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THE ROLE OF FERTILIZER IN MEETING DEVELOPING COUNTRIES' FOOD NEEDS

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The Role of Fertilizer in Meeting Developing Countries' Food Needs[1]

Food production in developing countries has become increasingly dependent on fertilizer during recent years. Although only a small proportion of total food production in most of these countries can be attributed to fertilizer, a considerable proportion of the production increase is brought about by increasing fertilizer usage along with the introduction of new fertilizer responsive crop varieties and other improved technology. The increasing dependence on fertilizer to meet current and emerging food needs and the limited control over fertilizer supplies, due to the dependence on imported fertilizer, fertilizer raw materials and/or feedstocks cause many developing country governments to attempt an expansion of national fertilizer production. The seriousness of the matter became abundantly clear in 1972-73, when the world was hit by fertilizer shortages, drastic increases in crude oil prices, and the oil embargo. Faced with absolute shortages and/or drastically increasing prices of fertilizer and feedstocks for fertilizer production, developing country governments suddenly realized the potential and, to some countries, real threat to food production caused by the heavy dependence on imports to satisfy internal fertilizer needs.[2]

Hence, while high levels of self-sufficiency in basic foods has been an important goal in most developing countries for some time, many of these countries are now attempting to increase the degree of self-sufficiency in fertilizer to assure increased control of fertilizer supplies and, in turn,

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[1]Prepared by Dr. Per Pinstrup-Andersen, Director, Agro-Economic Division, International Fertilizer Development Center, Florence, Alabama, for presentation to the 12th Annual Conference of the Missouri Valley Economic Association, Tulsa, Oklahoma, February 26-28, 1976.

[2]When the drastic increases in oil prices occurred, countries such as South Korea, Philippines, and Malaysia were totally dependent on Middle East feedstocks for their nitrogen production, while 78% of India's nitrogen production depended on this source (26).

food supplies. Whether these attempts will continue to receive as much attention as they did during the period of fertilizer shortage remains to be seen.

While it is generally agreed that the importance of fertilizer in food production of developing countries is increasing, this paper attempts to provide additional evidence on its past and potential future contribution to meeting world food needs. While some rough quantitative estimates are made of the contribution of fertilizer to food production in developing regions, lack of certain basic data prohibits an adequate treatment of this matter.

The paper consists of four sections. First, a brief discussion of the principal fertilizer market developments during recent years; second, a short section on current and emerging food needs and the limitations of production expansions alone in meeting such needs. The third and fourth sections deal with past and potential future contributions of fertilizer to cereal production.

Recent Fertilizer Market Developments

In a recent USDA publication, Reidinger (22) provides an excellent and up-to-date review of recent fertilizer market developments.[3] Hence, only a brief summary of this topic is provided here.

Following a period of decreasing fertilizer prices, the period 1971-74 experienced rapidly increasing fertilizer prices, absolute fertilizer shortages, and a resulting situation of panic on the part of importing countries. Reliable estimates of future supply/demand relationships were scarce and more attention was probably given to sensational predictions of "permanent fertilizer shortages" and resulting "mass starvation" than to the more well-founded predictions that supply and demand would soon again be balanced at reasonable prices, although above those of the 1968-70 period.

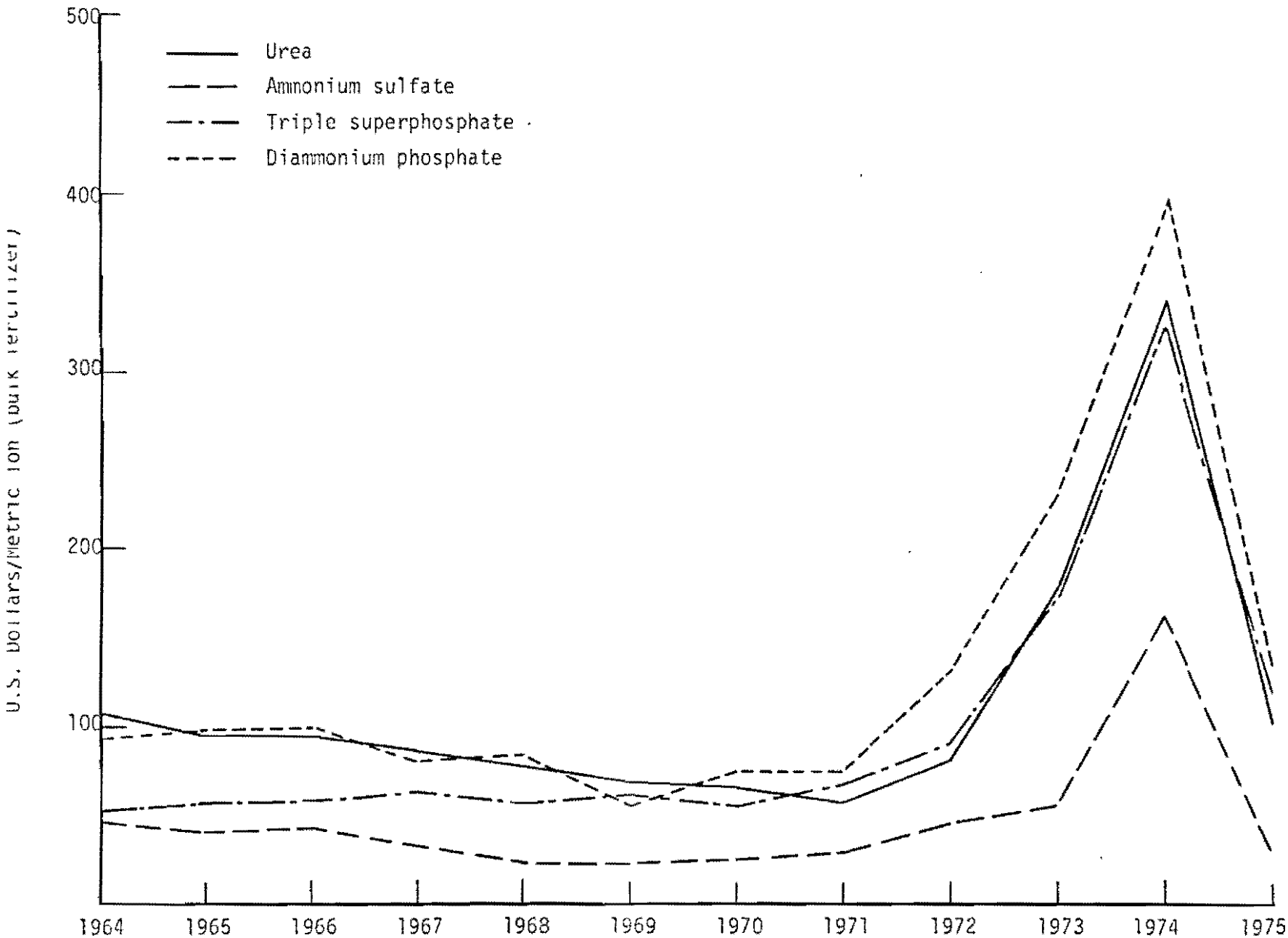
The high fertilizer prices and shortages arose from rapidly increasing fertilizer demand, which in turn was determined primarily by increasing food

[3] A number of other recent publications treat this topic, including (7, 11, 21, 26).

prices, and from a shortage of fertilizer production capacity, largely the result of cyclical investment patterns in the fertilizer industry (7). Increasing oil and phosphate rock prices further contributed to the price increases. However, prices rose further because importing countries attempted to assure sufficient fertilizers for the near future, under the assumption that prices would continue to increase. Thus, some countries purchased up to a year's supply in advance, with the result that prices went even higher. In the meantime, farmers were reducing fertilizer applications, either because of high prices or absolute shortages, and as importing countries' warehouses began to fill, demands and prices decreased. Figures 1 and 2 illustrate the drastic price changes for four fertilizers. Prices went from less than $100/ton during 1970 to $350-400/ton during the latter part of 1974. A year later, i.e., the end of last year, prices of the four fertilizers shown were back down to $100-150/ton. While increased capacity and high operating rates contributed to supply increases during 1973-74 slightly above those of previous years, the primary reason for the price falls during 1975 is probably the demand response to high prices. Thus, preliminary data from TVA indicate a reduction in fertilizer consumption from 1974 to 1975 while production continued to increase. The result has been increasing inventories. By June 1975, producer inventories of nitrogen and phosphate fertilizers were about double the June 1973 levels, and stocks of selected major fertilizers in international trade were about three times as large (22). According to preliminary data from TVA, inventories for nitrogen, phosphate, and potash in North America doubled from 1974 to 1975. Even larger inventory increases are estimated for Europe. The largest decreases in fertilizer consumption were found in North America and Europe, while increasing consumption was noted for South America. It should be stressed that these data are preliminary and subject to revision.

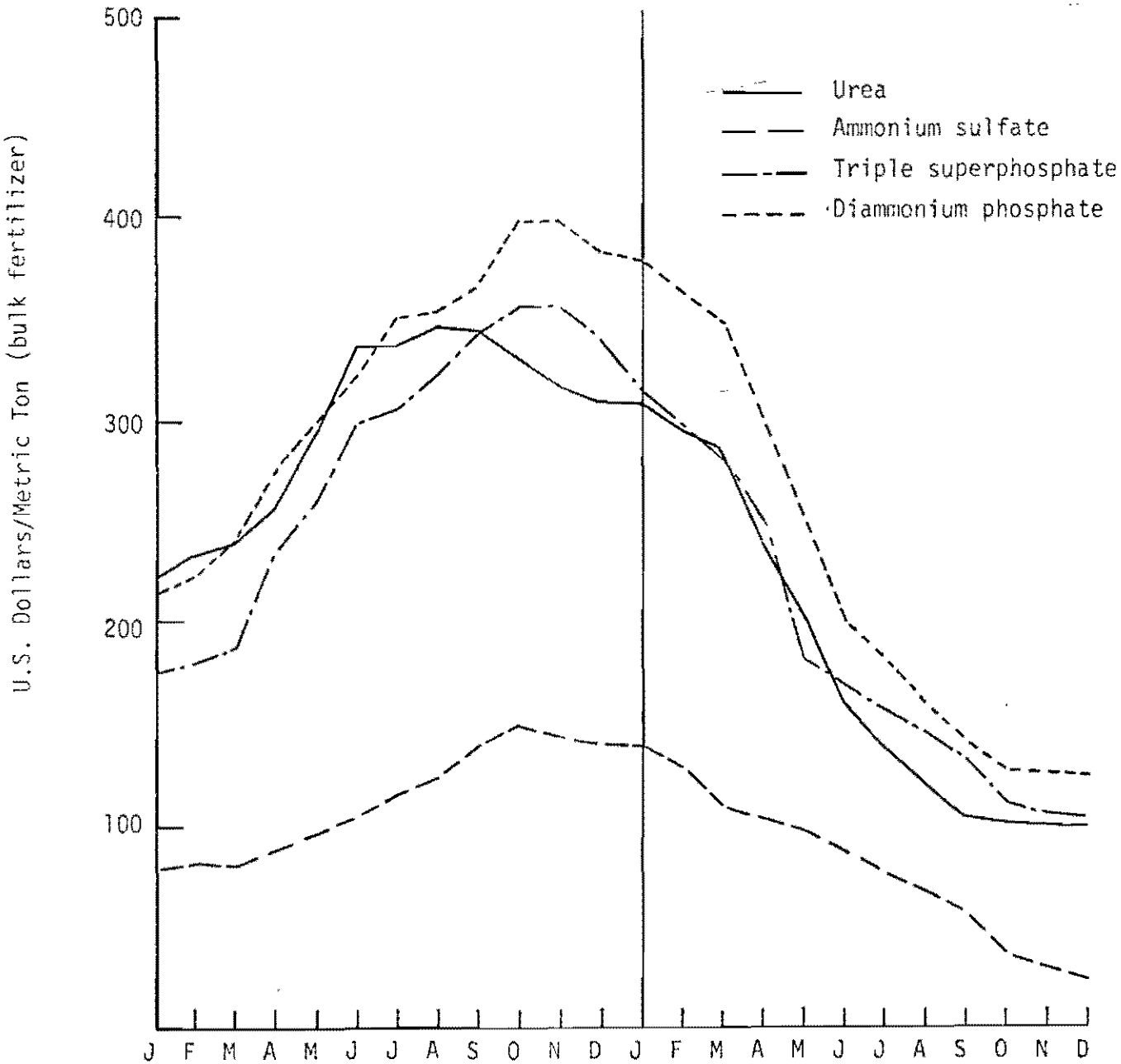
While farmers and importing country governments responded to price increases by reducing consumption, the fertilizer industry responded by planning

Figure 1. Fertilizer Price Trend Indicators, 1964-75*



*1964-74 prices based on AID tenders; 1975 prices are unofficial IFDC estimates. F.O.B., International Market.

Figure 2. Fertilizer Price Trend Indicators, 1974-75



Source: Unofficial IFDC estimate. F.O.B., International Market.

additional production capacity. Thus, TVA estimated in August of 1974 that about 33 million tons of new nitrogen production capacity had been announced to be on-stream before 1980. The total world nitrogen capacity was estimated to be 62.4 million tons in 1973. Hence, the increase amounts to more than 50%. It is likely, however, that considerably less than the announced new capacity will in fact materialize in view of the drastic price decreases during 1975.

Current and Emerging World Food Needs

Today's world population is around 5 billion and growing at about 2% per year. According to FAO data, world food production per capita for 1975 was equivalent to about 2,600 calories per day, i.e., sufficient to meet the energy requirements of the world population, if distributed according to needs (41). Although such data are not readily available for protein, it is likely that a similar situation would be encountered. However, a large portion of the world population suffers from insufficient calorie and protein intake. FAO suggests that at least 460 million people currently suffer from undernourishment (41) and that about half of the children under 5 years of age in the developing countries may be undernourished, accounting directly or indirectly for as high as one-half of the deaths in this age group.

Although undernourishment is caused by a large number of factors, it appears that the problem is basically one of unequal food distribution rather than absolute food shortage. Severe poverty prohibits large segments of the population from obtaining sufficient food, while lack of knowledge causes poor food distribution both among and within families. At the same time, food consumption of a small portion of the population far exceeds nutritional needs. Findings from a recent study in Cali, Colombia, illustrate the point (20). Average protein and calorie intakes for the Cali population as a whole were estimated to be 112 and 119% of nutritional requirements,

respectively. However, 36% of the population received insufficient quantities of protein, and calorie intakes were insufficient among 18% of the population. The lowest income group (18% of the population) spent 87% of their total incomes on food and obtained 72 and 89% of their protein and calorie requirements, respectively. In contrast, the highest income group (14% of the population) spent 35% of their incomes on food and consumed 204 and 178% of their protein and calorie requirements, respectively. Although the above findings are valid only for the location where the study was carried out, they support the global indications that the current food problem is basically one of maldistribution rather than lack of supply.[4]

It is utopia, of course, to expect that available food supplies would be distributed according to nutritional needs, particularly in a market oriented economy. Rather, food distribution is determined by effective demand, which in turn is determined by a number of factors including purchasing power and personal tastes and preferences.

Thus, while the current world food problem cannot be resolved unless available food and/or purchasing power are more equally distributed, expanded food production may reduce the severity of the problem or at least help to avoid worsening of the problem over time, by attempting to meet effective demands at current or reduced real food prices.

Changes in effective demands for food are determined primarily by changes in incomes and their distribution, and changes in population. Average annual growth in per capita incomes for the world as a whole during the period 1969-70 was 4.2%, while the population growth rate was 2.0% (45). Except for a few countries, there are no indications that the distribution of incomes has changed during that

[4]The FAO document entitled "Assessment of the World Food Situation, Present and Future," prepared for the World Food Conference further supports these indications: "In such widely dispersed countries as Brazil, India, and Tunisia, the 20% of the population with lowest income has half the per capita energy intake of the top 10%" (41).

period. Assuming, as a rough approximation, an income elasticity of demand for food of 0.3-0.4 for the world as a whole, and a population elasticity of demand for food equal to one, and assuming further that past rates of income and population growth will continue and the distribution of incomes will remain unchanged, effective demands for food would increase at an annual rate of 3.3-3.7%. This estimate corresponds closely to estimates made by the National Academy of Science (41) and the University of California Food Task Force (45) for the period until 1985. Failure to expand food supplies by an equal percentage would result in increasing real prices of food and a further deterioration of the nutritional status and consumer real incomes.

It should be stressed here that, in addition to improved distribution and expanded production of food, any long-run solution to the food/population problem must involve a reduction in population growth.

Past Contribution of Fertilizer

For the purpose of this discussion, it may be useful to separate increases in food production on the basis of whether they were caused by area or yield increases. Table 1 shows such a separation for cereals for three time periods. The compound annual rate of growth in cereal production in developing market economies as a group was slightly above 2.5% for the period 1948/52-1971/73. About 55% of this growth was due to yield increases. The relative importance of yield increases was high in the Far East, where little unused arable land was available and low in Latin America where considerable reserves of potentially arable land are found. The relative importance of increased area for production expansion is much higher for developing than for developed countries, as would be expected. The increasing importance of higher yields relative to expanded land area in Latin America, Asia, and developing countries as a whole, is clearly pointed out by the data for the two periods. The relative importance of yield in production expansions increases from 51%

Table 1. Estimated Increase in Area and Yields for Cereals 1948/52 - 1971/73 and Relative Contribution to Production Increases in Selected Regions

Region	Average Annual Compounded Rate of Increase in:						Relative Contribution to Production Increase (%)					
	Area			Yields			Area			Yields		
	(a)[1/]	(b)[1/]	(c)[1/]	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)
Africa	1.2	0.1	0.8	1.8	-0.5	0.9	35.3	-	43.9	64.7	-	56.1
Latin America	2.8	2.0	2.4	1.4	1.5	1.4	62.0	53.3	59.0	38.0	46.7	41.0
Near East	2.7	1.0	2.0	0.6	1.5	1.0	78.0	39.6	61.8	22.0	60.4	38.2
Far East	1.5	0.0	0.9	1.7	0.8	1.3	41.9	0.5	34.6	58.1	99.5	65.4
Developing market economies	1.7	0.5	1.2	1.6	0.9	1.3	48.7	37.0	45.6	51.3	63.0	54.4
World	0.8	0.6	0.7	2.0	2.7	2.3	24.1	19.9	21.8	75.9	80.1	78.2

1/ (a) refers to period 1948/52 - 1961/65.

(b) refers to period 1961/65 - 1971/73.

(c) refers to period 1948/52 - 1971/73.

Source: Estimated on the basis of area and yield data from: FAO, Production Yearbook, several years.

during the first, to 63% during the second period for the developing market economies as a whole.

Yield increases have been spectacular for wheat and rice in countries where a large proportion of these crops are produced from new high yielding varieties. Thus, during a 10-year period, rice yields in Pakistan increased by 73% while wheat yields increased 56% in India (table 2). The high yielding varieties of wheat and rice provided for higher net return per unit of land than before and farmers expanded the area of these crops at the expense of crops for which no high-yielding varieties had been developed. Hence, while the total area grown with cereals remained constant, a considerable crop substitution took place among the various cereals. This explains the area contribution shown in table 2.

To what extent was fertilizer responsible for the yield increases shown in tables 1 and 2? Fertilizer consumption for three periods of time is shown in table 3. Average annual consumption of nitrogen, phosphate, and potash in developing market economies as a whole during 1972-73 was 11.9 million tons of nutrients, or 14.8% of total world consumption. The compound growth rate in fertilizer consumption during the period 1948/52-1972/73 was 8-10% for the developing market economies and 6-10% for the world as a whole (table 4). Growth rates for developing market economies, as a group, increased from 3.8-6.9 during the first, to 14.3-15.3% during the second period. Considerable differences are found among individual countries.

Fertilizer usage per unit of land increased at a compound annual rate of 11.2% in developing market economies during 1960-74 (table 5). The highest percentage increase was found in the Far East while Europe provided the lowest percentage increase. The European consumption of fertilizer per unit of land is about 10 times that of Asia, 20 times that of Africa, and about 7 times that of Latin America. Although this relationship is changing in favor of developing

Table 2. Estimated Increase in Area and Yields and Relative Contribution to Production Increases for Wheat and Rice in Selected Countries, 1960/63 - 1970/73 (%)

	Total Increase for the Period (%)		Relative Contribution to Production Increase (%)	
	Area	Yields	Area	Yields
Wheat				
Pakistan	22.3	45.2	35	65
India	38.2	56.1	42	58
Rice				
Philippines	0.4	33.9	1	99
Pakistan	22.8	73.3	27	73
Malaysia	43.7	16.5	70	30
India	4.6	13.8	26	74
Indonesia	18.8	29.1	40	60

Source: Dana Dalrymple (2, pp. 22-23).

Table 3. Average Annual Fertilizer Consumption in Selected Regions of the World, for Three Periods of Time (Thousands of Tons of Nutrients)

Type	Period	Africa	Latin America	Near East	Far East	Developing Market Economies	Developed Market Economies	World	Percent Consumption in Developing Market Economies
Nitrogen	1948/52	33	116	94	617	860	-	4,309	19.9
	1961/65	113	596	358	980	2,052	9,149	14,972	13.7
	1972/73	412	1,717	1,142	3,560	6,840	17,154	37,214	18.4
Phosphate	1948/52	-	107	33	295	576	-	6,103	9.4
	1961/65	101	395	126	314	937	9,113	12,693	7.4
	1972/73	300	1,315	489	1,154	3,259	13,657	23,412	13.9
Potash	1948/52	28	55	5	163	250	-	4,503	5.6
	1961/65	74	247	12	167	500	7,204	10,272	4.9
	1972/73	190	839	41	732	1,804	11,043	19,767	9.1

Sources: FAO, 1974 Annual Fertilizer Review (39) and 1971 Production Yearbook (38).

Table 4. Compounded Annual Rate of Increase in Fertilizer Consumption in Selected Regions of the World, for Three Periods of Time (%)

Type	Period	Africa	Latin America	Near East	Far East	Developing Market Economies	Developed Market Economies	World
Nitrogen	1948/52-1961/65	10.0	13.4	10.9	3.6	6.9	-	10.1
	1961/65-1972/73	15.5	12.5	13.8	15.4	14.3	7.3	10.7
	1948/52-1972/73	12.2	13.0	12.0	8.3	9.9	-	10.3
Phosphate	1948/52-1961/65	-	10.5	10.8	0.5	3.8	-	5.8
	1961/65-1972/73	12.8	14.3	16.3	15.5	14.9	4.6	7.0
	1948/52-1972/73	-	12.7	13.0	6.4	8.2	-	6.3
Potash	1948/52-1961/65	7.9	12.3	6.7	0.2	5.5	-	6.6
	1961/65-1972/73	11.1	14.6	14.6	17.8	15.3	4.8	7.5
	1948/52-1972/73	9.2	13.2	9.9	7.1	9.4	-	7.0

Source: Estimated on the basis of data in table 3, using a compound interest equation.

Table 5. Fertilizer Consumption Per Hectare of Arable Land (Kg of Nutrients N, P_2O_5, K_2O), for Selected Years and Regions

Region	1960	1965	1970	1974	Annual Compounded Rate of Increase 1960-1974 (%)
Africa	1.5	2.0	3.6	5.0	9.0
Latin America	8.9	12.8	23.0	32.1	9.6
Near East	4.8	8.3	14.0	22.2	11.6
Far East	4.0	6.6	15.4	20.5	12.4
North America	33.3	53.6	69.7	79.5	6.4
Western Europe	97.3	129.3	173.5	200.4	5.3
Developing M.E.	4.2	6.6	13.3	18.6	11.2
Developed M.E.	54.7	76.1	94.7	109.0	5.0
World	21.4	32.7	46.3	56.8	7.2

Source: FAO, 1974 Annual Fertilizer Review (39). Rate of Increase Estimated by the Author.

countries, the absolute increase in per unit area fertilizer consumption during the last 15 years has been much higher in Europe (103 kg/ha) than in developing regions (3.5-23.2 kg/ha). Although there is no reason to believe that optimum quantities of fertilizer per unit of land would be the same for all regions, the data presented in table 5 suggest that a great potential exists for expanding food production in developing countries through additional fertilizer use.

Reliable information on fertilizer usage by crop in developing countries is scarce. Table 6 provides estimates of the percentage of fertilizer used for cereals in selected countries. On the basis of this information, it appears that cereals account for roughly 30% of all fertilizer used in Latin America, and about 60% in Asia. No such estimate can be made for Africa on the basis of available data.

The response to fertilizer depends on a variety of factors and differs among crops, crop varieties, regions, and farmers within a given region. An average response of 10 kg of grains for each kg of fertilizer (measured in terms of plant nutrients) applied in developing countries has been widely accepted as a rough approximation (18). If this rough estimate can be accepted as a sufficiently close approximation to the actual average response in developing countries, the contribution of fertilizer to cereal production can be estimated. The production function analysis offers an alternative approach to estimating the fertilizer contribution. Both methods are used in this analysis.

A production function developed by Evenson (6) for cereal grain production in 20 Asian/Middle Eastern countries was used. The function is based on 1,050 observations for the period 1948-71. Evenson estimated the elasticity of production, with respect to fertilizer, to be 0.0796. The compound annual rate of increase in cereal production due to fertilizer usage

Table 6. Percentage of Total Fertilizer Consumption Used for Cereals in Selected Countries

Country	Year	Percent Used for Cereals	Source of Information
India	1970/71	65	(40)
Thailand[a]	1970/71	33-50	(37)
Taiwan[a]	1968/69	75	(23)
South Vietnam	1970/71	75	(30)
Zaire	1973/74	4	(4)
Costa Rica	1971	11	(24)
Dominican Republic	1974	19	(8)
Colombia	1974	24	(5)
Brazil			(14)
Sao Paulo	1967	-	
Northeast	1967	-	
Rio Grande do Sul	1967	80	
Peru[b]	1965	20	(3)

[a]For rice only.

[b]Nitrogen only.

was then estimated on the basis of the elasticity of production and the estimated rate of increase in fertilizer consumption shown in table 4. It was assumed that the proportion of total fertilizer consumption applied to cereals remained constant over time.

The results obtained from applying the two methods are shown in table 7. Fertilizer was estimated to have added 48.2 million tons of cereals to the annual production in developing market economies as a group, during the period 1948/52-1972/73. This amounts to about 30% of total production increases and more than half of the yield increases during that period.[5] The contribution of fertilizer to production increases was smallest for Africa and largest for Asia. This reflects the larger increase in fertilizer consumption per unit of area in Asia. About two-thirds of the yield increases in Latin America were due to fertilizer, while less than half of the yield increases in the Far East were caused by this factor.[6]

The contribution of fertilizer to increases in world cereal production was estimated on the basis of a production function developed by Hayami and Ruttan (12) for total agricultural production in 37 countries, developed and developing, for the period 1957-62. They estimated elasticities of production with respect to fertilizer between 0.10 and 0.17. Using these elasticities, the contribution of fertilizer to total world cereal production was between 27.7 and 47.1% of the production increases between 1948/52-1972/73.

The proportion of total cereal production in developing market economies for 1972/73 attributed to fertilizer was estimated to be 15.2% (table 7).[7] Only 6.6% of the African cereal production was estimated to be due to fertilizer.

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[5] Christensen obtained a similar estimate for the United States for the period 1940-55. He estimated that 55% of yield increases was due to fertilizer (1).

[6] Herdt and Barker estimated the fertilizer contribution to increases in cereal production in the Far East to be 51% when a response ratio of 10:1 was used (13). Their estimate corresponds closely to the estimate obtained here with respect to yield contribution.

[7] Herdt and Barker estimated that 13.5-20.2% of total cereal production in the Far East was due to fertilizer (13). As would be expected, a much higher proportion of total production in the United States is due to fertilizer. The Council for Agricultural Science and Technology estimates that about one-third of the U.S. grain production is due to fertilizer (34).

Table 7. Estimated contribution of fertilizer to cereal grain production in developing market economies 1948/52-1972/73

	Africa	Latin America	Near East	Far East	Developing m.e.
Total increase in annual cereal production (1,000 tons)[a]	12.339	40.527	21.000	81.518	155.413
Estimated increase due to fertilizer (1,000 tons)[b]	2.523	10.779	9.240	26.226	48.243
Percentage of total production increase due to fertilizer[b]	20.4	26.6	-	32.2	31.0
Percentage of total yield increase due to fertilizer[b]	36.4	64.9	-	49.2	57.0
Estimated compounded annual rate of increase in cereal production due to fertilizers, %[c]	-	1.03	0.97	0.62	0.75
Percentage of total production increase due to fertilizer[c]	-	27.1	32.5	28.0	29.8
Percentage of total yield increase due to fertilizer[c]	-	66.1	85.1	42.8	54.8
Estimated percentage of total production 1972/73 due to fertilizer[d]	6.6	16.2	-	15.0	15.2

[a]Estimated on the basis of FAO, Production Yearbook, several years.

[b]Estimated on the basis of increases in fertilizer use for cereals and an average response rate of 10 kg of cereal grains per 1 kg of fertilizer (nutrients).

[c]Estimated on the basis of production function

[d]Total production due to fertilizer estimated on the basis of the average response rate of 10:1.

In addition to its importance in cereal grain production, fertilizer plays a major role in certain other crops, such as sugarcane, cotton, coffee, banana, and potatoes in developing countries. Lack of data prohibits an estimation of the contribution of fertilizer to yields and production of these crops.

Before finishing this section of the paper, a note of caution. The data used above to provide quantitative estimates of the contribution of fertilizer to cereal production suffer from uncertainty with respect to their ability to represent reality in an exact way. This problem is common to most analyses based on aggregate data from developing countries. Because data requirements of the two methods were somewhat different, the similarity of the estimates from the two methods places considerable confidence in the results. However, the results should be considered as rough approximations rather than exact estimates.

Future Role of Fertilizer

The future contribution of fertilizer to food production in developing countries will be determined by the quantity and quantity of fertilizer consumed, which, in turn, is determined by demand and supply, and the crop response. This section briefly discusses each of these topics and proceeds to make rough quantitative estimates of expected fertilizer contributions.

Fertilizer Demand--The demand function for fertilizer is basically derived from product demand and crop response functions. Hence, the quantity demanded is expected to be determined by the prices of fertilizer, agricultural products, and other inputs as well as the expected marginal product of fertilizer. However, a number of other factors tend to influence farm level fertilizer demand in developing countries. Scarcity of capital and credit, risk, uncertainty and

a number of other factors may limit fertilizer demands. While a thorough discussion of the farm level demand issues is beyond the scope of this paper, readers are referred to Dalrymple (2) and Timmer (27) for additional discussion and references. It may be concluded that much additional research is needed on the relationships determining fertilizer demand and actual consumption at the farm level to assist policymakers in developing countries.

Fertilizer Supply--A large part of fertilizer supplies in developing countries is imported. The resulting dependence on exporting countries for fertilizer, fertilizer raw materials and feedstock was discussed previously. As shown in table 8, developing countries account for about 18% of world nitrogen consumption but only 10% of world production. A similar situation is found for phosphate, while almost all the potash consumed in developing countries is imported. The current degree of self-sufficiency in nitrogen and phosphate in developing countries is 55-60% while it is 15% for potash (table 9). For developing market economies as a group, there has been a considerable increase in the rate of self-sufficiency in nitrogen and potash since 1968/69. However, the degree of self-sufficiency and its recent trend differ greatly among individual developing countries.

The increasing dependence on fertilizer for their food supply along with recent fertilizer shortages and drastic price increases in the world market have motivated many developing countries to attempt an expansion of domestic fertilizer production capacities. While the nitrogen production capacity of developing countries was estimated at 5.8 million tons in 1973, new plant announcements as of August 1974 would add another 6.5 million tons of capacity before the end of the 1970's (26). Although it is unlikely that the total announced capacity expansion will actually materialize, the actual increase is likely to be large. In comparison, Western Europe and North America have announced a capacity expansion from about 30 to 39 million tons, i.e., an increase of 30% as opposed to 112% for developing countries.

Table 8. Developing Countries' Share in World Production and Consumption, 1961/65 and 1973/74 (%)

	Production		Consumption	
	1961/65	1973/74	1961/65	1973/74
Nitrogen	6.1	10.2	13.7	18.2
Phosphates	3.7	8.5	7.4	14.2
Potash	0.5	1.3	4.9	9.2

Source: Estimated on the basis of data from: FAO, 1974 Annual Fertilizer Review (39).

Table 9. Degree of Self-Sufficiency in Fertilizers for the Developing Market Economies as a Whole, 1968/69 - 1973/74[a/]

Year	Nitrogen	Phosphates	Potash
1968/69	47.6	59.4	1.5
1969/70	51.8	55.9	7.1
1970/71	52.8	58.0	13.7
1971/72	55.9	63.1	20.4
1972/73	58.2	65.5	17.5
1973/74	56.5	61.7	14.8

[a]Production divided by consumption and multiplied by 100.

Source: Estimated on the basis of consumption and production data from: FAO, 1974 Annual Fertilizer Review (39).

Hence, while shortage of foreign exchange may be an important supply limiting factor in many developing countries at present, there are indications that the degree of self-sufficiency in fertilizer production will increase considerably before the end of the 1970's. It should be noted, however, that many of these countries are deficient in feedstock and fertilizer raw materials.

While the ownership of feedstock and raw materials is concentrated in relatively few countries,[8] no absolute shortages of these resources are likely to occur for a long time to come. World phosphate rock resources are estimated to be 76.1 billion tons, or sufficient for about 700 years at the current world rate of production. About 16 billion tons are estimated to be recoverable at current costs (150 years' consumption at current rates), while the remainder is expected to be recoverable only at higher costs and in some cases only with improved technology (22).

Total world potash resources are estimated to be 79 billion tons of K_2O, of which 10 billion tons are readily available reserves. Total world potash production during the year 1973/74 was 22 million tons of K_2O (22). Hence, no absolute shortage of raw materials is visualized. As in the case of phosphate rock, the concentration is heavy on the supply side. Canada accounts for about 40% of total world exports and 23% of total world production. Furthermore, 43% of all readily available potash reserves and about 85% of all known potash resources are found in that country (22).

Crop Response to Fertilizer--The response to fertilizer is determined by a large number of factors. The response of a particular crop to a particular nutrient is determined by the environment in which the crop grows, including soils,

[8] Similarly to the recent drastic increases in oil prices, the oligopsony-like situation in phosphate rock and potash resources offers ample opportunity for price manipulations on the part of the sellers. Morocco, for example, which is the largest exporter of phosphate rock, accounting for about one-third of all world exports, increased prices from $14 to $68/ton of phosphate rock between February 1973 and January 1975, i.e., an increase of nearly 400%. Recent fertilizer price falls, however, have brought this price down a little.

climatic conditions, cultural practices and use of other inputs such as insecticides, herbicides, and fungicides. When ideal environments are attempted, crop responses may be far above those obtained under normal farming conditions. Hence, experiment stations tend to obtain much higher responses than farmers. Herdt and Barker conclude that while responses of 20-30 kg of grain might be obtained for each kg of fertilizer applied to rice under experimental conditions, Asian farmers would probably not obtain more than 10-15 kg (13).

Most currently available chemical fertilizers have been developed to suit temperate zone agriculture. There are indications that new fertilizers focused on meeting the needs of tropical soils and crops may greatly increase the fertilizer efficiency in the tropics.

The crop variety is another factor that plays an important role in determining fertilizer response. Frequently, traditional varieties have low responses to fertilizers while new high yielding varieties tend to depend on fertilizer for exploiting their yield potential. Figure 3 illustrates the fertilizer response of three traditional and one improved rice variety. Disease and insect resistance frequently incorporated into new varieties likewise increase the on-farm response to fertilizer implicitly, because it reduces losses in crops where fertilizers may be applied. Hence, change from traditional to improved crop varieties may greatly increase fertilizer response, and, in turn, fertilizer demands. Sidhu (25) estimated that a change from traditional to improved wheat varieties in Punjab, India would increase fertilizer demand by 25%. For these reasons, the potential contribution of fertilizer must be determined, not in isolation, but as a component of the contribution of new agricultural technology in general. As the acreage with new high yielding varieties increases, the average fertilizer response will increase. Whether the increasing yields are due to the new variety or to fertilizer becomes an academic question. Both must be present.

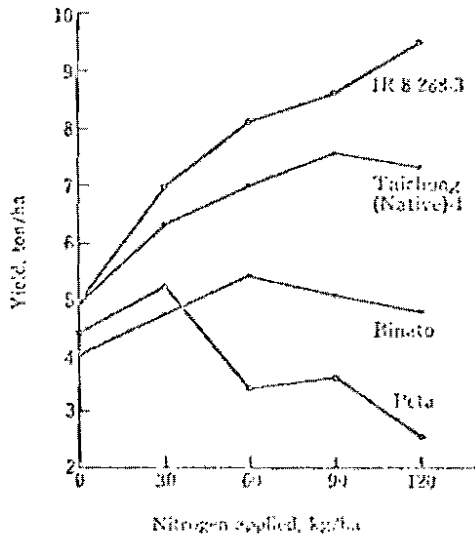

Fig. 3. Fertilizer response of IR-8 as compared to some other varieties (IRRI Reporter 1966). Dry season experiment.

Fertilizer Demand/Supply Projections--The fertilizer demand/supply projections vary greatly among organizations making the projections. The annual compound growth rates in world fertilizer demands projected for the period 1972/73-1980/81 by four organizations are shown in table 10. The difference between the smallest and the largest estimate vary from 30 to 86%. To further illustrate the difficulties with which policymakers are faced, when making decisions on the basis of expected future fertilizer market relationships, FAO estimated an increasing deficit, reaching 7 million tons of nitrogen and 4.6 million tons of phosphate by 1980/81 (22). The World Bank indicated a deficit of 8.4 and 3.8 million tons of these two nutrients by the same year. These projections were made in late 1973 or early 1974. In late 1974, TVA released forecasts showing a surplus of phosphate beginning in 1974 and reaching 1.9 million tons by 1977, and a surplus of nitrogen beginning in 1978. In the TVA estimates, a slight deficit would be reached by 1980, for both nutrients. The latest known FAO projections show a surplus of 1.7 million tons of nitrogen and 0.2 million tons of phosphate by 1980/81 (22). To complete the picture, in late 1973 or early 1974, FAO projected a deficit of over 1 million tons of nitrogen in 1975/76, i.e., at the present time. In fact, we are having a surplus with drastic price falls.

While there may be many reasons why reasonably accurate projections cannot be obtained, the most important ones probably are that inventory changes are difficult to monitor, that new investments in the fertilizer industry are only partially included, and that price changes are not explicitly used for the projections. What might be a "deficit" situation under 1969 prices might well turn into a "surplus" under 1974 prices. Thus, the market situation at the time when the projections are made seems to have an undue impact on the results of even long-run projections. Much methodological work seems needed, together with better data, to improve supply/demand projections for fertilizer. The recently created data bank at IFDC attempts to improve the availability of reliable data.

Table 10. Annual Compound Growth Rates of World Fertilizer Demand Used in Demand Projections for 1972/73 - 1980/81 by Four Organizations

	FAO[a]	IBRD[b]	UNIDO[c]	TVA/USDA[d]	Percentage Variation[e]
Nitrogen					
Africa	4.6	7.1	8.7	6.6	60.7
Latin America	7.6	8.5	10.6	9.5	33.0
Asia (market econ.)	9.5	13.1	9.8	9.1	38.5
Developing M.E.	8.4	11.3	9.9	9.0	30.1
World	6.0	7.2	8.3	6.6	32.7
Phosphate					
Africa	13.3	7.3	7.1	8.3	69.4
Latin America	14.2	7.8	9.5	10.4	61.1
Asia (market econ.)	15.9	14.0	13.8	8.5	56.7
Developing M.E.	15.0	11.1	10.9	9.3	49.2
World	7.2	5.3	6.5	5.1	34.8
Potash					
Africa	14.0	-	8.7	5.9	85.5
Latin America	17.8	-	8.5	13.0	71.0
Asia (market econ.)	15.3	-	13.2	8.5	55.3
Developing M.E.	16.4	-	10.7	10.5	47.1
World	7.0	-	5.4	4.8	38.4

[a]FAO Commission on Fertilizers (Revised): Recent Trends of World Fertilizer Market, October 1974.

[b]IBRD: Fertilizer Requirements of Developing Countries, Report No. 446, May 1974.

[c]UNIDO: Review of World Production, Consumption and International Trade in Fertilizer with Projections to 1975 and 1980. Presented at the Second Inter-Regional Symposium, Kiev, Russia, September 21-October 1, 1971.

[d]TVA/USDA: The World Fertilizer Situation - 1975, 1976 and 1980, WAS-5 (supplement), ERS, USDA, October 1974.

Estimates similar to those reported here were shown in a restricted discussion paper prepared for the 10th Meeting of the UNIDO/FAO/IBRD Working Group on Fertilizers, Rome 1975.

[e]The percentage difference as estimated here is defined as: Largest less smallest estimate, divided by the average of the four estimates and multiplied by 100.

While taking into account the uncertainty associated with fertilizer supply/demand projections, the latest projections for annual growth rates in fertilizer consumption in developing market economies up until 1980/81 are shown in table 11. These growth rates are below those estimated for the period 1961/65-1972/73 (table 4). There is little difference among regions, although the Far East and Africa show slightly higher growth rates than the other two regions.

Estimated Fertilizer Contribution--On the basis of the projected fertilizer consumption growth rates, and the earlier mentioned elasticity of production estimated by Evenson, the annual rate of increase in cereal production due to increasing fertilizer usage was estimated (table 12). According to these estimates, the projected expansion of fertilizer use in developing market economies would increase cereal production by a little less than 1% annually up to 1980/81. This amounts to about 35% of the projected increase in cereal demands for the region, or slightly above estimated past relative contribution. The results further suggest that 41% of total increases in cereal demands in the Far East will be met through expanded fertilizer use as compared with about 30% in the past (table 7), while only 28% of the Latin American cereal demand increases will be met through this means of production. The lower relative contribution of fertilizers in Latin America is likely to be compensated for by an increase in cultivated area. Large area increases are not likely to come about in the Far East. FAO projects that cultivated area will increase at the following annual rates during the period: Africa, 1.0%; Latin America, 1.1% Near East, 0.5%; Far East, 0.3%; and developing countries as a group, 0.7% (36). The proportion of these new areas that will be used for cereals will depend, at least to some extent, on relative

product prices. But the potential for expanding the cereal acreage, if demand increases are not met otherwise, seems to exist, at least in Latin America and Africa. However, if projected cereal demands are to be met, the use of yield increasing technology other than fertilizer must be expanded, particularly in the Far East, where new land is scare.

Table 11. Projected annual growth rates in fertilizer consumption 1973/74-1980/81, %

Annual growth rate, %	Africa	Latin America	Near East	Far East	Developing m.e.
Nitrogen	14.5	10.1	10.6	13.8	12.4
Phosphate	8.9	7.8	10.3	10.6	9.6
Potash	16.5	12.3	-	12.3	12.3

Source: FAO data reported in (22).

Table 12. Estimated compounded annual rate of growth in cereal production due to fertilizer (a), estimated compounded rate of growth in cereal demand (b), and percentage of demand increase met through fertilizer (c), 1973/74-1980/81

	(a)	(b)	(c)
Africa	1.08	3.3	32.7
Latin America	0.82	2.9	28.3
Near East	0.81	2.5	32.4
Far East	1.03	2.5	41.2
Developing m.e.	0.93	2.6	35.8

(a) is estimated from weighted annual growth rates of fertilizer using the elasticity of production estimated by Evenson, op.cit.

(b) is estimated on the basis of demand projections for cereals 1970-85 (45).

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