AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY
Batch 68

1. SUBJECT CLASSIFICATION

A. PRIMARY
Food production and nutrition — AF25-0000-0000

B. SECONDARY
Soil fertility,fertilizers,and plant nutrition

2. TITLE AND SUBTITLE
The demand for fertilizer at the farm level in developing nations

3. AUTHOR(S)
Dalrymple,D.G.

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1975	29p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS
AID/PPC

8. SUPPLEMENTARY NOTES *(Sponsoring Organization, Publishers, Availability)*

9. ABSTRACT

10. CONTROL NUMBER
PN-AAE452

11. PRICE OF DOCUMENT

12. DESCRIPTORS
Demand
Developing countries
Farms,small
Fertilizers

13. PROJECT NUMBER

14. CONTRACT NUMBER
AID/PPC

15. TYPE OF DOCUMENT

AID 590-1 (4-74)

Draft No. 2

November 26, 1975

THE DEMAND FOR FERTILIZER AT THE FARM LEVEL IN DEVELOPING NATIONS

by

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PREFACE

This paper was prepared at the request of the Executive Secretary of the Consultative Group on Food Production and Investment (CGFPI). It is intended to provide background for a review of the fertilizer question at the group's meeting in February 1976.

While the fertilizer problem was one of lack of supply a short while ago, it has subsequently turned into one of inadequate demand. This paper is designed to assist the CGFPI and other groups evaluate this new and more complex situation.

Although the literature on fertilizer is extensive, relatively little of it is devoted to the question of demand at the farm level in the developing countries. Hence this paper might be characterized as a preliminary set of notes and thoughts on an important but somewhat neglected subject. It is at most an introduction.

The paper is in part an outgrowth of an earlier report on Evaluating Fertilizer Subsidies in Developing Countries (AID, Discussion Paper No. 30, July 1975, 64 pp.). Readers who desire more general background on the world fertilizer situation wish to consult:

-Helen Hughes and Scott Pearson, Principal Issues Facing the World Fertilizer Economy, Agricultural Development Council, RTN Seminar Report, March 1975, 11 pp. (proceedings of a conference held in May 1974).

-Graham F. Donaldson, "Fertilizer Issues in the 1970's and Beyond," Development Digest (National Planning Association for AID), October 1975, pp. 3-17.

Those wishing to delve more deeply into some of the economic issues introduced in the paper are referred to:

-C. Peter Timmer, "The Demand for Fertilizer in Developing Countries," Food Research Institute Studies, Vol. 13, No. 3, 1974, pp. 197-224.

I am indebted to the following individuals who reviewed the first draft and provided helpful comments: Richard Reidinger of the U.S. Department of Agriculture; Paul Stengel of the International Fertilizer Development Center; Harold Steere of the World Bank; and David Redding and Donald McClelland of AID.

This paper was prepared while I was on part time detail from the Foreign Development Division, Economic Research Service, U.S. Department of Agriculture.

CONTENTS

1. INTRODUCTION

There has been widespread concern that the recent worldwide fertilizer crisis has led to a tapering off or reduction in fertilizer use in the developing countries - a development which could take the steam out of the green revolution and limit the needed rate of increase in food production.

At first, in 1974, the crisis was one of relatively short supplies. This led to a very sharp rise in prices. But even by paying higher prices, some developing countries were reportedly unable to obtain normal supplies of fertilizer. This severe supply shortage now appears to have largely passed.

As of late 1975, prices have dropped from peak levels, but they are still above pre-1972 levels, and appear to have led to a weakening of demand for fertilizer.1/ National fertilizer consumption has leveled off or dropped in many countries. Thus the supply problem of 1974 appears to have given away to a demand problem.

The challenge, therefore, is to develop policies and programs which will increase the demand for fertilizer. On the surface, it would seem that this task should be relatively easy. Simply lower fertilizer prices through some means (such as subsidies) or increase the prices paid for the farmers' product. These tasks in reality however, are far more complex and difficult to carry out.2/

One of the basic problems is that we know so very little about the nature of demand for fertilizer at the farm level in developing countries. Such information as we have is usually the by-product of some more general economic study. And most of what little information we have is based on the pre-crisis period.

Thus we are faced with the problem of developing appropriate policies and programs for the developing nations on the basis of very little information about the recent or current situation at the farm level. This is obviously a difficult and hazardous position. But we can at least turn to a brief review of what little data we have. This will at least provide a starting point.

2. BASIC FARM LEVEL RELATIONSHIPS

For much of the developing world, chemical fertilizer is a relatively new factor of production. While fertilizer has generally been used for many years for export or plantation crops, its use on food crops for domestic consumption is usually more recent. Hence it maybe helpful to outline some of the key points of the adoption process for technology. Then we shall move on to a review of the traditional demand factors. This will be followed by a review of farmers' views of factors influencing fertilizer use.

A. The Adoption Process for Technology

Generally the adoption of a technology follows the s-shaped curve depicted in Figure 1. Adoption moves fairly slowly at first, then speeds up, and then later tapers off. While the figure suggests that adoption by 100% of the farmers is eventually reached, this is seldom the case in agriculture. Numerous restraints - physical biological, or economic - result in a curve which often tapers off below 100%, particularly in developing countries.

Scattered empirical evidence suggests that fertilizer has followed this general pattern.3/ There is, however, a significant further dimension to the process: partial adoption. Just because a farmer starts using fertilizer does not mean that (1) he uses it on all his land or crops, or (2) that he uses recommended levels. In practice, farmers may use fertilizer on only a portion of their land and then at considerably less than recommended levels.4/ More complete measures of fertilizer adoption are clearly needed.

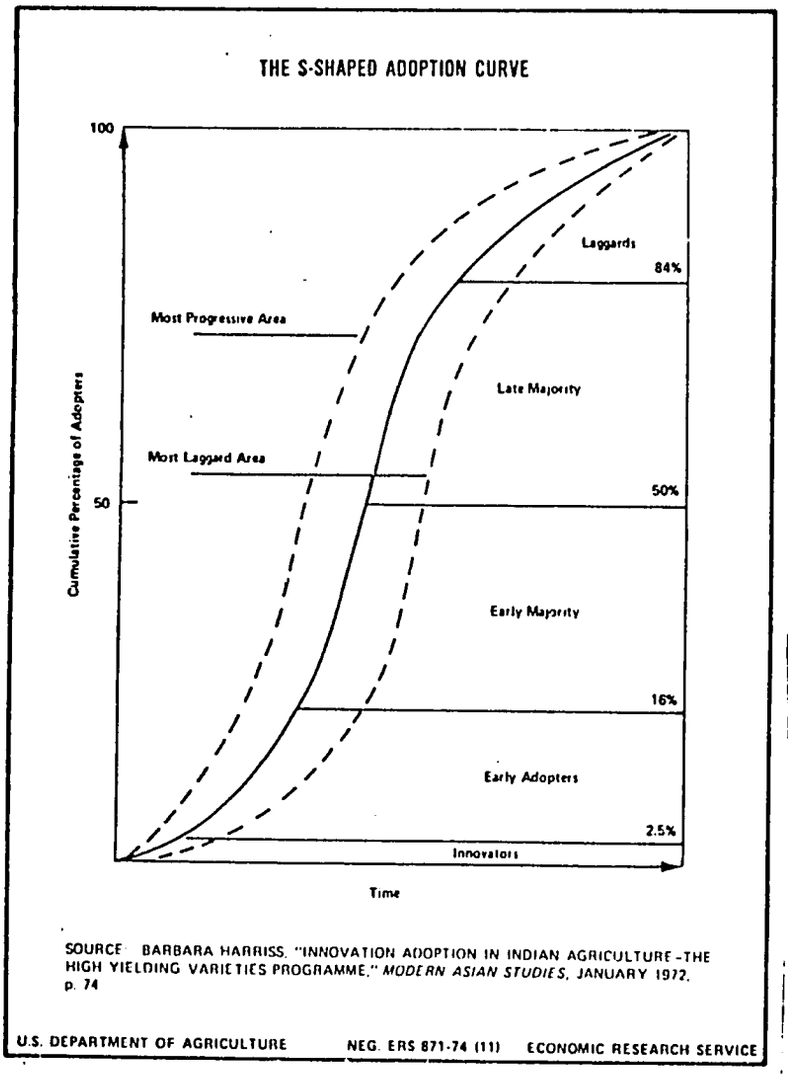
The degree to which the process behind the two decisions (to adopt, and if so how much) may differ is not entirely clear. Perhaps somewhat different factors are involved. Or perhaps similar factors are involved but they are weighed differently. In any event, there are well-known components of demand which would be involved to some (though not an exclusive) degree.

B. Components of Demand

Demand is the amount of a commodity which will be purchased at a given place and time at a given price. Obviously certain preconditions must exist: the product must be available at the right place at the right time. In the case of fertilizer in developing countries, these preconditions cannot be taken for granted; in fact they can present very substantial problems. Assuming them away for the moment, the critical factor becomes one of price.

In the case of fertilizer, however, the demand is a derived demand. Fertilizer is not, of course, consumed directly by humans; rather, the product of fertilizer usage is utilized. Thus fertilizer is important in terms of its contribution to crop production at the farm level. The determining factor for the decision maker, the individual farmer, is the profitability of fertilizer use.

FIGURE 1.


THE S-SHAPED ADOPTION CURVE
100
50
Cumulative Percentage of Adopters
Laggards
84%
Most Progressive Area
Late Majority
Most Laggard Area
50%
Early Majority
16%
Early Adopters
2.5%
Innovators
Time
SOURCE: BARBARA HARRISS, "INNOVATION ADOPTION IN INDIAN AGRICULTURE-THE HIGH YIELDING VARIETIES PROGRAMME," MODERN ASIAN STUDIES, JANUARY 1972, p. 74
U.S. DEPARTMENT OF AGRICULTURE
NEG. ERS 871-74 (11)
ECONOMIC RESEARCH SERVICE

Profitability, however, is determined by a range of factors, of which price of fertilizer is only one component. The three main factors are:

(1) The cost of fertilizer.

(2) The price of the crop.

(3) The fertilizer/crop production function.

The first and second can be directly influenced by the government; the third is a physical response function which is influenced by a myriad of physical and biological factors (one of the most important of which is weather). It is the latter that takes the question of profitability well beyond the traditional province of economists.

At the time the farmer buys fertilizer, only the first factor is known for certain.* He can only speculate about the likely price he will receive for his product and the production function. Also, if fertilizer is new to him, he may not know the optimum type or quantity to use. Thus there may be a considerable personal risk involved in using fertilizer. Hence the farmer may decide to use no fertilizer or less than he would if prospects or his knowledge were more certain.

In any case, prices comprise two out of the three components. And they may partially compensate for uncertainty about the third. While prices are key parameters of demand, a distinction must be drawn between potential demand and effective demand. Potential demand is just that; to become effective demand it must be backed up with the ability to pay (purchasing power). This ability is determined by the financial status of the farmer - the degree to which he has, or is able to get, funds to purchase fertilizer. Since many months can elapse between the time the fertilizer must be purchased and paid for and the time the crop is harvested, he may need extensive credit. This need would be particularly strong for the smaller and poorer farmers.

The third factor, the fertilizer response function, is dependent on so many factors that it virtually defies complete categorization. Certainly the crop variety itself would be of basic importance. So would the appropriateness of the fertilizer formulation. Numerous soil, water, and weather factors would also be involved. Some of these could be modified by government research and infrastructure activities; other may long remain beyond reach.

C. The Farmers' View

What has been said to date has certain elements of an armchair economic analysis. How do farmers view the constraints on fertilizer use? We can

*Even then he could face uncertainties in terms of what he has actually received; in some cases the fertilizer may be adultured, short on weight, or of poor quality.

cite a few scattered studies. The main limitation with them is that they were conducted before the recent crisis; prices were relatively normal and hence their importance in the present context would be understood. Moreover, the studies were limited to Asia.

Examination of the results reveals that, in some cases, price factors were of relatively modest significance as a restraint to fertilizer use. Frequently the two main elements were viewed as (1) environmental factors influencing the production function, and (2) financial factors centering on credit.

This outcome is graphically summarized in Figure 2 which is derived from a study of rice in 65 villages in six Asian countries in 1970 and 1971. Environment (principally measured by quantity and timing of rainfall) was the main constraint. It was followed in second place by a measure of the quality of irrigation. Credit availability (measured by proportion of farmers borrowing from formal credit sources) was third, and price (the nitrogen/paddy price ratio) was fourth.5/

Naturally, the relative importance of the factors varies from country to country, village to village, and crop to crop.

- India. A massive survey in India from 1968/69 to 1970/71 indicated that the main restraints on fertilizer use on several crops were:6/

Factor	Percent
Inadequacy of funds and credit	43.2
Inadequacy of water	38.8
Fertilizer supply problems	3.5
High cost	1.4
Risk	1.3
Excessive rains	0.6
Adversity to change	0.5
Other	21.3

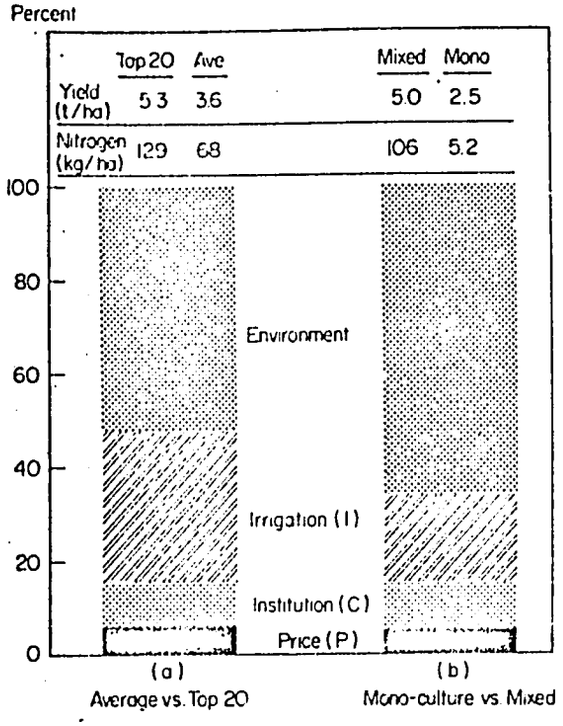
A more detailed analysis was carried out for wheat and rice with a slightly different grouping of variables. The significant factors influencing fertilizer use were:

- Percent of area irrigated
- Percent of area under HYV's
- Income level of household

For wheat, percent of area owned was also significant. In neither case was credit significant; one suspects that the financial influence was reflected by the income level of the household.7/ A much smaller study in Gujarat in 1969-70 produced results similar to the larger study noted above; an additional factor, preference for farm manure, was significant:8/

Figure 2.

FACTORS EXPLAINING DIFFERENCES
IN LEVEL OF NITROGEN USE ON
RICE, ASIA, 1970, 1971*



*Differences between (a) average and 20 highest users of nitrogen and (b) mono-culture and mixed farming.

Source: Randolph Barker and Teresa Anden; Factors Influencing the Use of Modern Rice Technology in the Study Areas," Changes in Rice Farming in Selected Areas of Asia, IRRI, 1975, p. 27.

Factor	Percent	
	Baroda	Junagadh
Inadequacy of finance	28.0	28.8
Lack of irrigation	23.6	28.8
Preference for farm manure	15.6	21.9
High price of fertilizer/low prices of crops	12.4	1.4
Imperfect supply arrangement	6.7	6.9
Other	13.7	12.2
Total	100	100

- Pakistan. Slightly different results were obtained in a survev in the Punjab of Pakistan in 1969/70.9/ Farmers who reported that fertilizer was "not easily available" were asked to give the reasons why. They responded as follows:

Factor	Percent
Price too high	94.7
Unable to get needed fertilizer on time	75.5
Lack of funds	75.0
Transportation problems	3.4
Other	0.2

Clearly, price appeared to be much more important a constraint than in India. Several other studies in Pakistan also showed that inadequate credit was a restraint for fertilizer use.

- Korea. In Korea, price of fertilizer was found to be a significant factor in one phase of study but not significant in another.10/

The picture that emerges from these few studies is that price, during a period of relatively normal prices, was not generally as important a factor in determining fertilizer use as economists might expect. Instead environmental factors and income/credit were often of major significance. Whether the same findings would have been found in other nations is unclear. And the effect of the recent crisis, when price would have been expected to become much more critical, is as yet undocumented.

3. ECONOMIC AND FINANCIAL FACTORS

The relative importance of economic and financial factors influencing fertilizer use varies, but both, as noted, are subject to some degree of government policy influence.

A. Economic Factors

The principal economic factors relate to price, but other related influences may also be relevant.

1. Prices

Fertilizer prices themselves are, naturally the major point of initial concern. But they must also be considered in relation to agricultural product prices. Farmers reactions to fertilizer price changes can be conveniently summarized in terms of price elasticity of demand.

a. Fertilizer Prices and Consumption. Changes in international fertilizer prices since 1963 are graphically portrayed in Figure 3. It will be noted that prices of urea declined from the mid 1960's through 1970 and 1971 and then began to increase. The increase became particularly pronounced in the last half of 1973 and in the first half of 1974. Thereafter, prices leveled off and dropped sharply though 1975. Prices of other fertilizers were somewhat more stable though 1973 and then also increased sharply (except for triple superphosphate which began to increase in price in 1972): they also declined sharply in 1975 (except potassium chloride). In evaluating these fluctuations it is important to realize that prices were unusually low during the 1968 to 1972 period; the period prior to 1968 was more normal. Thus price comparisons should be drawn with the earlier period.

In any case, the figure refers to international prices. Shipping costs would have to be added to get landed prices in developing countries. Duties, unloading and distribution costs (which tend to be higher in developing countries) would have to be added to get local costs. Actual prices paid by farmers might be inflated by black markets or the need to pay "gratuities" - the prevelance of both increasing in times of shortage.* On the other hand, fertilizer subsidies have been used in a number of developing nations and may have moderated price increases.11/ Thus, while farm prices undoubtedly increased significantly, it is difficult to generalize about the precise magnitude.

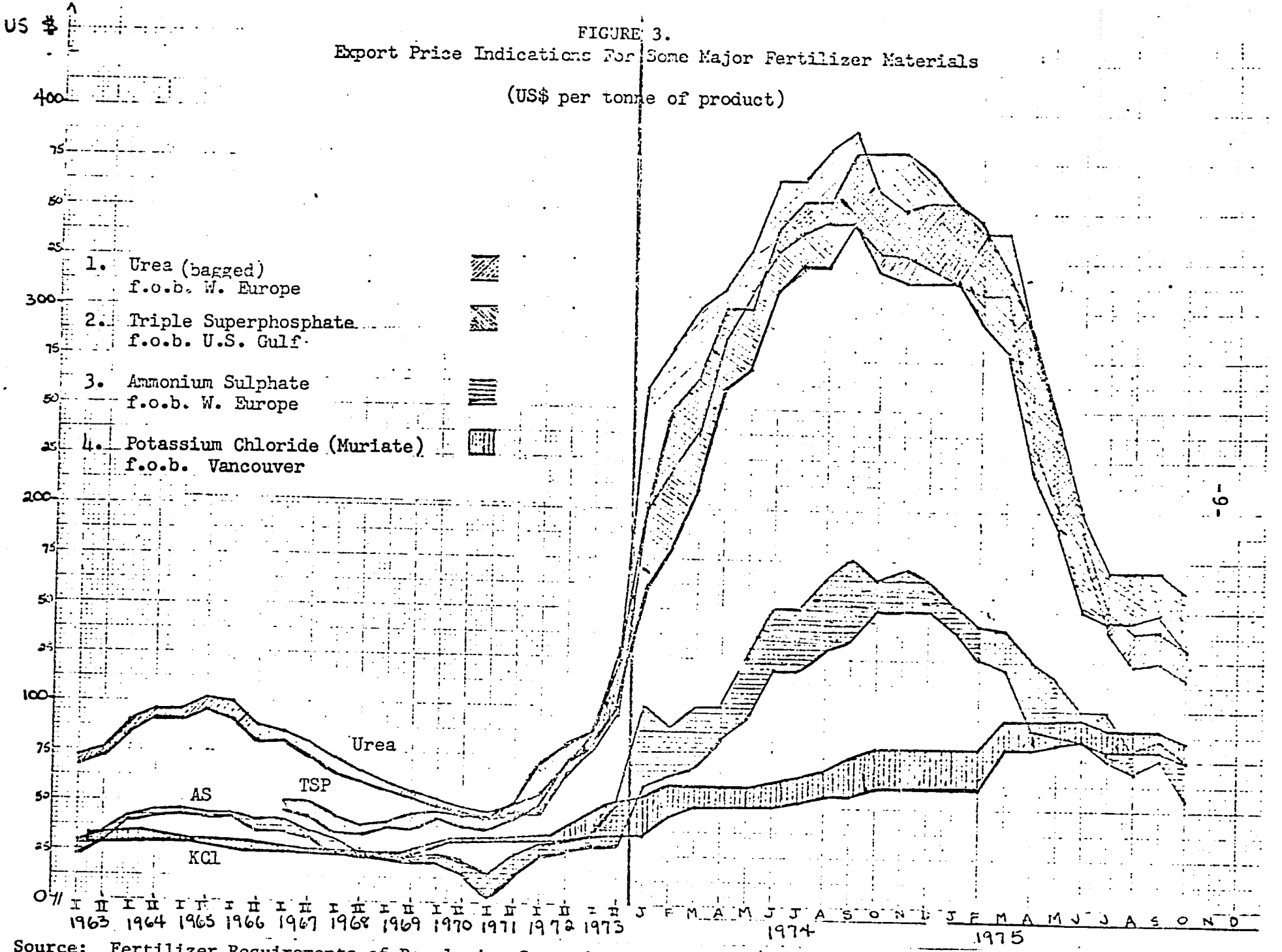
Concurrently, there appears to have been, as might be expected, a tapering off in the rate of growth in fertilizer use or even an overall decline in fertilizer consumption in many major developing nations. In Indonesia, normally a growth market of 10 to 12% a year, consumption was stagnent in 1974.12/ Moreover, fertilizer usage dropped 8.7% in India

*While black markets entail higher prices, some farmers may be willing to pay them in order to bypass government bureaucracy and/or to get the type of fertilizer when they want it. In other words, the black market may reflect not only a relative shortage of supply but also a dificient distribution system.

FIGURE 3.

Export Price Indications For Some Major Fertilizer Materials

(US$ per tonne of product)



Source: Fertilizer Requirements of Developing Countries - Revised Outlook in 1975, World Bank, Report No. 830, July 1975, p. 15. As updated by H.J. Sandri, Jr., Fertilizer Unit, Industrial Projects Division, November 4, 1975.

in 1974/75 (April-May) compared to 1973/74; the decline was 3% for nitrogen, 5.8% for phosphate, and 26.5% for potash.13/ Even larger declines have been reported for the Philippines in 1975. In some cases, fertilizer stockpiles have been inadvertantly accumulated because of the drop in consumption. While the stagnation or drop in consumption was undoubtedly the result of many factors beyond price alone, the massive rise in prices cannot be overlooked.

The preceeding consumption estimates refer only to overall disappearance at the national level. We do not know what happened to the allocation of fertilizer between individual commodities or between different sizes of farms. Fertilizer would be expected, in general, to flow to the crop where returns are the highest. Often, as noted earlier, much is on non-food crops for export. Whether the crisis resulted in a tilt away from use on food crops for domestic consumption is not known at this point. It might be assumed that the crisis has reduced fertilizer consumption more on small farms than on larger farms. A recent World Bank report states that many "small farmers have been discouraged by the recent developments from using new seed varieties dependent on high fertilizer use."14/

The outlook for fertilizer prices is uncertain. To the extent that they decline further, some of the demand and consumption problems noted above may be ameliorated. But to the extent that the recent price drop levels out or rises again, the problems will be exacerbated. To be on the safe side, allowance must be made for further fluctuations in establishing policies.

b. Fertilizer/Product Price Ratios.15/ The degree to which fertilizer use is affected is not, of course, entirely influenced by its cost as noted earlier, the price of the farmer's product is also of significance. Hence many economists and others have long made use of a fertilizer/product price ratio as a convenient way of handling the two. And in at least some cases they have found a close correlation with fertilizer application; in one study the price ratios were found to explain 85% of the variation in fertilizer application in a group of Asian nations in 1970. In other cases, the correlation is less evident.16/

Whether the two price elements are of equal weight in the farmer's mind is unlikely: he knows the cost of fertilizer when he buys it but the price of the resulting product is generally quite uncertain. To allow for these and the many other uncertainties that may intervene between time of application and harvest, a ratio of more than 1 to 1 is usually needed to encourage use. FAO states that "Widespread experience suggests that benefit/cost ratios for fertilizers below 2.0 or 2.5 (to 1) are usually insufficient to create a strong impetus for rapid increase in use."17/ (That is, the value of the additional product would have to be 2 to 25 times as high as the cost of the additional fertilizer). In the case of the developing countries the ratio may need to be even greater, perhaps as much as 3.0 to 1, or even higher.18/

Because of the enormous and rapid increase in fertilizer prices during 1974, one would have expected the ratio to decline. FAO recently compiled

some comparative benefit-cost ratios (or as FAO now refers to them, value/cost ratios) for 1973 and 1974. Of 12 cases, from 10 countries, the ratio declined in 9 and increased in 2, and was variable in 1. When the data were further broken down by individual crops, out of 54 entries the ratio declined in 41, remained the same in one, and rose in 12. The number of crop cases for which the ratio dropped below 2.0 increased from 7 to 17; of the latter, 10 were in countries where free market prices existed and 7 where government controlled prices were the rule. Thus for most crops in most areas, fertilizer use was less advantageous but was still profitable in terms of the minimal FAO guidelines.19/ Presumably the situation became more favorable with the drop in prices in 1975.

Price (or value/cost) ratios, however, are only a partial measure of the profitability of fertilizer use. Data compiled by the International Potash Institute for six countries in 1972 and 1974 indicate that while the ratio declined in five countries, net returns remained the same or even increased.20/ Similarly, FAO data show that in some areas where ratios have declined moderately, such as in Java, net returns actually increased.21/

The answer to what might seem a paradox has been suggested earlier; it lies in the physical response function to fertilizer and in the influence of other factors. Thus, it is probably true, as OECD stated in 1968: "no general ratio between cost and return can be laid down as being necessary to promote fertilizer use in the developing countries as a whole."22/ Numerous other factors are involved, some of which we will discuss in a subsequent section.

c. Price Elasticity of Demand.23/ If one is concerned solely with the effect of price changes on the quantity of fertilizer purchased, the relationship can be conveniently summarized in terms of the price elasticity of demand.*

As might be expected, the farm demand for fertilizers is relatively inelastic in the short run and elastic in the longer run. On the basis of data summarized for 6 countries (5 in Asia) by Timmer24/, one could anticipate that:

- The immediate impact of a relative price rise of 10% will be reduced fertilizer consumption of anywhere from 5 to 10%;
- In the longer run, if the same relative prices are maintained, a price increase of 10% might result in a reduction of consumption from 20 to 30%.

*Price elasticity of demand is the relationship between percentage variations in prices paid for a product and consequent variations in the quantity purchased. If price variations of say 10% lead to changes in the quantity purchased of less than 10%, the demand is considered inelastic. Similarly, if the result of the same price variation is a variation of more than 10%, the demand is considered elastic. Generally the elasticity of demand in the short run is less than it is in the longer run.

Several caveats might be introduced here. First, the data were derived during periods of more normal prices; it would be desirable to have comparable data for the more recent price period. Secondly, the same relative prices are not likely to be maintained in the longer run: a decline in fertilizer use may lead to a drop in food production which, in the absence of greater imports, will force food prices to rise relative to fertilizer prices, thus stimulating higher fertilizer application.* Thirdly, the data are aggregate in nature and the responses of individual groups may vary.

The short and long term relationships noted here are in part related to the farmers' likely position on the S-shaped total physical product curve (Figure 4). In areas of long-standing fertilizer use, farmers may have reached the upper level of the total product curve (e.g. section BC on curve TP in Figure 4; the marginal product curve declines in this zone). In areas where fertilizer use is more recent, farmers may be on the steeper part of the total product curve (e.g.section AB on curve TP). Thus, the newer adopters are more apt to get a larger response for a given input of fertilizer than the older adopters (the marginal physical product, curve MP, is greater).25/ Because of this greater response, as de Guia has put it, "newer fertilizer users would be less sensitive to fluctuations in prices than those for whom the use of fertilizer has become routine."26/

While an additional unit of fertilizer may produce a larger physical response on the farms which have just adopted fertilizer than those which have utilized it for some time, this effect may be counteracted by other forces. If, for instance, the newer adopters have a much lower income level, they are, in the face of price increases, less likely to maintain the same quantity of fertilizer purchases as the more experienced farmers. Thus the higher priced fertilizer may be directed into relatively less productive use on the more established farms. Hence, it seems likely that high prices for fertilizer will, as Timmer has put it, "hit the poor farmers and nations with high physical response rates relatively harder" than the wealthier farmers or nations.27/

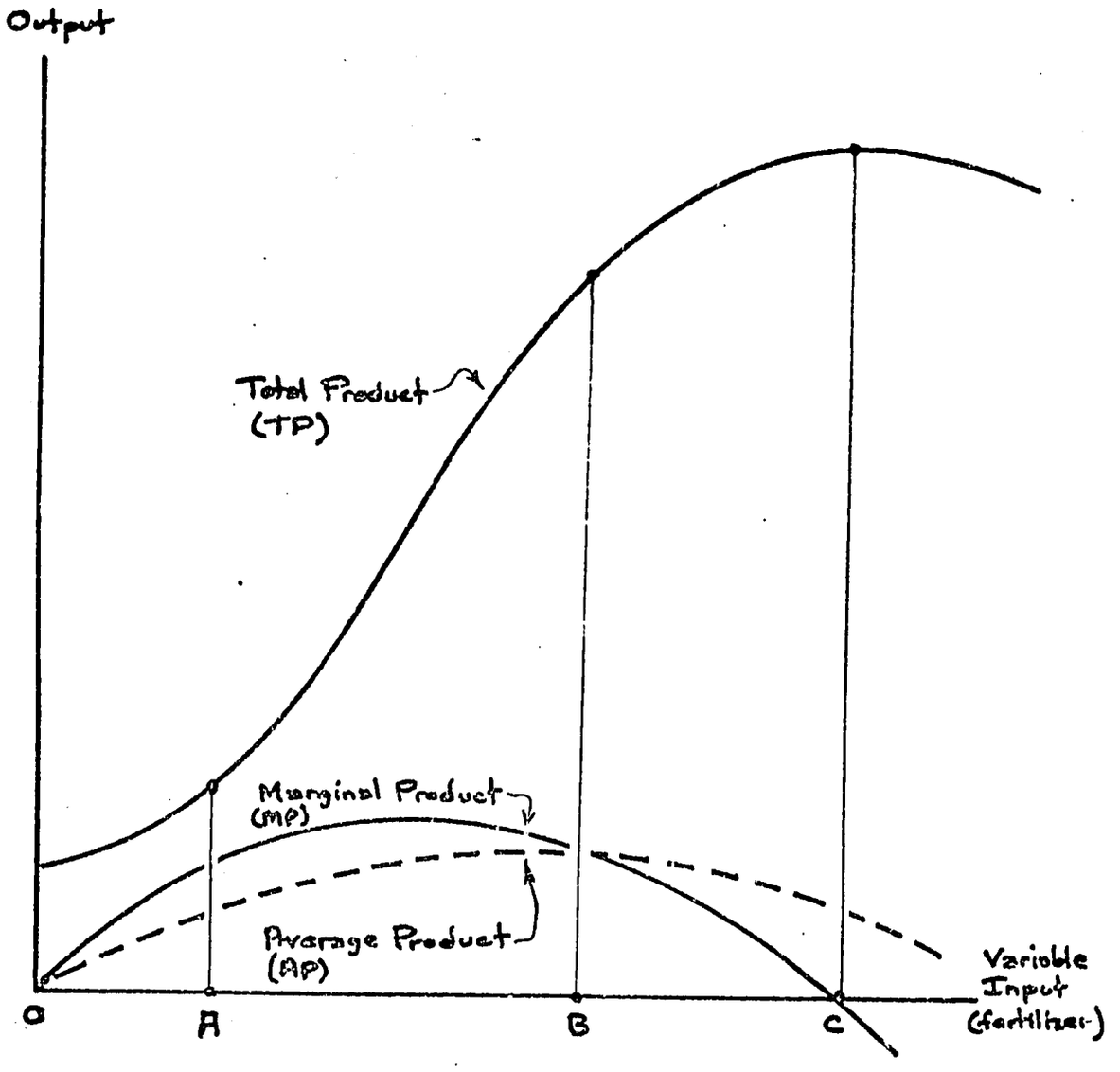
2. Risk, Uncertainty and Policy

The LDC farmer, as we have noted faces several types of risk once he has purchased fertilizer. First, he has to gamble that he will obtain at least a certain level of output for each unit of fertilizer applied. Whether he will depend on a wide array of biological, physical, and other factors. Secondly, he faces the risk of an uncertain price for his product.

*The nature and speed of this response mechanism will be influenced by the price elasticity of demand for the final product. It has been suggested that the demand for fertilizer is a derived demand: it is a function of the demand for the product it is used on. Thus, in times of crop shortages, prices are likely to rise most for those with more inelastic demand; this price rise is in turn likely to be reflected in a more inelastic demand for fertilzer. On the other hand, in times of crop surpluses, prices are apt to drop most for crops with more inelastic demands; this feature is also apt to be reflected in a more elastic demand for fertilizer.

FIGURE 4

GENERALIZED PRODUCTION FUNCTION



Governments can influence both sets of factors, but to do so requires quite different sets of policies. Modification of the environment, growing practices, etc., requires a broad range of long term agricultural development programs - from research to the development of infrastructure. Price programs can be more easily modified in the short run, both with respect to fertilizer and product. Yet price adjustments can reduce only part of the risk and uncertainty. And even if product prices were adjusted to a favorable level one season, some farmers may doubt that this will happen again the following season. Hence, as one economist points out, an uncertain improvement in product prices or small reductions in the cost of using fertilizer may have less influence than a definite improvement in the availability of a complementary input, such as irrigation, or in the varieties of crops commonly grown.28/

Thus, while an appropriate price ratio is usually a necessary condition for the increased use of fertilizer, it may not be a sufficient condition. Farmer confidence must be gained. Even then, more is needed, and this usually involves the broad and complex array of factors influencing the production function. One policy tool for handling some of the more extreme forms of production risk would be fertilizer* or crop insurance.29/ A favorable financial situation will also do much to accelerate the adoption process. We turn to the latter point in the next section.

B. Financial Factors

The importance of financial factors as a restraint to fertilizer purchases has been noted. Even with a favorable price ratio, farmers must have the purchasing power to acquire fertilizer. This takes cash, or in its absence, credit. Both are usually in short supply in developing countries. The vital role of credit in stimulating fertilizer use has been outlined in many papers and studies.30/

Credit can be a major factor in the several stages of the adoption of fertilizer technology - from the initial decision to purchase fertilizer to the decision of how much to apply. While the farmer's own resources may in many cases be sufficient to finance an initial small purchase, outside credit may be increasingly necessary as he wishes to step up his rate of application. In one study in India, for instance, once almost all farms in an irrigated area had adopted fertilizer, credit availability was the main factor influencing rates of application.31/

The precise importance of credit, however, tends to vary rather widely. A recent FAO bulletin stated that "in many countries in Latin America and Asia, about 70-80% of all fertilizer sales are made on a credit basis".32/

*Farmers might, as suggested by Reidinger, be reimbursed for the cost of the fertilizer if some natural disaster such as a flood or drought severely reduced its effectiveness. Reidinger has noted that this might be done by adding a small charge to the cost of each bag, but because of the modest funds likely involved, it could also be handled out of government appropriations.

Yet there are evidently substantial exceptions even in Asia: a recent AID document has summarized studies in Pakistan which indicate that in 1971 only about 13.5% of the fertilizer was purchased on credit;33/ a similar figure (14%) was found in Bangladesh.34/ The low proportions may have simply represented low levels of fertilizer use and/or limited availability of credit. In the case of Bangladesh, it was noted that the purchase may have been partly financed by farm income earned in subsidiary occupations. It is thought that the role of institutional credit has subsequently increased in Pakistan. In other nations, the role of traditional credit may well have long been substantially greater.

The capital or credit restraint is generally considered to be most severe on small farms. These farms, by their very nature (1) have few capital resources (and hence limited collateral) to start with, (2) have limited access to institutional or commercial sources of credit,* and (3) often have to pay considerably higher rates of interest.35/ An Indian study cited earlier revealed that inadequate funds and credit were reported more frequently on small farms (than for large farms) as a reason for not using fertilizer:36/

Farm Size	Frequency Cited
- hectares -	- percent -
0 - 2.5	47.9
2.5 - 8.5	38.7
8.5 +	6.3
All	43.2

Similarly, a survey in Pakistan in 1969/70 revealed that smaller farmers most often reported that funds were not available for fertilizer purchase:38/

Size of Holding	Non-Availability of Funds
- acres -	- percent -
2.5 - 7.5	81.6
7.5 - 12.5	77.6
12.5 - 25.0	79.2
25.0 - 50.0	47.4
50+	40.0
All	75.0

Thus there is some reason for believing that small farms are relatively capital short and that this limits fertilizer use.

There is also the possibility that the potential capital requirements of small farms could be higher on a per unit of land basis than larger farmers. Smaller farmers, in part of necessity, often till their land more

*As a result, the larger farms may actually use a relatively larger amount of credit for fertilizer purchases than smaller farmers. This was found to be the case in a survey in South Korea in 1972. 37/

intensively. They may grow more intensive crops and raise them more frequently (multiple cropping ratios are typically higher on small than large farms). Thus they might be able to utilize larger quantities of fertilizer per unit of land. Hence it was found in one study in India that in the face of improved technology, the small farms were not only capital starved, but "their capital requirements increase more compared to the medium size and large farms."39/

Therefore the increased availability of credit to small farmers, in many cases, might increase levels of fertilizer use. Several studies have suggested a positive linkage between the level of credit use and the level of fertilizer use on small farms. A previously cited survey in Pakistan in 1969/70 found that farmers in the 2.5 - 25 acre range who reported sufficient credit availability used higher rates of application (+35.2%) of nitrogen and dwarf wheat.40/ Similarly, in Guatemala, increased fertilizer use was associated with greater levels of credit use on small farms (0 to 10 ha.)41/ Simply increasing the quantity and conditions of availability of credit does not, of course, automatically mean that it will actually be used to buy fertilizer.

Moreover, it is not easy to say what the best method for increasing capital supplies to small farmers would be. Simply increasing the quantity of normal institutional types of credit may help the medium to large farmers more than the small farmers. The conditions under which credit is obtained may have to be changed also. Many techniques have been tried.* And recently several countries, including Pakistan and the Philippines (especially under its Masagana 99 program) have attempted to increase small farmer credit for fertilizer purchases. Evaluation of the techniques involved and the success of such programs, while an important task, is beyond the scope of this paper.

Clearly, credit is often a major factor in influencing the decision to use fertilizer, and probably more importantly, in determining the level of application. But while credit is important, its role may be overdramatized.** It is part of the more general problem of inadequate capital, and this is only one factor in the farmer's decision-making process. Hence, the simple provision of credit is seldom a panacea. Still, the availability of credit, especially for small farmers, may do much to facilitate the adoption of, and increase the levels of use of, fertilizer.

*Some of these involve tying the credit to the purchase of fertilizer. In Brazil loans were made for fertilizer purchases at interest rates well below the rate of inflation. In the wheat production program bank financing was contingent upon the wheat grower using certain minimum amounts of fertilizer. This program, however, did not necessarily reach the small grower.42/

**One recent writer refers to "hue and cry" about credit in the Philippines, but then perhaps goes to the other extreme and may understate its historical importance.43/

4. TECHNICAL AND OTHER FACTORS

Economic and financial factors play important, but not exclusive roles in determining the demand for, and use of, fertilizer. Technical factors may be of major significance. The key role of environment factors, particularly water supply, was noted earlier. Other factors of a social and infrastructure nature may also be important in some cases.

A. Technical Factors

Technical factors affect the profitability function through their influence on yields. While the technical factors are usually thought of in terms of the general biological and physical forces influencing plant growth, it is important to realize that (1) factors such as water supply have a significant impact on the effectiveness with which fertilizer is utilized by the plant, and (2) the composition, form, and time of application of the fertilizer itself can be of vital influence on its efficiency in a given situation. Some of these technical forces, as suggested earlier, are beyond control; others are clearly subject to modification.

There is a tendency to overlook the importance of technical factors in stimulating fertilizer use. This is particularly true in times of extreme price rise. Yet some have kept them in view. During the recent crisis, the International Rice Research Institute stated that:

> In the intermediate run [5-10 years]...we anticipate that adequate fertilizer supplies are likely to be available and that the major task will be to encourage increased use of fertilizer other than through higher food grain prices. The redirection of rice research toward the goal of greater efficiency in fertilizer use, and the continued emphasis on research in areas such as pest and disease resistence, water management, and drought tolerance will lead to more efficient use of available supplies and enhance the demand for fertilizer.44/

And in certain countries in the recent past, such as Brazil, technical factors such as the lack of responsiveness to fertilizer have been considered the main bottlenecks to increased use.45/ Both cases suggest a need for more basic and applied research on fertilization.

For many years, one of the limitations on the increased use of fertilizer on wheat and rice was the plant itself. Added fertilizer simply did not result in very significant increases in yield - and beyond a certain point could lead to decreased yields. The additional nutrients largely went into stalk growth and when the stem got too long, it was susceptible to lodging or falling over. In the early 1960's, new semi-dwarf varieties of wheat and rice were developed which had relatively short and stiff stems. As a result, the plants could make use of heavier applications of fertilizer. The differences in yield response between native and high-yielding varieties are depicted in Figure 5. In two of

FIGURE 5

GENERALIZED FERTILIZER RESPONSE CURVES

Rice and Wheat

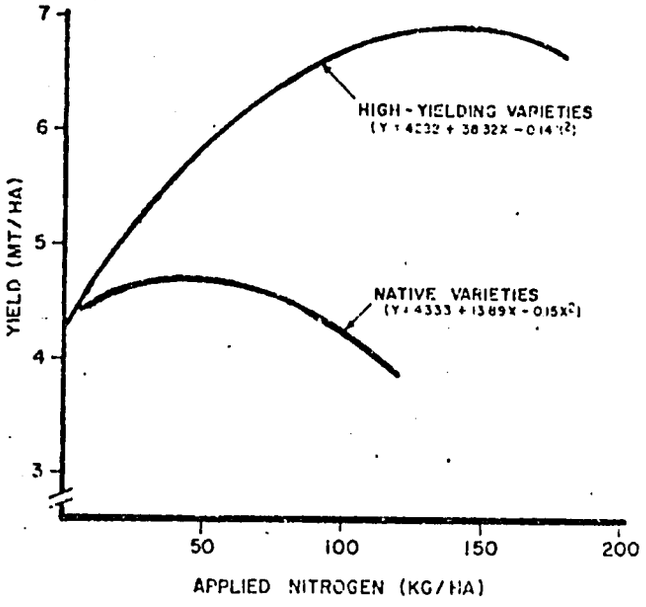


Figure 1. Generalized curve for the response of rice to nitrogen applications in the dry season

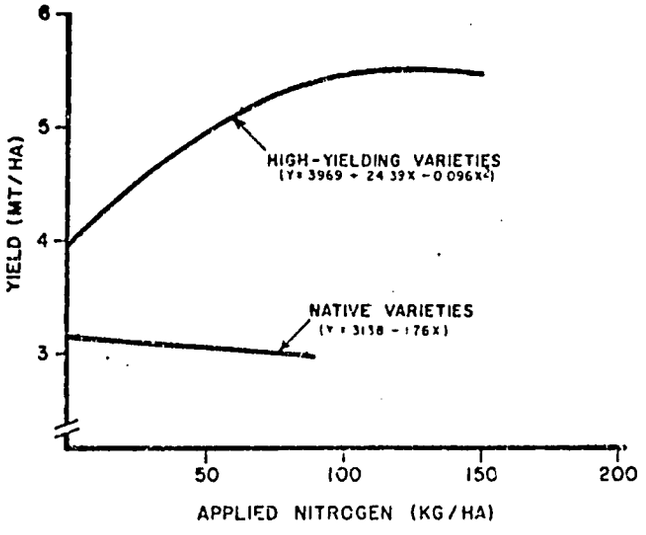


Figure 2. Generalized curve for the response of rice to nitrogen applications in the wet season.

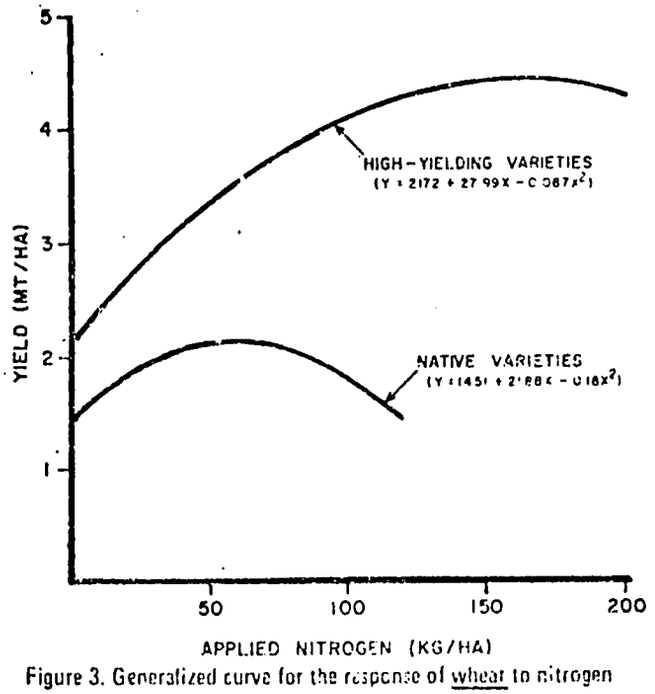


Figure 3. Generalized curve for the response of wheat to nitrogen applications.

Source: High-Yielding Cereals and Fertilizer Demand, TVA, 1970, Bulletin Y-4, pp. 6, 7, 8.

the three cases depicted, yields for a given level of input were higher at all levels of fertilizer application; in the third case they were higher at all but the lowest levels. While the yield responses would be expected to vary, the HYV's generally represented a more productive use of fertilizer. In some cases, the increased fertilizer use preceeded the adoption of the HYV's (such as the Punjab in India),46/ but in most instances the subsequent increase in fertilizer use paralled the increase in HYV's.

Other inputs are also needed. The most important is irrigation. Irrigation plays a multifaceted but highly interrelated role; it (1) stimulates increased plant yields (complementing the effect of fertilizer), (2) may encourage multiple or more intensive cropping (increasing the need for fertilizer), and (3) reduces the risk of yield fluctuations. The latter is particularly important for smaller farmers because of the financial risk represented by the cost of the fertilizer. It has been suggested that the net returns for fertilizer use have to be twice as high in rainfed areas as in irrigated areas in order to induce farmers to use fertilizer.47/ Uncertainty is of course, not completely eliminated with irrigation -- irrigation systems in LDC's are often inadequate -- but it does reduce a major risk element and thus increases the probability that the investment in fertilizer will pay off. Additional inputs enhancing fertilizer use include insecticides and fungicides or production practices which reduce yield uncertainty.

It is also important that fertilizer be designed or selected for local crops and growing conditions. And it must be applied at the right way at the right time. There are numerous stories (though little documentation) of fertilizer misuse in LDC's. Proper application cannot be taken for granted where fertilizer use is often a relatively recent phenomenon and where little may be known about its proper selection and use.

B. Other Factors

Although the list of factors influencing fertilizer use is already long and involved, it is not by any means complete. Many others might be noted. The social structure of the society, for instance, will influence farm size and the ownership and tenency conditions. These in turn will modify fertilizer purchases, either directly or indirectly (through, for instance, credit availability). Infrastructure -- such as the availability of transportation, communication, and storage facilities -- will influence the availability and cost of fertilizer, as well as the market and price for farm production. Improved input and output marketing facilities may have to accompany increased fertilizer use. Educational levels and the effectiveness of the extension service will influence farmer awareness of fertilizer and of most effective methods for its use. We will make no effort to pursue such matters further here. But certainly they should be considered in any comprehensive analysis of the demand for fertilizer.

5. SUMMARY AND CONCLUSIONS

If food production is to be increased in the developing nations in the future, fertilizer use (among other things) must be increased. This will require an increase in both fertilizer supply and demand. Considerable attention has recently been given to the problem of increasing supply. Much less consideration has been given to the concurrent need to increase the demand for fertilizer at the farm level.

It has often been assumed that fertilizer demand problems can be solved simply by increasing fertilizer supply and reducing price. The recent fertilizer crisis may have reienforced this opinion. What started out as a supply problem turned into a problem of high prices. And the price problem soon led to a weakening of demand for fertilizer which was reflected in lower consumption. Recent declines in fertilizer prices may lead to a strengthening of demand - but the declines may not have quite the restorative powers that some might expect.

While fertilizer price is unquestionably a major factor in determining fertilizer demand, other factors are also involved. Indeed, delineation of the full range of factors influencing fertilizer demand at the farm level is a complex task. It is also one which has received all too little study.

Despite the limited supply of information, it is evident that the key factor affecting fertilizer use at the farm level is profitability. This is determined by, in addition to fertilizer price, the price of the product and by a myriad of physical and biological factors influencing yield. These determine the potential demand for fertilizer - a potential which may vary between various food and non food crops.

To transform potential demand into effective demand requires purchasing power; in turn this may create a need for credit, especially among small farmers. Potential demand is also diluted by the risks and uncertainties involved in using fertilizer; these may reduce application rates below optimum levels.

Some of these factors may be significantly influenced by government policy and provide a substantial inducement to fertilizer use; others are more intractable. The simple adoption of one approach, such as the lowering of fertilizer prices, may be necessary but not sufficient. A number of actions - a package of them - may be necessary to increase fertilizer use on the desired crops.

To some extent, partial answers may be found outside the field of chemical fertilizer. Greater use might be made of organic and biological forms of fertilizer. Other techniques are possible. While potentially important and useful, these approaches are not likely to substitute for chemical fertilizer in the near future. Much of the answer, rather, is to be found in the improvement in the nature and use of present technology.

If the right combination of efforts is to be made with chemical fertilizer, however, much more needs to be known about the demand situation at the farm level. The increase in use requires, as a recent AID loan paper

put it, " a better understanding of the socio-economic factors which influence fertilizer purchase decisions of farmers with differing resources at their command."28/ Moreover, much more needs to be done in the way of designing appropriate types of fertilizers for LDC use in selecting appropriate types and mixtures for the individual farm or farm region.

A major resource for this task has been introduced in this process by the establishment of the International Fertilizer Development Center (IFDC) near TVA in Alabama. This group will be concerned with these questions. And it will seek to carry out its development work though international and national research organizations. In cooperation with FAO's ongoing fertilizer program with industry, a potent new force could be developed which could do much to encourage more productive fertilizer programs by the developing nations.

These international and national efforts will, however, require additional funding in the years ahead if they are to carry out their important task. If only a fraction of the funds spent on fertilizers by or for the LDC's had been directed to concurrent economic and technical research programs, some of the problems we now face might have been mitigated. It is to be hoped that such resources are forthcoming so that we can face future challenges in a more enlightened manner.

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