reduced by about 30 per cent.

Typical export prices of nitrogen fertilizers about quadrupled between June 1973 and the second half of 1974 when they peaked. In 1975, prices dropped by some 40 to 50 per cent. Export prices of phosphate fertilizers followed a similar course: triple superphosphate export price for spot sales (leading exporters) increased from about $100/ton mid-1973 to a peak approaching $400/ton by the end of 1974, but fell by about 50 per cent by mid-1975. Potash prices did not change so dramatically; as previously shown such fertilizers are largely produced and consumed in industrial countries.

Figure 1 shows the movement of world prices for the major finished fertilizers from 1965 to 1976.

Trade policy aspects

As previously shown, developing countries have so far not been major exporters of fertilizers to the developed countries accounting, in 1973, for about 7 per cent of total imports of fertilizers (SITC 561) into developed market economy countries.

Tariffs. Present trade in fertilizers is not significantly affected by tariffs or other obstacles. In most developed countries fertilizers, whether crude or manufactured, are treated more as a raw material than as a manufactured product, which is in line with their character of an essential input in agriculture. In the UNCTAD inventory of non-tariff barriers imposed by developed market economy countries to restrict imports of fertilizers there is only one entry, for Ireland, relating to superphosphates.[3]

The tariff regimes in Japan, the United States and the Economic Community of Europe are shown in Table 5.

The European Economic Community has applied the highest number of tariffs to fertilizer products. Benefits under the Generalised System of Preferences (GSP) generally reduce these tariffs to zero with ceilings applied as required. Countries associated with the EEC, and eligible for special preferences, may ship fertilizers at very low tariffs (the highest being 5 per cent) but without ceilings. Fertilizer quotas in the EEC in 1974 and 1975 were not attained, thus any fertilizers sent by developing countries entered duty-free.

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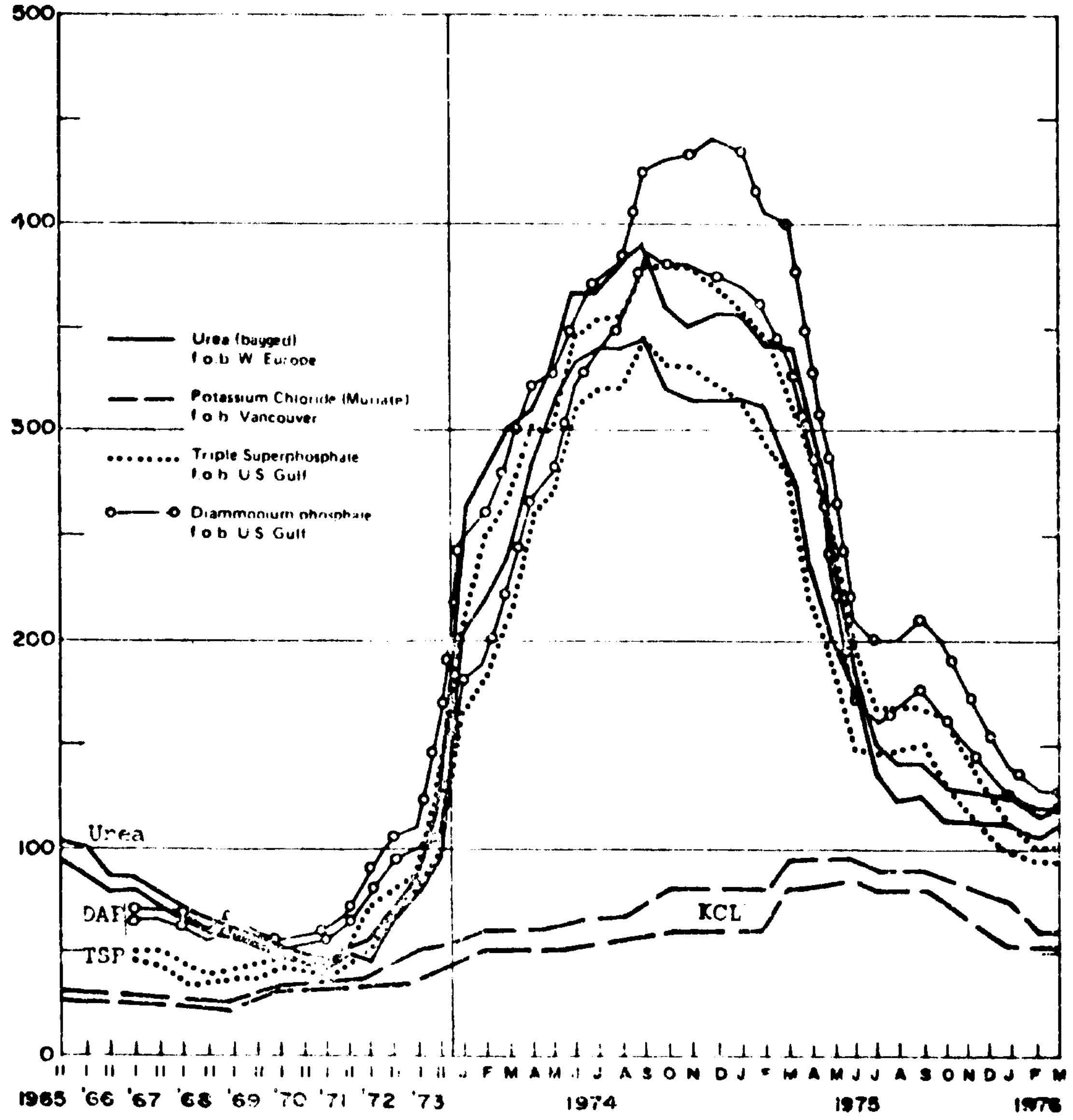
[3] See TD/B/C.2/115/Rev.1 (29 April 1974), page 88, Inventory of non-tariff barriers, including quantitative restrictions applied in developed market economy countries to products of particular export interest to developing countries.

Figure 1. Export prices for some major fertilizer materials, 1965 - 1976

($US/ton)



Note: The double lines indicate the price range for each product.

Source: World Bank, 1965 to October 1975 and November 1975 to March 1976, based on information obtained from various sources.

Annex Table 5. Barriers to trade in fertilizers

BTN	Description	Japan		United States		EEC		
		MFN	GSP	MFN	GSP	MFN	GSP	SP
2510	**Natural calcium phosphate rock**	**Free**	NA	**Free**	NA	**Free**	NA	NA
3101	Guano and other natural fertilizers	Free	NA	Free	NA	Free	NA	NA
3102	Natural sodium nitrate and other nitrogenous fertilizers (urea)	Free	NA	(Free (8) (4.0(1) (8.2(1)	NA YES YES	(Free(1) (8.0(1) (12.8(1)	NA YES YES	NA 1.6 5.0
3103	Double or triple phosphates	Free	NA	Free	NA	(Free(1) (2.4(1) (4.8(1)	NA YES YES	NA 0.2 1.9
3104	Mineral or chemical fertilizers, potassic	Free	NA	Free	NA	(Free(1) (2.4(1)	NA YES	NA 0.2
3105	Ammonium phosphates	Free	NA	Free	NA	(Free(1) (2.4(1) (Free(1) (4.8(2) (6.6(3) (8.0(3)	NA YES NA YES YES YES	NA 0.2 NA 0 0 1.8

Sources: UNCTAS secretariat computer tapes used by the MTN project

Explanation to symbols used:

MFN = Most favoured nation tariff
GSP = Generalized system of preferences: YES means no tariff applied but there may be a quantitative limit to duty-free entry. Number in parenthesis indicates the number of tariff lines at specific tariff rates
SP = Special preference accorded by EEC to associated countries and territories
NA = Not applicable (meaning no tariff)

Export cartels. In order to keep prices artifically high or to divide weak markets, restrictive business practices in the form of export cartels have existed in the past among producers of all three major types of fertilizer: phosphates, potash and nitrogen. However, the effectiveness of such cartels has been minimal and experience during the 1960s shows that in a weak market natural tendencies to compete continue to co-exist with cartels. During this period, evidence of antitrust cases in the United States against phosphate rock producers who had formed a Webb-Pomerene association (as allowed under US law) for the purpose of exporting to outside parties revolved around price fixing for sales under United States AID-financed commodity purchases. Court cases during this period established, however, that such purchases must be treated as domestic sales and are therefore not subject to antitrust exemptions on price fixing.[4] Despite the existence of such an association, prices were unstable throughout the period and only 44 per cent of all exports of phosphate fertilizers were sold by associated companies. In the case of potash, exports by members of the Potash Export Association, Inc. accounted for only about 24 per cent of total United States exports.

In Europe a potash export cartel was organized with the German producers exempted from the German cartel law prohibition and the French producers under government control. There appeared to be at the time (1960s) some agreement between the two. Still, the export cartel tried mainly to control the European market facing competition from Eastern European and North American producers.

The case of nitrogen fertilizers is somewhat different. Some members of the European industry organized Nitrex AG, a Swiss company recognized as the export cartel of these European producers. The cartel was organized to cope with North American and Japanese competition. It was, however, probably involved in some international price fixing with Japanese producers (but probably not North American ones since no export association exists

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[4] A good description of these is offered in UNCTAD document TD/B/390, Restrictive Business Practices: Studies on the United Kingdom of Great Britain and Northern Ireland, the United States of America, and Japan, United Nations, 1973, pp. 79-83.

among United States producers). The only evidence of this was provided in testimony before the United States Senate Subcommittee on Antitrust and Monopoly of the Committee on the Judiciary. Some superficial evidence of price fixing on bids for AID-financed purchases of fertilizers from non-United States producers in both Europe and Japan was at that time presented.[5]

The most important point to be made is that with the development in the developing countries of new sources of fertilizer production, price control will increasingly reflect the political objectives of their governments rather than the objectives of any privately organized export cartel. Thus, in the case of phosphate rock, the North American export price is significantly lower than the Moroccan one ($33 to $48). In the case of nitrogen fertilizers any privately sponsored export cartel in the past was ineffective (judging by the movement shown in prices). With the development of the vast new fertilizer potential in the Middle East, control of the world market price will no longer be in the hands of producers in developed countries with the sole possible exception of those producing potash fertilizers. It is unlikely, however, that they will be able to organize into any reasonably effective cartel under the present set of rules regulating such activities.

<u>Other export restrictions</u>. In developing countries fertilizer plants are being constructed partly to replace imports and partly to provide the country with a source of export earnings. Given the large size of a modern fertilizer plant, many such plants being built in developing countries will temporarily have exportable surpluses before domestic demand catches up. In the event that restrictive clauses are imposed as a condition for the transfer of technology, then the plant will be forced to operate at low capacity utilization and high unit costs. Little information on restrictive clauses is available but there appears to be no record of restrictions being imposed on the export of excess supplies.

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[5] See testimony by Robert O. Link an official of the United States Department of Agriculture, reported in TD/B/390, page 82.

Foreign assistance in the form of fertilizers - the case for untying foreign aid. Fertilizers have traditionally been one of the most important components of direct foreign assistance offered by development market economy countries to the developing countries. In the future fertilizers, possibly provided by producers in oil rich or phosphate rich developing countries, will play an increasingly vital role in the development efforts of these countries. The ability of developing country producers to supply developing country users at reasonable prices will depend upon these producers finding adequate financing for their poorer customers. Financial assistance provided by the developed countries, if untied, is one potential source.[6]

In 1973, foreign-assistance financed fertilizer purchases of developing countries accounted for at most 25 per cent of their total fertilizer imports. Member countries of the Development Assistance Committee (DAC) of the OECD provided about $150 million worth of fertilizers in that year. In 1974, the volume of their gifts remained about the same but the value more than doubled ($370 million).

Future pattern of world fertilizer trade

In an earlier chapter of the present report are presented two alternatives for the growth of the nitrogen and phosphate industry in developing countries. In the first, "Alternative A", the developing countries as a group are self-sufficient in these nutrients by the year 2000. In the second, "Alternative B", they have sufficient production capacity to maintain an export surplus to developed countries equal to 20 per cent of their production.

Before commenting further on the dramatic restructuring of the world nitrogen and phosphate fertilizer industry as outlined in the report, it is necessary to consider potash fertilizers. According to the UNIDO

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[6] OPEC countries have pledged $800 million to a special fund designed to aid the developing countries. Of this sum, $400 million is pledged to the International Fund for Agricultural Development (IFAD). Of the other $400 million, $200 million will be used for balance of payments support for the most seriously affected developing countries without "strings or conditions" attached. It could presumably be used for purchases of fertilizers from developed country, and also developing country, producers.

projections, developing countries (UNCTAD definition but excluding Yugoslavia) would in the year 2000 consume 11.4 million tons (nutrient content) of potash fertilizers whereas their production possibilities are limited.

No information exists on the future production of potash fertilizers in developing countries. For the sake of argument it is assumed here that this production will reach 3 million tons (nutrient content) in the year 2000, compared with 0.76 million tons in 1974.

The arbitrary (but by no means pessimistic) assumption that developing countries will be able to produce just 3 million tons (nutrient content) of potash fertilizers by the year 2000 leaves an import surplus of 8.4 million tons.[1] According to Alternative A this amount becomes the net fertilizer imports into developing countries in that year; according to Alternative B this amount reduces the net exports of developing countries of 24.1 million tons (relating to nitrogen and phosphate fertilizers) to 15.7 million tons for the three major nutrients taken together.

So far there has only been talk of aggregated net trading positions. As far as can be judged, the countries in North Africa rich in phosphate rock are likely to become major exporters of phosphate fertilizers (whether intermediate, phosphoric acid or finished) and the countries in the Middle East rich in hydrocarbons will become major exporters of nitrogen fertilizers (whether intermediate, anhydrous ammonia, or finished).

The Near East is already a net exporter of nitrogen fertilizers and also of potash fertilizer (Israel, but Jordan is also expected to become a producer and exporter of potash fertilizers) and North Africa is already a net exporter of phosphate fertilizers. In addition, new trade flows are likely to grow between developing countries in finished fertilizers. A great many developing countries without abundant resources of crude fertilizer materials are too small to support a fertilizer industry for their domestic market; regional co-operation and specialization is the answer to this problem.

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[1] It should be noted that the probable import surpluses of China and Yugoslavia are excluded from this total.

If developing countries succeed in achieving self-sufficiency in nitrogen and phosphate fertilizers by the year 2000 then, at the same time, the developed countries will lose their export surpluses. In 1973, the United States and Japan accounted for 61 per cent of the value of exports of nitrogen and phosphate fertilizers from developed market economy countries (excluding Austria, Australia, New Zealand and South Africa) to developing countries (excluding China but including Yugoslavia). In that year, as much as 80 per cent of United States fertilizer exports (excluding potash) went to developing countries; for Japan the share was 51 per cent (most of the remainder going to China) and for the Federal Republic of Germany, 38 per cent. In other major exporting countries (the Netherlands, Belgium-Luxembourg, Canada, Norway, France and Italy) the proportion exported to developing countries was much lower, an average of 21 per cent.

Chapter V

THE LOCATION OF FERTILIZER PLANTS

The selection of a site for a fertilizer factory has a significant effect upon the cost of the fertilizers the plant produces. It affects the cost of building the factory, the cost of operating it, and the cost of supplying the fertilizers to the farmer. It is necessary to identify the costs which are affected by plant location and to make a quantitative estimate of them in order to establish at which site minimum costs will be obtained. This process of site selection is important. if the peoples of the world are to be adequately fed there will have to be a massive increase in the consumption of fertilizers. Any increase in costs caused by the uneconomic location of fertilizer plants will restrict the increase in fertilizer consumption, leading to lower food production and higher food costs.

However important the economic factors are, it must be recognized that other factors have to be taken into account, which on occasion may not lead to the choice of a minimum-cost site. The interaction of politics and economics is a familiar feature of our developing industrial society. Governments, with a paramount responsibility for the welfare of their people, have found it both necessary and desirable to restrict the free play of economic forces, and this applies to the selection of industrial sites as well as to other aspects of economic life.

Nationally Governments may, by direction or by various forms of financial incentive, endeavour to limit industrial development in overcrowded areas and encourage it in underdeveloped or "depressed" areas. Internationally Governments may, for reasons of national self-sufficiency, decide to build their own fertilizer plants, even though this may increase the cost of fertilizers to the farmer.

The right of Governments to take such action cannot be gainsaid. However, it is important that the economic consequences of such decisions should be known beforehand, so that a decision can be reached in the light of all the relevant facts. Fortunately, on the international scene the development of many regional and economic groups or associations is leading to an increased awareness of the advantages of international co-operation and regional planning. This is particularly important to the development of the fertilizer industry where, owing to the economies of large-scale operation, the uneven distribution of raw materials, and the very high capital costs, the benefits of international co-operation and the penalties of independent action are considerable.

Apart from the action Governments take to modify or restrict the influence of economic factors, it should be noted that the way in which these economic factors are taken into account will vary according to the nature of the decision-making body.

A private commercial organization will select a site to give minimum cost, using in its calculations, for example, the market values of the various factors, transport costs, wage rates, interest rates, and foreign exchange rates. The final decision will of course be affected by any financial incentives that Government may offer to encourage the establishment of the factory in region A rather than region B; however, the important point is that the choice between different sites is made to maximize profits using the market values of the various cost components.

It may well be, however, that market values do not accurately represent the real value or cost of the various goods or services used, and that the minimum cost derived therefrom does not represent the optimum use of national resources. The wage structure may not reflect the real value to the nation of different kinds of skill and experience; the prices of different forms of transport may not correspond to their true costs; current interest rates may not reflect the true value of capital; and the official exchange rates may not be a satisfactory indicator of the value of foreign exchange. A governmental planning organization, which is concerned with the optimum allocation of national resources, may therefore replace market prices by rather different prices("shadow" prices) which are a better index of the value of the resources used.

This technique of appraisal, often known as "social cost-benefit analysis", is too specialized and complex to be pursued further here. However, it should be noted that the conventional calculation of minimum cost based upon market prices does not necessarily lead to the optimum use of national resources. [1]

In selecting a site, a reasonable balance should be struck between economic and social or political factors. A private commercial organization will naturally attach greatest weight to the economic factors, and may pay insufficient regard to social factors. If a Government wishes to ensure that these factors receive due weight, it must exercise some form of control, either directly through a "licence to build" or indirectly through various forms of financial incentive or penalty. With a governmental organization, on the other hand, the danger is that the economic factors may be under-emphasized since such organizations are frequently free from the ultimate financial accountability to which private commercial organizations are subject.

In the subsequent sections of this chapter factors affecting location are identified and discussed, first at national level and then at regional level. At the national level, the discussion is primarily concerned with an evaluation of the economic factors involved; on proceeding to the regional level, the interplay of economic and political forces assumes greater significance. Finally, the possibilities and advantages of regional co-operation are presented for five regions: Central America and the Caribbean; West Africa; East Africa; West Asia; and South-East Asia.

Principles of factory location

Factors involved

It was stated above that site selection affects the cost of both building and operating the factory, as well as the cost of supplying the fertilizer to the farmer: it affects capital costs, production costs, and distribution costs.

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[1] Guidelines for Project Evaluation. UNIDO 1972. ID/SER./H/2

The factors which cause these effects are:

- Transport: availability and cost, raw materials and markets
- Utilities: availability and cost of electric power and water
- Effluent disposal
- Nature of site
- Labour
- Infrastructure: housing, roads, railways, etc.

Other classifications are possible. Many authorities list separately the location of raw materials and that of markets, which are covered above under "transport". The availability of transport, electric power, water, and effluent disposal systems could legitimately be included in infrastructure; they are listed separately above owing to their importance.

Capital costs

A distinction has to be drawn between the effect of these factors on capital costs and their effect on production and distribution costs. The latter costs enter directly into the selling price of the fertilizer, whereas capital costs enter only indirectly and to an extent determined by company policy. At the low capital charges (18 1/3 per cent) used in Tables 1 and 2 of Chapter III, the difference in capital costs from one site to another could easily lead to 2 - 4 per cent difference in the cost of nitrogenous fertilizers, and 1½ - 2 per cent in the cost of phosphatic fertilizers. At more normal capital charges 25 - 30 per cent, the cost differences would be 3 - 5 per cent and 2 - 3 per cent respectively. These differences are significant and emphasize the need for careful site selection.

The factors which affect capital costs are: the choice between a new and a developed site; the cost of making road and rail connections to the site; the availability and reliability of power and water supplies and effluent disposal systems; the cost of transporting equipment to the site; and the suitability of the site for building operations.

The choice between a developed site and a new site is one which arises more frequently in developed than in developing countries. However, when it does arise, very thorough investigation is necessary because such features as the availability of road and rail connections, the existence of internal roads, offices, workshops, and the presence of water and power supplies make a developed site much cheaper. It is unlikely that a developed site will be in the ideal position with respect to raw material supplies and markets. However, since the capital costs of a developed site can be as much as 20 per cent lower than those of a new site, considerable extra transport costs can be borne.

A large fertilizer factory will produce up to 0.5 million tons of fertilizers a year and will bring in 0.5 - 1.0 million tons of raw materials. It must therefore have good road and rail connections to an adequate and reliable rail and road network. The cost of connecting the factory to such networks will depend on the distance of the site from the network and the nature of the ground to be traversed. This cost can be quite large, and it is usually necessary to select a site not more than a few kilometres from the nearest adequate road or railway.

Reliable power and water supplies are essential to the satisfactory operation of a fertilizer factory. A large factory will have a power demand of 10 - 20 mW. This can be obtained from an outside supplier or generated in the factory. The trend in developing countries is for power to be generated on site, thus making the factory independent of outside supplies. Although this will increase capital costs, it will normally have little effect on total production costs because it is usually possible to generate power at a cost comparable with that of outside supplies. Independent generation is almost always preferable where a long supply line would have to be installed. The availability or lack of external power supplies is not usually a major determining factor in the selection of a site.

The supply of water is a different matter. Fertilizer factories are large consumers of water (see under "Water", Chapter IV) and it is essential that they be located reasonably close to water supplies of satisfactory quality. The ideal site would be near to a river, where water can be pumped through coolers back to the river, thus saving the cost of cooling towers. Such sites are rarely available: more usually, water is taken from public supplies or specially pumped from nearby rivers or lakes. Occasionally, supplies may be obtained from wells sunk on site.

The disposal of gaseous, liquid, or solid wastes may present difficult problems and, in extreme cases, rule out certain sites altogether. Gaseous effluents can usually be made innocuous by suitable treatment; however, if particularly stringent standards are applied in populated areas, capital costs will be increased. Liquid effluents are more difficult, and often more expensive, to handle since ultimately they must be discharged into a large body of water. The cost of treatment before discharge depends upon the concentration of pollutants and the ratio of the volume discharged to the volume of the recipient water. On some sites, the discharge of liquid effluents may not be permitted. In such a situation, the plant must be so designed that liquid effluents are reduced to a minimum prior to their disposal on site or purification and recycling, with consequent increases in capital costs. Solid wastes are usually disposed of more easily, as long as adequate dumping grounds are available, preferably on site. Solid wastes are not normally produced on nitrogenous fertilizer plants, except when coal is used as a raw material. A large coal-based plant would produce 100,000 - 250,000 tons of ash a year, the quantity depending on the ash content of the coal. Phosphate fertilizer factories produce large amounts of by-product gypsum, about two tons for every ton of concentrated phosphate fertilizer. A large factory would, therefore, produce about one million tons a year. This is normally transported as slurry to the dumping ground, which must be close at hand, whereafter the water is drained off and recirculated. Special precautions may be required to prevent the contamination of adjacent land by fluorides. Phosphate factories, therefore, require large dumping grounds on or close to the factory site, and which are free from objection on environmental grounds.

The cost of transporting equipment to the site may be a significant item in total capital costs. In developing countries, 80 per cent or more of the equipment will come from overseas and the cost of moving it to a site remote from the port of entry may be appreciable. If there is a limitation on the size of individual items that can be shipped by rail or road, it may prove necessary to transport major vessels in two parts and to weld them together on site, or to use two smaller vessels in place of one large one. These expedients increasecapital costs.

The qualities of a good building site are obvious. It should be level, have good load-bearing properties and be free from abnormal occurences, such as floods, earth tremors or very high winds. The disadvantages most commonly experienced are the necessity for levelling, back-filling or piling, and the obstruction of access by major roads or railways.

In summary and assuming that a developed site is not available, the ideal minimum-cost site is close to existing road and rail systems, as well as to water supplies; it is not subject to unusually stringent effluent standards; it has reasonable facilities for the disposal of liquid and solid wastes; it does not entail excessive equipment transport costs; it is level and has good load-bearing properties. Such a site will not often be found; usually it is necessary to strike a balance between various advantages and disadvantages which, in order to compare different sites, should be set out in terms of the extra capital costs entailed.

Production and distribution costs

The most important factor is transport costs. Other factors are important: the cost of road and rail connections; the strength or weakness of the infrastructure; the problems of effluent disposal; and the availability of water. However, under normal circumstances, none has so decisive an influence as transport costs. A large modern factory will produce 0.5 million tons of fertilizer a year and consume 0.5-1.0 million tons of raw materials. Transport costs are therefore a major item in fertilizer costs. Differences in transport costs between one site and another frequently outweigh all other cost differences, and the location of a fertilizer factory is often determined by transport costs.

The ease with which raw materials can be transported and stored varies according to the nature of the raw material. Solids, such as phosphate rock, sulphur or coal, can be transported in standard rail or road vehicles and present no problems. Liquids, such a naphtha, fuel oil or ammonia, require special vehicles which are used exclusively for one material, and specially designed storage tanks are needed. Gases, such as natural gas, can be transported only by pipeline and their storage is not normally economic. Water is also transported by pipeline, but is relatively easily stored.

In this discussion, the term "transport costs" is given a wide interpretation. It covers the cost of operating a natural gas, oil or water pipe-line, as well as of effluent or waste removal: all the costs of transporting raw materials and supplies from their point of origin to the site, and of moving products and by-products from the site to their point of consumption or disposal.

In discussing the influence of transport costs on location, some authorities[2] have placed much emphasis on the "weight ratio" of the process; the weight of raw materials used per ton of product. It is argued that if the ratio is greater than unity, the plant should be located close to the source or port of entry of the raw materials. If the ratio is less than unity, the plant should be located close to its markets. The greater the deviation from unity, the more important it is that the plant should be close to its raw materials (ratio $>$ 1) or its markets (ratio $<$ 1). Weight ratios from some typical products and processes are given below:

Weight ratios for typical products and processes

Products	Raw materials			
	Naphtha	Fuel oil	Coals	Phosphate rock/sulphur
Urea	0.5	0.6	1.9	
Amm. nitrate	0.4	0.45	1.4	
Amm. sulphate	0.5	0.55	1.1	
Amm. phosphate				2.2.
Triple superphos.				1.9
Single superphos.				0.85

The table clearly shows why coal-based nitrogenous fertilizer plants are located close to the coalfield. It also explains the growing tendency

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[2] UNIDO Fertilizer Manual, Chapter XVII, page 174 (1967).

among phosphate rock producers to engage in the manufactur of concentrated phosphate fertilizers. The table also shows why this development did not take place until processes and markets for concentrated phosphates had been established: with single superphosphate, the balance is slightly in favour of locating plants close to their markets.

The table also suggests that oil-based nitrogenous fertilizer plants should be close to their markets. This implication should be treated with reserve for two reasons. First, if coal were used on these plants for power and steam generation, the weight ratio would be much nearer unity. Secondly, the weight ratio contains a fundamental weakness as an index of transport costs, since it assumes that transport costs per ton-mile are the same for all materials: this is certainly not true. Transport naphtha or fuel oil by road or rail requires special tank wagons which must be used exclusively for this traffic, making return loads impossible. Bagged fertilizers, and possibly bulk fertilizers as well, can be carried in general-purpose wagons for which return loads may be available. Consequently, the road or rail transport costs per ton-mile for naphtha and fuel oil are much higher than for fertilizers. It may be possible to reduce the cost of transporting naphtha or fuel oil by using a pipeline. The cost and feasibility of a pipeline depends upon the naphtha or fuel oil consumption and the nature of the ground to be traversed. For large factories, pipeline transport may be cheaper, it is certainly much more convenient.

The weight-ratio principle could be more appropriately expressed as the following transport-cost-ratio principle: "If the cost per mile of bringing to the factory the raw materials and supplies needed to make one ton of product is greater than the cost per mile of delivering one ton of product to the market, the factory should be located close to its raw materials. If it is less, the factory should be located close to its market."

The only way to compare transport costs for different sites is to obtain quotations for the different classes of traffic and the various methods of transport, including, where relevant, the cost of transporting gas, oil and water by pipeline, on the basis of which total transport charges can be estimated. The weight-ratio is a useful general guide, particularly when raw materials and products fall into the same transport category; however, it is no substitute for a detailed cost comparison for specific sites.

The influence of power and water supplies as well as of effluent or waste disposal has been considered above (see "Capital costs") and little remains to be added. In deciding whether, on a particular site, to generate power or to rely on external supplies, the probable frequency of power failures and the frequency and magnitude of voltage surges should be determined from past records. In respect of water supplies, the quality of available supplies should be considered, since this determines the cost of treatment both for boiler-feed and cooling water. Attention should also be paid to the seasonal variations in the flow of water sources or effluent recipients since these may limit the water supply or the permissible quantity of effluent.

The fertilizer industry is capital-intensive rather than labour-intensive; labour and management costs rarely amount to more than 10 per cent of production costs. However, the cost of labour is not a valid indication of its importance. Output lost due to operating faults or unsatisfactory maintenance may seriously increase costs and make production targets unattainable. In most developing countries and on most sites, extensive labour training is necessary, both before and after the start-up of the factory. The availability of skilled people may vary from site to site, but it is improbable that the cost of training will differ markedly from one site to another. The same cannot be said of housing costs. In remote areas, it may be necessary to provide a complete housing estate with shops and recreation facilities, and the capital and maintenance costs may be considerable.

Various items normally covered by the term "infrastructure" have already been touched upon above: the road and rail system, the existence and reliability of power and water supplies, the availability of labour, and housing. In its broadest sense, the term is used to denote the non-productive capital equipment and services that are available to maintain the life of a community. It covers transport and communications, power and water supplies, waste disposal, housing, shopping and other commercial and recreational facilities, educational institutions etc. From the point of view of selecting a site for a major industrial enterprise, infrastructure is important for both strictly practical and also more general reasons.

The adequacy and reliability of transport and communications are of major importance. The regular, prompt delivery of raw materials, spares and other supplies, and removal of the product are essential to the steady and continuous operation of the factory. Prompt delivery is also of primary importance in the contruction of the factory. Delays in the delivery of equipment to the site may well lead to very costly delays in the completion of construction.

Of equal importance is a reliable and efficient communications system whereby regular contact can be maintained with suppliers and customers. It is highly desirable that alternative transport systems should be available so that, should rail connections break down, [illegible] product can [illegible] quickly [illegible] road transport, or vice versa. A site with only one form of transport available to it would be [illegible] if its countervailing advantages are very great indeed. The disadvantages of a site with uncertain transport facilities can be overcome to some extent by providing more storage capacity for both raw materials and products than would be normally required. This is basically a form of insurance and, as in all insurance problems, it calls for a careful, and rather difficult, assessment of risks and premiums.

The presence of a developed industrial and commercial community within reasonable distance of the site is a distinct advantage. It will be a source of labour and of many of the miscellaneous supplies and services which the factory requires, thus helping to integrate the factory into the life of the local community. Perhaps the most important advantage, however, is that it enables factory employees to live a much fuller and more varied social life than they could as members of an isolated factory community. This leads to a socially healthier community, which, in the long term, is more efficient.

The influence of the local infrastructure on the selection of a site is not readily quantifiable. However, it is important and may on occasion be decisive, usually owing to the lack of adequate transport. The following quotation from a publication issued as early as 1969 underscores the importance of an adequate infrastructure.

"In developing countries the lack of suitable infrastructure lies at the root of delays in implementing projects. Farmers in a certain area may be taught how to increase crop yields substantially by the use of fertilizer only to find at harvest time that crops cannot be moved fast enough to the market because of inadequate roads or freight facilities. It does not suffice, therefore, to import machinery and up-to-date processes if the supporting infrastructure is lacking.

It would seem desirable to relate the growth of industrialization to the growth of infrastructure. In some developing countries a single superphosphate plant may be all the industrialization that the infrastructure can support. In others the infrastructure may be advanced enough to support a modern ammonia plant." [1]

The process of site selection

The amount of time and effort required to select a site obviously depends on the number of sites chosen for detailed comparison. This is much less than might at first be expected since the choice of sites is usually quite restricted.

If a factory has to compete with other manufacturers or imports, the areas in which it can operate economically may be few and fairly clearly defined. The factory must be reasonably close to its raw materials and/or its markets - a coalfield several hundred miles from a large fertilizer market is not likely to be a suitable source of raw material for fertilizer manufacture. For reasons of national policy, Government may specify the area in which the plant must be built. It must be within reasonable distance of an adequate water supply and close to a road and/or rail system, and the cost of connecting it to that system must not be excessive. The site itself must be suitable for building operations. Factors such as these usually determine the area in which the factory can be built and reduce the number of possible sites to two or three. Only when this process of elimination has been completed, can the detailed comparison of sites begin.

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[1] Factors Inhibiting the Indigenous Growth of the Fertilizer Industry in Developing Countries, page 9, UNIDO 1969 ID/13.

It is useful to distinguish three stages in this process. In the first stage, competition, the location of markets and raw materials, and government policy combine to define the general area. In the second stage, the need for a site close to water supplies and to a satisfactory transport system, and which is also suitable for building, leads to the identification of two or three sites in the general area selected in the first stage. In the third stage, a detailed cost comparison of the sites is made to enable the cheapest and most suitable site to be identified.

The first stage is general, whereas the second and third stages are specific. The initial stage takes the form of a general survey which can be carried out from an office desk, provided that the necessary information is available. The subsequent stages require detailed investigation and analysis, and much field work is involved. The distinction between the first and second stages is most relevant in complex situations where considerable competition and well-established fertilizer industry already exist.

Factory location and fertilizer industry planning

The technical and economic factors governing location were discussed above in general terms, basically in the context of deciding the location of a single fertilizer factory. If the context is widened to cover the planning of the fertilizer industry as a whole, including the possibilities and risks of international and regional co-operation, the foregoing discussion is still relevant because the basic economic factors affecting location still apply, while fresh possibilities are introduced and important non-economic considerations arise. The questions of location in this wider context are considered below. Such consideration is important because, if a reasonable degree of international or regional co-operation can be achieved, large savings in both capital and production costs are possible.

In recent years the rate of growth of the fertilizer industry in developing countries has markedly increased. From 1965 - 1970, the annual production of fertilizer nutrients in these countries increased by 3.5 million tons, from 1970 - 1975 by 6.5 million tons, and from 1975 - 1980 it is expected to increase by more than 14 million tons (Chapter II, Tables 1 and 7).

Initially, this expansion was undertaken in order to reduce the large expenditure of foreign currency on fertilizer imports, to use indigenous raw materials, and to develop an industrial structure. In the early 1970's considerable impetus was given to this expansion by **the serious instability of** the world fertilizer market. In mid-1972, urea was available on world markets at an f.o.b. price of $55 a ton. By the end of 1974, this price had risen to about $350 a ton, and supplies were difficult to obtain. Similar price rises were experienced for phosphate fertilizers in 1975. Prices have now fallen to more reasonable levels, but the bitter experience of many developing countries over this period has strengthened their determination to obtain much more control over the availability and price of fertilizers through the development of their own fertilizer industries. It is probable that the main cause of the instability of the world fertilizer market, which is common to other world market commodities, is a lack of balance between supply and demand. When supply exceeds demand, prices are low and the return on capital is insufficient to encourage investment. In due course demand, which increases at about 7 per cent a year, catches up with, and surpasses, supply. Prices rise sharply and investment is encouraged. In about three years, the new capacity comes on stream, supply is in excess of demand, and the cycle begins again.

Decreasing the dependence of developing countries on the world market will obviously mitigate the effects this cycle has on their economies. However, a number of developing countries lack either the market or the raw materials to justify the establishment of a viable fertilizer industry, and they must continue to rely on outside sources for their fertilizers. For those countries which have the market but lack the raw materials, the goal of national self-sufficiency in production would, in some cases, be prohibitively expensive. It is also likely to lead to a world surplus of production capacity which in turn would depress fertilizer prices, thus perpetuating the instability of the world market and preventing the rational development of the fertilizer industry.

Regional planning

If the fertilizer market is to be stabilized and the rational and economic development of the fertilizer industry is to be secured between developed and developing countries as well as among the developing countries themselves, some international co-operation in the establishment and location of fertilizer factories is essential: fertilizer planning on an international scale is required. The difficulties of obtaining at a global level the co-operation which planning requires are formidable, but at the regional or subregional level, the possibilities are real and the rewards considerable.

The aims of fertilizer industry planning are to effect a more rational distribution of manufacturing capacity, thereby providing an assured supply of fertilizers at minimum cost, and contributing stable prices, and to locate manufacturing capacity as widely as possible consistent with these aims.

The savings which it secures are obtained by maximum exploitation of the economies of scale: by establishing a limited number of large plants in optimum locations rather than numerous smaller plants in each country involved, and by locating the plants so as to minimize total transport costs for raw materials and products. The potential benefits of co-operation are obvious, but quantitative data are hard to come by. A recent study conducted by the International Fertilizer Development Centre (IFDC) ,in co-operation with the World Bank,of the benefits of co-operation among the ASEAN nations (Indonesia, Malaysia, the Philippines, Singapore and Thailand) is particularly interesting. [4] In the study estimates are made of the capital, production and transport costs of supplying the fertilizer requirements of the ASEAN group up to 1985, and various assumptions are made about the extent of co-operation among the member countries.

The extent of co-operation affects the number, size and location of the plants needed to meet the demand envisaged in 1985. In the first case (X in the table below), it is assumed that no constraints are placed on the size or location of plants by considerations of national self-sufficiency. Moreover, the number, size and location are fixed to given minimum total production cost for the area as a whole. In the second case (Y in the table below), it is assumed that each country in the group requires that manufacturing

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[4] The Potential for Regional Co-operation in Fertilizer - the ASEAN Group. International Fertilizer Development Centre. January 1976.

capacity for at least 75 per cent of its nitrogen fertilizer consumption be located in its own territory. This will, of course, increase production costs and fertilizer prices for the area as a whole. In the third case (Z in the table below) it is assumed that there is no co-operation in fertilizer manufacture and that each country produces in its own territory all the nitrogen and phosphate fertilizers that it consumes. This naturally gives the maximum production cost for the area. In each case total annual production is the same: 2.24 million tons N, 0.69 million tons P_2O_5 and 0.49 million tons K_2O.

Effect of regional co-operation on capital and production costs

Case	Capital	Annual production and transport costs Millions US$ (1975 basis)					
		Capital changes	Imports	Domestic raw mat.	Operating	Sea trans.	Total
X[a]	1440	200	193	68	202	30	693
Y[b]	1515	213	251	64	213	22	763
Z[c]	1550	216	285	54	217	18	790

Source: Extracted from IFDC report "The Potential for Regional Co-operation in Fertilizer - the ASEAN Group, Table 2.

a/ Plant location selected to give minimum cost;

b/ Each country produces at least 75 per cent of its N fertilizer requirements;

c/ Each country produces all its own N and P_2O_5 fertilizer requirements.

It is obvious that the financial benefits of co-operation are considerable. If the two extreme cases are considered, X with complete co-operation and Z with no co-operation, case X reduces capital costs by $110 million, approximately 7 per cent, and the savings in total operating and transport costs are $100 million a year, approximately 13 per cent. Even the limited extent of co-operation in case Y, with a minimum of 75 per cent self-sufficiency in nitrogen fertilizers, saves $75 million (5 per cent) in capital and $70 million a year (10 per cent) in production costs. A reduction of 10 - 13 per cent in the delivered cost of fertilizer is equivalent to $20 - 25 a ton of urea. This is a major saving and will lead to a greater use of fertilizers in the region, with a consequent increase in crop yields.

It should be noted that these benefits are obtained in an area not particularly well endowed with raw materials. The region has adequate supplies of natural gas for nitrogen fertilizers, but practically no phosphate and, at present, no potash. In better endowed regions, even greater savings should be possible. This IFDC study is important and encouraging, but it is most desirable that similar studies be undertaken for other regions so that a reliable body of data on the concrete advantages of international co-operation can be made available.

Co-operation at this level has, of course, other advantages. It achieves a significant expansion of intra-regional trade. It will encourage the flow into the region of private and institutional capital for fertilizer manufacture, thus simplifying the task of financing fertilizer expansion. Plants established under co-operative planned development may all be publicly-owned, but this is not an essential part of the scheme. Intergovernmental agreements on raw material supplies and fertilizer sales as well as the requisite freedom of intra-regional trade in fertilizers will give private capital an assurance which is often lacking. International co-operation will also strengthen bargaining capacity in the acquisition of foreign technology. If it is associated with the establishment of a regional information research and training centre, it will provide a valuable service to the region. This will lead to more informed action on fertilizer problems and, in due course, provide that body of trained and experienced people which is essential to industrial and agricultural development.

However, it is probable that the most important advantage, second only to the financial benefits, is the experience of corporate planning which regional co-operation provides. Furthermore, institutions are set up through which international co-operation can be developed and its problems hammered out in open discussion. Once experience has been gained, a working method developed and a co-operative spirit established, co-operation will be facilitated in other industries of common interest.

The financial advantages of international or intra-regional co-operation are large, and the less tangible benefits also considerable. However, co-operation on these scales presents problems which have to be considered in any realistic assessment. It requires joint agreement on plant location, based on economic criteria, with the implied willingness to depend on regional rather than national production facilities for a large part of national requirements. It calls for joint evaluation of national and regional demand since fertilizer factories are planned to meet demand some ten years hence. If the estimates are too high, production costs will increase unless additional export markets can be found. Free trade in fertilizer raw materials and products would be required, if the most economic locations are to be selected. Regional co-operation implies agreement on the sharing and timing of each country's contribution to the investment, as well as on long-term supply contracts for stated amounts of fertilizers at agreed prices. These contracts would have to include provisions for price reviews in order to meet changes in raw material and other costs, and penalty clauses would be needed in the event of failure to supply or accept supplies when available. Co-operation would also be required in shipping and/or internal transport arrangements.[5]

Provision for the review of contractual arrangements pertaining to such matters as financing, product sharing, product prices, free trade and shipping, is essential, if the agreements are to cope with changing economic conditions and unforeseen circumstances. The purpose of these agreements is to secure an equitable sharing of the responsibilities and benefits of regional co-operation: changing circumstances, however, may make an equitable agreement inequitable.

The essential factors are the will to co-operate and the desire for justice. Given these factors, the stresses to which the agreements may be subjected as a result of low world fertilizer prices or failure of regional supply, for example, can be overcome. If the will to co-operate is weak or if one party decides to pursue a temporary national advantage, no agreement will survive.

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[5] Regional Co-operation in Chemical Fertilizer, UNIDO/ESCAP, February 1976. DF/CFPD/3

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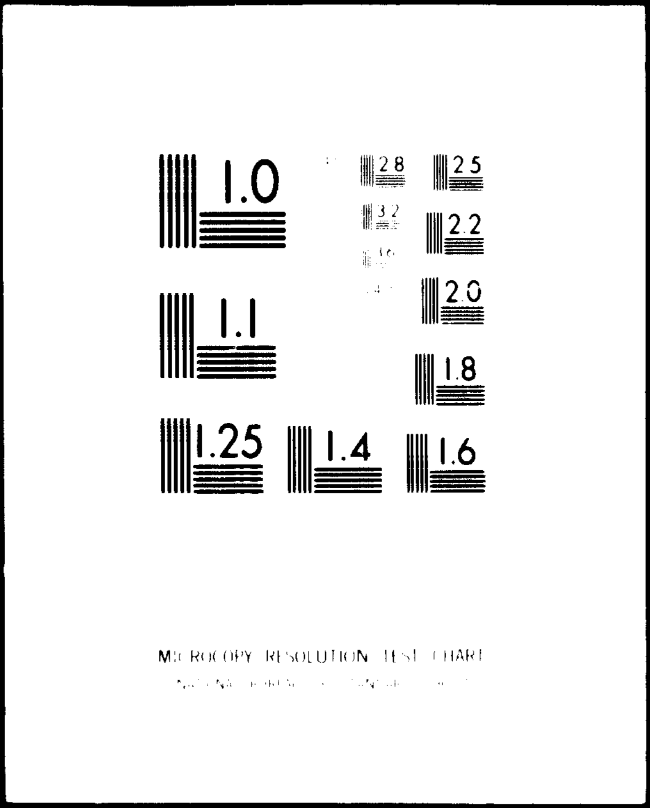

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The principal risks that Governments face in entering into regional co-operation agreements are that changes in Governments or political systems in the region may lead to a repudiation of the agreements. If the agreements are clearly beneficial to all signatories and if they are flexible enough to meet genuine difficulties this risk is appreciably reduced. The risks obviously increase as the number of participant countries increases, though the effects of individual repudiation are diminished. It is for this reason that large-scale international agreements are so difficult to conclude. If the mutual trust and confidence which are needed for regional agreements are lacking, the possibility of bi-lateral or tri-lateral co-operation should be explored. It is improbable that this will yield as great benefits as regional co-operation, but they may still be considerable and the risks are greatly reduced.

However, there is clear evidence on the international scene that developing countries are beginning to appreciate the advantages of increased co-operation among themselves, not only with respect to the deliberations and operations of international institutions, but also in their relations and negotiations with developed countries. If this co-operation can be developed to a point at which regional planning of the fertilizer industry becomes a practical proposition, a significant step forward will have been taken towards ensuring an adequate supply of food for the world's growing population.

Analysis of five regions

Five regional groupings were selected to illustrate the possibilities for regional co-operation in the production and distribution of fertilizers. Data on population, fertilizer consumption, fertilizer production and occurrence of fertilizer raw materials in the five regions are given in Tables 1 - 5.

South-East Asia. The region includes ten countries in the triangle: Burma - Indonesia - the Philippines.

Population 1975	347.6 million
Population 2000	634.8 million

(thousand tons)

1973/74	N	P_2O_5	K_2O
Fertilizer consumption	496	227	222
Fertilizer production	245	115	nil

The region has good supplies of natural gas and oil refinery products in several countries for the production of nitrogen fertilizer. The only phosphate rock reserves are in Vietnam; the only source of sulphur is from copper smelters in the Philippines; and the large reserves of potash in Thailand and Laos have never been developed.

Clearly, the production of all three nutrients can be developed further in the region despite the uncertainty of phosphate rock supplies from Vietram. The supply of sulphur in the Philippines is probably not large enough to permit self-sufficiency in phosphate fertilizer in the region.

An important study on this region entitled "The Potential of Regional Co-operation in Fertilizer - The ASEAN Group", was published by the International Fertilizer Development Center in January 1976. The report, however, includes only five Asian countries: Indonesia, Malaysia, the Philippines, Singapore and Thailand. The analysis gives a distorted picture of economic relationships of the fertilizer sector in South-East Asia since it fails to consider Brunei, Burma, Cambodia, Laos and, in particular, Vietnam.

West Asia. The region comprises 16 countries in the triangle: Turkey - Iran - Yemen.

Population 1975	120.5 million
Population 2000	239.7 million

	(thousand tons)		
1973/74	N	P_2O_5	K_2O
Fertilizer consumption	760	465	44
Fertilizer production	711	253	515

The region has adequate reserves of all raw materials needed to meet all its fertilizer needs for many years.

In 1973/74 the region was approximately balanced in nitrogen fertilizer but new capacity under construction in Iran, Iraq, Qater, Syria and Turkey will make the region a surplus nitrogen producer in the near future. Additional nitrogen capacity is also being planned in Bahrain, Kuwait, Oman, Saudi Arabia and the United Arab Emirates.

Phosphate fertilizer capacity should be expanded to meet the region's needs. Potash consumption is very small, but will undoubtedly increase in the future. In the meantime, surplus potash will be exported to Europe, Africa and South-East Asia.

West Africa. The region comprises 26 countries extending from Mauritania to Angola on the west coast of Africa. Zambia is included in both the West Africa and East Africa regions since it has railway connections with both coasts.

Population 1975	165.9 million
Population 2000	338.2 million

	(thousand tons)		
1973/74	N	P_2O_5	K_2O
Fertilizer consumption	84	56	55
Fertilizer production	18	27	263

The region has all raw materials, except sulphur, needed to meet its fertilizer needs. Sulphur could be supplied by developing further the copper smelters in Zaïre and Zambia, and possibly by extracting sulphur from natural gas in Angola, Gabon and Nigeria.

Consumption of all nutrients was far below that required to provide adequate food for 166 million people in 1975, and fertilizer consumption will have to increase greatly during the next decades in order to feed 338 million people in the year 2000.

An excellent opportunity exists for a large nitrogen fertilizer plant located in Nigeria, Gabon or Angola to supply the entire West African region. Phosphate fertilizer production should be expanded in Senegal and initiated in other countries with phosphate rock reserves, even if only single superphosphate is produced for local consumption.

Potash production in the Republic of Congo would be enough to meet the region's needs for many years, were it not for the fact that most of it is currently exported to Europe.

East Africa. The region comprises 13 independent states and one dependency (Réunion) extending from Ethiopia to Mozambique on the east coast of Africa.

Population 1975	114.0 million
Population 2000	239.1 million

1973/74	N	P_2O_5	K_2O
	(thousand tons)		
Fertilizer consumption	180	113	69
Fertilizer production	74	60	nil

The region has little natural gas (only in Mozambique, as yet undeveloped), but the numerous oil refineries could supply naphtha or fuel oil as feedstock for the production of nitrogen fertilizer. Furthermore, coal is available in Rhodesia and Zambia.

The only regional source of phosphate rock is in Uganda, but this might not be enough to meet the region's entire phosphate fertilizer requirements, even if transportation problems could be overcome. Moreover, the region has no sulphur supplies. The only regional source of potash, which has never been developed, is in Ethiopia.

Central America/ Caribbean region. The region comprises 20 independent countries and six dependencies in Central America, the northern sector of South America and the Caribbean. Mexico has not been included in this region because its large nitrogen fertilizer production will be almost entirely consumed on the domestic market, although phosphoric acid will remain a surplus product and thus be exported.

Population 1975	87.9 million
Population 2000	162.2 million

1973/74	N	P_2O_5	K_2O
	(thousand tons)		
Fertilizer consumption	613	243	291
Fertilizer production	221	108	nil

The region is well-supplied with natural gas and oil refinery products as feedstocks for nitrogen fertilizer production. Production should be expanded so that the region becomes self-sufficient in nitrogen fertilizer, which could also be exported from Venezuela, and Trinidad and Tobago.

The region does not have adequate phosphate rock nor sulphur to meet the region's phosphate fertilizer needs. Nevertheless, phosphate fertilizer production should be expanded to meet a larger share of the region's needs by importing phosphate rock from the United States and/or West Africa, and sulphur from the United States and/or Mexico. The region has no potash reserves and will have to continue to import potash.

Table 1: South-East Asia Region

(All countries in the triangle: Burma - Indonesia - Philippines)

	Population millions		1973/74 Fertilizer consumption '000 tons			Fertilizer production '000 tons			Raw materials available
	1975	2000	N	P_2O_5	K_2O	N	P_2O_5	K_2O	
Brunei	0.15	0.22	—	—	—	—	—	—	Gas, oil refinery
Burma	31.24	54.90	41.7	15.1	—	46.7	—	—	Gas, oil refineries
Cambodia	8.11	15.82	—	—	—	—	—	—	Oil refinery
Indonesia	136.72	238.65	—	—	—	91.0	—	—	Gas, oil refineries
Laos	3.30	5.73	0.1	0.1	—	—	—	—	Potash
Malaysia	12.09	22.05	112.7	36.7	112.3	46.2	24.3	—	Gas, oil refineries
Philippines	44.44	89.71	145.8	45.5	44.9	52.8	40.5	—	Oil refineries, sulphur
Singapore	2.25	3.13	1.0	1.0	1.0	—	—	—	Oil refineries
Thailand	42.09	85.62	70.0	44.7	40.1	8.0	—	—	Oil refineries, potash
Vietnam	67.25	118.94	124.9	83.7	23.4	—	50.0	—	Oil refineries, phosphate rock, coal
Regional Total	347.64	634.77	496.2	226.8	221.7	244.7	114.8	—	

Table 2: West Asia Region

(All countries in the triangle: Turkey - Iran - Yemen)

1973/74

	Population millions		Fertilizer consumption '000 tons			Fertilizer production '000 tons			Raw materials available
	1975	2000	N	P_2O_5	K_2O	N	P_2O_5	K_2O	
Bahrain	0.25	0.54	—	—	—	—	—	—	Gas, oil refinery
Cyprus	0.67	0.85	11.6	8.1	2.2	—	—	—	Oil Refinery, sulphur
Iran	32.92	66.59	176.8	113.9	1.0	142.8	73.6	—	Gas, oil refineries, phosphate rock, sulphur
Iraq	11.07	24.45	25.0	15.1	1.2	28.2	—	—	Gas, oil refineries, phosphate rock, sulphur
Israel	3.42	5.57	30.3	—	11.4	31.8	17.2	514.8	Oil refineries, phosphate rock, potash
Jordan	2.69	5.89	1.0	0.7	0.4	—	—	—	Oil refinery, phosphate rock, potash
Kuwait	1.09	3.18	—	—	—	289.3	—	—	Gas,oil refineries, sulphur
Lebanon	2.87	6.12	38.6	23.7	10.4	—	65.0	—	Oil refinery
Oman	0.77	1.64	—	—	—	—	—	—	Gas
Qatar	0.09	0.20	—	—	—	14.0	—	—	Gas, oil refinery
Saudi Arabia	8.97	18.60	4.0	1.2	3.2	60.7	—	—	Gas, oil refineries, phosphate rock
Syria	7.26	15.82	33.3	7.5	1.8	9.5	0.3	—	Gas, oil refineries, phosphate rock
Turkey	39.88	72.59	429.9	280.0	12.7	135.0	97.0	—	Oil refineries
United Arab Emirates	0.22	0.47	—	—	—	—	—	—	Gas, sulphur
Yemen	6.67	13.75	0.4	—	—	—	—	—	None
Democ. Yemen	1.70	3.43	—	—	—	—	—	—	Oil refinery
Regional Total	120.54	239.69	750.9	465.2	44.3	711.3	253.1	514.8	

Table 3: West Africa Region

(All coastal countries from Mauritania to Angola
plus all land-locked countries bordering on a coastal country)

1973/74

	Population millions		Fertilizer consumption '000 tons			Fertilizer production '000 tons			Raw materials available
	1975	2000	N	P_2O_5	K_2O	N	P_2O_5	K_2O	
Angola	6.35	12.46	12.3	8.1	7.8	—	—	—	Gas, oil refineries
Benin	3.07	5.92	1.3	1.5	1.6	—	—	—	Oil refinery
Cameroon	6.40	11.58	9.3	2.3	4.6	—	—	—	Gas
Cape Verde Islands	0.30	0.43	—	—	—	—	—	—	None
Central Afr. Rep.	1.79	3.36	0.9	0.4	0.3	—	—	—	None
Chad	4.02	6.91	2.2	1.4	1.1	—	—	—	None
Congo	1.35	2.72	1.0	0.1	4.0	—	—	263.0	Gas, potash
Equatorial Guinea	0.31	0.50	0.6	—	—	—	—	—	None
Gabon	0.53	0.66	—	—	—	—	—	—	Gas, oil refinery
Gambia	0.51	0.85	0.3	0.6	—	—	—	—	None
Ghana	9.87	21.16	1.0	2.7	2.1	—	—	—	Oil refinery
Guinea	4.42	8.46	0.8	0.1	0.1	—	—	—	Oil refinery
Guinea-Bissau	0.53	0.84	n.a.	n.a.	n.a.	—	—	—	None
Ivory Coast	4.89	9.62	6.0	7.3	14.9	5.0	7.0	—	Oil refinery
Liberia	1.71	3.22	2.2	0.8	0.4	—	—	—	Oil refinery
Mali	5.70	11.26	5.0	3.6	0.1	—	—	—	Phosphate rock
Mauritania	1.31	2.32	0.2	—	—	—	—	—	Phosphate rock (?)
Niger	4.60	9.57	0.2	0.1	0.1	—	—	—	Phosphate rock
Nigeria	62.93	134.92	4.7	4.1	2.5	—	—	—	Gas, oil refineries
Sao Tomé + Principe	0.08	0.88	—	—	—	—	—	—	None
Senegal	4.42	8.17	7.4	7.8	7.9	8.8	20.4	—	Phosphate rock, oil refinery
Sierra Leone	2.98	5.72	1.1	1.1	0.5	—	—	—	Oil refinery
Togo	2.25	4.64	0.3	0.2	0.2	—	—	—	Phosphate rock
Upper Volta	6.03	10.97	0.4	0.1	0.1	—	—	—	Phosphate rock
Zaïre	24.49	49.45	3.2	1.6	1.8	—	—	—	Oil refinery
Zambia	5.02	11.57	24.0	11.6	4.5	4.3	—	—	Oil refinery, coal
Regional Total	165.86	338.16	84.4	55.5	54.6	18.1	27.4	263.0	

Table 4: East Africa Region

(All coastal countries from Ethiopia to Mozambique plus land-locked countries bordering on a coastal country, and the major offshore islands)

1973/74

	Population millions		Fertilizer consumption '000 tons			Fertilizer production '000 tons			Raw materials available
	1975	2000	N	P_2O_5	K_2O	N	P_2O_5	K_2O	
Burundi	3.77	7.28	0.6	0.4	0.2	—	—	—	None
Ethiopia	27.98	53.67	9.1	10.1	0.1	—	—	—	Oil refinery, potash
Kenya	13.25	31.02	20.4	20.7	2.6	—	—	—	Oil refinery
Madagascar	8.02	17.78	5.0	3.5	4.6	—	—	—	Oil refinery
Malawi	4.92	9.54	7.3	3.9	2.1	—	—	—	None
Mauritius	0.90	1.26	11.2	3.3	11.7	—	—	—	None
Mozambique	9.24	17.65	9.0	3.2	1.8	8.0	3.0	—	Gas, oil refinery
Réunion	0.50	0.73	6.1	3.5	4.5	—	—	—	None
Rhodesia	6.28	15.15	70.0	44.0	32.0	60.0	44.0	—	Oil refinery, coal
Rwanda	4.20	8.71	0.4	0.1	0.6	—	—	—	None
Somalia	3.17	6.54	1.2	0.5	0.6	—	—	—	None
Tanzania	15.44	34.05	11.1	5.3	3.0	1.8	8.5	—	Oil refinery
Uganda	11.35	24.16	4.0	2.4	0.8	—	4.1	—	Phosphate rock
Zambia	5.02	11.57	24.0	11.6	4.5	4.3	—	—	Oil refinery, coal
Regional Total	114.04	239.11	179.9	112.5	69.1	74.1	59.6	—	

(All countries and major dependencies in Central America, Caribbean and the North Coast of South America from Colombia to French Guinea)

1973/74

	Population millions		Fertilizer consumption '000 tons			Fertilizer production '000 tons			Raw materials available
	1975	2000	N	P_2O_5	K_2O	N	P_2O_5	K_2O	
Bahamas	0.20	0.33	n.a.	n.a.	n.a.	—	—	—	Oil refinery
Barbados	0.25	0.29	2.2	0.2	2.8	—	—	—	Oil refinery
Belize	0.14	0.23	0.6	1.6	0.4	—	—	—	None
Colombia	25.89	51.46	153.8	66.8	53.2	85.8	73.5	—	Gas, oil refineries, phosphate rock
Costa Rica	1.99	3.70	34.0	10.0	20.0	27.0	—	—	Oil refinery
Cuba	9.48	15.27	130.4	50.3	96.6	20.0	10.5	—	Oil refineries
Dominican Rep.	5.12	11.76	40.6	13.9	21.3	—	—	—	Oil refineries
El Salvador	4.11	8.80	68.0	31.8	3.0	7.0	4.0	—	Oil refinery
French Guinea	0.06	0.12	n.a.	n.a.	n.a.	—	—	—	None
Grenada	0.10	0.11	n.a.	n.a.	n.a.	—	—	—	None
Guadeloupe	0.35	0.49	4.0	3.8	3.0	—	—	—	None
Guatemala	6.13	12.37	34.4	7.3	11.1	—	—	—	Oil refineries
Guyana	0.79	1.26	9.3	2.6	2.3	—	—	—	None
Haiti	4.55	7.05	0.7	0.2	0.5	—	—	—	None
Honduras	3.04	6.88	14.0	2.0	3.0	—	—	—	Oil refinery
Jamaica	2.03	2.73	11.0	3.6	7.0	3.0	—	—	Oil refinery
Martinique	0.36	0.49	4.5	3.9	4.4	—	—	—	Oil refinery
Netherlands Antilles	0.24	0.39	n.a.	n.a.	n.a.	6.6	—	—	Oil refineries, phosphate rock, sulphur
Nicaragua	2.32	5.15	35.0	12.0	7.5	—	—	—	Oil refinery
Panama	1.68	3.23	16.5	6.3	7.4	—	—	—	Oil refinery
Puerto Rico	2.90	3.72	Included with U.S.A.			Included with U.S.A.			Oil refineries
St. Lucia	0.11	0.13	1.5	1.3	3.0	—	—	—	None
St. Vincent	0.09	0.11	1.7	0.3	2.0	—	—	—	None
Surinam	0.42	0.99	2.3	0.4	0.4	—	—	—	None
Trinidad + Tobago	1.01	1.28	7.0	0.3	2.9	67.3	—	—	Gas, oil refineries, sulphur
Venezuela	12.21	23.55	40.8	23.5	21.0	4.6	14.6	—	Gas, oil refineries
Other islands	0.32	0.37	0.6	0.4	3.2	—	—	—	Oil refineries (St. Croix, Antigua)
Regional Total	87.89	162.17	612.9	243.0	291.0	221.3	107.6	—	

Chapter VI

MARKETING AND DISTRIBUTION

Introduction

Elsewhere in this study, the following estimates are given of expected world fertilizer consumption (in millions of tons of NPK):

	1980	2000
Developing countries	34	110
Developed countries	88	197
	122	307

Attention is also focused on the magnitude of the effort involved in building and financing the new fertilizer plants that will be needed to provide for this massive increase, and in supplying the raw materials which it will consume.

Production is only part of the story, however; the other part is marketing and distribution. There is no point in producing fertilizer unless the farmer believes that it is in his interest to use it and unless it can reach him in the form in which he wants it and at the time he needs it. This chapter, therefore, is written from the point of view of the main end consumer - the farmer.

In developing countries, most of the effort devoted to the fertilizer industry has gone into production; but over the next 25 years more attention and effort will have to be given to marketing. Bridging the gap between fertilizer production and consumption is a complex operation requiring the co-ordination of many skills and resources.

Persuading the farmer who does not use fertilizer to start using it, and the farmer who does use it to increase his consumption, will be more difficult than producing the fertilizer. Production has problems in training and management, but its major problems are technical. Marketing, on the other hand, though it has an important and basic requirement for technical services, is about people - of improving and developing practices which are often woven into a social fabric. The natural aptitudes and training needed by people working in marketing are therefore different from those needed for production.

A fair indication of the task confronting marketing and distribution organizations can be obtained by taking 1974 consumption as the starting point and comparing it with the figures for 2000. It can be inferred from recent appraisals by both FAO and the World Bank that facilities in some countries - particularly extension services, transport and ports - are already being strained to the limit of their capacity.

Millions of tons of nutrients (N, P_2O_5, K_2O)

	Consumption 1974	Expected consumption 2000	Per cent increase
Developing countries	19	110	550
Developed countries	64	197	320
	83	307	

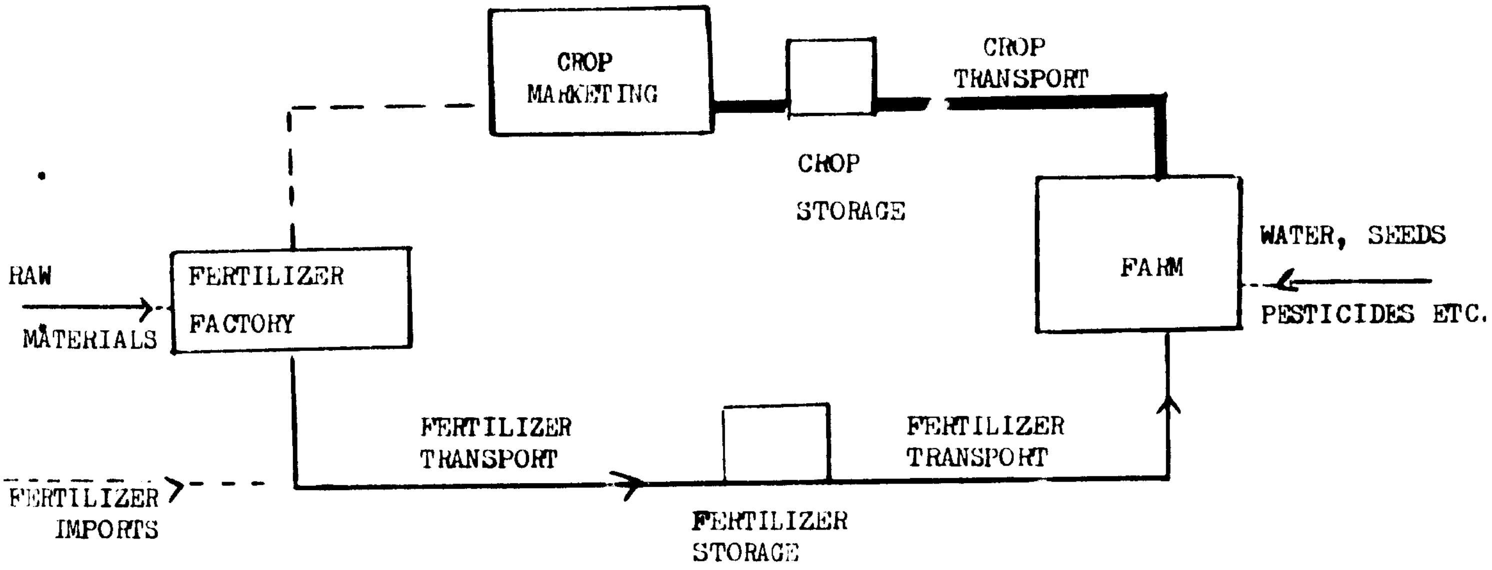
The tonnage to be handled by the distribution organization is obtained by converting these figures into millions of tons of solid fertilizer. Assuming an average content of 40 per cent in 1974 and 45 per cent in 2000, the following comparison is obtained:

	1974	2000
	(Millions of tons of solid fertilizer)	
Developing countries	48	244
Developed countries	160	437
	208	681

In the developing countries by the year 2000 therefore, capacity for storing and transporting to the farmer an additional 196 million tons of fertilizer per year must be provided - **four times the present capacity.**

The agricultural system

In considering the role of marketing and distribution in agriculture, it is useful to see it as part of an "agricultural system" comprising the fertilizer factory, fertilizer storage and transport, the farm, crop transport and storage, and crop marketing. A diagrammatic representation of the agricultural system is set out on the next page.



The diagram is simplified by the omission of the many different agencies which play some part in the working of the system; there is no reference, for example, to differing forms and ownership of transport, to co-operatives, private dealers or commission agents.

The purpose of the diagram is to illustrate the interdependence of various principal components of the system and their reliance on efficient transport and storage. The farmer and fertilizer factory depend totally on each other; so also do the farmer and the consumer through the crop marketing system. They are linked by transport and storage. If any part of the system performs inadequately or breaks down, it is impossible for the other parts to operate efficiently.

In spite of their interdependence, the parts of the system are often discussed in isolation, as if they were in watertight compartments, unconnected with, or uninfluenced by, any other part. This results in poor decisions, poor performance and high costs.

A particular example of the dangers of this approach is to consider the task of fertilizer marketing and distribution to be completed when the fertilizer is applied to the crop. The diagram makes it clear: there must be a continuing interest beyond this for two reasons.

First, experience shows that one ton of fertilizer efficiently used will produce five to ten tons of crops. The additional 196 million tons a year of fertilizer which it is forecast will be used on farms in developing countries by 2000 (compared with 1974) will need storage for up to ten times this amount of crops. This tonnage will have to move over the same roads, in the same transport network and be stored in the same stores as the fertilizer. Plans for fertilizer movement must therefore avoid competition for facilities. The load which the crop places on the transport system and its significance for fertilizer movement is indicated by the heavy dark line in the upper right-hand corner of the diagram.

Second, the crop marketing system must dispose of the crop at a price which enables the farmer to pay for his fertilizer and other inputs and to improve his standard of living. The dotted line in the top left-hand corner of the diagram represents the flow of money from the crop marketing system into the agricultural system, which closes the circuit and enables the system to continue in operation. If the farmer is dissatisfied, this will be reflected in his fertilizer use; the fertilizer marketing system will be the first to receive this message and will influence estimates of demand.

It is obvious that though all parts of the system are interdependent, the farmer plays the key role. He is the real risk-taker; he is the real productive element in the system; all the others are ancillary to him and are dependent on the results of his labour, his skill and his experience. In this context, it is immaterial whether he owns the land, rents it, or is simply employed as a manager; it all depends on him.

The role of marketing in the agricultural system is to create some of the conditions the farmer needs for developing his skills and improving his performance. These conditions are to have the right fertilizer available when wanted at the lowest cost possible and to ensure that it is used at the best time with maximum effect. The third requirement, receiving a good crop price, is outside the immediate role of marketing.

The farmer

The mechanisms of an agricultural system have been discussed and the point has been made that the farmer contributes the creative element without which nothing can be achieved.

It cannot be said too often or emphasized too strongly that the key to success is the farmer's skill in getting the land to yield its harvest. This skill can be improved by training, and the harvest can be increased by the skill being employed in better and more remunerative farming systems. It is the function of extension services (discussed below) to ensure that the farmer receives this knowledge. Using the help from this service, the farmer is the one whose decisions will determine how good or how bad the harvest will be in any particular circumstances. From his experience, the farmer will decide how and when to till the soil, when to sow and fertilize, what precautions to take, and when, against weather, pests, disease and finally, when to harvest. All through the period of preparation to harvest, he is balancing one set of variables against another, trying to optimize the results, hoping that he has calculated correctly the risks he must run; in brief that his judgement and investment decisions are sound.

Not only has the farmer to trust his judgement; so has everyone else involved in the agricultural system and the crop marketing system, including the consumer. This puts a great responsibility on the farmer. Why should he accept this responsibility, and what is likely to persuade him to take the extra risks involved in greater fertilizer expenditure? It is possible that one factor which is relevant is a desire to get the land to yield a richer harvest in response to his skills; he is anxious to use his creative talent better. Before he will take the extra risks, he must be confident that:

(a) The proposed modifications to the farming system and the method of introducing them are sound;

(b) He has or will readily acquire the farming skills needed to operate the modified system effectively;

(c) He himself will benefit as a result.

Sufficient is now known about how to introduce change and the importance of participation that it should not be too difficult to ensure that the farmer assesses the first two items favourably. The third, over which he has only partial control - he can control cost but not revenue - introduces uncertainty. This is the "make-or-break" point of the agricultural system.

The money for which the crop is exchanged comes from the consumer, i.e. if it is a food crop for home consumption - the general population. The price paid by the consumer for food must cover the costs of transport, storage, handling, interest, preserving, treatment, preparation and packing, together with the cost of such services as wholesaling and retailing and what is paid to the farmer for his crop.

From the revenue he receives for his crop the farmer has to pay his costs - fertilizer, rent, other purchased inputs - repay loans and make any other outgoings. At the end of the operation, he keeps what is left as recompense for his efforts and for investment next season. The farmer is literally the residuary legatee of the system. If he does not have enough left, his incentive to invest wanes, with the result that both fertilizer use and crop output fall.

Various studies have suggested the significance of the value/cost relationship in the farmer's decision first to use fertilizer and then to determine how much to use. The ratio relates the value of the resulting crop increase to the cost of the fertilizer input. It also shows some correlation with fertilizer use. When the ratio falls, particularly to or below 2:1, a drop in fertilizer consumption is often recorded. The disadvantage of this ratio is that it can only be constructed after the event, when the farmer has bought and used his fertilizer and harvested and sold his crop.

Two factors much more to the fore in the farmer's mind when deciding on fertilizer use are his estimate of his cash flow position and his view of the crop prices he is likely to obtain. On average, the cost of fertilizers represents 10-15 per cent of the total cost of farm inputs, although it can rise to as high as 40 per cent. Among traditional farmers, in particular, it can be a very much higher percentage, possibly in excess of 90 per cent, of cash outgoings. If the previous season's operation has resulted in a reduced cash flow, maintaining his fertilizer investment means taking the considerable risk that the next season will produce better results. If he considers the risk too great he will reduce his investment by (a) reducing his total expenditure on fertilizers; or (b) spending the same sum of money, but concentrating on buying N in preference to P and/or K.

Either way, crop output is reduced, although in the short term the second course of action is less severe in effect. (It is a policy which has considerable long-term risks.) A reduction in crop output is the reverse of what is being sought, but to avoid it the farmer must have confidence that he will receive what he considers an adequate return on his investment.

Government policy on food prices is the most important single factor in determining whether the farmer will have sufficient confidence to make the agricultural system work well.

Marketing

Four basic functions are involved in agricultural marketing:

(a)	Extension services.	This covers the development, transmission and application of farming and agronomic knowledge. It provides the technical and innovative input to farming.
(b)	Distribution.	This covers the handling, storage and transport of fertilizers and other supplies from the factory to the farm.
(c)	Financial services.	These provide credit and other necessary finance.
(d)	Selling.	This means promoting efficient use of fertilizers among dealers and farmers.

Whilst it is convenient to consider marketing in terms of these four functions, **it is important to remember that it is their combined and co-operative** action which provides the farmer with the services he needs and that in practice there is considerable overlapping.

Marketing is an optimizing operation that makes use of sophisticated mathematical techniques to ensure that "least" cost solutions are found for the operations involved. This is particularly true of distribution in which various possibilities regarding size and location of stores, and the routes and forms of transport must be considered.

A basic requirement of any marketing system is flexibility. Perhaps **the one thing that can always be relied upon is the intervention of some unexpected or unforeseen factor: the fertilizer factory breaks down, droughts or floods reduce crop yields, or a bridge is destroyed by floods.**

The system must be capable of adjusting itself quickly to a new situation. It must also be responsive to the gradual changes which occur, and be able to expand and to adapt to a continually changing and developing environment.

Extension services

Properly managed, farming is a highly productive, **stable,** capital-**intensive industry - but one with an important element** of risk **attached due to weather. Investment in farming is** long-term; **farming** systems **take time to develop and modify. To encourage this investment, a reasonable assurance of an acceptable return over a certain period is needed. The function of the**

extension service is to collaborate with the farmer in applying technical knowledge in the field, and in trying out new methods with the aim of improving agricultural productivity. The receptiveness of the farmer to the assistance which the extension service can provide depends directly upon the degree to which he is involved and participating in the development work. Three broad stages of farming development, in the context of fertilizer use, can be recognized:

(a)	Little or no use.	When traditional farming methods, which tend to be poor and inefficient, predominate. This is often found in the more remote areas of a country;
(b)	Some use.	When the fertilizer message has begun to get across to some farmers;
(c)	Considerable use.	This is often associated with non-food crops, but also with food crops grown near an urban population.

Each of these groups requires a different approach by the extension service, though this is more a matter of emphasis than of content. The basic plan is the same for all groups, but the immediate possibilities and method of approach will depend upon the farmer's own knowledge and background.

The first job of the extension service is to draw up a plan for the particular area, which should ideally be part of a national plan aimed at meeting needs and, if possible, providing also for exports in a form commanding higher rather than lower international prices. This process of preparing a comprehensive and integrated programme of crop improvement is one in which the farmers themselves must be involved. The aim is to make them feel that it is their plan. Even the subsistence farmer has much experience to contribute to the development of an improved system and, apart from the value of his local knowledge, gaining his co-operation is the first and most obvious step in winning acceptance for the plan.

Obtaining the data required for the plan is likely to involve investigation at both national and local levels. An assessment of national potential is a long-term, in-depth exercise requiring considerable experimental work. It is necessary for building up the extension services' bank of farming knowledge, covering many disciplines, upon which to draw in composing local plans. Another important purpose which this long-term survey serves is to identify the constraints upon expansion and to estimate what their removal might be worth in terms of additional output.

The assessment of local potential is obviously more detailed and takes into account such elements as the ability of the farmer, the need for soil rehabilitation, water management, land tenure and crop rotation. When it comes to composing the improved farm system, the aim is to create confidence in the mind of the farmer that not only is the system improved, but he has the farming skills needed to operate it successfully. To accomplish the latter, a simple farming routine has to be established. This has then to be put on record so that the farmer can readily refer to it. Literature is not the best method; radio and tapes are far more effective means of communication. Finally, some specific person should be available to whom the farmer (or the village) can refer problems. These are principally administrative matters; efficiently organised, they add much to the effectiveness of an extension service. They also permit better use to be made of the technical skills of the service.

In putting the plan into action the learning process must start gently, alterations and modifications emerging gradually from what is already known and being practised. In the shorter term, therefore, the early work of extension is likely to be concerned with improving the efficiency of what is already being done. This may mean that a considerable degree of farming skill must be developed before advanced techniques of crop production are introduced into the system. If an attempt is made to introduce improvements more quickly than the farmer can handle them, the result is likely to be less, and not more, production. The farmer must be encouraged to graduate steadily into the use of, for example, high-yielding varieties of grain. Only where soil fertility levels are at least modest, do differences in yield between new and old varieties become significant and justify the additional input cost.

The role of the extension service, therefore, is to prepare a comprehensive and integrated programme of crop improvement with the help and involvement of the farmer. Extension services in developing countries, however, are, for the most part, ineffective. Parts of the service may be provided by government departments and experimental stations, universities, and the fertilizer industry; but these activities are rarely comprehensive, and they lack cohesion. An effective extension service is expensive because highly skilled staff are needed and their efforts take time to show results. Nevertheless, without it, the required increase in fertilizer use and crop output will not come about.

Distribution

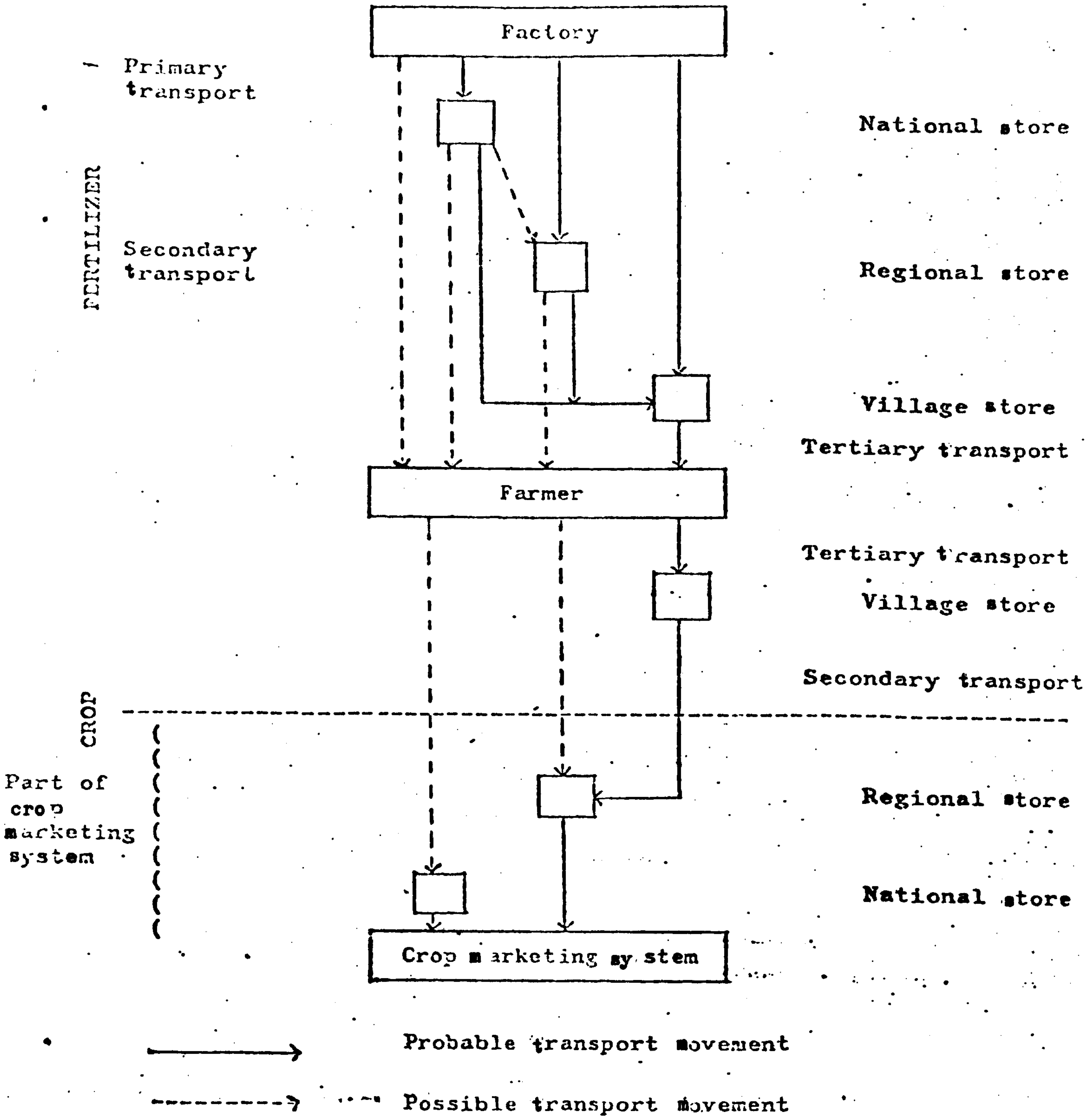
"Distribution" is the word normally used to describe the role played by transport, storage and handling. In recent years, however, the term "logistics" has been introduced; this reference to a military operation emphasizes the fact that meticulous study and planning are a vital first step, while in the execution of the plans, flexibility and imagination are essential for success. The objective is to get the fertilizer to the farmer when he has most need of it.

The role of distribution can be represented diagrammatically, as shown in the accompanying chart (which is simplified by excluding any reference to imports). Figures for plant nutrients (N, P_2O_5 and K_2O) cannot readily be used in discussing distribution, because it is the tonnage of product - not nutrient - to be moved which is relevant in this context. A product containing, say, 23 per cent N requires twice as much storage, twice the time to move a given tonnage of nitrogen, compared with urea (46 per cent N), using the same handling and loading equipment. Using the most concentrated solid fertilizers generally available, product tonnage is at least double the nutrient tonnage.

To be economic, fertilizer production must continue throughout the twelve months of the year. As with production, an economic and efficient transport operation depends upon a steady load. When there are two or three crops in a year, together with top dressing of some of them, the fertilizer demand may be sufficiently steady to cause few problems. However, other farming patterns may necessitate the accumulation of stocks in preparation for sowing seasons. Simple mathematical techniques should then be applied in planning despatch programmes.

Of equal importance to the supply of fertilizer to the farmer is the transporting of the crop to a "crop marketing system" which will convey it to the consumer. Details of such systems would not be relevant to the present study. What is important, however, is for the interchange between the agricultural marketing system and the crop marketing system to be effective and efficiently organized. There is no greater incentive-destroyer for a farmer than finding that his harvest is either not wanted or cannot be moved. The

Diagrammatic representation of distribution network



NOTE: **In the accompanying discussion it is assumed that:**

(a) **The farmer has means of moving the fertiliser from the village store and holding it on his farm - the same applying to his crop.**

(b) Factory storage is required for production purposes and cannot be made available to the distribution network.

proper use of fertilizer results in crop tonnages of from five to ten times the quantity of fertilizer used; this, moreover, arrives in a week or two at harvest and has to last until the next harvest of that particular crop. This poses considerable distribution problems of its own, and these must be solved if the agricultural system is to work efficiently.

The transport and storage of crops and fertilizer can present opposite problems. Harvest produces a large crop tonnage quickly, which has to be dispersed in the ensuing months; at sowing time, the fertilizer accumulated over possibly several months is used in a few weeks. At the centre of this transformation is the farmer whose skill brings it about and who has (a) to rely on others to supply him with the fertilizer when he can accept it and (b) to dispose properly of his harvest. The significance of this to the distribution function is the importance of precise timing and the double load placed upon the communications network, i.e. that of getting fertilizer to the farm, and later the crop from it. Moreover, some storage capacity, particularly that closest to the farmer, has to be used for both crop and fertilizer.

The diagram shows that the simplest arrangement is for the fertilizer to go direct from the factory to the farm, there to be stored until used. However, this is possible only to a limited extent; the greater part of the tonnage must use a more circuitous route. Only with a well developed farming system is it likely that a farmer can accept his fertilizer in the quantity and at the time most suitable for despatch from the factory. Moreover, apart from any question of crop and fertilizer competing for the same storage and transport facilities, the farming system itself imposes constraints. The farmer has to prepare his land, sow his crops, tend them and finally reap and store the harvest. All these operations must comply with an exacting time-table; it is a strict discipline. Ancillary tasks must be fitted into this time in such a way as to avoid interfering with the critical path. There are times, therefore, when the farmer is not interested in collecting or receiving his fertilizer. National and/or regional storage must therefore be available to ensure steady despatch from the factory and to enable individual load sizes to be adjusted to the capacity of the roads.

It is important that, if at all possible, fertilizer be put into storage only once between factory and farm: handling is costly and damages bags.

Moreover, a system which moves fertilizer through several stores on its way from factory to farmer incurs additional overhead expenses and may well give poorer service because of the more complicated administrative work involved.

Having mentioned the particular characteristics of the farming system which must be reflected in the distribution network, the size of the operation may best be illustrated by some figures. Assuming that a fertilizer factory produces 0.5 million tons per year, properly used, this will yield 2.5-5.0 million tons of crop per year; on average, 1,370 tons of fertilizer and 3,425-6,850 tons of crop must be transported every day of the year - a formidable task, particularly as every single ton must be stored for a longer or shorter period.

The extension services will provide information about farming systems and how they are expected to develop in various parts of the country. From this, crop and fertilizer estimates over a number of years can be derived, detailing in particular:

(a) The crop tonnage likely to be produced, when it will be ready to be transported, and the point to which it should be transported;

(b) The fertilizer tonnage required, its analyses, and where and when it will be used;

(c) The farming time-table to which the distribution pattern must conform.

The next step is fieldwork - a survey on the ground of communications. The carrying capacity of roads, railways, rivers and seaways must be assessed to find out what tonnage of grain can be moved out of a particular area and the tonnage of fertilizer that can be moved in. Examples of the kind of information needed are:

(a) The quality of the roads and the nature of the terrain;

(b) The speed and density of existing traffic;

(c) Bottlenecks existing in towns and villages or at crossroads;

(d) The influence of weather on particular routes;

(e) Estimates of travelling times between points;

(f) Maximum size vehicles which can use various routes;

(g) Fuel requirements en route.

This information is primarily concerned with road transport; similar data might be required for railways, rivers, canals or seaways. Particularly important for both rail and sea transport is the capacity of the loading and off-loading facilities available. An important characteristic of both these methods of transport when used in an agricultural system is that every ton they carry must also be carried by road, certainly after unloading and often prior to loading, both of which operations incur handling costs.

From the data collected a "model" of the network is prepared, including information on all known constraints. An essential constituent of this model is data on the input of fertilizer raw materials. Information concerning handling facilities at docks, and access to the factory and communications network is therefore required. The model should be a permanent central feature of the distribution operation and be regularly updated and consulted. Various mathematical techniques[1] such as Operational Research, Network Analysis and Linear Programming, can then be applied to determining "least cost" solutions that will meet the farmer's expected needs. In complex systems, analysis of the data for current operations and future planning may require a computer programme. More simple systems, however, may best be performed manually.

To the government, the model will indicate:

(a) Whether 0.5 million tons a year of fertilizer can be delivered to farms and whether the resulting crop can be collected and delivered into the crop marketing system. If the full quantities cannot be moved, it shows how much can be, from where and to what destination. Improvements which ought to be made to the communications network are shown with precision; for example, which bridges need widening or strengthening, which stretches of road need up-grading, the possibility of extending a railway system, what ports or docks needs improving. Equally important, it provides the time-scale against which improvements, alterations and additions are likely to be needed.

(b) The investment needed for conveying and storing the tonnage. Every ton produced has to be carried and stored and handled, sometimes more than once. This requires trucks, rail wagons and locomotives, in addition to storage places which have to be provided specifically

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[1] Possible use of such techniques are treated in a thesis prepared by Santo-Wod Park, Graduate School, University of Minnesota, 1975.

for the operation. (This is not because special equipment is needed, but no country can make its existing equipment expand to accommodate the additional load.)

(c) Where best to site the fertilizer factory in relation to the communications network. The location of the factory can significantly influence the transport operations both in certainty and cost. If it should be in a dock area for example, unexpected and unscheduled delays can occur which will make it difficult to work to a plan and/or require more vehicles to carry a given tonnage.

The distribution operator is given information which will help him to determine:

(a) The scope of the primary and secondary transport systems, with the number and optimum capacity of the vehicles required for them; the routes to be followed; the allocation of tonnage over various modes of transport available (road, rail, water); when the traffic should move and at what rate; and how long the various journeys should take.

(b) The best points at which to locate the storage and what tonnage should be stored at each point. The plan for putting into, and taking out of, each store can also be prepared.

(c) The amount of fuel required for the vehicles in the network, where supplies are best located and the delivery system needed to ensure that supplies are always available. Maintenance and breakdown facilities have to be located properly to ensure maximum availability of vehicles.

(d) The number of extra vehicles to be provided to cover for those under maintenance or broken down.

(e) The size of the organization for running the distribution network, and how it should be disposed.

(f) How the network should develop to maintain the service as the agricultural system itself expands.

Efficiently prepared, and in good time, the model will provide a valuable tool to decision-making. Reference has been made to the model giving a "least-cost" answer in optimizing the variables incorporated in it. There may be other matters to be considered before a decision is reached. These may move the model away from the "least-cost" pattern; the extent of this movement represents the cost of introducing the new factors thus helping to decide between what is desirable and what is possible.

In the agricultural system, timing is paramount and virtually inflexible. Everything is geared to the sowing and harvesting of the crop. Working efficiently to a well conceived plan is absolutely necessary if success is to be achieved. The plan must be prepared and communicated well in advance so that those who have to operate it can make adequate preparations. Experience shows that there are more failures involved in getting the fertilizer to the farmer than in shipping the crop away from him. There are no shades of grey in this operation; the fertilizer is available on the farm when it is needed, or it is not. If it is, the organization works; if it is not, the organization fails.

The organization of the distribution system obviously varies from one country to another. Also, within countries there is often more than one system. The general pattern is for the fertilizer producer or importing agency to sell to a wholesaler who may be a co-operative (there are several different types), state-controlled distributor, private wholesaler, or some combination of these. In turn, the wholesaler sells to the retailer, who makes the final sale to the farmer. As might be expected, because he is the contact with the farmer, there are many different kinds of retail-operator/village-dealer: rural and local co-operatives; commission agents; and crop-processing companies or federations, such as the sugar factories in Iran or the Coffee Growers' Federation in Colombia. This is the most important and influential part of the system. There is an established relationship between the retailer and his farmer customers.

Fertilizers are only one part, sometimes a very small part, of the retailer's business. Like the farmer, the retailer must be taught how significant they are for the growth of his business and the services which, in consequence, he should be able to provide the farmer. These include being able to advise on the correct fertilizer to use, and when and in what quantity it should be used.

Distribution costs can represent a significant proportion of the price the farmer pays for his fertilizer. The following table compares the order of margins in Europe with those in some developing countries (as a percentage of retail price):

	Europe	Developing countries
Total margin	10 - 20	20 - 40
Transport margin	4 - 7	6 - 15
Wholesale margin	2 - 5	14 - 25
Retail margin	4 - 8	

The nearly doubled level of the margins may be due in part to lack of infrastructure, but the variation in the figures for individual countries indicates that there is scope for improving operations in developing countries. A report from a West African country highlights a number of problems that are common to many other countries. For example:

- Fertilizers arriving late in the wrong quantities and to the wrong specifications;
- Insufficient and poor quality storage;
- Poor planning, resulting in double handling and storage and unnecessary transport;
- Inadequate distribution arrangements between district depots and villages;
- Unreliable stock records and confusion in issuing and accounting procedures.

These problems are within the power of management to solve by better estimating, planning, administration and supervision, and could save up to half the differences in margins.

Time plays a decisive role in determining investment in vehicles. For example, the movement of 1,370 tons per day of fertilizer by road in 20-ton trucks will require 69 trucks for each day. If the distribution network model shows that the average turnround time should be 4 days, 276 trucks will be required for the traffic (ignoring maintenance time and breakdowns). If for any reason the turnround time slips to 5 days, an additional 69 vehicles will be required to move the same tonnage or, what is more likely, because it **takes time to obtain vehicles,** the carrying capacity of the network falls by 20 per cent.

Finally, a physical check should be applied to the efficiency of the distribution network. Just as in a fertilizer factory a balance is struck between the raw materials going in and the products produced to ensure that there are no gross inefficiencies in the processes, so it is with distribution. The tonnage accepted for delivery has to be compared with what is actually delivered. Fertilizer is too valuable to be lost or wasted by careless transport, handling or storage.

Credit

The total amount of credit required in the system over-all depends on the cropping pattern, but even in favourable circumstances it can be as high as the production cost plus transport and storage for six months. Using the estimates given earlier in this study for a natural gas feedstock in a plant producing 0.5 million tons of urea, the full costs for six months are nearly $17 million. Adding a distribution margin of 25 per cent of retail price of $ [illegible] per ton gives a total credit requirement of approximately $ 3[illegible] million.

Working capital may come from several sources in addition to financial institutions. For example, the raw material supplier may give the fertilizer manufacturer 60 or 90 days' credit; in turn, the manufacturer may give credit to the wholesalers/retailers (though this is normally restricted to a month or 6 weeks), and they may then help the farmer. In many countries, fertilizer and crop pricing systems offer incentives to the farmer to buy and pay for his fertilizer early and to sell or receive payment for his crop late, which means that the farmer himself provides a significant part of the working capital in the system.

Such arrangements may be suited to the more successful farmers in well developed agricultural systems, but they are not relevant to the traditional farmers in most countries, who, from their own resources, cannot pay for the fertilizers they need to initiate a more productive system; it usually takes some years of intensive effort and help to break out of the "treadmill" operation in which they are confined. During this time, they need credit to bridge the gap between applying the fertilizer and harvesting the crop. It is estimated that in many countries of Latin America and Asia some 70-80 per cent of all fertilizer sales are made on a credit basis.

Providing credit to small farmers, and in particular ensuring its repayment, is a major problem for developing countries. Where an integrated production/processing scheme exists, such as those for sugar, cotton and tobacco, the problem is less serious, as the processing company can underwrite the loan. Similarly, where a farmer buys fertilizer and sells his crop through a co-operative society, it is possible to offset expenditure against subsequent income.

A considerable part of the problem is the immensity of the administrative system required to receive applications for credit, approve them, make the credit available, account for its use, and ultimately ensure repayment and close the transaction. Probably the simplest and most effective way is to inject the credit through the retailer, who knows his farmers and can accurately judge the risks and be able to safeguard his loan fairly easily. The way by which institutional credit can be made available to the retailer requires further and urgent investigation.

A principal difficulty will be to ensure that the credit is used for the stated purpose. Unless it is linked directly with the work of the extension services and promotion in developing more productive farming, the loan may not yield the results expected.

Generally speaking, the supply of credit to wholesalers and retailers is a relatively smaller problem provided their reputation is good. Fertilizers are rarely their main business, sometimes they represent only a small part of turnover, therefore there is other income and assets available for collateral.

There is a subsidiary matter of some importance to which thought should also be given. It is a characteristic of the agricultural system that intermittent revenue is allied to continuous expenditure. This can present a serious problem for a farmer - that of efficiently controlling his finances so that he has sufficient to invest in the next production cycle. Training the farmer to programme and control his cash flow is an important task in the establishment of an efficient farming system.

The loans so far discussed are basically short-term. They provide the farmer with the working capital needed to establish his farm as a going concern. However, as the agricultural system develops, the farmer will need larger, long-term loans to increase his fixed capital assets such as buildings, machinery and reservoirs. When the farmer is secure and well established, these loans will normally be available from banks and other financial institutions, but there will be cases, particularly where the farm is at an early stage of development and the farmer cannot establish his credit - worthiness when help from some person such as the sales representative or retailer in close touch with the local situation would be valuable.

Selling

Selling is the marketing function which promotes the efficient use of fertilizers by the farmer. When the extension services have developed a comprehensive programme of crop improvement through fertilizer use, it is the responsibility of the sales representative to establish and maintain regular contact with the farming community in his district. This work is essential in order that the efforts of the extension services will not be dissipated, rather that the results become widely known and applied; in this way, the use of fertilizer will become steadily more effective.

The sales representative has to forge a link between the farmer and the other parts of the agricultural system; he must be able to present the point of view of each to the other. It is obviously difficult for one person to maintain close personal contact with all the farmers in his district; he needs help and the most readily available source is the retailer.

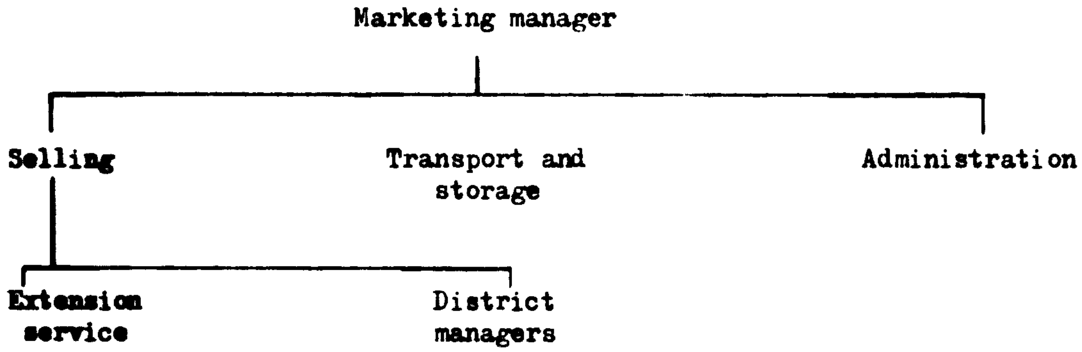
An established relationship exists between the retailer and his farmer customers. The sales representative must seek to build on this by widening the scope of the retailer's knowledge and activity. This means, inter alia, the organization of training sessions and courses.

Whenever possible, the sales representative should be employed by the fertilizer manufacturer, because this ensures a clear and direct channel of communication between producer and consumer. In many countries, however, the organisation of fertilizer marketing makes this impractical; in such cases, the responsibility for providing this essential service falls upon the wholesaler.

A model marketing system

In a number of countries, such as India, Iran and Bangladesh, fertilizer marketing is carried out separately by a state-controlled body. Some aspects of marketing are thus improved, compared with a more fragmented arrangement, but communication between marketing and production is sometimes difficult, resulting in fertilizer being delivered to the farmer at greater cost than need be.

A model marketing organization might be represented as follows:



The movement and storage of, say, a half million tons of fertilizer a year must be centrally planned by the transport and storage department, in co-operation with the district sales organization which knows where, when and in what quantities the fertilizer will be used. A programme of despatch to district stores is prepared, taking into account the various factors which affect movement. The warehousing techniques and staffing of the stores is the responsibility of the central department; the day-to-day running of the store is a district responsibility.

The running and major maintenance of the trucks serving the district depots, and liaison with the railway authority - if there are rail despatches - are also central planning responsibilities.

The (small) planning section of the transport and storage department works out the operation in detail, month by month, so that the whole organization knows when every ton of fertilizer will be moved, and its destination, when sales are estimated to be made, and where. A programme, to be regularly monitored, is prepared for each fertilizer year in advance. In the programme preparation, mathematical techniques are used as appropriate to obtain the "least cost" solution within the known constraints.

The administration section (also small) is responsible for the preparation of invoices, the keeping of physical and financial records, and the preparation and supervision of budgets.

The work of the extension services is organized by the selling manager; the work of the sales representative is organized on a district basis.

The World Bank Consultative Group on Food Production and Investment in Developing Countries gives the following specification for a model district:[1]

> It covers 6,400 sq. km and has 80 retailers, each with 1,200 farmer customers. No farmer is more than 5 km from a retailer. There are 10 sales representatives, and a Field Technical Service Department with soil-testing facilities. Some 35,000 tons per year of fertilizer are sold in bags. The store is capable of holding 10,500 tons. The retailers provide additional storage and transport from the district store.

There is one item in this specification about which another view may be preferable, namely the assumption that transport from the area store onwards will be provided by the buyer. Such an arrangement sacrifices valuable control of the operation at a critical point. Dealers (and farmers) have other interests besides fertilizer - such as moving grain and other produce, and collecting pesticides or other farm inputs. If left to their own devices they may well leave the collection of fertilizers to the last moment and then find that they cannot handle the quantity. Some transport, sufficient perhaps to move half the tonnage, will enable adequate control to be maintained.

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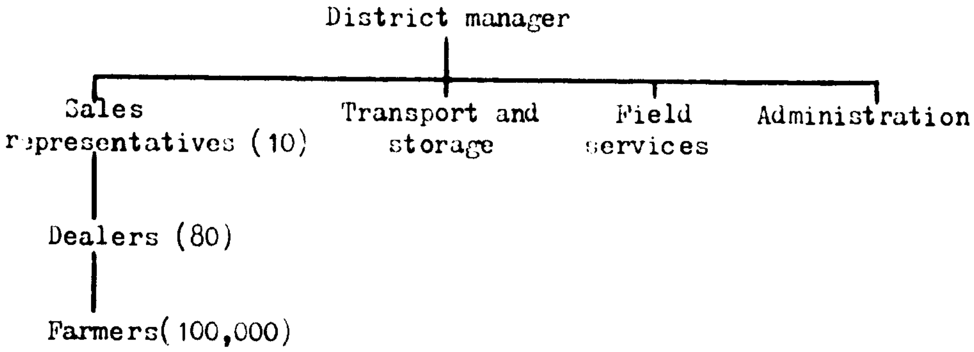
[1] Document F, Dec. 2, 1975, ref. FPI/76/1-7

With this qualification, a suitable district organization would be:



If a bulk-blending unit is available (and this is desirable), it will be located in the store and operated by the stores supervisor, who may therefore need additional training.

The district manager is responsible for the efficient management of his territory and the achievement of a specified performance by the use of resources allocated to him. They must be precisely defined in three annual budgets covering manpower, capital expenditure and operating expenditure receipts. These budgets are presented to, and agreed by, the marketing manager. The responsibility of the district team must be clear and precise; it must feel itself part of the district.

To market 0.5 million tons per year requires about 16 districts of the size defined. A sales manager could not reasonably control 16 district managers, but another level of control would not be desirable. Two possibilities exist: the first is that the individual district is too small (where farming is reasonably developed this might be so, but not where much basic promotion work is needed); the second is to nominate three district managers as senior district managers, who, in addition to their own operations, would have field supervision for four (or five) more districts.

The successful working of the organization depends, as has been indicated, on the co-operation the sales representatives develop with their retailers and the farmers. The availability and amount of storage, and the delivery programmes for both fertilizer and crops, can be worked out.

Professional advice on, for example, transport, storage and soil testing can be made available; and temporary financial problems can be discussed. All these, and other services, keep clear (particularly in the retailer's mind) the importance and value of fertilizers. The farmer, too, will be encouraged by such services.

The positive drive to use fertilizers thus gets through the system to where it is needed while, in addition, a channel is available for reporting on problems and difficulties that prevent or impede progress. To ensure that this drive is maintained, the distribution system should be kept as simple as possible. Ideally, there should only be one storage point between producer and farmer: at the retailer's. However, as this will seldom be achieved, an additional storage point (preferably linked with bulk-blending and bagging facilities) must be provided. Each storage point tends to dissipate the selling effort and to add cost, making it more difficult to get the fertilizer to the farmer as cheaply as would be desirable.

Resources

Bridging the gap between fertilizer production and efficient crop production has been the subject of considerable study in recent years. As a number of UN agencies, including UNIDO, have been active in this field and have made their findings widely available, a considerable and authoritative body of knowledge now exists. Two of the objectives have been:

(a) To analyse how, and with what degree of success, the task is being performed in a number of countries with a view to seeing that a reliable practical record is available to help others to adopt sound practices;

(b) To estimate the expected capital and running costs of a marketing and distribution system for fertilizers.

The studies have shown that wide variations exist in the methods, costs and controls by which fertilizers are marketed and distributed. They have also shown that, notwithstanding wide extremes in costs, there is a surprising similarity between countries in the ratio of these costs to the retail price of fertilizer.

With regard to the capital required for marketing and distribution, Professor F. W. Parker estimated in 1968 that for every dollar invested in fertilizer plant, another should be spent on equipment to deliver the fertilizer. This estimate has been scrutinized several times since it was made, most recently by FAO and the Consultative Group on Food Production and Investment in Developing Countries who, in December 1975, endorsed the original estimate.

One calculation was based on 310,000 tons delivered by rail to a bagging unit from whence it was despatched by truck to marketing centres. The onward movement and subsequent storage was considered the buyer's responsibility; his remuneration was in the retail margin. The marketing and distribution of 0.5 million tons has been taken in previous examples; while extrapolation from 0.31 million to 0.5 million may introduce errors into individual figures, the order of magnitude of the capital costs is unlikely to be seriously upset.

Capital costs for a marketing and distribution system

($US million, mid-1975)

	310,000 tons	500,000 tons
Process equipment	1.5	2.5
Transport equipment	10.3	15.0
Buildings	7.0	9.0
Land, roads, sidings, etc.	2.6	3.5
Marketing centres	17.6	24.0
	39.0	54.0
+ 20 per cent contingency	7.8	11.0
	46.8	65.0
Capital per ton of annual sales	151.0	130.0

The working capital estimate is based on a stated inventory, as follows:

Current assets	$US million, mid-1975,310,000 tons
Inventory	28.5
Accounts receivable	12.0
Cash	1.0
	41.5
Current liability	
Accounts payable	16.2
Operating cash	0.5
	16.7
Net working capital	24.8
+ 20 per cent contingency	5.0
	29.8

The working capital estimate for 500,000 tons would be $50 million.

The total capital employed for 0.5 million tons is therefore $115 million, or $250 per ton of annual sales. As the capital cost per ton/year for DAP is $240 and for potash is under $200, an NPK mixture has a capital cost similar to the marketing costs which have to be incurred.

Much of this expenditure, apart from working capital, is for the distribution network, and covers the purchase of items such as:

Vehicles and spares
Erection of stores
Handling equipment (for loading, unloading and stacking)
Tankers (for transporting fuel and spares)
Equipment for fuel-filling stations
Equipment for maintaining vehicles and setting up workshops

The capital figure excludes the cost of those developments to the national infrastructure, such as roads and railways. Of this expenditure the items which might not be available in local currency are the transport equipment (trucks, wagons, locomotives, railway track and appropriate spares), handling equipment (mobile cranes, forklift trucks) for stores, and the additional energy required to operate them.

Chapter VII

GOVERNMENT FERTILIZER POLICIES

World fertilizer consumption is expected to grow steadily during the next two decades, reaching a level 3.7 times that of the 1975 figure by the year 2000. However, the expansion of production capacities needed to satisfy this requirement calls for the immediate adoption of action-oriented policies by the developing countries. The purpose of this chapter is to focus attention on policies that have a direct bearing on increased production and equitable distribution.

Raw materials

Exploration

It is the prerogative of any government to determine how to make maximum and effective use of its own resources in order to achieve a certain degree of self-sufficiency, but in many developing countries only minimal exploration for mineral resources has taken place to date. This, in spite of the fact that one of the first requirements for asserting domestic control over natural resources and assuring that their utilization is compatible with long-run national objectives is a reliable indication of quantity, quality and the rate of depletion. Without this information, the formulation of effective policies and development plans is impossible. Serious encouragement of exploration, therefore, should be a primary policy objective.

Resource requirements in the case of fertilizers include natural gas, petroleum, coals, oil shale, oil sands, hydroelectric and hydrothermal energy, phosphate rock, and sulphur and potash minerals. Other useful resources are liming materials (calcite, dolomite, wollastonite) and micro-nutrient elements. Sodium minerals (natron or trona) are sometimes used as inputs for Rhenania-type processes. Magnesium silicate minerals (olivine or serpentine) may be used in the production of fused calcium-magnesium phosphate. In some cases, mineral resources may have dual uses; for instance, metal sulphide ores, such as copper sulphide, can supply sulphuric acid for fertilizer as well as valuable metals.

It may be government policy in some countries to have the public sector conduct the exploration programmes and extract and process the mineral resources, either through state-owned corporations, or directly, through government agencies. Similarly, government-supported institutions may be formed to engage in the exploration programme and research at subsequent production stages, or Governments may choose to have the private sector undertake both exploration and production. Relevant policies in this case might take a variety of forms, such as subsidies and capital allowances. However, whether the exploring is done publicly or privately, the Government's policy must take into account (a) the implications of resource ownership, and (b) the need to incorporate the findings of the explorations in the country's long-term plans for resource utilization and the development of resource-dependent sectors, such as the fertilizer sector.

Pricing

Indigenous raw materials for fertilizer manufacture may be subject to special price controls. This is often the case with ammonia feedstocks that have alternative applications as energy sources or petrochemical feedstocks. Pricing policies must reflect the priorities given to foreign exchange requirements and the development of domestic industries that are dependent on inputs of local raw materials.

The pricing of indigenous raw materials may be subject to a variety of development objectives, in addition to that of the fertilizer sector. Prices may be based on:

(a) The material's value for alternative uses. For example, the price of ammonia feedstock may be based on its value as a fuel for electricity generation. When there is no alternative use, the price may be zero or even negative. For instance, by-product sulphuric acid from smelter operations must be recovered to prevent atmospheric pollution; in some cases, using this by-product may be the only alternative to disposing of it;

(b) The import price of the same material or close substitutes;

(c) The export price of the resource which, in turn, can be based on international prices, a concept of market sharing with other major exporters, or the import price level for the country's major imports, such as manufactures or capital goods;

(d) A socially acceptable rate of return.

It is beyond the scope of this report to recommend one general pricing policy; a diversity of such policies exist in both developing and developed countries. Their impact, however, on development plans for priority sectors such as fertilizer must be given serious consideration. Price policy objectives for natural resources must be co-ordinated with sectoral development objectives.

Used domestic resources

A well-defined strategy for natural resource extraction is essential. This is especially true in the case of fertilizer, where domestic production and resource requirements may grow rapidly. Production responses to international price fluctuations must be evaluated in terms of foreign exchange requirements, resource endowments and domestic needs. In addition, an optimal policy for the use of depletable resources must be weighed against the need to raise food production where fertilizer inputs are vital.

Although the extraction of indigenous raw materials can, at times, be expensive in relation to the purchase of foreign supplies, other development objectives may make this step advisable. The decision may be justified by, inter alia, the limited foreign exchange available, the desire to increase domestic employment, or the need to safeguard against foreign manipulation of supplies or prices. In the case of fertilizers, policies to increase domestic resource content may have to be supplemented by policies that will ensure prices to the final domestic consumer being at least competitive with international prices.

When domestic resources are limited, it becomes necessary to allocate them among possible alternative uses. To take natural gas as an example:

since this is worth much more as ammonia feedstock than as an energy source, it may be appropriate in many cases to give priority to its use for ammonia production. On the other hand, when sulphur or sulphuric acid is in short supply, governments may choose to select fertilizer processes that do not use it, or that need minimum inputs of it.

The conservation of resources should also be taken into account. Practices such as flaring of natural gas or "high-grading" of ore deposits for quick, short-term exploitation should be discouraged as far as practicable. When low-grade ore must be removed in order to mine high-grade ore, thought should be given to stockpiling the low-grade material for future use, when conditions or technology warrant.

Import and export policies

Fertilizer responses to long-run fluctuations in international prices should be determined in the context of the formulation of a country's over-all resource policy. Specific trade policy considerations may include long-run plans regarding the export of resources which form fertilizer input and the proportion which could be allocated to the domestic fertilizer sector. One policy variant might involve the restriction of primary resource exports to levels sufficient to meet foreign exchange requirements, the residual being used locally. When resources are available locally, the government strategy should include plans for their eventual export in a processed form, i.e. as fertilizer.

Regional co-operation in the utilization of fertilizer raw materials may often be advantageous. It is particularly recommended in regions where raw materials of adequate quality and quantity are scattered among several countries, or where the fertilizer requirements of individual countries are not large enough to justify an economical scale of production.

Raw materials from other industries' by-products

Very often, by-products or co-products from other industries can be used as raw materials for fertilizer production. Examples are:

- Sulphur, recovered from sour gas, oil, or coal

- Sulphur or sulphuric acid from smelting sulphide ores of zinc, lead, copper, or nickel
- Apatite, from beneficiation of iron ore
- Basic slag or ammonium salts, from the steel industry
- Coke oven gas, refinery tail gas, or LPG for ammonia feedstock
- Ammonium sulphate, from caprolactum production
- Ammonium chloride, from soda ash production

Government policy can influence the utilization of these by-products in several ways. For instance, the government may require that sulphide ore be smelted in the country in order to recover sulphuric acid for fertilizer production, rather than export it for smelting elsewhere. If necessary, it may subsidize one industry, such as copper smelting, to ensure development of a phosphate industry. It is evident that government planning and co-ordination can be helpful in ensuring optimum use of by-products, and the integration of other industries with the fertilizer industries.

Fertilizer production

Planning for efficiency and economy

Fertilizer production, as with many other lines of production, is usually sensitive to economies of scale. Gains in efficiency are likely to come from encouraging economics of scale resulting from increased plant size. Much depends on the market and the competitive structure of the industry. Many multi-plant industries could, in theory, achieve greater economies of scale. The mere fact that demand is sufficient is no guarantee that these economies are being realized. In some case, the number of plants has proven to be too great for economies to be easily realized. Such a situation is sometimes the consequence of government policy: indiscriminate encouragement for example, through subsidies, of the fertilizer sector may lead to an overabundance of plants, thereby preventing the realization of economies of scale. Selective subsidization may be called for.

The types of fertilizer to be produced is another important consideration. Government policy should relate product demand at the farm level with products that can be produced most efficiently and economically by the industry. Sometimes this decision may involve a compromise between agronomic, economic, and technical factors. For instance, NP products (ammonium phosphates or nitrophosphates) are often more economical to produce and transport than straight materials. Again, the direct application of ground phosphate rock may be economically preferable in some cases to using expensive water-soluble phosphates. In any event, sufficient flexibility should be provided to permit leeway for future changes in types and quantities of product.

Plant location is another consideration which is subject to policy influence. For instance, the extent of regional co-operation or trade agreements will influence the choice of market area and source of raw materials, and hence the plant location. Or, a government may wish to locate a plant in an area of high unemployment, for either social or political reasons, or in market areas to minimize transportation problems. Government plans for improving transportation systems, waterways, and port facilities should also be taken into account.

When raw materials are to be imported, it is generally poor policy to build a facility that is dependent on a single source. In planning a phosphoric acid plant, for instance, provision should be made for the possibility of using phosphate rock from a variety of sources.

Maximizing capacity utilization and minimizing production cost

Capacity utilization of fertilizer production facilities averages only about 60 per cent in developing countries - even in those countries where fertilizer is in short supply and imports are required to make up the deficit. Low capacity utilization has a disastrous effect on production costs. Nevertheless, in several cases, plants in developing countries have operated for extended periods (several years) at, or above, rated capacity.

1/ Nitrogenous fertilizer is thought to offer such an example in some instances. See A. S. Manne (ed.), Investments for Capacity Utilization, (London, Allen and Unwin, 1967).

Distribution a[illegible] marketing

The organization and policies that influence fertilizer distribution and marketing are diverse and not easily generalized. Several salient characteristics which serve to categorize country approaches can be mentioned, however.

One is the choice of public or private sector ownership of the distribution agency. In many developing countries, distribution is the responsibility of a government agency. Private distributors, where they operate, are usually general trading firms. Co-operatives, owned by the consumer, and wholesale outlets operated by foreign suppliers, may also be found.

The degree of centralization and co-ordination at the national level is a second distinguishing feature. Alternatives for centralization range from a highly centralized government monopoly to a private monopoly. The other extreme is a completely decentralized and unintegrated system. A country's distribution programme may also be geared to a specific group of consumers determined according to the crops they produce, to regional development programmes, or to other criteria.

A final organizational characteristic is the extent to which these institutions are vertically integrated. Integration may combine fertilizer procurement with crop collection, processing and marketing. Distribution of fertilizers may be combined with rural credit and handled under the auspices of local lending institutions.

More specific economic or policy features may serve further to distinguish the approach adopted by a given country. For example, where fertilizer export is a prime consideration, collection may be centralized under one institution. In countries where distribution costs are high, public rail systems have sometimes been delegated the responsibility for local distribution. In so doing, preferential freight rates may be given to fertilizers, and the transportation costs are subsidized through rates paid for other non-essentials. Distribution channels may also be organized to follow the crop pattern. Where the agricultural sector exhibits marked "dualism" (i.e. two distinct sub-sectors, one producing cash crops for export, the other producing subsistence crops for home consumption), such a system can be effective.

There is often a need for a variety of fertilizer products. Different soils and crops may require different N:P_2O_5:K_2O ratios, and one or more secondary elements or micronutrients may be needed. Large plants seldom have the flexibility needed to produce a variety of products. Also, the basic manufacturing facilities can be widely separated. A nitrogen plant may be located near a source of natural gas, a phosphate plant near a phosphate rock deposit or source of by-products sulphuric acid, and potash may enter the country at ports. Assembling these materials at a single location involves unnecessary transportation costs. The solution to this problem will vary from one country to another. One system that has several advantages involves the further processing of basic products by mixing, bulk blending, or granulation. Although it is possible to classify the further processing of basic or intermediate fertilizer materials as a part of the production system, such processing more commonly is included in the marketing system. The type of marketing system, then, can often be influenced, either directly or indirectly, by government policy. Careful thought should be given to selecting a production-distribution-marketing system that will meet both present and future needs.

It is important that the type of marketing system used ensure the availability of fertilizer products with the proper nutrient ratio for each use. Failure to supply needed ratios is one of the major causes of inefficient fertilizer use. For example, in the State of Alabama, U.S.A., during the 1974-75 crop year, 83 per cent of the fertilizer sold had a P_2O_5:K_2O ratio of 1:1, but only 27 per cent of the soils tested needed this ratio. This situation was caused mainly by a lack of availability of other ratios.[2] Obviously, over one half of the farmers used fertilizer inefficiently by supplying either an excess of one nutrient or a deficiency of the other, or both. Increasing efficiency of fertilizer use (discussed further below)

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[2] Engelstad, O. P., and W. L. Parks. 1976. "Building of P and K in Soils and Effective Use of These Reserves". In TVA Fertilizer Conference (held 27-28 July 1976, Cincinnati, Ohio); Bulletin Y-106, pp. 50-58, July 1976, National Fertilizer Development Center, Tennessee Valley Authority, Muscle Shoals, Alabama.

should be a major goal. At the same time, it must be realized that increasing the number of ratios increases both the confusion for the farmer and the general cost of the fertilizer. Unless farmers are able to test their soils, or otherwise obtain reliable information about the specific nutrient ratios needed for each crop, there is little need for more than about three $P_2O_5:K_2O$ ratios. New ratios add to the cost of fertilizer because each grade must be registered, properly labelled, separately stored, and profitably marketed. Therefore, the policy should be to provide an adequate number of grades, but to avoid excess.

Development of infrastructure

When plans are made for expanding the production and use of fertilizer, one of the first bottlenecks in many countries is that of transportation. Movement each year of a few hundred tons of imported fertilizer from a dock poses few problems compared with moving a thousand tons per day from a modern plant. Even this daily movement is not a full indication of the transportation problem. Each ton of plant nutrients can be expected to increase grain production by approximately ten tons. Presumably, most of this increased production will need to move out of the production area and into the commidity marketing channels. Food problems cannot be resolved unless increased production of fertilizer is accompanied by a major improvement in transportation facilities. Similar improvements are needed in other aspects of infrastructure: electricity, communication, storage silos, warehouses, markets, etc. Again, the policy implications are clear: there must be a balanced development of infrastructure and fertilizer production, and the need for effective disposal of the additional food supplies must be considered.

Realistic requirement estimates

Realistic estimates of fertilizer requirement are a necessary basis for planning efficient production facilities, as stressed above. These data are equally important in planning an efficient marketing system. Future fertilizer requirements need to be detailed by region, district and season. The extent to which the calculation of national requirements is centralized or left to lower levels in the distribution chain varies from country to country.[3] In developing countries, however, the main issue is the co-ordination of national supply. For this purpose, some centralized authority may be required for the development of a marketing system that can accommodate planned production and still ensure an equitable distribution among regions, districts, and large and small farms.

In cases where supply is not sufficient, the government may allocate fertilizer in accordance with various criteria such as the following:

(a) When the food supply is critically short, priority may be given to the country's staples (which may include non-cash crops). Among these, the policy may favour those crops or varieties that respond most to fertilizer. Alternatively, policy may favour crops that provide the best balance of nutrients;

(b) Allocation may aim at achieving equitable distribution among provinces or districts, or among individual farmers in order to ameliorate the existing distribution of income or, perhaps, to reduce the rural-to-urban rate of migration by raising farm incomes;

(c) Allocation may favour crops that are largely intended for export and will have a favourable effect on foreign exchange. Such an approach might not be feasible, however, if food production for domestic purposes is jeopardized or if the country is already dependent on food imports.

Any system of allocation has its drawbacks. However, the unrestrained operation of market forces may seriously jeopardize agricultural development through a highly inequitable allocation of fertilizer inputs. Careful study of the allocation effects of specific policies and the over-all distribution programme are required.

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[3] A distinction should be made between studies estimating fertilizer requirements and demand estimates. Demand estimates are not likely to reflect a region's optimum requirements since: they can be biased due to the relative importance of high-income farms whereas estimated requirements are based on acreage, crop types etc., and are not influenced by the ability to buy.

Quality control

It is a function of government to draw up and enforce regulations relating to the quality of fertilizers. Enforcement of such regulations usually involves a system of inspection by government agents, at the manufacturing facility, in the distribution channels, or on the farm. Obviously, the closer to the farm the inspection, the less the opportunity for adulteration. The inspection may consist of checking the weight and taking samples for chemical analysis and determination of physical properties. A prescribed "tolerance" is usually permitted for deviation from guaranteed analysis, which allows for probable minor errors in manufacturing, mixing, or sampling.

Deficiencies in weight or analysis are penalized by a system of fines and/or payment of damages. The manufacturer, mixer, or distributor may be penalized for repeated violations by having his licence revoked. Criminal penalties may be imposed when there is clear evidence of intent to defraud.

Government regulations should not be so restrictive as to impose unnecessary hardship or expense on the manufacturer, or to prevent farmers from taking advantage of low-cost materials. For instance, a regulation that only water-soluble P_2O_5 can be claimed in a phosphate fertilizer may be unnecessarily restrictive and is seldom justified by agronomic data. A similar situation applies to water-insoluble nitrogen derived from either natural or synthetic sources. Such materials often are sold at a premium price because of their slow-release quality, which makes them more effective fertilizers in some situations. However, the nitrogen in some organic compounds is so slowly soluble as to be nearly worthless as a fertilizer.

In summary, government regulation of fertilizer quality should protect farmers against fraudulent practices and inferior products and provide necessary information about the quantity and quality of nutrient content. It should be flexible enough to permit the sale of low-cost materials or by-products while providing adequate information about their value.

Measures aimed at increasing use

Fertilizer use is determined primarily by fertilizer and agricultural product prices, the fertilizer response, and the presence or absence of constraints to its use, such as ignorance, risk and uncertainty, lack of credit, and limited availability. Successful government policy aimed at encouraging use must either provide the farmer with an economic incentive or remove or reduce the effect of existing constraints to obtaining potential economic benefits from expanding use.

Normally, economic incentives take the form of a reduction in fertilizer costs to the farmer, or an increase in the agronomic response to fertilizer through better balance of nutrients, better timing or placement of application, and other inputs (water supply, improved varieties, etc.).

The appropriate policy approach to increased fertilizer use depends, to some extent, upon the degree to which the farming community has already adopted commercial fertilizers. Farmer awareness is the most significant consideration in the early stages. Prices, even if kept at reasonable levels, can seem prohibitive to farmers lacking experience in the use of commercial fertilizers and knowledge of their effect on yields.[4] Once general acceptance is achieved, however, credit becomes a useful policy tool.

Increasing agricultural product prices

Agricultural price support policies are common in developing and developed countries. While some aim at price stabilization (discussed further below), others focus on raising agricultural product prices above free market prices in order to stimulate production. Increases in product prices make it profitable for the farmer to expand fertilizer use, but could be inflationary and run counter to other development objectives.

Many developing countries are faced with severe nutritional deficiencies, due mainly to lack of purchasing power. In others, even where malnutrition is not a major problem, food accounts for a large portion of the family income. The level of food prices is therefore of extreme importance in the development process of these countries. In such circumstances, policies to increase agricultural produce prices may not be in the best interest of the country - if the price increase is to be passed on to the consumer, as is usually the case.

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[4] The price elasticity of fertilizer has been found to be relatively low during the introductory period. Only after acceptance has been achieved it rises.

Increasing agronomic response

The agronomic response to fertilizer depends on a number of factors, including: soil characteristics; climatic variables such as rainfall pattern; irrigation; plant variety; disease and insect attacks; type and nutrient balance of fertilizer; and timeliness and form of application. Government policy aimed at increasing the response may focus on (a) research to improve fertilizer materials and application methods; (b) research to modify the factors mentioned above; and (c) extension work to assist farmers in applying current knowledge, materials and methods aimed at improving fertilizer efficiency. Only research to improve fertilizer materials and application methods (a) is discussed here; (b) and (c) are discussed later.

Removing constraints to fertilizer use

In addition to high fertilizer and crop prices and poor agronomic response, fertilizer use is affected by a number of constraints that may reduce profitability or dissuade the farmer. Constraints commonly encountered in developing countries include: *unavailability* of fertilizer where and when needed; *ignorance*; *risk and uncertainty*; *lack of credit*; *insecurity of land tenure*; *and shortage of complementary inputs*.

Unavailability. Failure to deliver the proper type of fertilizer at the time and place required is a significant impediment to expanded use. Activities aimed at increased fertilizer demand (e.g., price and credit subsidies) must be backed up by guarantees that sufficient supplies will be available. This element is frequently overlooked, resulting in fertilizer scarcities, black market operations, and reduced effectiveness in fertilizer promotion activities.

Ignorance. Farmers and extension workers are often inadequately informed about the kind and quantity of fertilizer to use and how and when to use it. Policy support for agronomic research is needed in order to generate the type of information farmers need regarding appropriate type of fertilizer, optimim quantities and timing, placement, etc. under various climatic, environmental, economic, and soil conditions. The results of such research should be disseminated through close collaboration between farmers and extension agents. In addition, the economic returns to be expected from increased fertilizer use should be clearly demonstrated. To facilitate on-farm trials and demonstrations, small quantities of fertilizer, at subsidized prices, should be made available to farmers not currently using it, along with information regarding its use.

Risk and uncertainty. The major natural or environmental hazards are rainfall, disease and insect attacks. Government policy aimed at improving irrigation, at developing and/or diffusing resistant varieties, at making pesticides available, and at improving crop management practices in general may have considerable impact on reducing risks and uncertainties resulting from such hazards.

While fertilizer price fluctuations may reduce the quantities used, they do not contribute greatly to risk because the farmer in most cases knows the actual price before purchasing and can react accordingly. Price fluctuations in agricultural products, on the other hand, introduce considerable risk and uncertainty. The economic optimum quantity of fertilizer varies according to the price of the agricultural product. Farmers faced with large product price fluctuations will tend to limit fertilizer use to levels that are approximately optimum at relatively low product prices. Thus, price stabilization programmes for agricultural produce can have a beneficial effect on fertilizer use.

Lack of credit. This factor can be a considerable constraint to fertilizer use and it is particularly important that it be rectified at the early stages of a fertilizer acceptance programme. Assuming that supplies of fertilizer are efficiently distributed, numerous credit system outlets at the local level will encourage fertilizer use as a continuous practice. Credit is of special significance to the small farmer with extremely limited working capital and borrowing ability. Policy alternatives, however, do not have to be restricted to commercial lending channels; financing mechanisms employing a credit-in-kind scheme for distribution of the fertilizer (along with other inputs, such as seed) can be introduced.

Government policy oriented toward providing guarantees to financial institutions and limiting the consequences to the farmer of crop failures is needed in many countries. Government-supported crop and credit insurance programmes should also be effective.

Insecurity of land tenure. When the same person or family owns the crop as well as the land on which it is produced, fertilizer use tends to be greater than when land and crop are separately owned. Tenant farmers often pay for all inputs, including fertilizer, but deliver a proportion of the crop to the landlord. Therefore, the tenants gains only a part of the return on his fertilizer investment. In such cases, the economically optimum quantity of fertilizer used is smaller for tenant farmers than for landowners. Output sharing between tenants and landlords should result in increased fertilizer use and agricultural output. Land reform policies oriented towards a shift from tenancy to ownership by the farmer, or at least towards promoting cost sharing between tenant and owner, would encourage fertilizer use.

The benefits of fertilizer use usually extend beyond one cropping season, but short-term tenancy arrangements and consequent uncertainty as to who will be the beneficiary of further fertilizer application.

Shortage of complementary inputs. The importance of proper irrigation and the use of pesticides, herbicides, and other production and management inputs to the reduction of risk and uncertainty was mentioned before. These factors are also important determinants of total fertilizer response. Varietal improvement is probably even more important, however; fertilizer response is far greater among improved rice and wheat varieties than among traditional ones. While increased response is a genetic characteristic (related to dwarf varieties and corresponding reduction to lodging), the farm-level response of traditional varieties may be further increased if they are made more resistent to certain diseases and insects. Government policy aimed at: promoting research on varietal improvement; testing and modifying improved materials from international and national agricultural research; and diffusion of improved materials to farmers, are likely to be effective in expanding fertilizer use and agricultural production. The distribution of these complementary inputs, like the distribution of fertilizer itself, is often geared to the needs only of the large farmers. Policy efforts should endeavour to ensure that the benefits of such research are available to small farmers as well.

Industrial employment and training

The development of a work force consistent with the planned growth in production capacity of an industrial sector requires policy action in much the same way as demand, investment and supply in that sector. Some policies and procedures that would be appropriate to the fertilizer industry are:

(a) The co-ordination of employment plans with the industry's short- and long-term objectives; and

(b) The development and implementation of training programmes that will ensure continuous and competent manning.

Specific features of the above might include:

- Management and supervisory training programmes;
- Extension programmes for dealer and farmer education;
- Training programmes for technicians, plant operators, and maintenance personnel;
- Marketing programmes, including distribution promotion, and sales, when and if appropriate;
- Definite commitments to and from foreign organizations that allow them to plan work force development programmes without the fear of their being terminated in mid-programme. (This will avoid high built-in costs to prevent losses and guarantee a trained work force);

(c) The development of personnel policies and/or practices to encourage efficiency and provide incentives. Examples are:

- Position descriptions that clearly define the work to be done;
- Salary scales that assure competitive pay and fringe benefits;
- Incentive plans that are challenging and attainable, based on standards of performance that are mutually acceptable; and
- Communication to the work force of alternative paths for advancement.

Subsidies

The practice of providing subsidies to encourage the production or use of fertilizer is a widespread one. The objectives of subsidy programmes are often related to the theme of the preceding section, "Measures aimed at increasing use". In developing countries, fertilizer subsidies may take many forms. In some, they may be regarded as a government obligation and become a semi-permanent feature of government policy. There is the danger, however, that, once instituted, the practice may be prolonged beyond the period when the initial objectives have been realized. On the other hand, there is a good reason to believe that subsidies can be an effective means of achieving development objectives when properly monitored and implemented. In view of the complexity of various subsidy programmes and the diversity of approaches to them, the subject is treated separately, and in considerable detail, in the Annex to this chapter.

Investment policies

It is estimated that fertilizer production objectives for the end of the century (Alternative A), will require capital investment in major nitrogen and phosphate plants of about $US51 billion over the period 1980-2000. If the developing countries are to become net exporters, however, capital costs will exceed this figure. Additional investment will be required in mining and benefication of raw materials and potash salts, in distribution and transport facilities and in infrastructure. Clearly, therefore, the total investment requirements will exceed $51 billion by a substantial amount.

New forms and mechanisms for investment will be required to channel such a large amount of capital into the development of the fertilizer sector and to ensure that over-all development objectives (e.g. minimal rates of inflation or sovereignty over natural resources) are not jeopardised in the process. Loans and grants have played a prominent role in financing the development of fertilizer plants in the past. At times, these have been on concessional terms for interest rates or repayment schedules. Often, however, their total cost has been considerable, and it is unlikely that this source will be adequate to provide funds of the magnitude mentioned above.

Investment capital falls into two general types: loans (bonds or debentures) that pay a fixed rate of return, and equity capital in which the rate of return depends on the profitability of the enterprise. The investor may not necessarily expect to receive his return directly in the form of cash. For instance, farmers, co-operatives, and plantation owners may invest to ensure a supply of fertilizer at a reasonable price. Their return may consist of a system of rebates or discounts on fertilizer used. Foreign organizations or governments may invest for the same reason. Raw material suppliers may invest to ensure a profitable market for their product (natural gas, phosphate rock, sulphuric acid, etc.).

Investment incentives through tax laws or concessions

The adjustment of tax laws is a common method of attracting investment to priority sectors. Such practices, however, call for continuous scrutiny and should be subject to certain qualifications. The following is a short list of policies frequently used to attract investment:

(a) Partial or complete exemption from industrial income tax levied on interest on bonds and debentures, or on dividends from fertilizer manufacturing operations;

(b) Tax holidays that permit new plants to operate for a specified number of years without paying property or income tax;

(c) Depletion allowances for organizations that own and use indigenous raw materials. (In theory, this allowance compensates the company for the diminishing of its raw material resources and encourages exploration for new resources);

(d) Development rebates based on the contribution to the national economy, or on the development of natural resources;

(e) Exemption from severance or excise taxes on raw materials used;

(f) Exemption from import duties on plant equipment, raw materials, spare parts and supplies;

(g) Exemptions from export taxes on fertilizers to make the products competitive on the world market. (Encouraging export of production in excess of domestic needs to keep plants operating at a high percentage of capacity and thereby lowering production costs); and

(h) Generous depreciation rates for tax purposes.

Such policies offer investors the prospect of relatively rapid recovery of their investment. Careful consideration should be given to their effect on the national economy, however, before implementing them.

In the fertilizer sector, foreign investment, and the role of transnational corporations, in particular, has been steadily increasing. The objectives of these corporations may not always be consistent with national strategies and policies. In the case of the developing countries, however, the consequences can be particularly serious in view of the relatively weak position of these countries vis-a-vis the transnational corporations.

Co-operation in harmonizing national policies on foreign investment could serve to improve the negotiating position of the developing countries. Yet, despite the difficulties that these countries encounter in their relations with the transnationals, they continue to compete to attract them. One type of competition practised is to offer a variety of concessions, such as those listed above. Only in rare cases, however, do these concessions raise the total flow of foreign investment into the developing country. The flow may be increased, for example, where transnational firms are under pressure to find new, cheap ways of processing goods for re-export. However, there are many instances where costs are less critical.

Examples include import-substitution industries and industries producing for export to oligopolistic markets. In such cases, the total flow of investment into the developing countries is not likely to be affected by competition among them. But, the distribution of investment among these countries may be substantially altered by the granting of concessions to the foreign investors. A country that fails to offer benefits to match those offered by other countries in the region risks losing its share of the foreign investment. Returns to the developing country from foreign investment can be considerably reduced through excessive competition of this sort. As mentioned above, however, the situation may be alleviated by co-operation among the developing countries affected. The problem is essentially a regional or sub-regional one that could be addressed by groups of developing countries. Such groups might endeavour to determine if their efforts to attract foreign investment in fertilizer tend to cancel one another. This could be one component in a larger regional or sub-regional approach to the development of the industry.

Developing countries might attempt to reach agreement, perhaps initially on a regional basis, on such matters as the maximum length of tax holidays, the extent of corporation income tax incentives, limits to accelerated depreciation, and the level and scope of investment credits.

Annex to Chapter VII

FERTILIZER SUBSIDIES

Direct subsidies

Direct price subsidies for fertilizer are common in most developing countries. They are usually paid directly by the government (a) to the farmer; or (b) to the distribution outlet. If sufficient control is exercised to ensure that they are in fact being reflected in the price of fertilizer to the farmer, direct subsidies may be a very effective means of expanding fertilizer use. If, however, the subsidy is such that it has a really significant impact on use, the programme may tend to be very expensive. Furthermore, unless policies to expand fertilizer supplies simultaneously with subsidies are introduced, the subsidies will promote fertilizer scarcities and the potential increase in use due to the price subsidy will only be partly realized.

While a permanent price subsidy can lead to fertilizer shortages, temporary subsidy programmes can cause rapid expansion of fertilizer consumption in countries with excess productive capacity and resulting high domestic prices. As consumption increases, capacity utilization goes up and per unit costs are reduced. This, in turn, reduces the need to continue the subsidy programme. The problem with temporary subsidies, however, is that once introduced they tend to be difficult to phase out.

(a) Subsidy to the farmer. The dominant trend in most developing countries is to fix the retail price to the farmer at a maximum level above which it cannot lawfully be sold. For nitrogenous fertilizers, the price per unit of nitrogen is usually considered a base for the pricing of all types. This may not always be true of phosphate fertilizer, but it holds true for potash types. The fixed retail price to farmers is different from one country to another and may bear no relation to the world market price. It may also differ from one material to another. Annex table 1 below shows the variations in fertiliser retail prices and fertiliser subsidy in four selected developing countries in 1974, a year

Annex table 1. Retail prices (A) and subsidies (B), in selected developing countries, 1974
($US/metric ton)

	Iran		Egypt		Bangladesh		Pakistan	
	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
Urea	129.0	221.0	160.0	315.0	179.0	244.0	150.0	343.0
Am. nit 26%	107.0	198.0	85.0	192.0	-	-	87.0	250.0
Am. nit 35.5%	-	-	108.0	239.0	-	-	-	-
Am. sulphate	76.0	22.0	68.0	30.0	-	-	68.0	26.0
Single superphosphate	-	-	43.0	17.5	-	-	44.0	-
Triple superphosphate	119.0	231.0	-	-	143.0	290.0	110.0	298.0
DAP	178.0	272.0	-	-	-	-	150.0	282.0
Pot. sulphate	141.0	-	75.0	37.5	107.0	48.0	-	-

Sources: Worked calculated data from various different sources, and FAO Fertilizer Industry Advisory Committee and ad hoc Working Party on the Economics of Fertilizer Use 1975.

of unusually high prices. These data represent the highest degree to which the fertilizers had hitherto been subsidized. On the basis of unified fertilizer rate of application of urea nitrogen, the subsidy values per hectare for four crops - cotton, wheat, maize, and rice - in these countries are presented in Annex table 2, for the sake of comparison. It can be seen that, on the basis of the world market price for each of the four crops, and for effective subsidy, productivity of one of the four ought to be at the highest level in Pakistan, followed by Egypt, Bangladesh, and Iran. In fact, however, this is not true, which explains the quite different applicability of fertilizer subsidy as far as its economic efficiency is concerned in different developing countries. In other words, the benefits of fertilizer subsidy enjoyed by farmers in developing countries vary considerably.

Annex table 2. Calculated subsidy for four crops, selected developing countries, 1974
($US/ha)

Crops	Urea Rate of application (N kg/ha)	Iran	Egypt	Bangladesh	Pakistan
Cotton	170	82	117	91	127
Wheat	200	95	135	105	143
Maize	220	106	152	117	165
Rice	120	57	82	63	89

(b) Subsidy to distribution outlet. The general trend among governments in developing countries is to have all fertilizer activities carried out by the public sector. However, in many countries of Asia (Iran, Indonesia, India, Pakistan) and South America (Chile, Brazil, Colombia, and Argentina) fertilizer distribution and marketing are carried out by both government and private sector. Information regarding subsidies to private dealers in many of these countries is not sufficient to make a complete analysis; nevertheless, it is known that they are incorporated in transportation and other distribution costs.

Indirect subsidies

The real price of fertilizer may be reduced in a number of ways other than through direct subsidies. One of the most common means is to make credit available to farmers at subsidized interest rates. Where fertilizer acceptance is a consideration, supervised credit may be offered, i.e. credit contingent upon the supervision of new users by technicians. Permanent subsidizing of credit for fertilizer may prove to be costly, of course. Long-term solutions for the problem of agricultural access to financial markets may include the replacement of informed credit markets by other institutional forms.

Risk and uncertainity in agricultural production and lack of credit security are probably the major causes of high interest rates and reluctance among commercial banks to provide agricultural credit. Government policy aimed at reducing the risk and uncertainty and providing additional security for the moneylenders in a way acceptable to the farmer would be more likely to provide higher benefits than subsidized interest rates. However, it is difficult to guarantee in advance that subsidies earmarked for fertilizer purchases will in fact lead to an increase in the use of fertilizer. For this reason, the impact of such programmes may be much smaller than expected.

Indirect subsidies may also take the form of support to, inter alia, (a) local fertilizer manufacturers; (b) discharging operations; (c) transportation systems; (d) storage agencies; or (e) rebagging systems.

(a) Subsidy to local manufacturers. Domestic fertilizer production is strongly subsidized in most of the developing countries in order to keep local prices at or below the level of those of imported fertilizer. This was particularly true before the sharp increase in world fertilizer prices in 1973/74. The table below shows a wide variation in the subsidies given to domestic industrial production in Bangladesh, Pakistan, and Egypt in 1974. Before 1974, some countries imposed high taxes on imported fertilizers. This policy was considered to be a means, in a sense, of protecting local industry and to be a subsidy for local production. The practice of paying direct cash subsidies to manufacturers on ex-factory sales price, prevails in countries where the fertilizer industry is otherwise permitted to operate on a free enterprise basis. In countries where the industry is government-owned, the subsidy is usually paid at the end of the fiscal year as a penalty production cost in the case of budgetary deficit.

Subsidy for domestic production, selected developing countries, 1974
($US/metric ton)

Fertilizer	Bangladesh	Pakistan	Egypt
Urea	46.0	63.48	-
AN	-	28.15[a]	25.0[b]
AS	-	1.31	-
TSP	138.0	-	-
SSP	-	-	2.60

Sources: FAO Fertilizer Industry Advisory Committee on the Economics of Fertilizer Use, and National Statistics Data.

a/ For AN 26 per cent N.

b/ For AN 33.5 per cent N.

(b) Subsidy to discharging operations. Fertilizer imported by the public sector in the developing countries is usually bought on a "cost-including-freight" basis. Unloading costs are borne by the importer. These add considerably to the final costs. In addition, inefficient ship-to-shore handling is often a cause of serious losses. Sometimes, too, the cost of delays in unloading the transport ships has to be borne by the government. No detailed information is available at the present time regarding the real economic effects of such processes upon fertilizer costs in most developing countries. Whether all or part of them are paid by the governments or built into the wholesale fertilizer cost has to be clarified in the future for different countries. However, information available from Egypt reveals that discharging costs per metric ton in that country reached $13 million in 1974, the total sum of $1,350 million for fertilizer imports of about 100,000 metric tons of different types being carried entirely by the government.

(c) Subsidy to transportation systems. Costs of loading, transporting and unloading fertilizer tend to be higher in developing than in developed countries, thus adding to the retail prices. Where the government has set a ceiling for retail prices, the dealers are usually required to carry those additional costs. Where the government is the sole agency for fertilizer marketing, however, it absorbs the costs as a fertilizer subsidy.

(d) Subsidy to storage agencies. The repeated storing of fertilizers - first at factory warehouses, then at central warehouses and finally at co-operative societies or dealers' stores - results in relatively high costs. Local fertilizer producers in developing countries are responsible for the first type of storage and pay for it themselves as part of the over-all cost. The same principle is applicable to storage by dealers and traders. Storage in central warehouses or co-operative stores, which are usually government-owned, is often covered by the government and hence considered an additional subsidy.

(e) Subsidy to rebagging systems. Repeated moving and changes in the storage of fertilizers, even if they are stored and bagged for a long time or under pressure of high stacks, results in considerable damage because of the low durability of the bag material. The only solution to this problem is rebagging. In most cases, this takes place at the intermediate stage, at the centralized warehouses or co-operative stores. Rebagging costs are often borne by the government as part of an indirect cash subsidy.

The effects of fertilizer subsidy

Experience has shown that fertilizer subsidy has both advantages and disadvantages. Unless the subsidy is efficiently administered and implemented, its effect will not be wholly satisfactory. However, in general, subsidies have proven effective in the promotion and use of fertilizers. In Egypt, for example, in 1959/60, when no subsidy was allocated, nitrogen consumption was only 140,000 metric tons. With continued subsidy, however, it reached 410,000 metric tons in 1974/75, representing an increase of about 300 per cent of annual rate of growth of 20 per cent. There are many such reports of the success of fertilizer subsidy programmes in developing countries. The following table shows the dramatic effect of subsidy on fertilizer consumption in Brazil over a 20-year period.

Subsidy practices in Brazil, 1950-1970

	Subsidy	Consumption (thousands of metric tons)
1950	No	88.5
1958	Yes	249.7
1962	No	236.8
1966	Yes	281.1
1968	Yes	601.7
1970	Yes	820.0

Source: Fertilizer Use and Agricultural Development in Brazil. Economics and Sociology Occasional Paper No. 163 by W. C. Nelson and R. L. Meyer, Department of Agricultural Economics and Rural Sociology, Ohio State University, 1973.

The following table shows the effect on fertilizer consumption in Pakistan when the subsidy was changed from one year to another.

Effect on consumption in Pakistan of changes in subsidy

	Subsidy (mill. Rs)	Consumption (metric ton $N+P_2O_5+K_2O$)
1965/66	63	70,487
1966/67	124	111,834
1969/70	112	307,711
1972/73	199	436,495

Source: Study on Fertilizer Subsidies in Selected Countries, (FAO/FIAC, 1975).

On the other hand, the practice of providing subsidies is not necessarily to be intended for prolonged use. It should last only for the period needed to attain a margin of relief. An economically balanced agricultural structure is not necessarily an unsubsidized one, but for purposes of long-term policy planning, this may be the objective. The continuation of fertilizer subsidies over long periods has led, in many cases, to a dependent agricultural structure. Farmers in certain developing countries with stable subsidy systems are accepting the subsidies as their right, and figuring their returns accordingly. It should always be borne in mind that subsidies constitute a heavy drain on the budgets of developing countries.

Alternatives to subsidizing

As fertilizer subsidy programmes started only about 25 years ago, any verdict upon their effectiveness would still be premature, especially as full information regarding their use in developing countries is lacking. However, subsidies have proved successful in most of these countries. The degree of subsidy justification in one country may not necessarily match that of another. It is the farmers' standard of living, their actual need for subsidy, education level, and social status which create the personal attitude and eagerness to catch up with new technology and planning, their appreciation of the subsidy programmes, and their willingness to co-operate seriously.

Available indicators reveal that under certain conditions and specifications of agricultural structure, fertilizer subsidy is indispensable in developing countries. Where the agricultural sector is run completely by the government with emphasis on enforcing crop rotation and certain crop patterns with a view to marketing the great majority of farm products, fertilizer subsidy becomes an important component of the agricultural system. In countries where fertilizer use is something of a new trend in agriculture, a subsidy may be far more instrumental in promoting fertilizer use and crop production than any alternative system.

In Brazil and India, attempts were made to substitute fertilizer subsidy with crop price support. But as far as fertilizer use and consumption were concerned, it was found that they dropped sharply, along with crop production - and crop prices on the black market were enhanced considerably.

Finally, the two fertilizer subsidy systems mentioned earlier - direct and indirect - together with a moderately scaled crop price support policy, can work as a strong promotional tool for fertilizer use and crop production, if the national budget has the financial resources required for rather a long period of time.

SUMMARIES OF FERTILIZER SUBSIDY POLICIES IN SELECTED DEVELOPING COUNTRIES

1. Egypt

Up to 1960, the fertilizer industry was strictly a private sector concern. Annual consumption at that time was about 140,000 tons of nitrogen, 38,000 tons of P_2O_5, and 500 tons of K_2O. There were only two plants in operation: one producing calcium nitrate at an annual capacity of 38,000 tons of nitrogen, and another producing superphosphate (single) at an annual capacity of 15,000 tons of P_2O_5. The balance was imported through foreign agencies which handled marketing, transportation, and distribution at competitive free prices. The only fertilizers in use were sodium nitrate from Chile, calcium nitrate, ammonium sulphate, ammonium sulphate nitrate, single superphosphate, and potassium sulphate.

In 1960, the Government took remedial steps by:

- Establishing a Fertilizer Fund Foundation
- Setting up a fertilizer credit system, and fertilizer subsidy regulations
- Originating a fertilizer policy programme
- Strengthening the agricultural extension service
- Nationalizing the domestic plants
- Starting a fertilizer control law
- Phasing out all customs duties on imported fertilizer

Since then, imports have been arranged through tenders financed by the Government, and local production has been mainly a public sector responsibility. Transportation, distribution, and storage - down to the co-operative societies where the fertilizers are distributed to the farmers - are the responsibility of government bodies.

Egypt's present 5-year plan (1976-1980) calls for self-sufficiency in nitrogenous and phosphatic fertilizers. Estimates for local production to the year 2000 are shown in Annex table 3. Present production is around 180,000 tons of nitrogen in the forms of ammonium nitrate 31 per cent N and ammonium sulphate. Projected production in 1980/81 should be 500,000 tons of nitrogen as urea, ammonium nitrate, calcium nitrate, ammonium sulphate, and ammonia. Further production in 2000 is expected to reach 750,000 tons of nitrogen. Since projected consumption will not cover that much, it is expected to have a surplus on hand for export. In fact, the plan anticipates covering all local consumption by domestic production in 1980 and starting nitrogen exports by 1981.

Annex table 3. Estimated future nitrogenous fertilizer production, imports, consumption, and exports in Egypt, 1975-2000 (1,000 m t of N)

	Production	Imports	Consumption	Exports
1975/1976	180	210	390	-
1980/1981	500	-	480	20
1985/1986	590	-	480	110
1990/1991	620	-	500	120
1995/1996	750	-	500	250
2000	750	-	520	230

For phosphate fertilizers, the present production (85,000 tons of P_2O_5 in 1975/76) is sufficient for local use with a little margin for export (Annex table 4). However, the plan calls for steadily increasing phosphate fertilizers up to 1980 at moderate rate of growth, with production stepping up sharply thereafter to the year 2000, expecially for export purposes. The only present production is single superphosphate. Further expansions will be in triple superphosphate, mono- and di-ammonium phosphate, and phosphoric acid. Rock phosphate is produced and exported in large quantities. In 1974 about 459,000 tons were shipped abroad. Potash fertilizers are not manufactured in Egypt, consumption being dependent mainly upon imports.

Annex table 4. Estimated future phosphate fertilizer production, imports, consumption, and exports in Egypt, 1975-2000 (Millions of tons of P_2O_5)

	Production	Imports	Consumption	Exports
1975/1976	85	-	75	10
1980/1981	110	-	100	10
1985/1986	150	-	120	30
1990/1991	210	-	130	80
1995/1996	270	-	130	140
2000	300	-	150	150

Nitrogenous fertilizers mostly are needed in Egyptian agriculture. A steady annual growth rate of nitrogen consumption has been attained in the last nine years. In 1973/74, it totalled 380,000 tons of elemental nitrogen with an average annual rate of increase of 8 per cent. It should reach 520,000 tons by the year 2000 (Annex table 3). Farmers in Egypt at the present time are well aware of the necessity of nitrogen for their production and are pressing for higher quotas.

Phosphate consumption was about 75,000 tons of P_2O_5 in 1974 and of slower growth rate than nitrogen. Projections for the future call for the attainment of a total consumption of 100,000 tons in 1980 and 150,000 tons in the year 2000 (Annex table 4).

For a long time, Egypt was a prominent fertilizer importer. In 1973/74, imports accounted for 68 per cent of the yearly consumption. It is expected, however, that self-sufficiency in nitrogenous fertilizer will be reached by 1978 (Annex table 3).

Fertilizer imports are dealt with by the Fertilizer Import Board, which has final authority on prices, terms of contracts, and payments.

On delivery, the fertilizers are handled by the Central Credit and Co-operative Bank, from the port down to central and district warehouses. The Agricultural Stabilization Fund has full responsibility for handling, and pays all expenses for discharging, transportation, storage, and distribution. Actually, there is no fertilizer marketing in the usual sense of the term in Egypt.

Prices and subsidies

Government policy regarding fertilizer prices and subsidies has been consistent since 1960. Fertilizer rates for each crop and region are determined prior to the season and issued publicly by the Ministry of Agriculture. Crop pattern is usually decided upon according to the national plan, and hence fertilizer requirements become a matter of simple calculation.

Fertilizer retail prices to farmers were set according to local production costs, with a little interest margin on the capital cost, in 1960. This was done for ammonium nitrate, ammonium sulphate, and calcium nitrate, which were the only domestic products at that time. Prices of imported types were adjusted to the nitrogen unit at domestic cost. Up to the present time, the Government has kept a very strict price policy, with no increases on retail prices allowed.

Pressure caused by world fertilizer price fluctuations and the increasing costs for local manufacturers are met with higher subsidy rates for both retail and ex-factory prices. In 1974, the retail price subsidy on imported fertilizers reached over $US 200 million, apart from domestic industry penalty costs, as shown in the table below.

Under conditions of low world market price, the fertilizer subsidy on imported types becomes nil or a back return to the Government, as was practised in the early 1970s'.

Retail price fertilizer subsidy, and domestic industry penalty cost of production, Egypt, 1973-1975
($US million)

	Retail price subsidy	Penalty production cost
1973	62.5	3.7
1974	201.6	7.2
1975	103.2	4.8
1976 (estimated)	86.4	5.0

Source: Agricultural Stabilization Fund - Egypt.

2. Bangladesh

In the last ten years, fertilizer consumption in Bangladesh has increased steadily at a considerable rate. Some 86 per cent of the total consumption is devoted to rice, which covers about 82 per cent of the cropped area.

Data on fertilizer consumption development in Bangladesh show actual nitrogen, phosphate, and potash consumption tonnages of 122,000, 44,000, and 11,000 respectively for the year 1973/74 giving a total of 177,000 tons. Short-term programming estimates call for consumption of 682,000 tons by 1978 - this to be doubled by 1980/81. The main fertilizer types in use are urea, ammonium sulphate, ammonium nitrate, single and triple superphosphate, and muriate of potash.

Facilities for domestic production stand at full capacity of 205,000 tons nitrogen, mostly in the form of urea, and 198,000 tons of P_2O_5 in the form of triple superphosphate. However, the practical efficiency of the existing plants is still very low (30-70 per cent) due to difficulties in procuring spare parts and raw materials, especially rock phosphate of low chloride content. There are plans for the establishment of a new plant for manufacturing 528,000 tons of urea per year to be on-stream by 1977/78. No long-term projections have been reported.

Imports have fluctuated sharply from one year to another, owing mainly to low foreign exchange resources and the war. The low efficiency of domestic plants, especially for phosphate production, necessitated the importation of 260,000 tons of phosphate in 1973/74. All potash fertilizers are secured through imports. Nitrogen fertilizer imports represent 8-15 per cent of annual total consumption.

Policies on prices and subsidies

Credit for fertilizer in the past was available only to land-owning farmers through money-lenders and commercial sources. Recently, however, the Government introduced a co-operative credit programme which makes credit available to small farmers at the village level. It may be too early to evaluate the effect of this credit upon fertilizer use at the present time, as the programme, while growing rapidly, is only at an initial stage.

Up to 1974, the Government had maintained constant retail prices for fertilizers, regardless of transportation and distribution costs. Fertilizer prices had been subsidized (table below) by over 50 per cent. At the end of 1974, the heavy burden of this subsidy, due to rapidly increasing fertilizer use and shortages of budget allowance, obliged the Government to increase fertilizer prices twice. The Government is now planning to end subsidy by increasing retail prices.

Retail fertilizer prices and subsidy in Bangladesh, 1974
($US/ton)

	Urea	TSP	Muriate of potash
Price	179	143	107
Subsidy (imports)	244	290	48
Subsidy (domestic prod.)	46	138	-

Source: A study on fertilizer subsidies in selected countries (FAO/FIAC, 1975)

In an effort to diminish the negative psychological effect of phasing out the subsidy, and to offset the increase in fertilizer prices that will be caused by subsidy removal and custom tax rates, the Government intends to increase the paddy crop price by 100 per cent, or even more. The new value/cost ratio is still favourable. Government action on subsidy removal has thus far been due to political pressure, but the policy remains to reduce and to discontinue fertilizer subsidy, hopefully by 1978.

It is difficult at the present time to label fertilizer subsidy policies in Bangladesh as a success or failure, given the relative newness of the practice. However, since the use of fertilizer has increased in the last four years, the subsidy can be said to have achieved its first goal, namely the promotion of fertilizer use.

Chapter VIII

CONSIDERATIONS FOR FUTURE ACTION

As emphasized at the outset, this study constitutes a first attempt by UNIDO to assess the fertilizer industry sector on a global scale up to the year 2000. The central theme of the study is that both national and regional policies must be related to projected fertilizer demand and production. Furthermore, the study points up a number of topics which have to be discussed and investigated further. These topics are summarized below:

(a) In developing the projection methodology applied to this study, a basic constraint was the limited time available to complete the work. Therefore, a model was devised relating consumption to time as the only independent variable on the assumption that the past fertilizer/time relationship will continue in the future.

In forming alternative scenarios of future growth, further study would be needed to make allowance for the effects that the actual growth of fertilizer demand and supply will have on this relationship, including changing economic conditions, improved crop varieties, the development of crops with reduced fertilizer requirement, more effective techniques of fertilizer utilization as well as other scientific and technological developments. Scenarios could also take into account fertilizer consumption projections based on such factors as food requirements, raw material constraints and fertilizer requirements of non-food crops.

(b) Within the framework of the two fertilizer production alternatives presented, as well as of any other alternatives based on future forecasting models, the distribution of production capacity and the location of industry will have to be studied further with a view to identifying alternative solutions to be discussed and acted upon by the parties concerned.

(c) In order to ensure achievement of the production level required for the world as a whole, studies should be made of the development of a monitoring system for production and trade, as well as of a system of guarantees for meeting agreed production targets.

(d) A comparative study should be made of existing fertilizer production policies at the national and regional level with a view to identifying alternative policies for production rationalization and its integration with agricultural development policies as well as with policies governing the industrial and mining sectors, the outputs of which are needed to attain fertilizer production targets.

(e) The relevant experience and knowledge acquired hitherto by many developing countries could be effectively applied to the development of fertilizer production in other developing countries. To the extent that the experience and capabilities thus acquired are considered appplicable, policies will have to be studied and elaborated with a view to facilitating and strengthening co-operation among developing countries in such areas as investment, technology, engineering and construction, training and joint production schemes. Specific attention should be devoted to developing and promoting the most effective means of exchanging information among developing countries as well as measures to monitor fertilizer production.

(f) Furthermore, the advantages and implications of promoting foreign private investment in this sector should be examined further. If, within the framework of overall economic priorities, preferential treatment for foreign investors is justified, the limits, incentives and guarantees to be offered should be elaborated.

(g) Further research should also be carried out into pricing structures and policies and their implications for prices paid by fertilizer users, the development of the fertilizer industry, the creation of an investment climate, and trade.

(h) The fertilizer technology market is highly competitive: the problems that occur in the developing countries are not so much related to the acquisition of know-how as to its more effective utilization. This latter problem should be closely studied, particularly in relation to local requirements and policy objectives. Study is also required of the nature and scope of fertilizer development policies in which the availability of investment capital is not necessarily tied to the acquisition of licences or know-how.

(i) Further research is also needed into the causes underlying the present low levels of capacity utilization in developing countries, as a step towards enhancing the level of production and ensuring that production targets are met by existing and new capacities.

(j) Trends in feedstock use and the resultant utilization of appropriate technologies have been estimated only roughly. Since technological changes will affect capital expenditure as it relates to production targets, developments in fertilizer-related technologies need to be continuously monitored and more accurately forecast.

ANNEX

MANPOWER AND TRAINING REQUIREMENTS

Many developing countries lack facilities for training exclusively in the fertilizer industry. But in view of the large capacity of present and planned single-stream fertilizer plants, greater efforts to train good technicians and engineers are called for. The new plants use bigger machines and more sophisticated instruments than the old, and even a minor delay in rectifying defects can mean huge losses (of the order of $30,000 for each day of production loss). In these plants, down-time has to be kept to a minimum: this means that much more attention to the development of specialized expertise for the erection and maintenance of critical equipment will be required. For example, specialized welders, needed for quick maintenance, repair and erection of high-pressure vessels and piping, have to be trained, as have staff for rigorous inspection work following breakdown. Each operator, supervisor and manager will be responsible for equipment and machinery many times more in value than what it was ten years ago.

In new plants, the investment per employee is 6-10 times higher than in the older plants. This means that better skilled and higher qualified workers will be required to man each position. In the developing countries that have training facilities, these will hardly be sufficient to train the estimated 300,000 personnel required between the years 1985-2000. This will mean training an additional 20,000 workers every year for the 15 years involved. These would be distributed roughly as follows:

Category	Personnel	Per cent
Management	500	2.5
Technical	4,300	21.5
Maintenance and operative	11,340	56.7
Marketing	760	3.8
Others (non-technical)	3,100	15.5
	20,000	100.0

Source: Based on Tables 1 and 2 below.

As can be seen from the above, about 30 per cent of the total personnel requirement is technical, maintenance and operative. It is emphasized, however, that each category of staff listed above is essential. The contribution of a well trained and skilled work force is as vital for the success of a fertilizer plant as that of the supervisory and managerial force.

It is assumed here that manpower requirements in any new unit can only be partially met through the training of engineers, chemists and technicians fresh from educational institutions. A possible 50 per cent of the requirement could be met by giving the new recruits 1-3 years' practical training in existing units. The better part of the total manpower required has to come from existing operating units. Cost estimates for training are usually based on the assumption that by far the greater portion of training will continue to be given on the job, with additional physical facilities being added to meet the training needs. These facilities include: training centres; modern teaching equipment; libraries; and workshops. These would be regarded as non-recurrent costs; staff salaries, consultant fees, travel, subsistence and contingencies would count as recurrent costs.

The capital to be invested in training is small when compared with the returns that can be expected from running fertilizer establishments efficiently, with well trained personnel. Each operating factory must maximize its resources in order to train at least the stipulated number of personnel required, and build-in a provision to ensure that these training efforts, and the persons trained, are fully utilized.

Evaluation of future manpower requirements

The data on average manpower requirements for fertilizer plants presented in Tables 1 and 2 are drawn from the manning patterns of large-scale units expected to go into operation within the next few years. The effect of the local level of industrialization on the personnel requirements of the developing countries is not considered in these estimates, this being an area requiring further individual study. Further, the manpower requirement estimates made for ammonia-urea plants are based on the use of natural gas, fuel oil or naphtha as feed stock.

Nitrogen fertilizer plants based on coal and needing little additional manpower for raw material handling are ignored here as these plants constitute only 17 per cent of the new plants expected by the year 2000.

In the case of phosphate fertilizer production, it is assumed that fertilizer production will be 20 per cent TSP and 80 per cent M/DAP. A 600 TPD phosphoric acid unit comprises a 1,650 TPD sulphuric acid plant, a 600 TPD phosphoric acid plant, and a matching DAP or TSP unit.

The estimation of manpower requirements for fertilizer plants to the year 2000 is in principle simplified by the product of average number of manpower requirements and the total number of plants that would be coming on-stream in the future. The total number, in both developed and developing countries, is given in Chapter III to this study. The estimates of manpower obviously depend on capacity, process adopted, number of streams, feed stock, and whether a grassroot project or expansion of an existing plant is envisaged, but, on the basis of the information given in Chapter III, the estimated requirements in the developing countries alone between years 1985 and 2000 would be in the order of 300,000 personnel.

No attempts are made here to phase the yearly requirements of trained personnel to man the fertilizer establishments on the basis of plants targeted up to 2000. No precision on actual requirements on a yearly basis can be claimed unless the actual dates of commissioning of these plants are known. Considering the time within which the additional manpower will be required, the constraints in training this manpower and the physical facilities which have to be generated, the chances of erring are really more on the side of shortage than excess.

Table 1. Number of plants, and personnel requirements: N fertilizer

	Developing countries			Developed countries		
	1985	1990	2000	1985	1990	2000
				Alternative A		
Number of plants						
1,000 TPD ammonia plants	37	45	117	53	61	211
1,720 TPD urea plants	31	33	89	49	53	185
Personnel requirements						
Management	465	495	1,335	735	795	2,775
Technical (supervisory)	6,368	6,936	18,584	2,478	2,706	9,432
Maintenance and operating	15,760	17,310	46,270	7,964	8,728	30,406
Marketing	1,023	1,089	2,937	588	636	2,220
Others (non-technical)	4,278	4,554	12,282	3,332	3,604	12,500
Total	27,894	30,384	81,408	15,095	16,469	57,413
				Alternative B		
Number of plants						
1,000 TPD ammonia plants	45	80	159	45	28	167
1,720 TPD urea plants	38	62	125	39	23	148
Personnel requirements						
Management	570	930	1,875	585	345	2,220
Technical (supervisory)	7,796	12,904	25,952	1,992	1,185	7,533
Maintenance and operating	19,285	32,090	64,480	6,926	3,835	24,269
Marketing	1,254	2,046	4,125	468	276	1,776
Others (non-technical)	5,244	8,556	17,250	2,652	1,564	10,064
Total	34,149	56,526	113,682	12,123	7,205	45,862

Table 2. Number of plants, and personnel requirements: phosphate fertilizers

	Developing countries			Developed countries		
	1985	1990	2000	1985	1990	2000
			Alternative A			
Number of plants						
600 TPD P. acid units	24	28	95	30	48	128
Personnel requirements						
Management	504	588	1,995	630	1,008	2,688
Technical (supervisory)	2,136	2,692	8,455	660	1,056	2,816
Maintenance and operating	6,480	7,560	25,650	3,600	5,760	15,360
Marketing	480	560	1,900	240	384	1,024
Others (non-technical)	1,800	2,100	7,125	720	1,632	4,352
Total	11,400	13,300	45,220	5,850	9,840	26,240
			Alternative B			
Number of plants						
600 TPD P. acid plants	24	52	119	30	27	104
Personnel requirements						
Management	504	1,092	2,499	630	567	2,184
Technical (supervisory)	2,136	4,628	10,591	660	594	2,288
Maintenance and operating	6,480	14,040	32,130	3,600	3,240	12,480
Marketing	480	1,040	2,380	240	216	832
Others (non-technical)	1,800	3,900	8,925	720	918	3,536
Total	11,400	24,700	56,525	5,850	5,535	21,320

Appendix. CASE STUDIES OF [illegible]
SELECTED DEVELOPING COUNTRIES

A. Pusri fertilizer plants: Indonesia

Production and maintenance

Much of the training of Pusri II operating and maintenance superintendents was carried out abroad. The training of maintenance personnel was also conducted abroad, by equipment suppliers. In the future, however, Pusri II will be used as a training ground for superintendents, while maintenance personnel need only go the suppliers' shops abroad whenever a new type of machinery is introduced (as with the training for Pusri II before it came on-stream). New staff will be hired for Pusri III and trained to take the places of experienced Pusri II staff who will then be moved to Pusri III. Selected candidates in administrative fields connected with production will be sent abroad to attend short courses conducted by the Institute for Management Education and Development, which will continue to provide the instruction in Palembang. Medical personnel working in the plants will spend 18 months abroad, part of it in formal education and training.

Marketing and distribution

Training for marketing and distribution personnel has so far followed a logical approach, which has apparently been effective. First, headquarters personnel are trained in marketing principles and procedures by Pusri's marketing consultants (Agrar-und-Hydrotechnik), as well as by senior Pusri staff and "outside" training agencies. This training is then disseminated to staff in regional offices, who in turn train distributors (private businessmen), who in turn train retailers. To handle the marketing and distribution of the new Pusri III and IV output, the same method of training will be used, but four groups will require special attention: retail outlets, warehousemen, bulk terminal staff, and new ship management and operating personnel.

For the first three of these roups, a series of short courses has been planned in such a way that the consultants and experienced Pusri staff can handle the instruction. This is not possible, however, in the case of the shipping personnel. The training of this category of staff requires a large and varied programme in a field that is partly new to Pusri. When Pusri III comes on-stream, the corporation will own and operate its own fleet of three special fertilizer bulk carriers. The half-dozen current staff members in the Bulk Shipping Section of Pusri's Djakarta office will have to be doubled by late 1976 and about 25 new officers will need to be trained to join the fleet. Pusri's shipping consultants have worked out an acceptable training plan involving institutions in Indonesia and abroad, including the shipyards of construction. Short courses and on-the-job training are planned in the following fields: operations, crewing, accounts and records, stores and spares, documentation, and general subjects such as insurance. Officers and crewmen would, of course, be already qualified when recruited, but the senior officers would require special training in operating bulk urea vessels. They, in turn, would train junior officers and crewmen. It should be added that Pusri does have experience in shore-based operation of chartered vessels in the field of scheduling, communications, and accounting, for example, but this is far short of the capability required as owners, managers, and operators of their own vessels.

Financial and administrative staff

Training of financial staff has been conducted by consultants, with the assistance of Pusri staff. The method is based upon comprehensive operations accounting manuals and construction cost manuals that were prepared for Pusri in 1971 and 1972. This approach, with adaptations to allow for organizational changes made in 1975, will be continued. A conversion course will be given to update existing staff. In addition, new accountants will be given a familiarization course and new sub-graduates will be trained on the job in their special parts of the system. A course in finance for non-accounting managers has been proposed for about 120 managers and assistant managers of cost centres.

It is desired to recruit four graduate accountants in the last quarter of 1975 and eleven more in 1976, but the consultants estimate that actually Pusri will be able to recruit only four or five because of competition. The only way to meet the shortfall is to upgrade, by intensive training, a number of existing sub-graduate accounting staff to the point where they can perform the duties of graduate accountants. The present consultants are willing to undertake such a training programme in-house and are equipped to do so.

Training for non-Pusri staff

Largely as a means of retaining its own experienced staff, Pusri plans to offer training programmes for staff of other nitrogenous fertilizer plants expected to come on stream in the next few years. A few operations and maintenance personnel at the sub-professional level have already received some training in the Pusri plant. The bulk of the training requirement for staff to man the future plants will be on the production side, and will be carried out in the Palembang plants and Training Center, preceded by the same type of contractors' training abroad as was given to operators and maintenance staff in Pusri II, III, and IV. Following this training, personnel will be able to return to their own plants for a few months of on-site precommissioning training. Similarly, marketing and distribution personnel will be trained in small numbers at the Djakarta and regional offices of Pusri and will be encouraged, in turn, to train staff in their own branches and also those of the distributors. Key financial personnel will also be trained in small numbers at Pusri's Djakarta headquarters.

B. Fertilizer Corporation of India (FCI)

Functions and organizational set-up of training centres

The functions of the training courses are (a) to train recent graduates and diploma holders to tackle the complexities of fertilizer manufacture; and (b) to provide a well-knit programme for the development of technical and managerial personnel already employed at different levels.

The 13 units/divisions of FCI throughout the country, have their own training centres which have a total capacity to train 400 graduate engineers, 600 diploma holders and 1,000 craftsmen trainees.

Training begins in the earliest phase of the project activities, the immediate task being to train people, mostly local, for skilled work in a fertilizer plant using highly sophisticated technology.

The chief training and manpower adviser is located at the FCI central office in New Delhi. He takes the general policy decisions and draws up the guidelines that determine future training activities. The heads of each unit training centre are under the administrative jurisdiction of their unit general manager and are free to organize any particular course to suit the needs of their local unit.

In order to avoid duplication of training courses at the various units, each training centre specializes in a chosen field. Thus, Sindri Training Institute offers special courses in process control instrumentation; Trombay in advanced training facilities for welding and plant operation with sophisticated equipment for process simulation; Nangal in electrical; and Gorakhpur in fitting trades. Employees and trainees are sent to one of these institutes depending upon their inclination and technical aptitude. Some of them are sent to two or more institutes to familiarize them with different processes and equipment.

Over-all personality development of trainees

The effectiveness of a supervisor or manager does not depend only upon his technical competence but also on his personality. The personality of a trainee takes shape depending upon what he does, not only during the working hours but also when he is away from the shop-floor. FCI places great emphasis on this aspect.

Excellent hostel facilities are provided at each of the training institutes. The trainees are normally accommodated in double rooms. They organize their social and cultural activities through various committees manned by their representatives and under the guidance of the training staff. These include debates, variety programmes, get-togethers, picnics, and dramas. The trainees manage their messes on a co-operative basis entirely by themselves.

Extensive facilities for reading room, library, and indoor and outdoor games are provided in each hostel. Every year competitions, tournaments and athletic meetings are organized and the successful competitors are awarded prizes and certificates of merit. The trainees are encouraged to develop their personality through the organization of hobby centres at each institute. Photography and electronics are popular hobbies and all facilities are provided for instruction and practical experience in these fields.

Training activities can be broadly grouped as follows: new entrants; employees; and others.

Training Scheme for new entrants

(a) Junior executive trainees:

  (i) Technical cadre;
  (ii) Commercial and administrative cadre;

(b) Chargeman trainees/sr. operatives and technicians;

(c) Craftsmen trainees.

(a) Junior executive trainees. Engineering graduates in mechanical, chemical, electrical engineering, instrumentation, and post-graduate degree of diploma holders in business administration, law, arts, commerce, etc., are eligible for this cadre of trainees.

The programme is to train junior executives with sufficient potentialities for advancement to middle and higher levels of management. After imparting the necessary practical skill in technical matters during the first year of training, the second year programme mainly aims at imparting various supervisory and managerial skills.

During the two-year training period trainees receive a monthly stipend. They are bound by an agreement to complete their training and to serve the Corporation for a period of five years after the completion of their training.

Immediately after training, they are placed as junior engineers/ officers in various departments such as production, design, maintenance, industria engineering, sales and purchase, personnel administration, etc.

(b) Chargeman trainees/senior operators and technicians. Diploma holders (three-year course) in electrical, mechanical, or echmical engineering, or holders of a B.Sc. in physics, chemistry, or mathematics are recruited as chargeman trainees for two years of training. This programme consists mostly of imparting technical and supervisory skills.After successful completion of training they are bound by an agreement to serve the Corporation for a period of five years and are absorbed as first-line supervisors on the shop-floor.

(c) The craftsmen training scheme. This has now been replaced by Act Trainees described later. However, in the case of new projects, the bulk of operators and technicians are recruited through the craftsmen training scheme of three years duration and minimum qualifications of matriculation with science and mathematics. After the successful completion of training, they are absorbed as grade II operators/technicians. Service conditions are the same as for other trainees. Specialized trade skills have been developed in each trade such as welder, instrumentation operator, machine operator, electrician, etc., at one of the training centres of the Corporation.

Training schemes for current employees

(a) Part-time classes;
(b) Employees development courses.

(a) Part-time classes. As the personnel gain experience in the factory, they need the urge for more responsibility and better opportunities. To allow them to improve upon their knowledge without interfering with their normal duties, part-time classes are conducted by each of the training centres. All the courses are generally run for a year and are as follows:

1. Guidance classes for AMIE and AMII Chem.E.
2. Advanced
3. Basic
4. Pre-Basic
5. Foreign Language

1. Guidance classes for AMIE and AMII Chem. E. These courses are provided by the training centres in the evening hours.

2. Advanced courses. Advanced courses in different fields such as production, mechanical, and electrical engineering and instrumentation are arranged by the training centres. Candidates who pass the final examination are given one grade increment and a certificate, considered within the corporation as the equivalent to a Diploma in Engineering or a B.Sc. The Institute of Engineers (India) has recognized this course as an exempting qualification fromtheir studentship examination.

3. Basic courses. This course has two streams, technical for plant personnel and non-technical for secretarial staff. Candidates qualifying in these examinations are also given grade increments. Passing of this course is considered within the Corporation as equivalent to an Intermediate in Science or Arts.

4. **Pre-basic courses.** Candidates with some knowledge of English and mathematics are admitted to this course, duration of which is one year. The syllabus consists of English, physics, chemistry, mathematics and social sciences. Successful candidates get a grade increment. Passing this course is considered within the Corporation to be the equivalent of matriculation or Higher Secondary.

5. **Foreign language classes.** Italian, German, French and Russian language classes are conducted for engineers to enable them to read and translate technical literature, data, etc., in the above languages.

(b) **Employees development courses.** Developments in the technological field are phenomenal. Unless special efforts are made either by an individual or an organization, it is not possible for employees to keep themselves up-to-date with these developments.

FCI's employees development courses are based on this theory. The courses cater to the needs of all categories of employees such as technicians, supervisors, junior, middle and senior managers. The help of senior managers and outside professional experts and institutions is sought whenever necessary in organising the following courses:

1. Managerial development
2. Supervisory development
3. Operators, technician development
4. Refresher

1. **Managerial development courses.** Techniques adopted for such courses include lectures by experts from inside and outside the Corporation combined with discussions, simulation exercises, role playing, etc. FCI runs a fully-fledged Institute of Management Development for the training of senior executives. Courses are based on need and the contents decided upon by the Institute.

2. **Supervisory development courses.** Different supervisory techniques are taught full-time for one week to supervisors. FCI has developed these courses. A lecture-cum-discussion technique is adopted.

3. Operators/technicians development courses. FCI's main work-force consists of personnel who have had thorough practical skill of the job but lack theoretical knowledge. To overcome this, a course has been devised for process operators/technicians for one week, full-time. The course is of pure science and allied information on the processes and equipment common to the plants.

4. Refresher courses. These courses are designed for employees to keep up with the latest knowledge and skills in their fields. They include instruction on subjects such as measuring instruments, special welding techniques, boiler operation, machining, safety, etc.

(c) Training schemes for others. These schemes cater mainly for the following:

1. ACT apprentices
2. Vocational trainees
3. Foreign trainees

1. Apprentices under the act (1961 amendment 1973). As a statutory obligation under the Apprenticeship Act, 1961, a number of apprentices have to be trained in various designated trades such as electrician, fitter, machinist, welder, turner, graduate engineers and diploma-holders, etc. The period, stipend and minimum qualifications are fixed under the Act. Apprentices are provided with rentfree accommodation and other amenities just like other trainees. For this category of trainees, the Corporation has no obligation to provide employment after the completion of the training.

2. Vocational trainees. Many of the technical and managerial institutes have factory training as a part of their curricular.

3. Foreign trainees. The FCI training organization also undertakes the training of foreign nationals sponsored under various international co-ordination plans such as Colombo Plan, etc., to help sister nations to develop their specialists in the field of fertilizer technology and production. A number of nominees have been trained for various terms from France, Australia, West Germany, Sri Lanka, Indonesia and several far eastern and southeast Asian countries.

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