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Bangladesh Policy Options for the Development of the Fertilizer Sector

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ABBREVIATIONS AND SYMBOLS

Countries and Organizations

ADB	Asian Development Bank
BADC	Bangladesh Agricultural Development Corporation
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BCIC	Bangladesh Chemical Industries Corporation
BRRI	Bangladesh Rice Research Institute
CUFL	Chittagong Urea Fertilizer Limited
DA(EM)	Directorate of Agriculture, (Extension and Management)
EIU	Economist Intelligence Unit
FAO	Food and Agriculture Organization of United Nations
GOB	Government of the People's Republic of Bangladesh
IFAD	International Fund for Agricultural Development
IFDC	International Fertilizer Development Center
INSFFER	International Network on Soil Fertility and Fertilizer Evaluation for Rice
IRDP	Integrated Rural Development Program
IRRI	International Rice Research Institute
KAFCO	Karnaphuli Fertilizer Company
KSS	Krishi Samabaya Samity (Village Cooperative)
MAF	Ministry of Agriculture and Forests
NGFF	Natural Gas Fertilizer Factory
PC	Planning Commission (GOB)
PPD	Plant Protection Directorate (MAF)
PUFP	Polash Urea Fertilizer Project
TCCA	Thana Central Cooperative Association
U.S.	United States of America
USAID	U.S. Agency for International Development
UFF	Urea Fertilizer Factory
UNDP	United Nations Development Program
ZFCL	Zia Fertilizer Chemicals Limited

Fertilizers and Fertilizer Materials

AN	Ammonium Nitrate
AS	Ammonium Sulfate
DAP	Diammonium Phosphate
GPR	Ground Phosphate Rock
GSSP	Granular Single Superphosphate
GTSP	Granular Triple Superphosphate
K	Potassium
K_2O	Potassium Expressed as Potassium Oxide
MAP	Monoammonium Phosphate
MP	Muriate of Potash (Potassium Chloride)
N	Nitrogen
NPK	Multinutrient Fertilizer Containing N, P, and K
P	Phosphorus
P_2O_5	Phosphorus Expressed as Phosphorus Pentoxide
PAPR	Partially Acidulated Phosphate Rock
PR	Phosphate Rock
S	Sulfur
SCU	Sulfur-Coated Urea
SGTSP	Semigranular Triple Superphosphate
SP	Sulfate of Potash (Potassium Sulfate)
SPM	Sulfate of Potash Magnesia (Potassium Magnesium Sulfate)
SSP	Single Superphosphate
TSP	Triple Superphosphate
USG	Urea Supergranule
Zn	Zinc

Abbreviations of Terms

ADP	Annual Development Plan
BFN	Biologically fixed nitrogen
c. & f.	Cost and freight
ft^3	Cubic feet
FAQ	Fair average quality
FFYP	First Five-Year Plan
f.o.b.	Free on board
FY	Fertilizer or Fiscal Year Ending June 30
FYM	Farmyard manure
GDP	Gross domestic product
HCP	Hard core program
HYV	High-yielding variety
IRR	Irrigated
LIV	Local improved variety
LV	Local variety
M	Thousand
MM	Million
MMCF	Million cubic feet
MMCFD	Million cubic feet per day
MTFPP	Medium-Term Foodgrain Production Plan
NACP	Normal Agricultural Credit Program
NFSP	National Fertilizer Storage Plan
NMS	New Marketing System
OMS	Old Marketing System
PDP	Primary distribution point
RF	Rainfed
SACP	Special Agricultural Credit Program
SFYP	Second Five-Year Plan
TFYP	Third Five-Year Plan
tpd	Tons per day
tpy	Tons per year
TYP	Two-Year Plan
TSC	Thana Sales Center

Glossary

Aman	Rice (paddy) planted before or during the monsoon rains (which begin in June) and harvested in November-January; B. aman is broadcast aman; T. aman is transplanted aman.
Aman season	The period in which aman rice is grown; covers all crops grown during this period.
Atta	Flour.
Aus	Rice (paddy) planted during March-April and harvested during June-September.
Aus season	The period in which aus rice is grown; covers all crops grown during this period.
Boro	Rice (paddy) planted in November-January and harvested during April-June.
Boro season	The period in which boro rice is grown; covers all crops grown during this period.
Paddy	Unhulled rice.
Thana	Administrative unit comprising several villages.

Units of Measure

1 pound (lb) = 453.59 grams (g) = 0.4862 seers

1 kilogram (kg) = 1,000 g = 2.2046 lb = 1.07 seers

1 short ton (st) = 2,000 lb = 0.90718 metric ton = 0.8929 long ton

1 metric ton (mt) = 1,000 kg = 1.1023 st = 0.9842 long ton = 26.82 maunds

1 long ton (ton)[1] = 2,240 lb = 1.01605 mt = 27.22 maunds

1 maund (md) = 40 seers = 82.27 lb = 37.3 kg

1 seer = 2.05675 lb = 0.9329 kg

1 square mile (mi^2) = 2.59 square kilometers (km^2) = 640 acres = 259 hectares

1 U.S. Dollar = 20.37 Taka (March 1982)

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1. Unless otherwise indicated the term tons used in this report refers to long tons.

EXECUTIVE BRIEF

The increased and more efficient use of fertilizer is a key element in plans to raise foodgrain production to self-sufficiency levels in Bangladesh. This report on fertilizer-related issues and policy options was prepared at the request of the Bangladesh Agricultural Development Corporation (BADC) to respond to the need for more clearly defined and coordinated fertilizer supply and use policies linked to and supportive of national agricultural sector and food supply development objectives and programs.

To facilitate review and appraisal for possible implementation, the main, broadly stated fertilizer policy issues and options are summarized under three categories--Fertilizer Use, Supply, and Marketing and Distribution. Encompassed are those areas in which policy actions are required to ensure the adequate, timely, and cost-efficient supply, delivery and farmer use of fertilizer.

FERTILIZER USE

Fertilizer use policy should focus on motivating and assisting farmers in making more efficient and profitable use of fertilizers and organic matter. Policy actions are needed to plan and implement strengthened programs to generate, evaluate, codify, and disseminate crop response and fertilizer use information that is more responsive to farmer needs.

AGRONOMIC DATA BASE

Issue

Development of additional more site-specific quantitative crop response data needed to provide the basis for improving fertilizer recommendations, to aid in the formulation of fertilizer allocation schemes, and to facilitate estimates of fertilizer nutrient requirements.

Policy Options

1. Expedite development and implementation of the national coordinated soil fertility and fertilizer use research program involving the multidisciplinary talents of scientists from appropriate government research and planning institutes.

2. Devise and implement expanded and improved experiment station and farm-level research programs to determine individual nutrient needs and crop response functions for major crops under applicable yield affecting constraints.
3. Refine economic optimum levels of fertilizer use based on crop response tests, practical farm management conditions, realistic cost/benefit relationships, and relevant farmer risk and socioeconomic factors.
4. Expand and accelerate soil survey and classification programs; prepare thana-level soil series maps.

FERTILIZER RECOMMENDATIONS

Issue

Formulating fertilizer recommendations better attuned to localized soil characteristics, crop production conditions, and management systems.

Policy Options

1. Using agronomic data base information, formulate fertilizer recommendations for crops in areas of common soil characteristics by crop responses and economic returns.
2. Prepare and distribute to local extension specialists and fertilizer dealers generalized recommendations with guidelines for modifying them to specific use conditions.

TECHNOLOGY TRANSFER

Issue

Strengthening farmer knowledge on proper and profitable use of fertilizer to stimulate fertilizer use and efficiency.

Policy Options

1. Develop agroeconomically sound fertilizer recommendations more attuned to the needs of individual farmers.
2. Train extension personnel and fertilizer dealers in applying fertilizer recommendations to farmer assistance programs.
3. Expand extension programs and dealer market development activities to increase and broaden farmer contacts.

FERTILIZER USE EFFICIENCY

Issue

Determining the efficiency of use of new and/or improved nutrient sources and management systems under Bangladesh conditions.

Policy Options

1. Establish a coordinated fertilizer efficiency project, using the government research institutes involved in developing agronomic data, to evaluate deep placement of nitrogen (N) for rice and new N and phosphorus (P) sources and application practices, train personnel in fertilizer efficiency research, and assess farmer acceptance of new technologies.
2. Evaluate suitability of diammonium phosphate (DAP) for rice and delineate use areas.
3. Determine possible gains in efficiency from deep placement of urea for rice; evaluate suitability of sulfur-coated urea (SCU).
4. Determine the suitability of phosphate rock (PR) and partially acidulated phosphate rock (PAPR) for important soils and crops and delineate recommended use areas.

PLANT NUTRIENT AND ORGANIC MATTER RECYCLING

Issue

Preserving and/or improving soil organic matter and plant nutrient levels to improve soil fertility and productivity.

Policy Options

1. Increase supplies of fuel wood, building materials, litter, and animal feedstuffs of plant origin so that total crop residue removal will no longer be necessary.
2. Monitor Indian experience with biogas and test successful approaches under Bangladesh conditions.

Issue

Increasing and improving the recycling of human, animal, and plant wastes.

Policy Options

1. Develop educational programs stressing the value of nutrient and organic matter recycling.
2. Investigate the economics of sewage, urban waste, and village-level composting projects.
3. Implement technically and economically viable projects.

Issue

Increasing biologically fixed nitrogen (BFN) as a nitrogen source.

Policy Options

1. Review status of research on the use of azolla, blue-green algae, and other nitrogen-fixing organisms.
2. Evaluate applicability of BFN schemes to Bangladesh situation.
3. Encourage adaptive research on appropriate schemes.

FERTILIZER ALLOCATION

Issue

Formulating fertilizer allocation schemes under conditions of adequate and short supply.

Policy Options

1. In periods of abundant supply, permit free market forces to allocate fertilizer supplies.
2. During periods of short supply, prioritize allocations on the basis of highest marginal return to individual nutrient use on targeted food crops taking into consideration national and regional economic, social, and political ramifications.
3. Develop agroeconomic data base to facilitate development of priority rankings of marginal returns to fertilizer use by crop and by region in accordance with preestablished crop production goals.

NUTRIENT REQUIREMENTS TO MEET CROP PRODUCTION GOALS

Issue

Improved estimation of plant nutrient requirements to meet specified crop production goals.

Policy Options

1. Develop appropriate crop response data base.
2. Set specific crop production targets for major food and industrial crops.

AGRICULTURAL DEVELOPMENT POLICIES

Issue

Improving and expanding irrigation, drainage, and flood control and reassessing targets in these areas.

Policy Options

1. Review irrigation and drainage activities and programs for fixing more realistic targets.
2. Consolidate irrigation and drainage programs under a single irrigation research and development authority.

Issue

Development and supply of high-yielding variety (HYV) seeds suitable to Bangladesh's soil, water, and climatic conditions.

Policy Options

1. Improve seed procurement, particularly wheat, and distribution programs.
2. Accelerate indigenous research for development of improved varieties for Aman season particularly.

Issue

The timely and adequate availability of agricultural credit for private-sector supply, distribution, and financing of agricultural inputs commensurate with financial constraints faced by input dealers and farmers.

Policy Options

1. Streamline and strengthen the existing financial institutions responsible for supplying institutional credit for agriculture.
2. Review and assess the agricultural credit needs of both the farm input dealers and the farm sector.
3. Improve credit delivery and procurement procedures.

Issue

Simultaneous determination of incentive levels of fertilizer and crop prices and fertilizer subsidy.

Policy Options

1. Obtain proper estimates of output supply price elasticities and elasticities of supply with respect to price of fertilizer; use these to evaluate the impact of given policy changes on foodgrain production and to establish appropriate levels of prices and subsidy for desired output targets.
2. Maintain fertilizer and crop prices in line with the international prices through free imports and exports.

Issue

Effecting and maintaining consistency between fertilizer use (demand) expansion policies and agricultural development and fertilizer supply and pricing policies.

Policy Options

1. Develop, monitor, and regularly refine fertilizer use estimates based on realistic assessments of the impact and attainment levels of the land development (irrigation, drainage, and water control), HYV seed, agricultural credit, and input-output pricing components of agricultural development policy to which fertilizer use is tied.
2. Improve the efficiency of the fertilizer supply and marketing and distribution systems to ensure adequate and timely supplies at the lowest cost to the farmer.
3. Implement policies to enhance the capabilities and performance of public- and private-sector organizations for delivering increased quantities of fertilizers on a timely basis to a larger number of farmers.

FERTILIZER SUPPLY

Fertilizer supply policy should continue to be directed to maximizing self-sufficiency in fertilizer supply by increasing output and lowering cost of domestic production and by implementing more cost-effective import programs.

SUPPLY PLANNING

Issue

Reconciling nitrogen/phosphate production capacity and potash import planning with realistic estimates of future market demand.

Policy Options

1. Train fertilizer forecasters, develop appropriate data sources, refine forecasting techniques.
2. Designate a single agency to prepare and update on a regular, rolling basis a 10-year forecast of fertilizer demand by nutrient and product under agronomically acceptable scenarios for alternative product mixes.

NATURAL GAS SUPPLY

Issue

Ensuring natural gas supply to meet projected requirements of existing and new ammonia/urea plants.

Policy Options

1. Expand exploration programs to develop new gas reserves.
2. Upgrade and expand gas delivery system.
3. Develop a priority system for natural gas use; assign top priority for use in fertilizer manufacture.

NITROGEN PRODUCTION

Issue

Increasing production and lowering cost of urea manufacture at existing units by removing manpower, physical, and financial constraints.

Policy Options

1. Relax manpower constraint by expanding training facilities and programs to train larger numbers of plant operators and upgrade management and plant personnel skills. Reduce exodus of technical personnel by increasing incentives for in-country work and instituting controls on emigration.

2. Relieve the physical resources constraint by providing full government support to planned donor-funded plant rehabilitation and production improvement projects.
3. Overcome the financial resources constraint by providing local and foreign currency funds for the purchase of raw materials and plant equipment and supplies necessary for proper plant operation.

Issue

Reducing new ammonia/urea plant construction time and attaining satisfactory plant operating rates.

Policy Options

1. Improve overall project development and implementation procedures.
2. Improve coordination between involved government agencies and external organizations supplying financial, technical, and project management assistance.
3. Staff new plants with a core of experienced management and operating personnel from existing plants. Provide on-the-job training for other technical personnel well in advance of new plant startup.

PHOSPHATE PRODUCTION

Issue

Developing a cost-effective national phosphate supply system founded on maximum domestic production of lowest cost, agronomically suitable phosphate fertilizers supplemented by minimum cost, agronomically acceptable phosphate product imports.

Policy Options

1. Initiate a comprehensive study of the technical and economic feasibility of alternative phosphate supply schemes including the following:
   a. Alternative methods for the domestic production of triple superphosphate (TSP) including the manufacture of a semigranulated versus fully granulated product.
   b. The agronomic suitability and domestic production of DAP.
   c. The agronomic suitability and domestic production of PAPR products.
   d. The use of phosphate rock as a direct application form of phosphate.

e. Comparison of the economic feasibility of importing alternate phosphate products versus domestic manufacture.

Issue

Increasing TSP production from existing units by removing manpower, physical, and financial constraints.

Policy Options

1. Expand and intensify manpower development and training programs.
2. Complete Chittagong rehabilitation program.
3. Provide funds for purchase of raw materials and plant supplies.

POTASH SUPPLY

Issue

Implementing a cost-effective import program for lowest cost, agronomically suitable potash fertilizer.

Policy Options

1. Continue present supply policy of importing lowest cost, standard grade muriate of potash for general use.
2. Devise improved procurement and import management programs (see section on Fertilizer Import Policy).

SULFUR SUPPLY

Issue

Developing economical sources of agricultural sulfur.

Policy Options

1. Implement a study of the technical and economic feasibility of applying known processes for converting sulfur in waste gypsum to usable forms of agricultural sulfur.
2. Determine areas of potential use for elemental sulfur and of sulfate of potash and sulfate of potash magnesium as dual sources of sulfur and potash.
3. Promote the expanded recovery and use of gypsum where agronomically feasible.

FERTILIZER IMPORTS

Issue

Improving procurement planning and purchasing practices to lower cost and foreign currency expenditures.

Policy Options

1. Implement training programs to upgrade the expertise of import procurement personnel in all aspects of world market fertilizer purchasing and shipping.
2. Develop annual import schedules in accordance with overall marketing and sourcing plans.
3. Improve coordination procedures with fertilizer donor agencies to facilitate import planning and scheduling.
4. Purchase fertilizers from lowest cost sources during off-peak seasons in supplier-country.
5. Ship in most economical cargo lots commensurate with port receiving, handling, and storage capabilities.
6. Improve superintendence procedures to assure quality and quantity control.

Issue

Developing import management strategies to lower cost and conserve foreign exchange.

Policy Options

1. Import lowest cost, agro-economically desirable fertilizer products.
2. Import DAP in place of TSP to reduce urea import costs during periods of domestic urea supply deficit, when international market price relationships of DAP, TSP, and urea are favorable. In periods of exportable urea surpluses, import DAP to generate foreign exchange when market conditions permit.
3. Continue to import standard grade MP as general purpose potash fertilizer.
4. Maximize the importation of fertilizers in bulk form. Implement lowest cost bulk unloading and bagging strategies.

FERTILIZER MARKETING AND DISTRIBUTION

Under the New Marketing System (NMS), increases in farmer access to and use of fertilizer and economies of distribution were to be achieved by transferring most of BADC's local marketing functions and associated costs to private retail dealers. The BADC's marketing role was transformed to that of wholesaling fertilizers to dealers from a greatly reduced number of strategically located fertilizer distribution points. Significant progress has been made in meeting the objectives of the NMS, but constraints to full-scale implementation remain.

FERTILIZER MARKETING

Near term fertilizer marketing policy should concentrate on implementing the NMS and improving its operational efficiency. Also, policy direction is needed for longer range development and improvement of the fertilizer marketing system.

Issue

Reduction of BADC marketing costs by decreasing primary distribution point (PDP) sales points to minimum number required to provide dealers and farmers with needed fertilizers in a timely and cost-effective manner.

Policy Options

1. Continue to enforce current thana sales center (TSC) closure policy.
2. Restrict operation of TSCs to remote areas and locations where retail dealer cannot provide proper farmer service.

Issue

Improving PDP operational efficiency, and lowering BADC and dealer costs, by hastening dealer order processing and lifting time.

Policy Options

1. Allow PDP storekeepers to process orders without prior approval by Thana Inspectors.
2. Increase minimum lifting quantities.

Issue

Ensuring timely supply of desired fertilizers at PDP warehouse level to meet consumer demand.

Policy Options

1. Improve short- and long-range market demand forecasting and planning techniques.
2. Develop improved annual market plan and monitor performance against plan.
3. Expedite implementation of recently developed stock control and accounting system.

Issue

Expanding the dealer's role in stimulating fertilizer sales by improved and expanded technical assistance and market development programs.

Policy Options

1. Expedite ongoing dealer development and training programs to enhance business management, sales promotion, and farmer servicing skills.
2. Restructure scale of dealer commissions to provide appropriate financial incentives. Institute volume and seasonal discounts to promote off-season movement.
3. Provide short-term loans to finance fertilizer inventories. Develop programs to encourage dealers to extend short-term credit to farmers.
4. Expedite organization of competitive wholesale dealer network.
5. Simplify dealer registration procedures and ease record keeping and inspection regulations to encourage new dealer registration and enhance dealer performance.
6. Develop a dealer trade association.
7. Institute dealer awards to recognize superior performance in sales and farmer service.

Issue

Increasing the effectiveness of the NMS through functional and staffing adjustments in the organization of BADC's Supply Wing.

Policy Options

1. Provide full personnel and material support to BADC dealer development and training function.
2. Establish and staff appropriate credit function to develop and carry out dealer and farmer credit programs.
3. Strengthen BADC's marketing planning and monitoring functions.
4. Expand BADC dealer service and farmer assistance programs; coordinate latter with MAF extension service.

FERTILIZER DISTRIBUTION

Issue

Making the most effective use of existing transportation facilities.

Policy Options

1. Plan movements well in advance and on a regular basis around the year from production units or points of import to PDP level.
2. Improve transport procurement and contracting procedures on basis of regular movement schedules.
3. Collaborate with Bangladesh Chemical Industries Corporation (BCIC) and Bangladesh Railways in developing and operating the unit train system as envisaged under the World Bank fertilizer distribution improvement project.

Issue

Improvement in planning and control of fertilizer movements and stock levels.

Policy Options

1. Implement IFDC-recommended inventory control and stock accounting procedures.
2. Develop centralized marketing and distribution data center.
3. Develop central control unit to plan and coordinate all transportation and storage activities on the basis of regular movement and stock-building plan at PDP level to meet forecast requirements.

Issue

Improvement in operating and design features of PDP warehouses.

Policy Options

1. Modify, as needed, and implement IFDC-recommended warehouse management program.
2. Improve plant operating control and security by limiting access to working areas.
3. Provide all-weather loading/offloading areas and lighting to permit continuous operation.
4. For new construction, re-evaluate the need for the type of auxiliary structures at PDP sites. Re-evaluate warehouse roof design and construction.
5. Re-evaluate ventilation provisions and procedures for warehouses in which urea is to be stored.

Issue

Encouraging provision of warehousing at village and retail level to receive full load consignments.

Policy Options

1. Provide financial incentives for constructing fertilizer storage facilities.
2. Develop appropriate designs for village and retail level warehouses.

FUTURE DEVELOPMENT OF THE FERTILIZER SUPPLY SYSTEM

Issue

Improving the operational efficiency of the overall Bangladesh fertilizer supply system to assure timely availability and expanded and efficient use of fertilizers at least cost to the GOB and the nation's farmers.

Policy Options

1. Initiate a study of the practicability and potential improvements in overall supply system efficiency and cost which would result from integrating production and marketing/distribution functions now handled by separate government organizations.
2. In line with current GOB thinking, study the feasibility and potential benefits of various approaches to transferring the marketing function and/or the production function to the private sector.

I. SUMMARY AND CONCLUSIONS

Bangladesh agricultural development planning is keyed to achieving self-sufficiency in foodgrain production to overcome the persistent and pervasive food shortages that have plagued the nation. Despite intermittent periods of record output in recent years, crop production has failed to keep pace with the needs of a burgeoning population. Agricultural productivity in Bangladesh ranks among the lowest in the world. Yields of rice, its premier foodgrain, are about 50% of the average yield in Asia. Most of its arable land is being cultivated, but only about one-half of it is double-cropped. Increases in crop production will have to be achieved through more intensive land use and management and will require greater reliance on improved technologies and farm inputs.

The Medium-Term Foodgrain Production Plan (MTFPP), prepared as the blueprint for attaining foodgrain self-sufficiency by 1985, attempts to introduce a needed dimension of order to the management of the longer term and more technologically oriented development of the nation's largely subsistence-type agriculture. It recognizes the constraints that have limited crop production in the past and presents programs and budgets for meeting its production targets of 17.5 million tons of rice and 2.5 million tons of wheat. The combined foodgrain production target of 20 million tons is about 7 million tons higher than production in 1977/78, the benchmark year.

Essentially all of the new production is to be derived from more intensive use of land currently under cultivation through major expansions in the use of irrigation, improved varieties, fertilizers, and other inputs. Over one-half of the increase in production is related to improved and expanded water control. Irrigated acreage is to be doubled to 7.2 million acres, and drainage and flood control improvements are to be applied to 2.0 million acres. Institutionally supplied high-yielding variety (HYV) seed is expected to show a tenfold increase to about 58,000 tons. Fertilizer use is projected to more than double to about 1.9 million tons in 1985. The extent to which the ambitious objectives of the MTFPP can be achieved will be dependent on how effectively the necessary resources and management skills can be assembled and applied. The prognosis, which is not favorable, is discussed in a succeeding section that deals with the implications of MTFPP input policies.

FERTILIZER USE

Despite significant increases in recent years, fertilizer use in Bangladesh is low compared with that of many other Asian countries. Approximately 65% of the nation's farmers use fertilizers. About 50% of the planted acreage is fertilized; average use is about 0.9 maunds of nutrient per acre of fertilized area. Less than half of the cultivatable acreage is double-cropped. Based on current fertilizer recommendations, which are subject to review, farmers who use fertilizers could profitably increase the use of nitrogen (N) by 50%-90% and potassium (K) by 25%-40%, except for Boro paddy and wheat, which appear to be fertilized at near recommended levels. Given current usage levels and limited cropping intensity, the potential for expanding fertilizer use and raising crop production is good.

Fertilizer use can be increased by the application of policies which relax or remove those constraints that prevent the farmer from realizing the full economic benefits of proper fertilizer use. In Bangladesh, a major impediment to expanded and efficient use of fertilizer is the lack of a reliable and organized agronomic data base on the crop and site-specific factors that dictate the nature of the crop response function and thus determine the economic optimum level of fertilizer use on farmers' fields.

To stimulate fertilizer use, government policy instruments are needed to strengthen programs to generate, organize, and disseminate crop yield response and related fertilizer use information and thus to guide farmers in the most efficient and rewarding use of fertilizer. A summary of recommended fertilizer use policies and strategies follows.

Agronomic Data Base Development

To develop the necessary agronomic data base, the nature of the crop yield response function must be more fully determined under the wide variety of farm-level crop production conditions which apply to the principal crop growing areas.

To resolve this issue, it is recommended that the Government of the People's Republic of Bangladesh (GOB) accelerate the development of a policy calling for the mobilization of the nation's agricultural research institutions and resources into a national, coordinated soil fertility and fertilizer use

program. This endeavor would have as its objectives (1) assessing the existing agronomic knowledge base and (2) developing and implementing basic and farm-level research programs to generate and codify information needed to characterize the nature of the crop response functions under varying farming conditions.

Implementing the proposed soil fertility and fertilizer use program, based in part on the data base assembled for this report by Bangladeshi and International Fertilizer Development Center (IFDC) scientists, entails the following strategies and/or methodologies:

1. Soil Classification--Expand and accelerate soil classification at the series and type level; prepare thana-level soil series maps.
2. Crop Production--Determine and codify crop production capabilities of land areas on the basis of identified soil series groups, land forms, degree of water control, and suitability for different crop varieties.
3. Nutrient Usage--Determine or confirm the need for individual fertilizer nutrients, including basally applied nitrogen (N) and phosphorus (P) in the form of diammonium phosphate (DAP), under identified crop production situations by conducting fertilizer trials in farmers' fields.
4. Crop Response Function--Establish response functions for principal crops under prevailing crop management practices. Develop information on economic optimum levels of fertilizer use under identified farming conditions.
5. New Nutrient Sources--Investigate at the experiment station and farm levels the effectiveness of new or improved fertilizer materials under differing methods of placement and timing and develop yield response curves accordingly. Evaluate tested materials in terms of cost, returns, and farmer acceptance. Nutrient source evaluations should include (a) urea (including large granule type) placement for rice, (b) phosphate rock (PR) and partially acidulated phosphate rock (PAPR) on acid and neutral soils, (c) suitability of alternative sulfur sources for various soils, and (d) zinc, where needed.

Fertilizer Recommendations

Agro-economically sound fertilizer recommendations are a basic tool in promoting the efficient and profitable use of fertilizer. They generally influence the quantity of fertilizer the farmer will use and, hence, his level of crop production. Although significant progress has been made in developing fertilizer recommendations, further refinements appear necessary.

The main issues concerning improvement of current fertilizer recommendations relate to (1) the lack of consideration of localized crop production conditions, i.e., fertility status of soils and practical levels of farm management, in stratifying farmers' fields on which fertilizer trials are conducted and from which generalized recommendations are determined, (2) limitations in the design of some field trials which preclude estimation of crop response curves and lead to the development of recommended rates and cost/benefit ratios from selected treatments, and (3) the use of improper fertilizer and crop prices in the determination of cost/benefit relationships.

Additionally, questions have been raised concerning the need for basal applications of N, as it affects the possible use of DAP for rice, and the now universally recommended need for P and K for all crops on all soils in Bangladesh. Zinc and sulfur deficiencies have only recently been observed and further trials are required to establish recommendations for these elements.

To surmount the fertilizer recommendation constraint to increased efficiency of fertilizer use it is suggested that a permanent committee on fertilizer recommendations be appointed by the Bangladesh Agricultural Research Council (BARC) to develop procedures and formulate fertilizer recommendations. Subcommittees would be appointed to establish recommendations on a regional and crop basis.

The following strategies are suggested to guide the development of improved recommendations:

1. Classify the various crop production conditions, e.g., crop species and variety, season, soil properties, water control, climate, and practical management limitations, which apply nationwide.
2. On the basis of soil and/or plant analyses and field trials, delineate the areas and crop production conditions under which responses to an applied nutrient are obtained.
3. Determine, from tests on farmers' fields, crop response functions for varying rates of application for different nutrient sources and methods and times of application under identified cropping conditions.
4. Prepare crop response functions for localized crop production conditions. On the basis of local conditions of crop growth and farmer management capabilities, formulate recommended fertilizer rates for farmer use, by locality.

Fertilizer Technology Transfer

Increases in fertilizer use in periods of adequate availability are hindered by the farmer's lack of knowledge of the proper and profitable use of fertilizer. According to a recent IFDC survey, less than 10% of the farmers and dealers queried had been contacted by extension service personnel. Most said that they were in need of technical assistance.

Removing or relaxing the technical assistance constraint to the expanded and efficient use of fertilizer will require policy decisions to (1) develop a sound agro-economic data base as noted earlier, (2) develop and implement programs to train extension personnel and fertilizer dealers in assisting farmers, and (3) expand and strengthen extension programs and fertilizer dealer market development programs to inform farmers of appropriate fertilizer technology.

The following strategies are among those needed to implement the expanded technical assistance programs:

1. Development of Agronomic Data Base--For the longer term, this activity would be vested in the national soil fertility and fertilizer use program suggested above. For the immediate term, available fertilizer use information currently under review should be updated as deemed necessary by BARC and other agricultural research institutes.
2. Information Preparation--The Directorate of Agriculture, (Extension and Management) (DA[EM]), in cooperation with government agricultural research institutes, would prepare the needed educational materials in the form most useful to extension agents operating at the farm contact level.
3. Personnel Training--The DA(EM) would develop and carry out programs to train thana- and union-level extension officers in fertilizer use technology and in ways to most effectively transfer modern agricultural technology to farmers. The DA(EM), in cooperation with the Bangladesh Agricultural Development Corporation (BADC) training officer, would provide similar training to fertilizer dealers.
4. Farmer Education--Fertilizer demonstrations, farmer meetings, and field days would be made regular features of DA(EM)'s extension and BADC's market development programs; all should involve active farmer participation.
5. Other Extension Activities--The DA(EM), BADC, and agricultural research institutions would maintain liaison and cooperate with the Food and Agriculture Organization (FAO) of the United Nations, the World Bank, IFDC,

and other international agencies that are or may be engaged in fertilizer extension and promotion activities.

Organic Fertilizers

Analyses of the IFDC/BARC farm survey data indicated the following in regard to the current status of organic residue use:

1. The overall use of farmyard manure, compost, and ashes as fertilizers is very low; use in 1979/80 averaged about 21.3 md/acre.
2. The use varied considerably across seasons and crops; usage was greater in the Aus season than in the Boro or Aman seasons.
3. The impact of organic manures on crop yields was substantially smaller than that of chemical fertilizers; the use of the latter increased yields between 10 and 100 times that of the organic manures.
4. Farmers use organic materials as a supplement to rather than as a substitute for commercial fertilizers.

Given the restrictions in expanding future supply and the need to use animal dung as fuel, the use of organic manures is expected to remain small and to have little impact on crop production.

Although the crop production potential of recycling organic residues is limited, it is suggested that government policies encourage the farm-level use of organic crop residues and village wastes as part of its overall resource conservation policy. The following strategies would support the expanded or more efficient use of organic manure:

1. Evaluate the quantities and composition of organic materials potentially available and actually used by farmers.
2. Promote the conservation and use of organic fertilizers as a complement to sound agricultural input usage.
3. Monitor, over the long term, changes in the soil organic matter level to identify both areas of depletion and accumulation.

Fertilizer Demand Projections

Reliable estimates of future fertilizer demand are necessary prerequisites to planning future fertilizer supply, marketing and distribution strategies,

infrastructure requirements, and resource allocations. Fertilizer nutrient consumption has increased from about 145,000 mt in 1970/71 to 413,000 mt in 1980-81. Growth in usage, which has been closely related to supply availability, has been very erratic. In the past 3 years, increases in usage have declined somewhat from the average annual growth rate of about 11%, which had been experienced over the past decade as a whole.

The main policy issue relates to the reliability of the projected fertilizer demand estimates that are being used as the basis of forward fertilizer supply and distribution planning in Bangladesh. The IFDC estimates of the 1989/90 total nutrient demand are about 30% lower than the GOB estimates for that period. According to the IFDC projections, 1989/90 demand is forecast at 545,000 mt N; 266,000 mt P_2O_5, and 60,000 mt K_2O. The corresponding GOB Planning Commission estimates, as derived from projections of individual fertilizer product demand, are 644,000 mt N, 460,000 mt P_2O_5, and 120,000 mt K_2O. The lower IFDC projections are supported by data derived from the IFDC/BARC farm survey discussed later. The demand projections of other Bangladeshi forecasters vary widely depending on the time and method of forecast preparation.

The reliability of Bangladesh fertilizer demand forecasts can be enhanced by improving both the data base and mechanisms used in projecting fertilizer demand. The following broad strategies are suggested:

1. Designate a single agency to prepare fertilizer supply and demand projections.
2. Improve processes for collecting and recording relevant and reliable data on a consistent and continuing basis.
3. Train fertilizer market planners concerning the nature and practices of the fertilizer industry and the fertilizer market on which analyses and forecasts are based.
4. Train fertilizer analysts and market planners in data processing and fertilizer demand forecasting methods.

Fertilizer Allocation

When fertilizer supplies are adequate, there is no need to allocate fertilizer. Free-market forces will influence marginal returns from fertilizer use and dictate the pattern of use by farmers. When food and fertilizer are in short supply, both marginal returns from fertilizer use and minimum crop requirements should be considered, taking into account national and regional economic, social, and political factors.

The main policy issues in developing a fertilizer allocation system based on marginal return rankings, by crop and by region, are (1) establishing minimum crop production requirements for all crops and regions and (2) expanding the crop response data base to permit the determination and rankings of production increases from the incremental use of plant nutrients for all crops under various crop growing conditions. Policy decisions are necessary to generate the data needed to develop a fertilizer allocation system which will provide maximum production of targeted crops from minimum levels of plant nutrient use.

Analysis of Selected Agricultural Development Policies

The data generated from the IFDC/BARC in-depth farm survey were analyzed to assess the degree to which the crop production goals and other input targets of MTFPP might be achieved. The conclusions drawn from these analyses follow.

Irrigation Policy

The proposed doubling of irrigated area (from 3.6 to 7.2 million acres) could increase average paddy and wheat yields by about 17.25%. About 0.5% would be attributed to the direct effect of irrigation. About 14.50% and 2.25% would be attributed to the 100% and 31.6% increase in the use of HYV seeds and fertilizer, respectively, which result from the increased area under irrigation. If one-half of the newly irrigated area (3.6 million acres) is sown to foodgrains each season, the total area cropped annually would increase by 20%, leading to a corresponding increase of 20% in total paddy and wheat production and a 20% increase for the demand for HYV seeds and fertilizer.

By 1984/85 the cumulative impact of the MTFPP irrigation policy would be a 120% increase in the use of HYV seeds, a 51.6% increase in fertilizer demand, and a 37.25% increase in paddy and wheat production in Bangladesh. Clearly, implementation of the MTFPP irrigation policy will not accomplish the 53% gain in foodgrain output needed to meet the 20 million ton goal set for 1984/85. Also, under the proposed irrigation policy, fertilizer demand will fall short of the 126% gain to 1.9 million tons envisaged under the MTFPP. Likewise, the use of HYV seeds will not reach the 58,000 ton level predicted for 1984/85.

Drainage and Flood Control Policy

The MTFPP policy to improve water control on about 2 million acres, or 20% of the land affecting Aman and Aus crops, is expected to increase the use of HYV by about 19.4%, fertilizers by about 5.0%, and foodgrain yields by about 1.5%. Larger increases in foodgrain production would be expected if this water control policy were to have an effect on the total area sown to foodgrains in the Aman and Aus seasons.

HYV Seed Use Policy

Under the MTFPP, significant increases in crop yields are ascribed to the continued switch from local traditional varieties to HYV seeds. The overall increases in average yields prompted by the past increased use of HYV seeds have begun to taper off as more marginal land has been brought under HYV cultivation. Indigenous research to develop HYV seed varieties more suitable for Bangladesh soil, water, and climatic conditions must be an important component of longer term crop production policy. In the short term, policies must be designed to provide a timely, adequate, and cost-effective supply of HYV seeds to farmers to meet the 140% increase in demand expected to result from the implementation of the MTFPP irrigation and water control strategies. The development of improved crop varieties could aid in sustaining crop yields even in the absence of improved irrigation and other water control measures.

Fertilizer Use Policy

On the basis of fertilizer demand elasticity estimates developed from the IFDC/BARC farm data, the proposed doubling of irrigated area under the MTFPP is expected to increase fertilizer demand by 31.6%, about 10.5% directly as a result of irrigation and 21.1% from the increased use of HYVs. Assuming that this increase in irrigated area brings about a 20% gain in total area cropped annually, then fertilizer demand would grow by an additional 20%. The overall effect of the MTFPP irrigation policy would be a 51.6% increase in fertilizer demand. An additional 5.0% increase in fertilizer demand is expected from the application of improved drainage and flood control measures. Implementation of the MTFPP irrigation and improved water control strategies is thus expected to increase fertilizer demand by 56.6% in 1984/85, about one-half of the 126% increase in demand postulated under MTFPP.

Fertilizer and Output Price Policy

Fertilizer and foodgrain price policies affect the use of fertilizer, other inputs, and foodgrain yields by providing or denying incentives to farmers to grow crops. In Bangladesh, farm-level foodgrain prices are affected by, among other factors, the level of procurement prices set by the government and the level of existing foodgrain stocks. In addition to the government price procurement policy aimed at supporting the farm price of rice, Bangladesh also has subsidy policies on fertilizers and other inputs. Both policies seek to provide incentives to farmers to increase crop production. With respect to fertilizer price, current government policy is geared toward continued progressive elimination of the fertilizer subsidy. According to the IFDC/BARC farm survey data, the subsidy reduction policy has caused the farm-level fertilizer/paddy price ratio to increase from about 1.2 in the 1979 Aman season to about 1.8 in the 1980 Aman season.

The lack of appropriate estimates of output supply price elasticities and elasticities of supply with respect to fertilizer price precludes the evaluation of the impact of given output and/or fertilizer price policies on foodgrain production in Bangladesh. However, fertilizer demand elasticity estimates derived from the IFDC/BARC study indicate that changes in the fertilizer/paddy price ratio have a significant impact on fertilizer demand and, thus, foodgrain production. The 3-season average fertilizer demand elasticity estimate with respect to the fertilizer/paddy price ratio was -1.02.

Agricultural Credit Policy

The problem of availability of credit and the cost of credit are serious constraints to the increased use of fertilizer and other production inputs and, therefore, they limit crop output. Credit availability has increased in recent years but expanded use has been hampered by problems in the delivery system. The IFDC/BARC farm data reveal that (1) the number of farmers using institutional agricultural credit is small, less than 6%; (2) the use of agricultural credit varies considerably by geographical region and crop season; (3) use of credit is positively correlated with farmer ownership of land and physical assets, with larger farmers having the highest credit use; and (4) the use of credit had a small but statistically significant positive influence on the use of fertilizer.

The low level of credit use and the relatively low levels of use of fertilizer and other inputs by farmers suggest that improvements in the availability and delivery of credit could enhance farmer use of modern farm inputs and stimulate crop production.

Employment Policy

The MTFPP attempts to reduce the alarmingly high rate of unemployment which afflicts the rural society. The analyses of IFDC/BARC farm data indicate that implementation of the MTFPP irrigation and drainage and flood control strategies could increase the employment of farm labor by about 30.3%. It is expected that implementation of these policies would also have a beneficial effect on employment of off-farm labor: Increased employment would result from the marketing and distribution of additional quantities of fertilizers and other agricultural inputs and outputs.

FERTILIZER SUPPLY

Increased production and a slackening in the rate of increase of demand in the past two years have acted to diminish, somewhat, Bangladesh heavy dependency on imports for its fertilizer supply. In 1980/81 domestic production accounted for about 56% of the total supply of approximately 769,000 mt of all products procured by BADC. In that year, about 337,000 mt, valued at about US $98 million, was imported.

The main fertilizer supply issues confronting Bangladesh are (1) increasing local production, based on indigenous raw materials, to increase fertilizer self-sufficiency and (2) effecting more cost-effective import supply programs. Both strategies support the national fertilizer supply objective of reducing foreign exchange outlays for fertilizer.

Fertilizer Production

Fertilizer Raw Materials

Bangladesh possesses recoverable reserves of natural gas estimated at about 9.6 trillion ft^3. Gas is produced from four fields in the east to supply

ammonia plants at Ghorasal, Fenchuganj, and Ashuganj. A new field is to be developed at Bakhrabad to supply ammonia plants planned for Chittagong. Gas reserves are believed to be adequate to support planned ammonia capacity, but use is confined to immediate production areas for lack of an adequate transmission system. Disruptions in gas supply have reduced ammonia production at Ghorasal.

To assure a continuing and reliable supply of natural gas to existing and planned ammonia plants, the following measures should be considered:

1. Assessing natural gas policy with the objective of setting priorities for gas use based on its economic value for alternative uses.
2. Expanding exploration programs, particularly in the western regions of the country, to seek and develop new reserves.
3. Improving and expanding the natural gas delivery system to broaden the area of present and potential gas use.

Nitrogen

Urea is the predominant nitrogen fertilizer made and used in Bangladesh. In 1980/81, BADC procured 358,000 mt of urea from the Bangladesh Chemical Industries Corporation (BCIC) and 64,000 mt from imports; the c. & f. value of the latter was about US $15 million. Because of production economies associated with indigenous natural gas use, urea will undoubtedly remain the mainstay of nitrogen supply in the future. Small quantities of domestically produced ammonium sulfate and increasing quantities of imported DAP are also used. The use of DAP may become more important in the immediate future.

Urea is produced at three plants: Natural Gas Fertilizer Factory (NGFF) at Fenchuganj; Urea Fertilizer Factory (UFF) at Ghorasal; and Zia Fertilizer Chemicals, Ltd. (ZFCL) at Ashuganj. These plants have a combined installed capacity of 874,000 mt. In 1980/81 combined production from NGFF and UFF was about 315,000 mt. The ZFCL plant was commissioned in December 1981. Production in 1981/82, including ZFCL, is projected at 618,000 mt. Production at NGFF and UFF has been unacceptably low; capacity utilization rates have averaged less than 60% in the past decade. Despite low operating rates, the reported cost of domestically produced urea, based on low-priced natural gas, is below the cost of imported urea. Two new urea plants with a combined annual capacity of about 610,000 mt are planned for Ghorasal and Chittagong; additional capacity at other locations is being discussed. Additionally, a 525,000 mtpy export-oriented plant is being planned for Chittagong.

The GOB nitrogen supply policy calls for achieving urea self-sufficiency and developing an export capability by upgrading existing facilities and constructing new plants to use indigenous natural gas.

To successfully implement this policy, it will be necessary to develop sound projections of domestic market demand and cost-effective product mix to satisfy this demand; overcome the human, physical, and financial constraints to operation of existing plants; and facilitate the planning, organization, and execution of new plant construction programs.

The following strategies are recommended to enhance nitrogen supply:

1. Market Demand and Product Mix Determinations--Improve market demand projections by following previously given recommendations. Devise marketing and supply strategies that use imported DAP, to the extent that it is agro-economically feasible to do so, to replace a portion of the N and P_2O_5 now provided as urea and triple superphosphate. Granular urea should be the product of choice for new plants.
2. Human Resources--Upgrade management and worker skills by expanding and strengthening training facilities, programs, and worker participation. Stem the outflow of experienced technical personnel and thus assure needed expertise by improving worker incentives, imposing time minimums as a condition of employment, restricting worker departures, and/or training larger numbers of technicians.
3. Plant Improvement--Provide full government support to the World Bank and other donor agencies that sponsor plant rehabilitation programs and seek to improve plant production by (a) providing for equipment replacements and additions, (b) modifying plant processes, (c) improving maintenance, and (d) increasing reliability of raw materials and utility supplies.
4. New Plant Construction--Minimize plant construction time and attain suitable operating rates by improving the coordination processes entailed in new project development, with or without donor assistance.
5. Financial Resources--Take steps to provide, on a timely basis, local and foreign currency funds to purchase raw materials and plant supplies required to assure continuous and high-level plant performance.

Phosphate

Triple superphosphate (TSP) of domestic and imported origin is the main phosphate fertilizer used in Bangladesh. In 1980/81, BADC purchased 74,000 mt and 194,000 mt of TSP from BCIC and foreign sources, respectively.

The 1980/81 c. & f. value of imported TSP was about US $61 million. Lesser quantities of DAP and minor amounts of ground phosphate rock (GPR), both imported, are also used. In 1980/81 about 36,000 mt of DAP was imported; the c. & f. value was approximately US $13 million.

The TSP is produced at Chittagong in two units with a combined annual design capacity of 152,000 mt. Production is based entirely on imported sulfur and phosphate rock. The TSP plant performance has been poor. Plagued by equipment failures, excessive maintenance downtime, and raw material and power supply outages, capacity utilization rates have averaged about 30% during the past 5 years. In 1979/80 production reportedly reached a record high of about 71,000 mt. The TSP production cost in 1979/80 exceeded the c. & f. value of imported TSP. The Chittagong units are to be rehabilitated under a donor assistance program in 1982/83. Plant equipment and utility supplies are to be improved, and a granulation unit is to be installed. Annual production, reported to be increased to 110,000-120,000 mt, will fall far short of projected market demand.

Current phosphate supply policy is aimed at increasing domestic production by rehabilitating the Chittagong facility and alleviating the human, physical, and financial constraints associated with past TSP production. As in the case of nitrogen production, the strategies to overcome these constraints to production include (1) expanding and intensifying manpower development facilities and programs, (2) expediting plant rehabilitation programs, and (3) providing funds to purchase needed raw materials and plant supplies.

An IFDC report, prepared as a background paper for this study, raises serious questions relating to the course and adequacy of current phosphate supply policy. Based on a preliminary review of the economics of current and alternative phosphate supply schemes, it recommends a thorough study of several alternative phosphate supply systems:

1. The local production or import of agronomically suitable phosphates, such as PAPR, which may be more cost effective than TSP.
2. More economical methods for producing TSP.
3. The import of DAP in place of TSP.
4. Producing a semi-granular rather than a fully granulated TSP as presently contemplated.

Potash

Muriate of potash (MP) is the sole source of potash used in Bangladesh. All is imported. In 1980/81 imports totaled about 43,000 mt; the c. & f. value

was about US $9 million. Because MP is the lowest cost source of fertilizer potash available, it is certain to remain the predominant potash source in the future.

Bangladesh possesses no known potash mineral base to support local production; therefore, the potash supply policy should be focused on implementing cost-effective import programs for agronomically suitable potash materials. It is recommended that the present policy of importing standard grade MP, the lowest cost yet agronomically suitable form of fertilizer potash, be continued.

Sulfur

Agronomists have suggested a potential need for about 18,000 tpy of sulfur (S) to counteract recently observed crop deficiencies. Bangladesh has no known reserves of sulfur. A 2-year supply of about 43,000 mt of sulfur is presently available in the waste gypsum that has been produced at the Chittagong TSP complex.

The IFDC phosphate strategy study referred to earlier also made a preliminary assessment of sulfur sources suitable for use in Bangladesh. This study indicated that ammonium sulfate, made from Chittagong waste gypsum, was the most economical source of agricultural sulfur for use in Bangladesh. The report stresses the need for a more rigorous study of the economic merits of alternative sulfur supply schemes. For the immediate future greater emphasis should be placed on marketing dried gypsum.

Fertilizer Imports

Nitrogen imports should decline as domestic production is expanded in the years ahead, but the need to import substantial and increasing tonnages of phosphate and potash will continue. Import policy must focus on lowering import costs and foreign currency expenditures through judicious product selection and improved procurement strategies.

The main import-related constraints to fertilizer supply are (1) a chronic lack of foreign exchange to purchase fertilizers that forces reliance on donor assistance, (2) deficiencies in the procurement process that lead to disruptions in orderly supply, and (3) lack of adequate port facilities that increase the time and cost of handling incoming cargos.

Foreign Exchange

Substantial savings in foreign exchange can be achieved by implementing a policy to import fertilizer products that are least expensive and yet agronomically suitable. Recommendations include these product-related import strategies:

1. Nitrogen/Phosphate--Consider including DAP in future fertilizer supply strategy to the degree permitted by prudent agronomic practices. In periods of domestic urea supply deficits, importing DAP in place of TSP will reduce urea import needs and lower import costs depending on the price relationships of DAP, TSP, and urea. On the basis of the c. & f. values of urea, TSP, and DAP imported in 1980/81, nearly US $50 may be saved by importing 1 mt of DAP in place of 1 mt of TSP and 0.39 mt of urea. During periods of exportable surpluses, again depending on product price relationships, consider the importation of DAP and export of urea to generate foreign exchange.
2. Potash--Continue importing standard grade MP as the general purpose source of potash. About US $10/mt in c. & f. cost might be saved by importing standard rather than coarse grade MP, the next cheapest form.

Procurement Practices

Import policy obviously must be directed to purchasing fertilizers of defined quantity and quality at the lowest delivered cost and effecting timely deliveries of imported materials to satisfy marketing plans. The chief policy concerns to the orderly and cost-effective purchase and delivery of offshore fertilizers are (1) the lack of adequate and timely availability of funds which necessitates reliance on donor assistance and introduces elements of uncertainty and confusion into import planning and (2) deficiencies in knowledge of international fertilizer marketing, procurement, and shipping practices on the part of government procurement and planning personnel.

The following strategies are offered to overcome these procurement-related constraints:

1. Donor Assisted Purchases--Improve coordination procedures; attempt to develop more uniform donor loan and grant agreements to facilitate import planning and purchasing.
2. Procurement Practices--Develop import programs based on (a) scheduling shipments from supplier countries in their offpeak seasons when inventories are highest and prices lowest, (b) making shipments in the largest feasible cargo sizes to secure lowest ocean freights, (c) scheduling vessel arrivals to

coincide with availability of port facilities and in-country storage capacity, (d) purchasing in bulk form, and (e) improving superintendence procedures.

3. International Market Knowledge--(a) Establish and implement training programs covering world market fertilizer sources, pricing structure, sales practices, ocean freight, supplier capabilities, etc., and (b) arrange counterpart participation in IFDC procurement consultancy scheduled for the fall of 1982.

FERTILIZER MARKETING AND DISTRIBUTION

Fertilizer Marketing

In Bangladesh the fertilizer marketing and distribution function has been assigned to BADC, an autonomous government entity operating under the jurisdiction of the Ministry of Agriculture and Forests (MAF). BADC bears the responsibility for procuring, distributing, and selling virtually all of the fertilizer consumed domestically. Administratively, fertilizer sales are organized on a divisional, district, and thana level.

Sales in 1980/81 amounted to about 875,000 tons. In that year urea accounted for about 64% of total sales, TSP about 25%, and DAP and MP about 5% each. Viewed regionally, 1979/80 sales were distributed among divisions as follows: Chittagong 31%, Khulna 28%, Dacca 26%, and Rajshahi 15%. On a district basis, sales were highest in the Comilla, Dacca, and Chittagong districts, which represented about 15%, 9%, and 8% of national sales, respectively. Fertilizer sales are seasonal and correspond to the three main cropping seasons. During 1978/79 and 1979/80, annual sales averaged 29%, 32%, and 39% in the Aus, Aman, and Boro seasons, respectively. Fertilizers have been sold to farmers at prices fixed and subsidized by the government. In April 1982 farm-level prices were deregulated on a trial basis in the Chittagong Division. The apparent success of the trial program suggests that price deregulation in other divisions should be considered. Prices have risen steadily, reflecting past rises in world market prices and reductions in the government subsidy. Effective July 1, 1982, the prices were as follows: urea 148 TK/md, powdered TSP 110 TK/md, granular TSP 140 TK/md, DAP 148 TK/md, and MP 110 TK/md.

In December 1978, BADC instituted a New Marketing System (NMS) on a trial basis in the Chittagong Division. This system was gradually expanded to all

Divisions in July 1980. The central aim of the NMS is to promote the expansion and equity of fertilizer use by increasing the efficiency of the fertilizer delivery system. Most of BADC's local marketing and distribution functions were to be transferred to private and cooperative retail dealers. It was believed that these retail dealers would be more responsive to meeting farmers' needs in a more cost-effective manner than that achieved under the previous heavily public sector-oriented Old Marketing System (OMS).

The structure and operation of the NMS were founded on the following concepts:

1. The BADC would confine its sales to dealers to sales from a restricted number of primary distribution points (PDPs) and local factories rather than to the inordinately large number of thana sales centers (TSCs). Retail dealers would bear the cost of transporting purchased fertilizers from the sourcing point to their dealerships and would thereby lower BADC's distribution costs.
2. Dealer licensing regulations would be liberalized. Any individual or organization could register as a fertilizer dealer and buy and sell fertilizers anywhere in the country, except in a restricted border area.
3. Dealer commissions would be adjusted to provide the incentive necessary to aggressively promote fertilizer sales. Quantity discounts would be offered to encourage development of a wholesale dealer apparatus.
4. Institutional credit programs would be developed to assist dealers and farmers in financing fertilizer purchases.

The innovative reforms of the NMS have fostered improvements in the marketing system, but in some instances ineffective implementation measures have hindered the realization of the potential benefits of the NMS. The main problem areas were failure to close surplus TSCs promptly, lack of product availability and choice, time-consuming dealer lifting procedures, inadequacy of dealer commissions, erosion of the fertilizer marketing role of TCCAs, and inadequate dealer and farmer credit delivery systems. Under the NMS, TSC closures have been expedited, dealer commissions modified, and credit systems have been formulated.

The main fertilizer marketing-related policy considerations relate to (1) removing the constraints that have impeded implementation of the NMS and (2) instituting organizational and operational reforms to support and expedite the improved performance of the NMS.

NMS Implementation

The following changes in, or reinforcement of, NMS implementation policy would revitalize the implementation process and improve the efficiency and cost effectiveness of NMS.

1. Sales Points--Reexamine the role of the TSC in dealer sales program. To reduce operating costs, continue to enforce the present policy directive calling for closure of all TSCs whose sales have declined to less than 50% of OMS volume.
2. Order Processing--To expedite dealer liftings at PDPs, permit warehouse storekeepers to process orders as received instead of requiring prior approval by Thana Inspectors. Increase the minimum lifting quantity from 1 ton to 3 tons to reduce processing and handling time.
3. Sales Planning--To provide dealers with the quantities and types of fertilizers required to satisfy farmer demand, improve short- and long-range market demand forecasting techniques and plans. Coordinate marketing plan supply needs with product sourcing, movement, and storage capabilities. Monitor sales performance against plan.
4. Dealer Motivation--To encourage greater dealer involvement in promoting fertilizer sales, continue to examine and restructure the scale of dealer commissions to provide adequate compensation for dealer investments in time and capital. Provide for volume and seasonal discounts, based on cost reductions to BADC, to promote off-season movement.

   Expedite implementation of dealer training programs to improve the business management, fertilizer selling, and market development (farmer assistance) skills to enable dealers to expand sales and profits and make fertilizer retailing a financially more attractive business.

   Continue to cooperate with government and banking authorities in devising and implementing schemes for providing dealers with short-term credit to finance fertilizer inventories. Encourage dealers to extend short-term credit to farmers.

   Institute dealer awards to recognize and reward superior performance against established sales and farmer service criteria.

   Develop closer working relationships between dealers and BADC sales staff; streamline dealer recordkeeping requirements and inspections.
5. Thana Central Cooperative Association (TCCA)--Encourage continued participation of TCCA in fertilizer wholesaling to foster increased and equitable competition with private sector dealers and thereby improve farmer service.

6. BADC Organization--Adjust the organizational structure and staff to support the basic NMS strategy of strengthening the dealer's role in fertilizer marketing. Staff and programs will need to be strengthened to implement planned dealer training and credit activities and to aid dealers in developing intensified fertilizer promotion programs.

   Strengthen BADC and fertilizer dealer farmer assistance capabilities and programs to complement the extension activities of MAF.

7. Fertilizer Control--Establish and enforce fertilizer control standards to encourage production of ongrade fertilizers and discourage product adulteration and short weighing at the source and dealer levels.

Fertilizer Distribution

Distribution System Issues and Options

Although local shortages of supply have arisen because of inadequacies in infrastructure and organization, in the past year almost a million tons of fertilizer was distributed throughout Bangladesh.

Additionally, over at least the past decade, studies on the Bangladesh fertililizer system and transportation systems have proceeded on a continuous basis. Several major studies have investigated various aspects of fertilizer import, handling, transportation, and storage that affect BADC interests. Considerable effort and investment is therefore already committed to improvements of the infrastructure and of BADC facilities and organization. There remains, however, the need for considerable additional capital expenditure on physical distribution facilities throughout Bangladesh, as well as attention to improvements in organization and planning. A review of the overall system was conducted by IFDC for BADC in 1981, and work is in progress on many of the problem issues.

Significant savings in overall cost of imported fertilizer and in foreign exchange can be made by importing in bulk and bagging in the ports, rather than importing bagged fertilizer. A recent calculation indicates a saving of $4 million overall and $9 million in foreign exchange at 1982/83 import levels (275,000 mt) by importing in bulk. The BADC efforts to convert bagged to bulk imports should be continued on a priority basis.

The railway system is currently in poor condition and is not realizing its potential for movement of commodities. The World Bank Fertilizer Transportation Improvement Project now in progress involves a major investment in improving

rail facilities specifically for fertilizer movement. An important component is the introduction of unit train services for fertilizer movements from the factories and ports. The BADC should maintain close contact with these developments.

On road and waterway movements, existing facilities are adequate to move the required tonnages. With investments and improvements planned in these systems, there should be adequate carrying capacity available for future fertilizer movement requirements. The BADC problems with movement by truck or barge have dealt more with contract and payment procedures than with equipment availability. Steps being taken to overcome these problems should be continued.

The need for adequate warehousing in the consuming areas was recognized at an early stage by BADC, and considerable assistance was given by a range of donors, particularly the United States Agency for International Development (USAID), in providing warehousing accommodation to supplement BADC's own construction programs. Under the National Fertilizer Storage Plan (NFSP), a total of 657,500 tons of in-country storage accommodation is envisaged to meet 1985 requirements. This includes 162,500 tons of transit capacity at 11 locations and 495,000 tons of PDP capacity at 88 locations.

With improvements in infrastructure, transportation, and management systems, this storage should be adequate for requirements beyond 1985, particularly with attention to storage at dealer and village level. It is recommended that emphasis be given to construction of storage at dealer and village levels in the 20- to 100-ton capacity range. This will complement the current changes under the NMS that recommend transferring the TSCs to dealers. Many of these are of 200- or 400-ton capacity.

For overall efficient operation of the system, improvements in organization, planning, and operation are essential. These were addressed earlier in the marketing section. The BADC should proceed with establishing a central control unit to serve as a data base and control center for all supply, distribution, marketing, and financial functions and operations.

Future Development of the Fertilizer Supply System

Integration of Production and Marketing/Distribution Functions

In Bangladesh, domestic fertilizer production responsibilities are shared by BCIC and ZFCL, while the marketing and distribution function is vested in BADC. The main policy issue facing a fertilizer sector operating under such

a division of responsibilities and authorities is one of coordinating both functions to effect a least cost overall supply system.

To facilitate the establishment of a more cost-effective integrated production-distribution system, wherein shipments to field warehouses are made on a regular planned schedule which corresponds to highest plant operating rates, it is suggested that the GOB conduct an in-depth study of the feasibility of consolidating the fertilizer production and marketing functions under one national fertilizer organization with overall responsibility for the development and operation of all phases of the Bangladesh fertilizer sector.

Private Sector Fertilizer Supply System

Planning the longer term development of the overall fertilizer supply system to improve performance and cost effectiveness is a major issue facing the GOB.

In line with the GOB's recent emphasis on transferring the operation of industries from the public sector to the private sector, consideration should be given to private-sector operation of the marketing and distribution function, the production function, or both, either as separately operated entities, or as one entity responsible for production and marketing and distribution. Action should not be taken precipitously however; careful government studies should be made to determine the potential benefits of this transfer and the forms it might take.

II. INTRODUCTION

The potentially important contribution of fertilizers in stimulating sorely needed food production in Bangladesh is unquestioned. In spite of this awareness, as evidenced by increased consumption of fertilizer and other agricultural inputs in recent years, uncertainty and apprehension persist as to the best way to provide an adequate supply of fertilizer and to derive maximum benefits from its use in the years ahead. The GOB, through its agricultural and planning institutions, clearly appreciates the need to chart ever more sharply defined strategies to overcome the already burdensome impediments to fertilizer supply and use, the number and complexity of which will certainly increase as greater reliance is necessarily placed on fertilizers in meeting planned food-grain self-sufficiency targets.

Aware of this need, the Chairman of BADC, the entity of the Ministry of Agriculture and Forests responsible for fertilizer marketing and distribution, called on IFDC for assistance in formulating fertilizer supply and use policies consistent with GOB agricultural development plans and associated food production goals. It was proposed that this activity be included under the ongoing BADC/IFDC fertilizer marketing and distribution consultancy services agreement, which is being funded by USAID as part of its Fertilizer Distribution Improvement Project.

IFDC, in association with representatives of BADC, USAID, MAF, the Planning Commission (PC), and BCIC, prepared a draft project outline (Annex I) to clarify the nature of this activity. This was supported by a subsequent memorandum (Annex II) issued by the MAF authorizing the preparation of a "Bangladesh Fertilizer Supply and Use Policy Consensus Report" to define strategies for an optimal allocation of external and internal resources for fertilizer supply and use consistent with national food production plans. A committee of senior Bangladeshi scientists was selected to prepare background papers assessing specific subject matter areas in accordance with specified terms of reference (Annex III).

The subject matter review papers were presented and tentative recommendations for fertilizer supply and use policies were developed at a seminar held in Dacca in March 1981. Participants included policymakers, senior administrators, and scientists of MAF, PC, BADC, BCIC, and representatives of the donor community. Copies of the review papers and proceedings of the seminar are on file in the BADC library; titles of the papers are listed in Annex IV. A draft report, available at the BADC library, entitled "Bangladesh Fertilizer Supply and Use Policy

Consensus Report" was subsequently prepared by a group of selected Bangladeshi and IFDC scientists at a workshop held at IFDC Headquarters in April 1981.

Although the draft report portrayed, as was the intention of its authors, a consensus on fertilizer policy issues and strategies, the comments of national policy-level reviewers indicated the need for a more sharply focused policy document with a broader scope for application by planners and managers of the nation's agricultural sector. Thus, the fertilizer policy report has evolved from a consensus document to its present form--a more definitive policy document intended to provide guidance in identifying and formulating national-level fertilizer supply and use policies that are compatible with and linked to the food production component of overall agricultural sector development plans. The policy issues and the accompanying policy/strategy options discussed here are based on the draft policy consensus report and the background papers prepared by Bangladeshi experts as supplemented by information derived from IFDC studies dealing with various aspects of fertilizer supply and use.

This document deals with fertilizer supply and demand issues as they relate, in the main, to the attainment of the food production goals enunciated in the Medium-Term Foodgrain Production Plan (MTFPP). The MTFPP is the blueprint for achieving the FY 1985 foodgrain self-sufficiency target of the Second Five-Year Plan (SFYP) of the GOB. In keeping with the broader and longer term objectives of this effort, consideration is given to developing policy issues and strategies that would be applicable throughout the entire decade of the 1980s.

Although the important interrelationships between fertilizer and other input policies related to irrigation, pest control and modern seed varieties are recognized, no attempt is made to develop policy issues or strategies governing these elements of agricultural development, nor has any attempt been made to monitor and evaluate progress in implementing MTFPP programs. To do so would be to venture far beyond the scope of this endeavor. Where applicable, however, the fertilizer policies discussed herein have been linked to the agricultural input strategies put forward in the MTFPP.

The opening sections of this report provide an overview of the Bangladesh agricultural sector with emphasis on the objectives of sector planning and the role of fertilizers in agricultural development. The key fertilizer policy issues affecting use and supply are brought into focus and addressed in succeeding sections. In keeping with the restated objectives of this effort, policy options are presented, where possible, for overcoming the constraints on the availability and/or efficient use of fertilizers necessary to

achieve established foodgrain production targets. In cases where data limitations or other factors preclude the delineation of definitive policy options, suggestions are offered for developing the necessary knowledge base. The fertilizer policy options given herein are creatures of the moment, mandated by existing conditions or those foreseen for the near future. They are necessarily subject to change as the premises on which they were based change. Accordingly, this type of study should be repeated as needs dictate to ensure that all elements of fertilizer sector development are in harmony with overall agricultural development plans.

Grateful acknowledgment is made for the support and assistance given this endeavor by the management and staffs of MAF, BADC, BCIC, BARC, the PC, and other government bodies. The USAID support of this effort also merits acknowledgment. Recognition should be afforded FAO, UNDP, the World Bank, and other service and donor agencies which, although not directly involved in this study, have contributed to the advancement of agriculture in Bangladesh and whose experiences have been drawn upon in the preparation of this document.

III. AGRICULTURAL DEVELOPMENT

Background

Bangladesh, a nation of some 90 million inhabitants crowded into an area of about 35 million acres, ranks as one of the poorest of the world's developing countries. Agriculture is the mainstay, however tenuous, of the national economy and contributes about 55% to gross domestic product (GDP). Crop production, mainly in the form of foodgrains, is the dominant agricultural subsector accounting for about 80% of the value of annual farm output. Over 90% of its people reside in rural areas; about 80% derive their livelihood from agriculture. About one-half of its farmers are effectively landless, owning no land or less than 0.5 acres. The average per capita annual wage is less than $100; farm wages are generally lower. Approximately one-third of the working population is unemployed or underemployed. Unemployment is particularly acute among the rural population. The outlook for increased employment is bleak, since the possibility for extending the area under cultivation is practically nonexistent. Malnutrition is widespread and severe. Nearly 87% of the farm dwellers subsist below the poverty level as defined by a minimum daily requirement of 2,122 calories. On average, the nation's overall population fares only marginally better.

The nation's chronic food shortages stem from the sluggish and erratic growth of domestic crop production which, all too often, has been adversely affected by the forces of nature and has failed to match the pace of population growth. Although record foodgrain production levels were achieved in the late 1970s, the annual rate of growth of food output during most of that decade averaged slightly less than 2%; in contrast, the population growth rate was close to 3%. As a consequence, the nation has grown increasingly dependent on imports for its foodgrain requirements. In 1969/70, Bangladesh imported about 1.55 million tons. A decade later, in 1979/80, a year of abnormally adverse weather conditions, imports approximated 2.7 million tons. Financing of food imports has exerted a negative impact on the country's limited foreign exchange reserves, these resources having been used, in part, to pay for the importation of donor-community food grains provided at concessionary terms. During the period 1973/74-1977/78, payments for foodgrain imports totaled US $1.6 billion; in 1979/80, the estimated expenditure was US $0.8 billion.

Agricultural productivity in Bangladesh ranks among the lowest in the world. Yields of rice, grown on three-quarters of the cropped acreage, average about 0.5 mt/acre, only about 50% of the average yield in Asia. Most of the arable land is already under cultivation, but only about one-half of it is double cropped. Expansion of crop production will necessarily have to come from increased yields based on more intensive and cost-effective land and input use.

The relatively high native fertility of its alluvial soils, the abundance of water resources, and the large farm labor force provide a basis for optimism that food production in Bangladesh can be raised significantly if the required human, physical, and financial resources for change can be effectively assembled and applied.

The central thrust of GOB agricultural development planning in the post-War of Independence era has been to attain self-sufficiency in foodgrain production as a means for alleviating persistent and widespread food shortages. Despite the ostensibly high priorities accorded agricultural sector development in a succession of national economic development plans, agriculture development has followed a torturous path strewn with formidable and, at times, seemingly unsurmountable obstacles of internal and external origin, all too frequently exacerbated by natural calamities.

First Five-Year Plan (FFYP)

The First Five-Year Plan (FFYP) for 1973/74-1977/78 was concerned primarily with reconstructing the war-ravaged economy, reducing poverty, and achieving social justice. Attainment of food self-sufficiency was the major goal of agricultural sector development. Doomed to failure almost immediately by global inflation and recession and unfavorable weather, plan priorities were recast into a Hard Core Programme (HCP) to be operative during the last 3 years of the FFYP.

Plan performance improved under the HCP, but overall achievements fell far short of FFYP targets largely because of the weakness of the world economy and its debilitating effect on availability of domestic and foreign financing, the lack of skilled manpower, inadequate institutional infrastrusture, and the vagaries of nature. Agricultural sector growth (3.7%/year) lagged behind GDP growth (4.0%/year), and its share of GDP declined from 61% to 57% during the plan period. Food output (2%/year) failed to keep pace with population growth

(3%/year). Although a record foodgrain production was established in 1977/78, this level was about 15% below the plan target. During the FFYP, food imports increased as did reliance on foreign aid. About 60% of the irrigated acreage target of 4.92 million acres was realized. Seed distribution was hampered by bottlenecks in the supply system. Fertilizer nutrient use rose about 80% to 336,000 tons ($N + P + K_2O$) in 1977/78, but its rate of use of 24.1 lb/acre was among the lowest in the world.

Two-Year Plan

Despite its limitations, the FFYP served to better define the complex nature of the agricultural development issues to be resolved and provided a better understanding of the financial, physical, and management resources required for successful plan implementation. The uncertainty of foreign aid, the need to reorient policies, and the desirability of concluding ongoing projects with available resources led to postponing the development of a Second Five-Year Plan (SFYP) in favor of a Two-Year Plan (TYP) for 1978/79-1979/80.

The TYP also fell short of its goals. The GDP grew at an estimated 5%/year while the average annual growth rate of the agricultural sector declined to 3.1% versus 3.7% during the FFYP. Annual foodgrain production in 1978/79 and 1979/80 approximated that of the 13.1 million ton record set in 1977/78. Food imports increased to 2.7 million tons in 1979/80 because of drought and floods. Little progress was made in population control. Irrigated area rose about 15% to 3.65 million acres. The rate of growth of fertilizer nutrient use showed signs of stabilizing. In 1979/80, total nutrient use was 401,000 tons, up about 15% from 1977/78.

Second Five-Year Plan

The basic objectives of the SFYP (1980/81-1984/85) closely parallel those of the earlier plans noted above. Its main theme is to reduce poverty in the heavily populated, poverty-ridden rural areas by accelerating development of the agricultural sector. Attaining self-sufficiency in foodgrains, at a higher level of per capita consumption, is a major goal of the SFYP as it had been of earlier plans.

To stimulate foodgrain output, the GOB formulated a Medium-Term Foodgrain Production Plan (MTFPP) to serve as a blueprint for achieving foodgrain self-sufficiency by 1984/85, the terminal year of the SFYP. To avoid repetition, the salient features of the SFYP, at they pertain to fertilizer and other agricultural input and output targets and their relation to foodgrain production, are included in the discussion of the MTFPP which follows.

Medium-Term Foodgrain Production Plan

The MTFPP represents an attempt to bring an additional dimension of order and coherence to managing the longer term and technologically focused development of the nation's still largely subsistence-type agriculture. In the past, plans for agricultural sector growth often have been administered on a crisis, ad hoc basis in a continuing effort to avert the omnipresent danger of catastrophic famine occasioned by recurring shortfalls in food supply. Planning and management of such essentially short-term food policy have further strained the nation's already limited administrative and financial capabilities.

The MTFPP provides a basis for linking anticipated fertilizer supply, marketing and distribution, and use factors with the latest and most definitive information available on foodgrain production plans and goals. Obviously, fertilizer supply and use policies must be coordinated with the nation's overall economic and agricultural development plans.

Concepts and Strategies

The central strategy of the MTFPP is to stimulate agricultural production, mainly foodgrains, by providing the nation's predominantly small and resource-limited farmers with a more stable, less risk-prone production environment. This is to be accomplished with the following measures:

1. Providing farmers with assured foodgrain price incentives by improving the government's foodgrain procurement system, encouraging private trade, and upgrading the transportation infrastructure. Adequate output prices are of singular importance in view of the planned elimination of fertilizer subsidies by 1984/85.
2. Improving water control capabilities through increased public financing of irrigation, drainage, and flood protection projects.

3. Assuring adequate and timely supplies of fertilizer, seeds, and other inputs to match anticipated demand.

To support these programs, agricultural institutes involved in research, extension, credit, and input supply are to be strengthened with additional staff, equipment, and funds.

The principal goals of MTFPP expressed in terms of main output and input targets are summarized in Table III-1.

Output Targets

The MTFPP deals almost exclusively with rice and wheat, which collectively account for about 85% of Bangladeshi total calorie intake. The plan calls for a gross production of 20 million tons, about 17.5 million tons of rice and 2.5 million tons of wheat in 1984/85. The combined targeted output is about 7 million tons above production in 1977/78, the benchmark year; about 68% of the anticipated increase is attributed to rice.

Bangladesh population in 1984/85 is projected to be 102 million. If the targeted gross output is reduced by about 10% to account for seed and animal feed uses, and losses, the net tonnage (18 million tons) available for human consumption will provide an average of 15.5 oz per person per day. This amount is equivalent to a daily intake of 1,525 calories, about 70% of the average minimum daily requirement.

Significant changes in cropping patterns and yields are foreseen under the MTFPP (Table III-2). Essentially all of the expected new production is to be derived from more intensive use of land currently under cultivation, through a combination of expanded use of HYV and local improved variety (LIV) seeds, irrigation, and improved cultural practices (Table III-3). Over half of the new production is related to improvement and expansion of irrigation. In the past, expansion of Boro rice and wheat acreage provided the basis for expanded foodgrain production. Under the MTFPP plan, irrigation and flood control are expected to allow a more evenly distributed growth in all four crops--Boro, Aus, and Aman rice and wheat.

Input Targets

Under the MTFPP major emphasis is placed on spurring output through expanding and accelerating the use of principal production inputs associated with modern agricultural technology. Water control is closely related to the use of other modern inputs; therefore, it has a critical role in achieving production goals.

Table III-1. MTFPP Output/Input Targets

Output/Input	Pre-MTFPP			MTFPP					MTFPP Increment
	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	
Foodgrain production (gross) million tons	13.1	13.0	13.3	15.4	16.2	17.3	18.6	20.0	6.7
Fertilizer (million tons)	0.715	0.730	0.840	1.000	1.200	1.430	1.665	1.900	1.060
Irrigated acres (million acres)									
Minor	1.810	2.050	2.230	2.620	3.142	3.898	4.560	5.250	3.020
Major	0.150	0.180	0.200	0.293	0.376	0.549	0.755	0.970	0.770
Traditional	1.200	1.200	1.200	1.000	1.000	1.000	1.000	1.000	-0.200
TOTAL	3.160	3.430	3.630	3.913	4.518	5.447	6.315	7.220	3.590

Source: Government of Bangladesh (1981).

Table III-2. MTFPP Foodgrain Production Targets by Crop

Crop	Benchmark 1977/78			Target 1984/85		
	Area	Yield	Production	Area	Yield	Production
	10^6 acres	mt/acre	10^6 mt	10^6 acres	mt/acre	10^6 mt
Rice						
Aus						
Rainfed	7.70	0.37	2.88	6.20	0.51	3.20
Irrigated	0.20	1.00	0.20	1.80	1.00	1.80
Total	7.90	0.39	3.08	8.00	0.62	5.00
Boro	2.70	0.83	2.24	3.75	0.93	3.58
Aman						
Rainfed	13.99	0.51	7.25	13.00	0.59	7.80
Irrigated	0.20	0.93	0.18	1.10	1.00	1.10
Total	14.19	0.53	7.43	14.10	0.62	8.90
Total Rice	24.79	0.51	12.75	25.84	0.67	17.48
Wheat						
Rainfed	0.08	0.30	0.02	1.10	0.50	0.55
Irrigated	0.39	0.80	0.31	1.80	1.10	1.98
Total Wheat	0.47	0.70	0.33	2.90	0.87	2.53
Total Rice and Wheat	25.26		13.08	28.75		20.01
Other Crops	5.94			6.00		
Total Cropped Area	31.20			31.75		
Net Cultivated Area	22.50			22.50		
Cropping intensity	139%			154%		

Source: Government of Bangladesh (1981).

Table III-3. Sources of Incremental Foodgrain Production in 1984/85[a]

	Million Tons
Benchmark production, 1977/78	13.1
Contribution from:	
Switch to rainfed HYV for Aus/Aman (2.5 million acres @ 0.4 tons/acre)	1.0
Expansion of rainfed wheat area (1.0 million acres @ 0.5 tons/acre)	0.5
Improved cultural practices (2.5 million acres at an improved yield of 1 maund/acre)	1.0
Improved use of existing irrigation facilities for Boro/wheat/early Aus cultivation (500,000 acres at 1 ton/acre)	0.5
New irrigation facilities for Boro/wheat/early Aus cultivation (3.0 million acres @ 1 ton/acre)	3.0
Supplementary Aus/Aman irrigation (2.00 million acres @ 0.25 tons/acre)	0.5
Drainage and flood control protection (1.5 million acres @ 0.25 tons/acre)	0.4
Gross 1984/85 production	20.0
Less 10% contingency for adverse weather, program shortfalls, etc.	2.0
Net fiscal year production	18.0

a. See source table for detailed assumptions used in estimating contributions by source.

Source: Government of Bangladesh (1981).

Water Control--The major contribution to increased foodgrain production under MTFPP is to come from a doubling of irrigated acreage from about 3.6 million acres to 7.2 million acres in 1984/85 and improving drainage and flood control on about 2.0 million acres to benefit mainly Aman and Aus rice production.

The irrigation component of the MTFPP comprises so-called minor irrigation projects that are technically simple and that have a low per-acre cost. The projects involve low-level lift pumps, deep and shallow tubewells, and hand tubewells, and they will be responsible for about 80% of the incremental irrigated area to be developed under the plan (Table III-4). Increases in irrigated acreage will depend largely on the pace of tubewell installations which will in turn be governed by the efficiency of procurement and distribution of equipment and the adequacy of farmer incentives to install such systems.

Fertilizer--The MTFPP calls for fertilizer use to more than double by 1984/85. This projection is based on future usage conforming to a 17% annual growth rate. About 80% of 1984/85 fertilizer demand is slated to be used on paddy and wheat (Table III-5). Again, most of the increase in fertilizer use is expected to arise from more efficient and expanded use of irrigation and other water control projects.

Regarding fertilizer supply, the MTFPP cites the need for stabilizing domestic fertilizer production and bolstering supply with timely imports controlled by strict procurement schedules. Improvements in fertilizer distribution expected to accrue from new warehouses being built under the national warehouse construction program are also noted. The institution of the New Marketing System oriented toward the private-sector dealer is expected to benefit the farmers; increased retailer competition is foreseen as improving fertilizer availability and lowering farm-gate prices.

HYV Seed--The MTFPP envisages a major increase in the use of HYV and LIV seeds. Institutionally supplied HYV seed is expected to register a tenfold increase from a current level of about 6,200 tons (1,700 tons of paddy and 4,500 tons of wheat) to about 58,000 tons (13,000 tons of paddy and 45,000 tons of wheat) in 1984/85. The seed requirements given in the MTFPP are at wide variance with those presented in the SFYP. Adequacy of supply of HYV seeds is a critical factor to the success of the MTFPP. More wheat seed is required as are increased supplies of BR-10 and BR-11 Aman rice varieties which show better response to fertilizer. The existing contract seed grower system is to be enlarged, and significant investments are to be made in four seed production projects.

Table III-4. Summary of MTFPP Irrigation Program

Program Category	Benchmark 1977/78		Actual		Target 1984/85	
	No. Operating	Area (million acres)	No. Operating	Area (million acres)	No. Operating	Area (million acres)
Minor irrigation						
Low level pump	36,700	1.36	38,600	1.40	51,000	2.00
Deep tube well	7,500	0.34	10,000	0.55	25,000	1.50
Shallow tube well	12,000	0.10	20,000	0.22	130,000	1.60
Hand tube well	40,000	0.01	100,000	0.06	500,000	0.15
TOTAL		1.81		2.23		5.25
Major irrigation		0.15		0.20		0.97
Traditional irrigation		1.20		1.20		1.00
GRAND TOTAL		3.16		3.63		7.22

Source: Government of Bangladesh (1981).

Table III-5. MTFPP Projected Fertilizer Requirements for 1984/85

	Thousand Tons
Benchmark estimated consumption for paddy and wheat 1978/79	594
Sources of increased fertilizer use:	
Switch to rainfed HYV Aus/Aman (2.3 million acres @ 150 lb/acre)	154
Expansion of rainfed wheat (0.9 million acres @ 50 lb/acre)	20
Improved cultural practices (assured half of incremental production due to fertilizer use at response ratio of 3:1)	149
Improved capacity utilization of existing irrigation plus new irrigation (3.5 million acres incremental Boro HYV, early Aus HYV, and wheat at 300 lb/acre)	470
Supplementary irrigation (2.0 million acre increment at 100 lb/acre)	89
Drainage and flood control (1.5 million acre increment at 100 lb/acre)	67
Total required for paddy and wheat	1,543
plus 20% for other crops	309
Total all crops	1,852
Contingency	38
GRAND TOTAL	1,900

Source: Government of Bangladesh (1981).

Pesticides--The success of the MTFPP pest control program is seen to be largely dependent on the judicious and expeditious authorization of input licenses and foreign exchange requirements to the pesticide marketing system now controlled by the private sector. A large public investment is slated for strengthening the Plant Protection Directorate (PPD) of the Ministry of Agriculture. Responsibilities of the new PPD would include (1) the timely dissemination of information on pest infestations to extension workers, farmers, and the pesticide trade and (2) ensuring safety in the choice and handling of pesticides.

Other Inputs--With animal draft power expected to continue as the predominant source of farm power in the foreseeable future, the MTFPP provides for an animal health care program to improve the quality, health, and productivity of draft animals currently in poor condition.

Major investments are to be made to improve the marketing, storage, and transportation of foodgrains. These improvements include (1) the construction of 1 million tons of foodgrain storage capacity in producing areas and (2) the improvement of the rural road network, particularly farm to market roads.

To provide farmers with the technical information required to make efficient use of farm inputs, particularly HYV-fertilizer technology and water control, significant investments are proposed for expanding and strengthening agricultural research, extension and training facilities, and programs. Major investments are also planned to expand the programs of other rural institutions, including cooperatives, the Integrated Rural Development Program (IRDP) and the rural electrification program.

Implementation Cost

The total financial cost, from public and private sources, of implementing the MTFPP plan approximates US $5.4 billion based on constant 1980 prices. Total public sector investment expenditures are estimated at about US $3.2 billion, with private sector financing contributing about US $2.1 billion. The foreign exchange requirement is projected at about US $2.9 billion.

A schedule of proposed expenditures by principal investment categories is given in Table III-6. About 85% of the total estimated outlay is directed to these programs related to improving the farmers' economic and natural environment: (1) irrigation, drainage, and flood control (35%); (2) input delivery and distribution systems (41%); and (3) marketing and distribution systems and infrastructure (10%). Lesser investments are designated for strengthening rural

Table III-6. Summary of MTFPP Projected Financial Requirements (US $ Billion at Constant 1980 Prices)

Cost Component	Sector: Public[a]	Sector: Private[b]	Total MTFPP[c]	Foreign Exchange Needs
Minor irrigation	0.56	0.67[d]	1.23	0.76
Major irrigation, drainage/flood control	0.63	-	0.63	0.22
Fertilizer, pesticides and seeds	0.71	1.47[d]	2.18	1.46
Marketing, storage, and transport	0.55	-	0.55	0.18
Subtotal	2.45	2.14	4.59	2.62
Research, extension, and training	0.17	-	0.17	0.06
Rural institutions and infrastructure	0.60	-	0.60	0.22
TOTAL	3.22	2.14	5.36	2.90

a. Gross outlays net of recoveries from the private sector sale of irrigation equipment, fertilizer, etc.
b. Private sector purchases under a excludes private sector investments in hand.
c. Excludes public sector investments realized through mobilization of voluntary labor.
d. Private sector share of financing 54% and 67%, respectively, in minor irrigation and supply of recurrent inputs. Achievement of given levels based on assuring investment incentives.

Source: Government of Bangladesh (1981).

institutions and infrastructure and for expanding agricultural research, extension, and training.

Implementation of the MTFPP will require major external financial support. The plan provides potential donors with a comprehensive portfolio of specific and prioritized investment programs to facilitate donor project assessment and selection.

The unsatisfactory levels of foodgrain production in the past have been ascribed largely to the long delays and excessive cost overruns encountered in implementing earlier agricultural and irrigation development plans. Major constraints to improved plan implementation and mobilization of foreign aid have been cited as (1) lack of well-prepared and clearly focused investment projects and programs, (2) delays in equipment procurement and contracting, (3) inadequate and uncertain budget allocations and delays in release of funds, and (4) inadequate monitoring due in part to poor information flows.

The MTFPP recognizes the need for change in implementation procedures and sets forth corrective measures to facilitate achievement of its ambitious targets. The scope of the MTFPP requires human, physical, and financial resources far beyond those accorded in earlier agricultural development efforts. The success of the MTFPP will depend on how effectively these resources are assembled and managed in implementing the program.

Fertilizer Policy Aspects of Agricultural Development

As employed in this report, the term "fertilizer policy" is used to denote those aspects of public policy that impinge, directly or indirectly, on the functions of the national fertilizer sector or any of its components. Because of the interrelationships between the fertilizer sector and other segments of the nation's agriculture, industry, and commerce, fertilizer policies form an integral part of overall national economic development planning. Accordingly, to be effective, fertilizer policies must be consistent with the aims of stated national goals and directed to achieving them in a properly sequenced and cost-effective manner.

In predominantly agricultural countries, such as Bangladesh, overall national development is tied directly to the rate and level of growth of agriculture. In land-scarce Bangladesh, agricultural growth and food output will

have to depend largely on increasing productivity through the expanded application of yield-augmenting inputs and technologies. As demonstrated in Bangladesh and elsewhere, fertilizer use enhances land productivity by increasing crop yields and, in so doing, eases the nutrient constraint to multiple cropping and land development programs. Proper and expanded use of fertilizer is one obvious path to overcoming the nation's agricultural land constraint.

Since fertilizer use generally increases crop yields in excess of corresponding incremental farm labor requirements, it can be seen as an effective tool for enhancing the productivity of farm labor. Also, as fertilizer production, distribution, and use are expanded, backward and forward linkages are developed which give rise to additional agricultural and industrial employment. The employment feature of fertilizer use is of particular appeal to labor-surplus Bangladesh. Increases in crop production may contribute to foreign exchange savings or earnings by reducing imports or expanding exports; this is also important to foreign exchange-poor Bangladesh.

Well aware of the benefits of and the potential for expanded fertilizer use, GOB policymakers are concerned with how to bring about the desired level of fertilizer use in the most cost-effective manner. There is a recognized need to identify those fertilizer supply and use constraints that limit the expanded and efficient use of fertilizers and to formulate policies and strategies to overcome them.

Elements of Fertilizer Policy

Fertilizer Use--Fertilizer use is, primarily, determined by the cost and benefit factors associated with its use. These include fertilizer and crop prices, crop response to fertilizers, availability and cost of complementary inputs (irrigation, HYV seeds, pest control chemicals), availability and cost of credit, adequacy and timeliness of fertilizer supply, level of fertilizer use knowledge, and the degree of economic and weather-related uncertainty or risk associated with agricultural production.

Experience has shown that effective government fertilizer use policies are those that afford farmers adequate economic incentives to increase fertilizer use or that relax or remove the constraints limiting their receiving potential economic benefits from using more fertilizers. Fertilizer use policies aimed at providing these economic incentives include (a) decreasing fertilizer prices

through subsidy or credit mechanisms, (b) increasing crop prices via price support or stabilization programs, (c) increasing crop response to fertilizer use through the adoption of improved fertilizer management practices such as nutrient balance, timing, and placement, and (d) increasing crop yields by expanded use of other inputs including water control, HYV seeds, and pest control chemicals.

Certain types of policies help to provide knowledge of the fertilizer response function. This information is needed to determine the economic optimum level of on-the-farm fertilizer use, and it will lead ultimately to increased crop response to fertilizer. Examples of such policies are (a) expanding agronomic research programs to generate information concerning the type of fertilizer to use and optimum quantities, timing, and placement under varying soil, climatic, and economic conditions; (b) supporting research to improve fertilizer materials and application methods; (c) increasing research to modify and improve water control capability and use of complementary inputs; and (d) expanding extension programs to hasten technology transfer that will aid farmers in applying existing and new fertilizer technologies.

Fertilizer Supply--The potential benefits of establishing a national fertilizer production capability, based on either indigenous or foreign raw materials as is economically feasible, can spur agricultural and industrial development of the nation and provide such ancillary benefits as security of fertilizer supply and price, foreign exchange savings or earnings, increased employment, and technological advancement; other benefits will emanate from decreased dependence on uncontrollable international market forces. Many developing countries have found that establishing local production facilities tends to promote increased fertilizer use.

Fertilizer supply-related policies usually pertain to the exploitation of indigenous fertilizer raw materials and the construction of fertilizer plants, based on the use of native or imported raw materials, to produce fertilizers for domestic consumption or export.

Policies related to resource development are generally directed to discovering and characterizing fertilizer raw materials reserves. Policies dealing with ownership of reserves, responsibilities for development, and incentives to stimulate exploration, evaluation, and exploitation of these reserves are required to assure their orderly and expeditious development. Where importation of fertilizer raw materials is required to sustain local

production, policies related to import duties, quantity limitations, and preferential trade agreements will be needed.

Policy decisions to construct new or expanded fertilizer production facilities must be based on realistic estimates of present and future market demand, coupled with the assessment of the government's ability to provide the raw materials, utilities, manpower, and financial resources necessary to build and operate the proposed plants at levels of cost that are competitive with alternative sources of supply. The construction of facilities to meet domestic or export market needs will necessitate policy decisions relating to the type, size, location, and operational jurisdiction of the proposed facilities. All of these policies will be shaped to some degree by the cost involved in providing the infrastructure required for the raw materials and finished product delivery systems. The type of ownership, public or private, of the production facilities and, if public, designation of the organization(s) responsible for operation of the plant and marketing and distribution system are singularly important aspects of government policy. Pollution control aspects of the manufacture, transport, and use of fertilizers will require policy actions.

Fertilizer Marketing and Distribution--The type (public, private, or mixed) and organizational features of the marketing and distribution system are determined by government policies that dictate its ownership and mode of operation. If responsibilities for operation of the fertilizer production and distribution systems are assigned to different government agencies, clearly defined policies will be needed to delineate areas of responsibility of the individual organizations; this will facilitate effective coordination in planning production and in moving fertilizer from plants to market areas. Government policies will be required to govern private sector and cooperative organizations engaged in fertilizer production and/or distribution.

Policies and strategies will have to be formulated for the balanced development of production and distribution infrastructure to ensure effective operation of both functions.

Realistic estimates of market demand are essential in preparing short- and long-term marketing plans and in planning the development and operation of an efficient national fertilizer sector. Government policy should delineate the agency responsible for organizing and preparing the short- and long-term market forecasts to be used for market planning and sector development purposes. Procurement policies and programs should effect the timely and cost-effective purchase and delivery of fertilizers required to satisfy market demand.

Policies and strategies relating to sales prices and practices must be developed, implemented, and monitored. Coordinating the farmer assistance activities of various government agencies involved in fertilizer research, extension, and marketing often requires government policy action. The government must also develop policies for allocating fertilizer supplies in times of shortage and national need.

IV. FERTILIZER USE

The agronomic issues that influence crop response to fertilizers are the nature of soil resources; irrigation; drainage; climate; pest incidence; crop species and varieties; nutrient sources; and rate, time, and placement of fertilizer. Some estimates of the influence of irrigation, drainage, and adoption of high-yielding varieties on fertilizer use and crop production are given in a joint BARC/IFDC report (Sidhu, Baanante, and Ahsan, 1982) and in succeeding sections of this document. Climate and pest incidence influence crop yields and crop responses to fertilizer but are not easy to quantify and even more difficult to predict. Thus, the agronomic issues discussed herein are confined to soil resources, crops, nutrient sources, and fertilization practices and their influence on crop response to applied nutrients.

Soils

Geomorphologically, the soils of Bangladesh are 80% floodplain and deltaic sediments, 8% terraces, and 12% hills. The largest group of soils are recent deposits from the Ganges, Brahmaputra, and Meghna river systems (Figure IV-1). Mineralogically, there are three kinds of sediments in the floodplains and deltas (Brammer, 1978):

1. Brahmaputra, Tista, and old Meghna estuarine sediments contain large amounts of biotite and feldspars but no calcium carbonate. Clays are mixed: kaolinite, illite, and chlorite.
2. Ganges sediments contain sand and clay minerals similar to sediments from the other three rivers, but in addition they contain calcium carbonate and montmorillonite clay.
3. Sediments derived from the eastern hills have small amounts of weatherable minerals and contain mixed kaolinite, illite, and chlorite clays.

The terrace soils are principally in two tracts: Madhupur and Barind. Each was developed on Madhupur clay of tertiary age. The Madhupur tract consists of a network of valleys and ridges, whereas the Barind tract is predominantly level. The Madhupur clay has weathered to various degrees depending on drainage in different areas but contains small amounts of weatherable minerals in all areas.

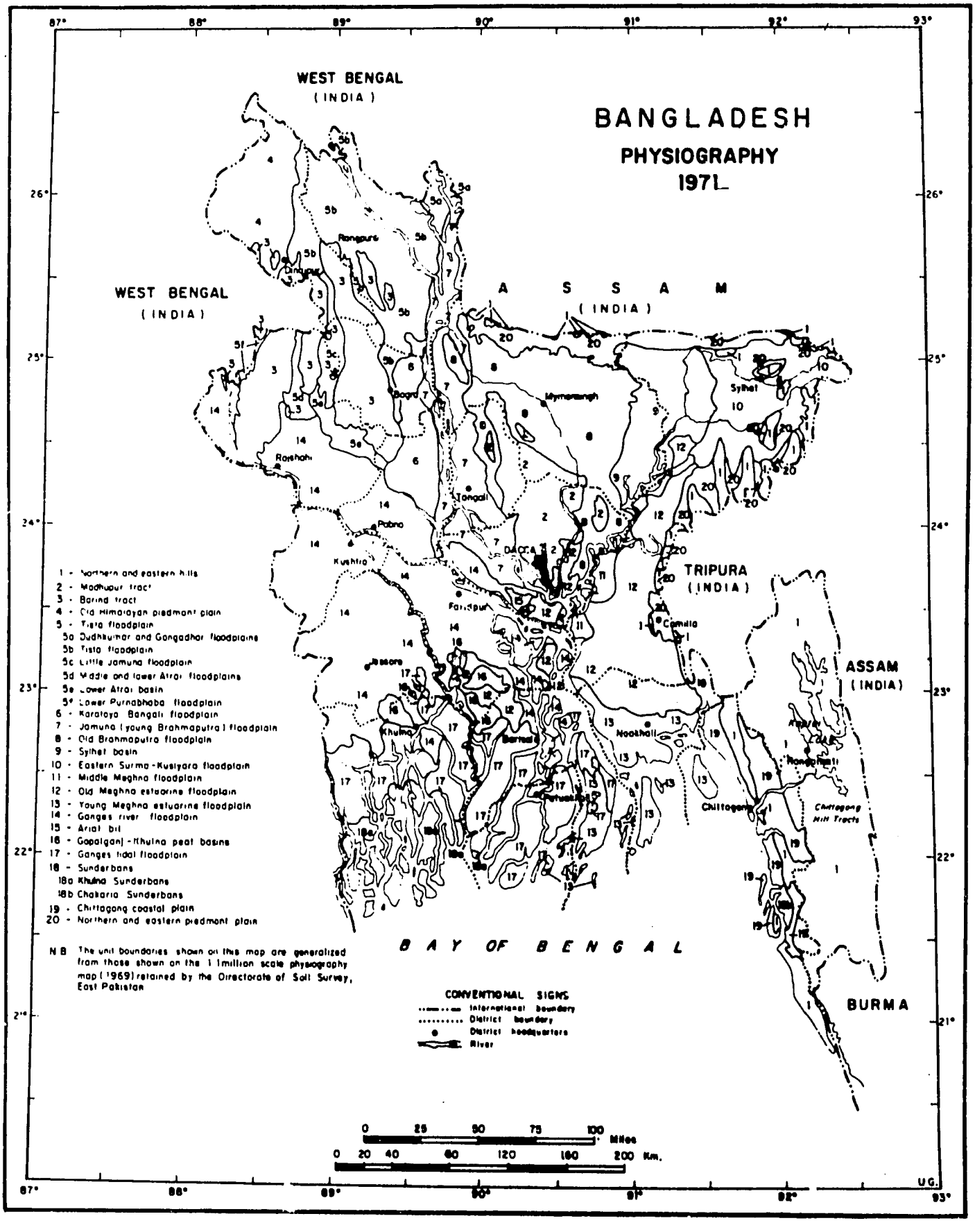

Figure IV-1. Bangladesh Physiography.

Source: Soil Survey Project, Bangladesh Agricultural Development Possibilities, AGL:SF/PAK6, Tech. Rpt. 2, UNDP, FAO, Rome. 1971.

The eastern and northern hill soils are derived from tertiary and quaternary sands and shales. Mineralogically, these soils have small amounts of micas and weatherable minerals; small areas contain calcium carbonate and moderate amounts of feldspars, amphiboles, or pyrites.

In broad-scale classification, groups of soils that have formed in the same way and that are similar in appearance are classified into soil types. In Bangladesh, soils are classified and mapped as 17 general soil types (Huq, 1981). Floodplain soils cover about 17.5 million acres, whereas hill soils cover 4.4; terraces, 3.1; acid basin clay, 2.5; alluvium, 2.2; piedmont, 1.1; acid sulfate, 1.1; and peat, 0.9 million acres. Selected characteristics of general soil types are listed in Table IV-1. Generally, the terrace, piedmont, and brown hill soils are of lower fertility than the alluvial and floodplain soils; however, there is great variability within units. Because most lands are flooded with rainwater or the raised groundwater table, the general fertility status is principally related to the nature of parent material rather than to the new sediments provided by current flooding. Flooding by silty waters is restricted to the foothills areas, tidal floodplains, and on some land near major river channels.

On a national scale, the soils are mapped as general soil units (Figure IV-2) because areas of the individual types are often too small to map. Also, certain types occur regularly and rather systematically in associations. Soil types within the general units differ in texture, moisture holding capacity, and level of soil fertility. Thus, the general soil-type classification system is not well suited as a basis for fertilizer recommendations. The soil series or family level of classification should provide a better basis.

About 500 soil series have been identified in Bangladesh. Mapping at the soil series level has not been done. Even at the soil series level, soil fertility status varies to some extent, primarily because of past cropping and management history. Although closer working relationships are developing between personnel involved in soil survey and soil fertility work, few fertilizer trial sites have been classified at the series level.

Policy Options Related to Soil Classification

Soil classification at the series and type level, including laboratory characterization, should be undertaken. Each of the 17 soil types should be rated for productivity of the major and minor crops produced in Bangladesh.

Table IV-1. Selected Characteristics of General Soil Types in Bangladesh

General Soil Type	Topsoil Texture[a]	Topsoil Reaction[b]	Subsoil Texture[a]	Subsoil Reaction[b]	Permeability	Fertility Status	Crop Area[c]	Principal Crops
1. N Cal Alluvium	S, Si, Cl	Neut.	S, Si, Cl	Neut.	Variable	Good	626	Mixed (Aus-Aman)
2. Cal Alluvium	S, Si, Cl	Cal.	S, Si, Cl	Cal	Variable	Good	2,290	T. Aman, Aus/Jute-Rabi
3. Acid sulfate	L, Cl	V. acid	Cl	V. acid	Slow	Fair-Poor	370	T. Aman
4. Peat	-	Acid	-	Acid	Rapid	Fair-Poor	879	B. Aman
5. Grey Fldpln	L, Cl	Acid	SiL, Cl	Neut.	Mod-slow	Fair-Good	8,115	Aus/Jute-T. Aman-Fallow/ Rabi, Mixed (Aus-Aman), B. Aman
6. Grey Piedmont	L, S	V. acid	L, S, Cl	Acid	Mod-slow	Fair	1,115	Aus-T. Aman-Boro
7. Acid basin clay	Cl	V. acid	Cl	V. acid	Very slow	Fair	2,504	Boro
8. NCal DGy Fldpln	L, Cl	Acid	SiL, Cl	Neut.	Mod-slow	Good	3,364	Aus/Jute-T. Aman-Fallow/ Rabi, Mixed (Aus-Aman)
9. Cal DGy Fldpln	Cl	Acid-neut.	Cl	Neut.-alk.	Mod-slow	Good	2,704	B. Aman-Rabi/Fallow, Mixed (Aus-Aman)-Rabi/Fallow
10. Cal Br Fldpln	L, Cl	Cal	L, SiCl	Alk.	Mod-rapid	Good	2,473	Aus/Jute-Rabi (Wheat, Pulses, Sugarcane)
11. NCal Br Fldpln	SL, SiL	Acid	SL, SiL	Acid	Rapid	Fair	882	Aus/Jute-Rabi (Sugarcane)
12. Black Terrace	SL	Acid-V. acid	SL	Acid	Moderate	Fair	226	T. Aman
13. Brown Hill	L	V. acid	L, S. Cl	Acid-V. acid	Rapid	Poor	4,389	Forest, Shifting Cultivation (Aus, Vegetables), Tea, Pineapple
14. Sh R-Br Terrace	L, Cl	V. acid	Cl, L	V. acid	Slow	Poor	98	Aus/Fiber Crops, Forest
15. Dp. R-Br Terrace	SL, ClL	V. acid	ClL, Cl	V. acid	Mod-rapid	Poor	980	Aus/Fiber Crops, Sesemum, Horticulture, Forest
16. Br Mtld Terrace	L, ClL	V. acid	ClL, Cl	V. acid	Mod-rapid	Poor	1,885	Aus-T. Aman
17. Grey Terrace	Si	Acid	Cl	Neut.-acid	Mod-slow	Poor	109	Fallow/Aus-T. Aman

a. S = sand, Si = silt, L = loan, Cl = clay.
b. Neut. = neutral, Cal. = calcareous, Alk. = alkaline, V. = very.
c. Area = '000 acres.

Source: Huq (1981).

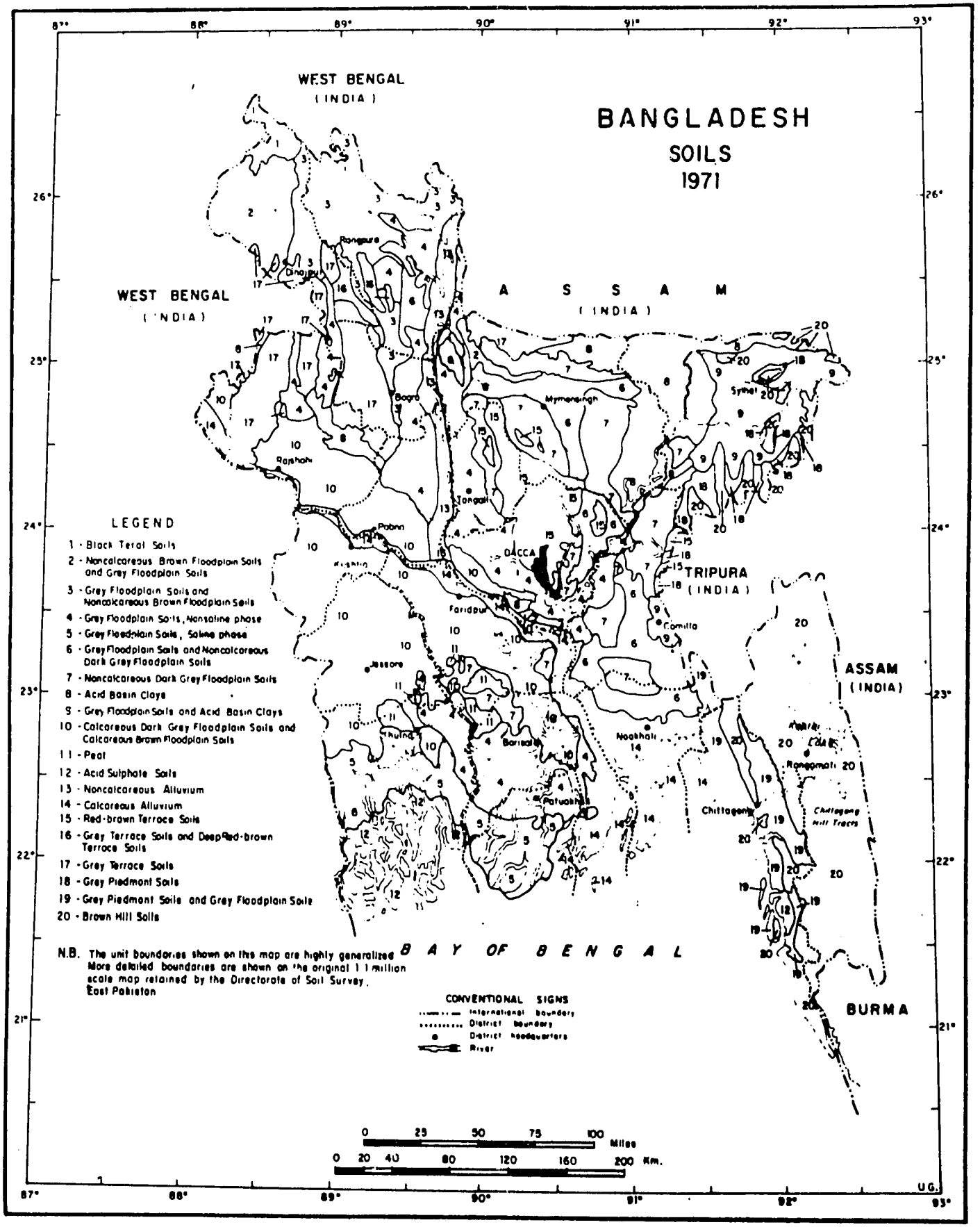

Figure IV-2. Bangladesh Soils.

Source: Soil Survey Project, Bangladesh Agricultural Development Possibilities, AGL:SF/PAK6, Tech. Rpt. 2, UNDP, FAO, Rome. 1971.

Ratings should be made for zero, moderate, and high levels of fertilization. Soils and areas that have a very high potential for production, such as irrigated and potentially irrigated soils, should receive priority.

Efforts need to be further developed and coordinated at all levels to better define the soil fertility status of soils and to aid in refining fertilizer recommendations. Thana maps identifying soil series need to be completed as soon as possible for use in siting soil fertility trials and in advising farmers about levels of fertilizer use and land use in general.

The cost of bringing marginal land into production should be compared with the cost of increasing production on the present acreage of cropped land and priorities based on economic returns should be developed.

Cropping Patterns

Land-use patterns are often complex, especially on floodplain landscapes. Hydrological characteristics, such as soil permeability and moisture holding capacity, largely determine the type of rice crop (Aus, Aman, or Boro as well as the cultivars used and method of planting) and the kinds of dryland crop, if any, that are grown in rotation or intermixed with rice. During the monsoon season, dryland crops are limited to upland areas which are not flooded or waterlogged and in the rabi season to soils with adequate moisture reserves or supplemental irrigation.

Aus rice is seeded premonsoon on both flooded and nonflooded land. Varieties are photoperiod-insensitive and are harvested during the monsoon (July/August). Thus, Aus is limited to land that is not deeply flooded or where deep flooding occurs after July/August. In the latter areas, mixed Aus-broadcast Aman are often seeded. Jute may be grown under flooding conditions similar to those of Aus, but it is generally grown only on silty soils where a good seed bed can be prepared. Where water depth is shallow during July and August, transplanted Aman is common. Aman varieties are photoperiod-sensitive and are harvested after the monsoon (November/December). Boro rice varieties are photoperiod-insensitive and are planted early in the dry season (November/December). Boro is grown either as the only crop on land that is deeply flooded during the monsoon (not used for B. Aman) or following T. Aman on less deeply flooded land. Boro is mainly irrigated and has competition from wheat for both land area and water on better drained soils, particularly in the north.

A land use association map (Figure IV-3) shows areas where common crop rotations and cropping associations are grown. Those cropping patterns are summarized below:

Cropping Patterns	Land Types
Aus/Jute-Rabi	High and medium highland Permeable
Aus/Jute-T. Aman Aus/Jute-T. Aman-Rabi	High and medium highland Moderately to slowly permeable
T. Aman; Aus-T. Aman	Level high and medium highland Very slowly permeable
T. Aman-Boro	Level high and medium highland Slowly permeable (irrigated)
Mixed (Aus-B. Aman)-Rabi	Medium high to lowland
Aus/Jute-B. Aman-Rabi	Moderately to slowly permeable Good moisture holding capacity
B. Aman; B. Aman-Rabi	Lowland-early and rapid flooding Slowly permeable
Boro	Medium lowland to lowland Very slowly permeable Wet and dry season or irrigated
Mixed (Aus-Upland)	Permeable hill soils

Irrigation and drainage projects result in marked changes in cropping patterns. Irrigation leads to intensified cropping by permitting an additional crop during the year, generally Boro rice on slowly permeable soils and wheat, potato or vegetables on more permeable soils.

The area being cropped at present is known. There also are estimates of land areas that are cropped more than once during the year and of land that has a potential for cropping should various constraints be removed. Available areas by soil type or groups of soil types which are or could be planted to specific crops are unknown. Productivity ratings have not been made for all crops on all soils units, especially on a systematic, comparative basis.

Policy Options Related to Cropping Practices

More pertinent information should be compiled concerning land areas of specific soil types that are currently cropped to specific crops or have a potential to be cropped to individual crops. This type of information should be developed in conjunction with the conduct of fertilizer trials and variety

Figure IV-3

LEGEND

MAIN LAND USE		SECONDARY LAND USE
1.	Mainly broadcast aus and transplanted aman rotations	
1a	Broadcast aus or jute followed by transplanted aman and rabi crops	Broadcast aus followed by rabi crops
1b	ditto	-
1c	Broadcast aus or jute followed by transplanted aman	Broadcast aus followed by rabi crops
1d	ditto	Broadcast aman
1e	ditto	ditto and grassland
1f	ditto	-
2.	Mainly transplanted aman rotations	
2a	Transplanted aman	Broadcast aus followed by transplanted aman and rabi crops
2b	ditto	Broadcast aus followed by transplanted aman
2c	ditto	ditto and grassland
2d	ditto	Broadcast aus followed by rabi crops
2e	ditto	Grassland, bare
2f	ditto	-
3.	Mixed aus and deepwater aman rotations	
3a	Mixed aus and deepwater aman or jute followed by rabi crops	Broadcast aus or jute followed by rabi crops
3b	ditto	Deepwater aman
3c	Mixed aus and deepwater aman, partly followed by rabi crops	Deepwater aman; broadcast aus or jute followed by rabi crops
4.	Deepwater aman rotations	
4a	Deepwater aman followed by rabi crops	Mixed aus and deepwater aman followed by rabi crops
4b	Deepwater aman	Broadcast aus or jute followed by transplanted aman; some boro
4c	ditto	Mixed aus and deepwater aman or jute, partly followed by rabi crops
4d	ditto	Kharif and rabi vegetables, potatoes
4e	ditto	Boro
4f	ditto	Boro; transplanted aman; broadcast aus followed by transplanted aman
4g	ditto	Broadcast aus; jute; rabi crops; bare
4h	ditto	Swamp grassland
5.	Boro	Deepwater aman; grassland
6.	Broadcast aus and rabi crop rotations	
6a	Broadcast aus or mesta, partly followed by rabi crops	Transplanted aman; broadcast aus followed by transplanted aman; fruit trees
6b	ditto	ditto; also forest; boro; deepwater aman
7.	Forest, bamboo and grassland	
7a	Mainly forest	Grassland
7b	Mainly grassland regrowth	Forest; bamboo; jhum cultivation; transplanted aman (in valleys)

N.B. 1. Land use in most parts of East Pakistan is complex, mainly due to close adjustment of cropping practices to land levels in relation to flooding. Different crop rotations are usually found on higher, intermediate and lower parts of the landscape.

2. This map is highly generalized. For further details, individual soil survey area reports should be consulted.

3. There has been a considerable expansion in boro cultivation in some units since the time of survey during the years 1964-70.

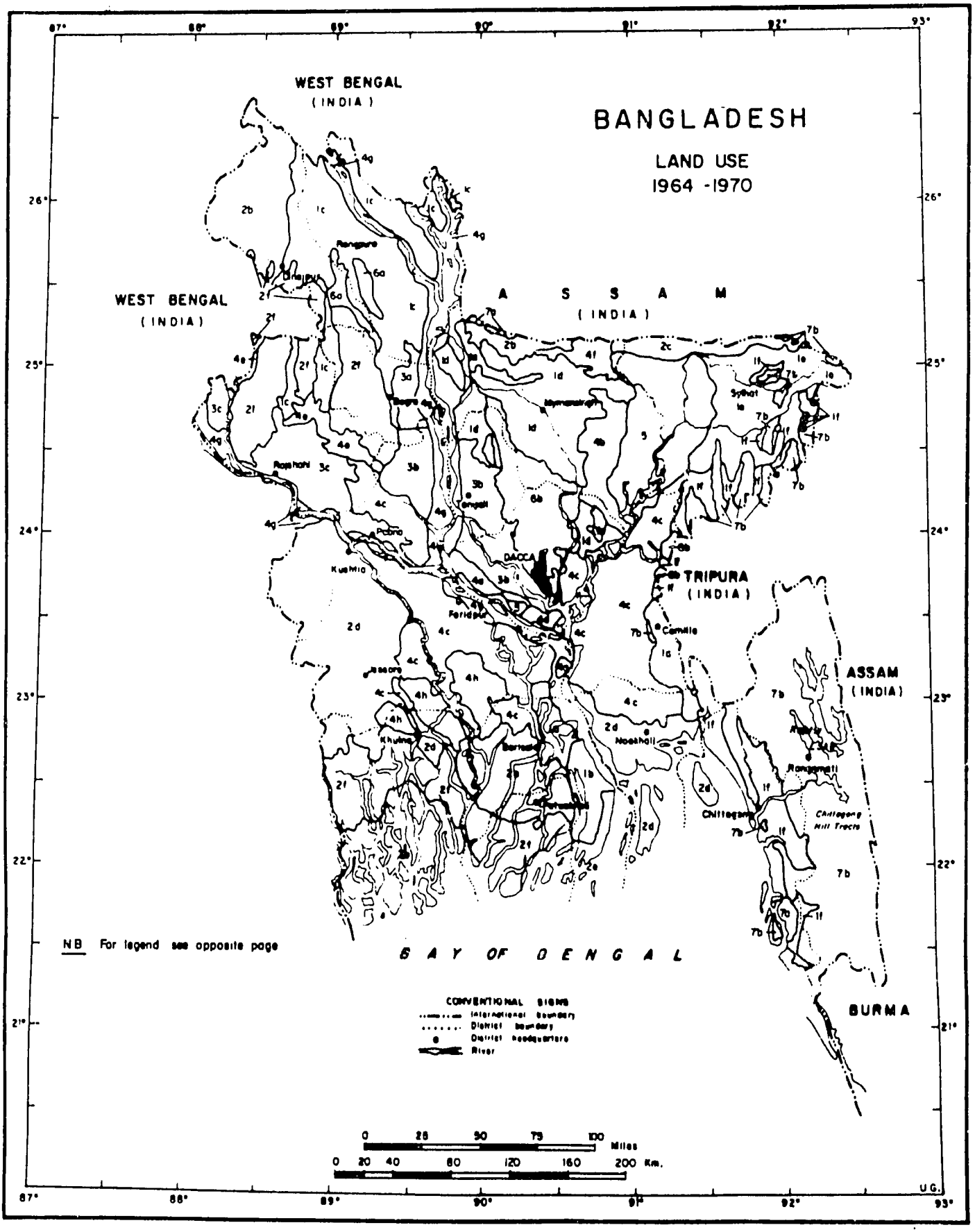

Figure IV-3. Bangladesh Land Use.

Source: Soil Survey Project, Bangladesh Agricultural Development Possibilities, AGL:SF/PAK6, Tech. Rpt. 2, UNDP, FAO, Rome. 1971.

trials. The data are needed for determining the productivity of various areas, the areas for specialized research, and the areas needing special extension activities. A key use will be to predict nutrient requirements for given crop production goals under different cropping patterns and to estimate the costs and benefits of alternative approaches to meeting crop production goals.

Information on land use, by soil type, together with crop response data will be useful in formulating policies and strategies for allocation of nutrients to achieve various objectives such as increasing nutrient efficiency, setting and meeting crop production goals, and altering equity situations.

Farm-Level Fertilizer Use

The previously mentioned BARC/IFDC report provides the most complete estimate of farm-level use of fertilizer in selected districts of Bangladesh. Average fertilizer use levels in the sample areas are shown in Table IV-2. These data show that more than 60% of the farmers use fertilizer in each season and that about 51% of the cropped area is fertilized in both the Boro and Aman season and 45% is fertilized in the Aus season. Levels of fertilizer use decrease in the order of Boro, Aus, and Aman in terms of use per acre of cropped area and of fertilized area. According to national statistics, fertilizer use averages 0.70 md/acre of cropped land.

The farm survey data showed that on the farms sampled average fertilizer use during the three seasons is 0.91 md/acre of cropped area, and 1.79 md/acre of fertilized area. Total nutrient use level for the three seasons averages 0.44 md/acre of cropped area and 0.86 md/acre of fertilized area on the sampled farms.

For the sampled farms, the ratios of total fertilizer nutrient consumption are:

Boro	$N:P_2O_5:K_2O = 3.6:2.3:1$
Aus	$N:P_2O_5:K_2O = 3.2:1.7:1$
Aman	$N:P_2O_5:K_2O = 4.2:2.3:1$
Three seasons	$N:P_2O_5:K_2O = 3.7:2.2:1$

However, based upon national annual sales figures for 1979/80 the nutrient ratios are 9.2:4.2:1. This indicates that on the survey farms consumption of K was 1.9 times the rate of the country in comparison with P and 2.5

Table IV-2. Aggregate Summary of Fertilizer Use Data From Farm Survey

	Boro 1979/80	Aus 1980	Aman 1980	All Three Seasons
Farmers in sample, number	1,616	1,687	1,792	5,095
Farmers using fertilizer, number	1,097	1,039	1,142	3,278
Farmers using fertilizer, % of sample	68.0	61.6	63.7	64.3
Cropped area, acre	2,268.6	2,408.6	3,510.9	8,188.1
Fertilized area,[a] acre	1,166.4	1,154.0	1,853.2	4,173.6
Fertilized area,[a] % cropped area	50.5	44.6	51.8	48.0
Fertilizer use				
Urea, md	1,316.4	1,180.4	1,652.9	4,149.7
TSP, md	755.4	691.8	900.0	2,347.2
DAP, md	90.1	6.5	12.7	109.3
MP, md	284.4	284.6	300.4	869.4
TOTAL md	2,446.3	2,163.3	2,866.0	7,475.6
Level of fertilizer use				
Urea, md/acre cropped area	0.58	0.49	0.47	0.51
TSP, md/acre cropped area	0.33	0.29	0.26	0.29
DAP, md/acre cropped area	0.04	<0.01	<0.01	0.01
MP, md/acre cropped area	0.13	0.12	0.09	0.11
TOTAL, md/acre cropped area	1.08	0.90	0.82	0.91
Level of fertilizer use				
Urea, md/acre fertilized area	1.13	1.02	0.89	0.99
TSP, md/acre fertilized area	0.65	0.60	0.49	0.56
DAP, md/acre fertilized area	0.08	0.01	0.01	0.03
MP, md/acre fertilized area	0.24	0.25	0.16	0.21
TOTAL, md/acre fertilized area	2.10	1.87	1.55	1.79
Level of fertilizer nutrient use				
N, md/acre cropped area	0.27	0.22	0.22	0.24
P_2O_5, md/acre cropped area	0.17	0.13	0.12	0.14
K_2O, md/acre cropped area	0.08	0.07	0.05	0.06
N + P_2O_5 + K_2O, md/acre cropped area	0.52	0.42	0.39	0.44
Level of fertilizer nutrient use				
N, md/acre fertilized area	0.53	0.47	0.41	0.46
P_2O_5, md/acre fertilized area	0.34	0.28	0.23	0.27
K_2O, md/acre fertilized area	0.11	0.15	0.10	0.13
N + P_2O_5 + K_2O, md/acre fertilized area	0.98	0.90	0.74	0.86

a. Fertilized area is defined as area which received either urea, TSP, DAP, or MP.

Source: Sidhu, Baanante, and Ahsan (1982).

times the rate of the country in comparison with N. National sales in 1979/80 indicate that nutrient use levels for N, P_2O_5, and K_2O were 0.21, 0.10, and 0.02 md/acre of cropped land, respectively. On the sampled farms, fertilizer nutrient use levels for N, P_2O_5, and K_2O were 0.24, 0.14, and 0.06 md/acre of cropped land, respectively.

As shown in Table IV-3, less crop land is fertilized with P than with N, and less with K than with P, in each of the three seasons. About 50% of the cropped land is fertilized with N during each season; 21% to 37% of cropped land is fertilized with P; and 16% to 23% is fertilized with K during the seasons of the survey year. A greater percentage of cropped land is fertilized with P and K, and higher rates are used during the Boro season than during the Aus or Aman seasons. Potentially higher yields and greater responses to P and K under irrigated crop production is probably an important factor. (About 75% of rice and about 46% of wheat is irrigated during the Boro season.) About 7% to 10% of rice is irrigated during the Aus and much less in the Aman season. A much greater percentage of cropped land in paddy is fertilized under irrigation than under rainfed production (about 10% more in Boro, 50% more in Aus, and 46% more in Aman season).

Of the 6,741 acres of paddy and wheat in the sample farms, 36% was planted to HYVs. Of the area under HYVs, 85% was fertilized, whereas 41% of the area under local varieties (LVs) was fertilized. For the combination of the three seasons, the N, P_2O_5, and K_2O rates were 0.45, 0.16, and 0.07 md/acre of cropped land, respectively, for HYVs; for LVs, the rates were 0.06, <0.01, and <0.01.

As an aggregate of the three seasons, the farm survey data indicate that 82%, 70%, and 62% of the irrigated paddy area is fertilized with N, P, and K, respectively (Table IV-4); the percentages for rainfed rice are 49%, 25%, and 13%. Rates of fertilizer nutrient application in the fertilized areas (where individual nutrients were used) are 0.70, 0.56, and 0.37 md/acre under irrigation and 0.40, 0.33, and 0.28 md/acre of N, P_2O_5, and K_2O, respectively, in rainfed area.

The data (Table IV-4) also show that 86%, 64%, and 46% of the paddy cropped area in the sample where HYVs were used was fertilized with N, P, and K, respectively. Of the paddy area cropped to LVs, 41%, 18%, and 9% of the area was fertilized with N, P, and K, respectively. Ratios of nutrient use rates in the fertilized areas planted to HYVs of paddy were similar to ratios in irrigated areas.

Table IV-3. Cropped Area, Area Fertilized, and Nutrient Application Rates by Crops and Seasons on Farms in the Farm Survey in Bangladesh 1979/80

Season or Crop	Cropped Area Sampled	Portion of Cropped Area Fertilized[a]			Average Application Rate					
		N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
	(acre)	(% of cropped area)			(md/acre of cropped area)			(md/acre of fertilized area)[a]		
Boro 1979/80	2,239.92	50.7	37.6	23.2	0.33	0.17	0.08	0.65	0.45	0.34
Paddy	634.27	64.1	49.1	34.3	0.53	0.27	0.12	0.83	0.55	0.35
IRR	483.88	69.3	49.6	37.3	0.51	0.27	0.13	0.74	0.54	0.35
IRR-HYV	313.77	95.8	72.2	55.9	0.75	0.41	0.19	0.78	0.57	0.34
IRR-LV	170.11	14.9	4.5	4.3	0.07	0.01	0.01	0.47	0.22	0.23
RF	149.25	48.3	41.7	24.4	0.56	0.29	0.07	1.16	0.70	0.29
RF-HYV	81.08	88.5	80.3	38.8	0.98	0.52	0.14	1.11	0.65	0.36
RF-LV	68.17	7.3	2.2	5.6	0.05	0.01	0	0.68	0.45	0
HYV	398.52	94.4	75.9	52.7	0.79	0.43	0.19	0.84	0.57	0.36
LV	241.50	12.9	3.8	3.3	0.07	0.01	0.01	0.54	0.33	0.20
Wheat	672.20	79.8	60.0	35.1	0.40	0.27	0.12	0.50	0.45	0.35
HYV	639.20	81.6	62.5	36.8	0.41	0.28	0.13	0.50	0.45	0.35
LV	33.00	44.5	11.8	2.7	0.16	0.05	0.01	0.36	0.42	0.37
Pulse	609.26	7.5	4.4	1.0	0.03	0.01	0	0.40	0.32	0.36
Oil seed	135.30	27.9	14.8	4.8	0.13	0.05	0.02	0.47	0.34	0.34
Potato	34.10	55.5	32.5	22.6	0.43	0.24	0.16	0.77	0.74	0.71
Kawn	41.08	65.2	63.9	62.0	0.39	0.22	0.28	0.60	0.34	0.45
Chili	21.00	51.0	14.0	4.0	0.21	0.06	0.01	0.41	0.43	0.25
Spices	27.80	11.5	4.3	2.2	0.06	0.03	0.01	0.52	0.70	0.45
Vegetables	13.23	54.0	42.9	9.5	0.42	0.20	0.03	0.78	0.47	0.32
Tobacco	23.03	95.7	87.2	72.3	0.70	0.61	0.33	0.73	0.70	0.46
Aus 1980	2,387.14	46.6	21.4	16.1	0.19	0.09	0.05	0.41	0.42	0.31
Paddy	1,948.45	50.6	25.2	19.1	0.22	0.11	0.06	0.43	0.44	0.31
IRR	206.04	97.7	97.1	93.8	0.69	.57	0.35	0.71	0.59	0.37
IRR-HYV	205.70	97.7	97.1	93.8	0.69	.57	0.35	0.71	0.59	0.37
IRR-LV	.34	100.0	0	0	.36	0	0	0.36	0	0
RF	1,764.38	47.1	19.5	13.4	.18	0.07	.04	0.38	0.36	0.30
RF-HYV	212.58	76.7	46.7	29.5	.43	.24	.11	0.56	0.51	0.37
RF-LV	1,551.80	43.2	15.9	11.3	.15	.05	.03	0.35	0.31	0.27
HYV	416.64	84.9	67.5	54.7	0.52	0.35	0.20	0.61	0.52	0.37
LV	1,555.50	43.2	16.1	11.3	0.16	0.05	0.03	0.37	0.34	0.29
Oilseed	4.62	28.6	28.6	14.3	0.37	0.09	0.02	1.29	0.31	0.14
Jute	415.80	32.3	6.7	4.8	0.10	0.02	0.02	0.31	0.30	0.36
Kawn	13.64	4.5	0	0	0.02	0	0	0.44	0	0

(Continued)

Table IV-3. Cropped Area, Area Fertilized and Nutrient Application Rates by Crops and Seasons on Farms in the Farm Survey in Bangladesh 1979/80 (Continued)

Season or Crop	Cropped Area Sampled	Portion of Cropped Area Fertilized[a]			Average Application Rate					
		N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
	(acre)	(% of cropped area)			(md/acre of cropped area)			(md/acre of fertilized area)[a]		
Aman 1980	3,483.46	52.2	30.1	16.4	0.21	0.10	0.05	0.40	0.33	0.30
Paddy	3,454.58	52.4	30.2	16.5	0.21	0.11	0.05	0.40	0.36	0.30
IRR	229.34	96.5	90.0	86.3	0.62	0.50	0.34	0.64	0.56	0.39
IRR-HYV	213.02	96.8	92.6	89.2	0.65	0.53	0.35	0.67	0.55	0.39
IRR-LV	16.32	64.7	26.5	26.5	0.25	0.16	0.12	0.39	0.60	0.45
RF	3,207.24	50.3	27.1	7.3	0.19	0.08	0.03	0.38	0.30	0.41
RF-HYV	727.75	80.6	48.8	28.6	0.41	0.18	0.08	0.51	0.37	0.26
RF-LV	2,479.49	41.6	20.8	1.1	0.12	0.05	<0.01	0.29	0.24	<0.01
HYV	956.12	83.4	57.0	39.2	0.45	0.24	0.12	0.54	0.42	0.31
LV	2,500.83	41.7	21.0	8.6	0.14	0.06	0.02	0.34	0.29	0.23
Pulses	9.62	3.8	3.8	3.8	0.02	0.03	0.02	0.53	0.79	0.53
Kawn	0.36	100.0	0	0	0.26	0	0	0.26	0	0
Sugarcane	11.52	40.6	9.4	6.3	0.17	0.03	0.03	0.41	0.29	0.41
Cotton	1.26	100.0	100.0	28.6	0.58	0.68	0.10	0.58	0.68	0.10
Three Seasons										
Paddy	6,037	54	32	19	0.26	0.13	0.06	0.47	0.41	0.36
Boro	634	64	49	34	0.51	0.28	0.12	0.80	0.56	0.35
Aus	1,948	51	25	19	0.22	0.11	0.06	0.43	0.43	0.32
Aman	3,455	52	30	16	0.21	0.11	0.05	0.40	0.41	0.28
Wheat	672	80	60	35	0.40	0.27	0.12	0.50	0.45	0.36
Jute	416	32	7	5	0.10	0.02	0.02	0.31	0.33	0.36
Pulses	619	7	4	1	0.03	0.01	<0.01	0.41	0.33	0.37
Oilseed	140	28	15	5	0.13	0.05	0.02	0.47	0.35	0.32
Kawn	55	50	48	46	0.30	0.17	0.21	0.59	0.35	0.45
Potato	34	55	0	23	0.38	0	0.16	0.70	0	0.72
Sugarcane	12	41	9	6	0.17	0.03	0.03	0.41	0.29	0.41

a. Fertilized area refers to area fertilized with the individual nutrient.

Source: Sidhu, Baanante, and Ahsan (1982).

Table IV-4. Paddy Areas Cropped, Areas Fertilized, and Fertilizer Nutrient Use--Three Seasons for Sampled Farms

Category	Cropped Area (Acre)	Fertilizer Nutrient (md)	Area Fertilized % of Cropped	Area Fertilized Acre	Nutrient Rate Cropped Area (md/acre)	Nutrient Rate Fertilized Area (md/acre)
			Nitrogen			
IRR	919	531	82	758	0.58	0.70
RF	5,121	1,011	49	2,516	0.20	0.40
HYV	1,771	962	86	1,527	0.54	0.63
LV	4,298	616	41	1,746	0.14	0.35
			P_2O_5			
IRR	919	363	70	646	0.39	0.56
RF	5,121	423	25	1,276	0.08	0.33
HYV	1,771	547	64	1,129	0.31	0.48
LV	4,298	230	18	785	0.05	0.29
			K_2O			
IRR	919	213	62	572	0.23	0.37
RF	5,121	191	13	686	0.04	0.28
HYV	1,771	274	46	813	0.15	0.34
LV	4,298	99	9	399	0.02	0.25

Source: Sidhu, Baanante, and Ahsan (1982).

Of the approximately 8,100 acres within the farm survey sample, paddy occupied 74%, wheat and pulses each occupied 8%, and jute occupied 5% of the cropped areas. About 95% of the wheat area was planted to HYVs. Approximately 80%, 60%, and 35% of the area cropped to wheat was fertilized with N, P, and K, respectively. [Average rates of nutrient use in the areas fertilized with the individual nutrients were 0.60, 0.37, and 0.35 md/acre of N, P_2O_5, and K_2O, respectively. Thus, nutrient use in the fertilized area was 72%, 67%, and 100% of the N, P_2O_5, and K_2O rates for Boro paddy.] About 7%, 4% and 1% of the cropped areas of pulses was fertilized with N, P, and K, respectively. Of the cropped area in jute, about 32% was fertilized with N and less than 10% was fertilized with P or K.

The survey data support the conclusion that where P and K fertilizers are being used by farmers, N, P_2O_5, and K_2O are used in ratios of about 4:3:2. If a problem exists in unbalanced fertilization, it would appear to be among the farmers who fail to use P and/or K fertilizers. However, "balanced" fertilization on the national scale or even by an administrative region does not imply nutrient consumption ratios of 4:3:2 or necessarily ratios approximating that value. As an example, it is considered that farmers in both the states of Illinois and California of the United States are using nutrients at near balanced levels. Yet, the nutrient consumption ratios are 1.2:0.6:1 in Illinois and 7.9:2.7:1 in California. The point is that balanced fertilizer nutrient use depends upon the soils, crops, yield levels, cropping systems, and other factors. An attempt to analyze some of these factors will be covered in a later section.

Crop Response to Fertilizers

A knowledge of the nature of the crop response function is vital to formulating fertilizer recommendations for farmers. Also, it is a major component in the methodology for determining nutrient requirements for various crop production goals. There are many variables that must be measured in developing crop response information.

Crop response to fertilizers depends upon the available supply of nutrients from sources other than fertilizers (soil, water, and organic materials) and nutrient requirement to obtain a crop yield for a given species and variety or cultivar. The adequacy of the soil (or soil, water, and organic materials) to supply nutrients is estimated by measuring yield and nutrient concentration

or nutrient uptake for plants grown in the soil and/or by estimating the quantity of available nutrients by chemical analysis and by correlating those data with plant growth. An insufficient supply of any one nutrient limits the plant in expressing its growth potential. Thus, to obtain optimum growth, all required plant nutrients must be available to the plant in at least some minimum quantity and on a timely basis. The required quantity and timeliness of nutrient availability depend upon the growth characteristics of the plant and other parameters which influence plant growth. Some of these parameters are site specific; among these are landform and climatic characteristics. The latter include solar radiation, day length, temperature, and sufficiency or excess of water, although water control may be exercised to some extent. Of course, climatic parameters vary from season to season and from year to year, and the variations must be taken into account when estimating crop yields and needed nutrient supply. Climatic factors may affect nutrient supply as well as plant growth characteristics.

Other parameters that greatly affect the growth of plants, and thus the needed supply of nutrients, are related to crop production practices. These are management parameters, and the level is identified by the degree to which the practices are performed to give maximum growth within the physical setting. Levels of management depend also upon timeliness and proficiency of performance. Some important management practices are land preparation, variety selection, planting dates, disease and insect control, weed control, water control, and harvest dates.

Crop response to fertilizer nutrients depends upon both available supply of nutrients without fertilizer and crop requirement for nutrients. In most studies, the crop response to fertilizers from applied research trials (even in farmers' fields) overestimates the optimal levels of fertilizer required under actual farming conditions. This is primarily because the generally higher levels of management that are practiced in the research trials give yields and nutrient requirements that are higher than farmers would obtain. This yield gap (difference in actual farmer yield and potential farmer yield) caused by differences in level of management is a result of both biological constraints and socio-economic constraints faced by farmers.

A methodology has been developed by the International Rice Research Institute (IRRI) to study the nature of farmer constraints and their effect upon rice yields (Gomez, 1977). Studies in six Asian countries between 1974 and 1977 showed that fertilizer rate and timing of application accounted for 53% and 42% of the yield gap in the dry and wet seasons, respectively (De Datta, 1981).

Improved insect control accounted for 34% and 44% of the yield gap in dry and wet seasons, and only about 13% (each season) of the differences in yield were attributed to improved weed control.

Studies in Bangladesh indicated that in the Boro season, fertilizer rates higher than the farmers' rates contributed 1,300 kg of paddy/ha above the farmers' rate and added a net return of 2,150 takas/ha (Ahsan and Hoque, 1977). Better weed control added 400 kg of paddy/ha and a net return of 1,100 takas, whereas application of insecticide gave no increased yield. In the Aus season higher rates of fertilizer gave about 100 kg of paddy/ha; improved weeding and application of insecticide gave no yield increase, however, and none of the higher levels of inputs were profitable.

In Table IV-5, crop yields and responses to fertilizer nutrients obtained from applied research trials on farmers' fields are contrasted with those estimated from aggregate farm survey data. Although the two sets of data do not necessarily represent the same populations in terms of physical and biological constraints, the contrast is remarkable. The footnotes for Table IV-5 explain how the data were developed.

Estimates of crop yields without fertilizer do not differ greatly between the two methods, except that, for the Aman season those yields are lower in the case of the fertilizer trials. However, there are great differences in the estimated crop responses to applied nutrients: trial data indicate responses that are 2 to 3 times greater than the farm survey data analysis for each rice crop and 7 to 8 times greater for wheat. Management constraints could account for some of the differences, but crop responses as estimated by the analyses of farm survey data are considered to be extremely low. In particular, it is unreasonable to consider lower responses of Boro rice as compared with Aus rice. Also, the constraints study noted above found that the differential response (between high and low fertilizer rates) was 10-16 kg of paddy/kg of additional nutrient, and this result is similar to the trial data.

Policy Options for Defining Crop Responses to Fertilizers

Actual crop responses obtained by farmers under various crop production situations must be determined to permit the formulation of reasonable fertilizer-related policies. Two methodologies for further research are recommended.

1. Conduct additional studies similar to the constraints research that was mentioned above. Farmers included in this study should be selected from those included in the farm survey.

Table IV-5. Contrast of Estimated Crop Responses to Nutrients--Applied Research Trials Versus Farm Survey Data

Crop	Year	Response Function[a]	Optimum Rate (kg/ha)	Nutrient Rate[b] (kg/ha)	Average Crop Response[c] (kg/kg nutrient)	Partitioned Yield Increase[c] (kg/ha)	Estimated Yield Increase (kg/ha)
			On-Farm Research Trials				
Boro	1979/80	$Y = 2{,}763 + 22.04\ N - 0.083\ N^2$	113	78	15.6	1,217	
		$3{,}382 + 17.42\ P - 0.109\ P^2$	74	53	11.6	615	
		$3{,}780 + 15.80\ K - 0.115\ K^2$	45	33	12.0	396	
			232	164			2,228
Aus	1979	$2{,}589 + 12.79\ N - 0.054\ N^2$	88	56	9.8	549	
		$2{,}789 + 13.44\ P - 0.074\ P^2$	68	48	9.9	475	
		$3{,}085 + 11.76\ K - 0.113\ K^2$	46	34	7.9	269	
			202	138			1,293
Aman	1979	$2{,}085 + 10.63\ N - 0.026\ N^2$	160	50	9.3	465	
		$1{,}641 + 9.94\ P - 0.034\ P^2$	84	41	8.5	348	
		3,134 not estimated	-	29 (40)	(13.1)	380[d]	
			-	120			1,193
Wheat	1979/80	$1{,}377 + 27.86\ N - 0.129\ N^2$	95	70	18.8	1,316	
		$1{,}703 + 17.20\ P - 0.100\ P^2$	73	34	13.8	469	
		$1{,}880 + 15.92\ K - 0.110\ K^2$	65	32	14.4	461	
			233	136			2,246
			Farm Survey Data				
Boro	1979/80	$Y = 2{,}898 + 4.37\ F - 0.54\ F^2$	248	164	3.4		560
Aus	1980	$Y = 2{,}494 + 4.95\ F$	-	138	5.0		690
Aman	1980	$Y = 2{,}664 + 3.78\ F$	-	120	3.8		456
Wheat	1979/80	$Y = 1{,}167 + 2.08\ F$	-	136	2.1		286

a. Functions were developed from pooled research trial data over 6 soil map units which included 51, 31, 42, and 39 trials for Boro, Aus, Aman paddy, and wheat, respectively. Functions for farm survey data are from the joint BARC/IFDC report (Sidhu, Baanante, and Ahsan. 1982).

b. This is the average rate per unit of fertilized area (individual nutrient) as determined for HYV by season, in the farm survey.

c. Estimated from response functions for the stated nutrient rate.

d. Only 0 and 40 kg of K_2O/ha were used in trials. The value 380 is the product of 29 times 13.1.

2. The farm survey data, which pertain to crop response to fertilizer, should be analyzed in greater detail. Some types of data stratification would be applicable. Also, when soil analysis data from the survey farms become available, they should be included for the more detailed analysis.

The "Fertilizer Recommendations" section that follows contains other recommendations for defining crop response to fertilizers.

Fertilizer Recommendations

The development of appropriate fertilizer recommendations is an important issue in devising strategies for increasing food production through fertilizer use. Fertilizer recommendations are made in terms of quantities of plant nutrients to be applied at specified times, by stated methods, from specified sources, and under identified conditions for crop production. Since all conditions under which crops are produced on individual farms cannot be identified nor can recommendations be made for a multitude of specific conditions, fertilizer recommendations are generalized on the basis of stratified groups of conditions considered to influence crop response to applied nutrients. The criteria used and the degree of stratification are important factors in determining how relevant the recommendations are.

Recommendations must also be refined by considering certain social, cultural, and economic constraints. The benefits of fertilizer use are influenced by how well the recommendations fit the farm situation and the degree to which farmers follow recommendations. In turn, the efficiency of fertilizer use and the quantity used affect the level of crop production and returns to investment in fertilizer for the farmer and the nation.

Current Recommendations

Current fertilizer recommendations are contained in a BARC publication (BARC, 1979) prepared by a subcommittee composed of representatives from "various soil research organizations." Recommended rates of nutrients and fertilizers, and method and time of application for cropping conditions were stratified on the basis of rainfed or irrigated, season, crop species and variety, and soil map unit. The principal source of farm-level crop response data from which the recommendations were developed was generated by the Soil Fertility and Soil Testing Institute which is now the On-Farm Research Division of the Bangladesh

Agricultural Research Institute (BARI) and by the Joint Extension Directorate/ FAO/UNDP Fertilizer Project. Those data were supplemented with data from various research institutes and development boards.

The On-Farm Research Division of BARI has one fieldman stationed at each of 200 thana experimental centers to conduct trials in farmers' fields under the supervision of District Scientific Officers (Elahi, 1981). Management, scientific officers, and support staff are located at the headquarters in Dacca. Four regional soil testing laboratories have been established to support the field trial work. The Dacca laboratory is operational, and the other laboratories are in various stages of readiness. When sufficient soil-testing data are generated, analyses by correlation of crop response and soil test values are planned. Additionally, plans are being formulated to identify the soils of experimental fields at the soil series level with the assistance of soil survey personnel. The implementation of these activities should lead to improved fertilizer recommendations.

Also, improved recommendations over the long term will come from a project recently initiated by the BARC to study the correlation between soil conditions and crop response. The project involves soil chemists, fertility specialists, and surveyors to systematically investigate crop response to nutrients and correlate this with soil survey information and soil test values for selected benchmark soils; the information will be used for extrapolating fertilizer recommendations and for extension training activities.

Current recommendations are made on the basis of mean observed crop responses from trials on specific soil map units, statistical significance of those responses, estimated net profits, and benefit/cost ratios. As noted in the soils section of this document, soil properties vary greatly within a soil map unit. Thus, basing the recommendation on observed means of yields within these groups may give very poor estimates for a large number of farmers. For example, if 50% of the trials indicated that no K should be applied and 50% indicated that 60 lb of K_2O/acre should be applied, the mean would be 30 lb of K_2O/acre and this may give a statistically significant yield difference from control. But 50% of farmers would be reducing net profits by the cost of the K, while the other 50% would use less K than that needed to maximize profits. This hypothetical situation may not be unrealistic within the current system of stratification. One report states that "80% of Bangladesh soils are formed over recent or subrecent alluvium that contain considerable weatherable minerals" (Karim, 1980). Most of those soils are expected to contain high levels of K.

Stratification on the basis of soil series or groups of soil series, which give a similar response, will improve the recommendations.

The design (selected treatments) of all current trials does not permit the adequate estimation of response curves or surfaces. Thus, recommended rates are estimated by considering mean observed yields and estimated profits and benefit/cost ratios from selected treatments. Design of all trials to estimate response curves for more closely stratified conditions is needed.

In estimating net profits and benefit/cost ratios, official prices are used. These prices may not be appropriate for estimating the actual net profit or benefit/cost ratios that the farmer may expect from a given yield increase. The farmer may incur costs in obtaining and transporting fertilizer to the field and in applying the fertilizer in the field. Such items should be added to the cost of the fertilizer. Likewise, there are costs involved in harvesting the additional crop and in marketing the product. These costs should be subtracted from the actual price for which the farmer sells the crop. Thus, the true cost of fertilizer (applied to the field) and the true value of the crop (in the field) should be used in determining the rate of fertilizer to maximize profit for an estimated crop response situation.

The estimated optimum return, even after considering the above factors, also may need to be moderated because of the risk associated with obtaining the estimated crop response and the estimated cost/price relationship.

Recommendations regarding specific nutrients must also be considered. For nitrogen, the recommendation of a basal dressing for all rice is the principal issue. It is recognized that the greatest potential losses may occur from applications at this time because the plant requirement is small. However, basal dressings of urea can be incorporated into the soil during the last harrowing before transplanting which reduces somewhat nitrogen losses due to ammonia volatilization. Furthermore, delaying the application of N may result in lower yield if sufficient soil N is not initially present and may also mean an additional labor requirement since farmers could have applied N together with P and/or K (where used) as a basal dressing. Current recommendations in all rice-growing areas include part of the total N as a basal dressing; however, fertilizer research needs to be conducted in Bangladesh on the effectiveness of basal N under various conditions. The possible lack of a need for basal N is an argument against the use of DAP since the P should be applied as a basal dressing and the efficiency of the N applied in this way when DAP is used is unknown.

Phosphate is recommended for all crops on all soils in Bangladesh. The need for P on all soils, however, is being questioned.[1] Islam noted that some soils do not need applications of P; his conclusion was based upon soil analysis data and calculated nutrient availability and crop uptake data. This issue will likely be resolved when soil analysis data are accumulated from fertilizer trial sites and correlation analyses are completed.

Potassium is recommended for all crops on all soils in Bangladesh. This recommendation is questioned even more than the recommendation for phosphate.[2] Tyrchniewicz and Soper (1980) have also concluded that most crops are not likely to respond to K applications in the Ganges floodplain, the fresh water tidal floodplain, or the saline tidal zone. They observed that only 8% of soil samples from those areas (representing 25% of cropped area) contained exchangeable K at a level where wheat or rice would be expected to respond to applied K.

Sulfur recommendations are not contained in the "Fertilizer Guide." According to A.J.M.A. Islam (1980), sulfur deficiency in rice was first detected at the Bangladesh Rice Research Institute (BRRI) station at Joydebpur in 1976. Since that time, S deficiencies have been observed at other locations. At the workshop on Sulfur Nutrition in Rice, conducted by BRRI in December 1978, various S deficiencies and causes thereof were identified, results of the comparison of certain S sources were reported, and recommendations were adopted for the conduct of surveys to identify the S status of soils of Bangladesh. During March and April 1981, a study team consisting of representatives from BRRI, BARI, DA(EM), BADC, BCIC, and IFDC visited India, the Philippines, and the United States to study relevant S work in those countries. The team reported findings and made recommendations.[3]

The systematic study of S problems in Bangladesh has only begun. Studies consist of field observations, superimposed trials, and chemical analysis of soil and plant samples. Estimates of areas that may be affected by S deficiency are about two million acres. Sulfur deficiencies have been associated with the light-textured acidic soils of the Barind tract, heavy-textured acidic soils of the Madhupur tract, and poorly drained waterlogged soils of some irrigation projects.

The various reports have attributed S deficiencies in crops to several factors:

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1. See, for example, A.J.M.A. Islam (1981) and Hussain (1980).
2. Karim (1980), A.J.M.A. Islam (1981), and Hussain (1980) discuss potassium recommendations.
3. The findings are available in an unpublished report entitled "Zinc-Sulfur Deficiency Strategy for Bangladesh."

1. Continuous S removal under intensive cropping.
2. Lack of S additions in fertilizers.
3. Low S content in rainwater and irrigation water.
4. Declining organic matter levels.
5. Continuous flooding conditions.
6. Leaching losses under conditions of high rainfall.

Zinc recommendations are not contained in the "Fertilizer Guide," and the development of recommendations is only slightly ahead of that for S. In Bangladesh, zinc (Zn) deficiencies in rice were first observed in the early 1970s. The state of knowledge of Zn deficiencies in Bangladesh was discussed at a workshop organized by BRRI (BRRI, 1980). It was concluded that Zn deficiencies occur primarily on soils identified by the following conditions:

1. High pH.
2. Continuously wet or poorly drained.
3. Low Zn content.
4. High organic matter content.

These conditions exist on the Gangetic floodplain (high pH), certain irrigation projects (continuously wet), peat basins (high organic matter content), and sandy soils (low Zn content). Areas where rice may respond to Zn applications may cover as much as two million acres.

Studies of Zn problems are being conducted through superimposed trials and soil and plant analysis.

Policy Options for Improving Fertilizer Recommendations

Improving fertilizer recommendations has two major components: the development and the implementation of the recommendations. Development is primarily a research activity, but it must have assistance from extension personnel and fertilizer dealers who know the farmers' crop production situations. Implementation is a knowledge transfer activity to be conducted by extension personnel and fertilizer dealers with the assistance of researchers.

1. Development--The recommended strategy for developing fertilizer recommendations for farmers generally follows the plan of action that is being implemented in Bangladesh. Certain refinements are suggested, particularly in stratifying study areas, designing trials, analyzing and interpreting data, and involving personnel with expertise in various disciplines.

In the following text, basic considerations and principles to be used in developing relevant fertilizer recommendations are reemphasized and then some strategies for the development of those recommendations are discussed.

The requirements for nutrient additions depend upon the nutrient supply from other sources (soil, water, and organic materials), efficiencies with which the additions are utilized, and the crop requirement to produce a given yield. Various factors, as previously discussed, determine the supply of nutrients from other sources. The efficiency of utilization may be influenced by soil properties, hydrology, nutrient source, time and method of nutrient application, and how well the rate of application meets the actual requirement for the yield that is obtained. The crop requirement for a nutrient is influenced principally by crop species and yield. Within practical limits, yield is determined by the nature of yield constraints concerning certain soil properties, climatic factors, water control, incidence of pests, and many crop production management factors. When any parameter that affects yield is at a limiting level, it decreases the requirement for a nutrient.

In developing fertilizer recommendations the economics of use of the nutrient must be considered along with the physical crop requirement. This is often influenced by the social, cultural, and economic condition of the farmer. Thus, the different populations (in terms of nutrient supply from other sources and crop requirements) for which fertilizer recommendations are to be made must be identified. Therefore, it is important to involve personnel with varied expertise when selecting categories of populations for the purpose of developing fertilizer recommendations.

The following are recommended strategies (currently adopted to some degree by BARC) to use in developing relevant fertilizer recommendations for farmers.

A. Organization

(1) BARC should appoint a permanent committee for fertilizer recommendations. The committee membership should have expertise in soils, agronomy, extension, statistics, economics of fertilizer use, and socioeconomics. This committee would regularly and systematically review data and formulate new fertilizer recommendations and review and develop procedures for the formulation of recommendations.

(2) BARC should appoint crop subcommittees to represent each major crop. Membership would consist of representatives from the

permanent committee and individuals appointed on the basis of expertise in the production of individual crops. These subcommittees would review, compile, and submit relevant data to the permanent committee.

(3) BARC should appoint various regional subcommittees. These subcommittees would be composed of members from the permanent committee together with individuals having particular knowledge of actual crop production problems and practices in the various regions. These subcommittees would review fertilizer recommendations in terms of their applicability to regional situations and provide information for consideration by the permanent committee for possible modification of recommendations.

B. Procedures

(1) The first phase in developing fertilizer recommendations is to separate the various crop production conditions into groups. The principle in making such a separation is to provide great differences between groups but little variation within each group. The grouping would consider crop requirements with physical limitations to crop yield (crop species and variety, season, soil properties, water control, and climate) and crop requirements under management limitations (degree to which farmers are able and willing to control inputs other than fertilizer). This procedure has application for all extensive fertilizer recommendation work.

(2) The second phase is to delineate the areas and conditions under which a crop responds to an applied nutrient. These delineations may be made on the basis of soil and/or plant analysis and field trials conducted in farmers' fields. The trials may be simple replicated treatments consisting of zero and a practical rate of the individual nutrient being studied or a single treatment superimposed on a treatment in other trials. Parameters other than the nutrient under study should be at levels that are consistent with the category being represented. Care must be taken in choosing the trial sites so that a number of sites are included in each category for which information is desired. Therefore certain characteristics of the site and the farmer must be obtained before establishing the trial. Analysis and interpretation of data obtained from these trials will delineate the crops and the

conditions for which a response to an applied nutrient may be expected. The results do not provide information about the other aspects of fertilizer recommendations (rates, sources, and time and method of applicaton). Those aspects cannot be effectively studied until areas of probable response are determined. This procedure has specific application to developing improved recommendations for P, K, S, and Zn.

(3) The third phase consists of determining crop response to rates of application and may begin when it is known that crop response to a given nutrient is most likely to be obtained. This aspect must be studied in relation to nutrient source and method and time of application since these factors may influence crop response to rates of applied nutrient. The comments on crop response delineation studies apply also to site selection and levels of other parameters. In this phase, replicated trials are conducted in farmers' fields (selected to represent various categories of crop production conditions). The treatments include rates of application of an individual nutrient and may include sources, time, or method of application. When the latter comparisons are included, each variable should be used at all rates in order to properly interpret results.

(4) The fourth phase consists of formulating fertilizer recommendations. This process includes analysis and interpretation of results of phase three with special emphasis upon economic and socioeconomic considerations. The previously mentioned considerations for estimating farmer costs and prices and the possible risks in obtaining either estimated yield increases or cost/price relationships must be examined. Once a representative crop response curve is defined for a given and documented crop production situation, that response curve may be used year after year. However, it must be developed over a number of years to represent the uncontrolled variations. New estimates need to be made only when some factor that influences crop response is introduced into the crop production situation or when the pattern of uncontrolled factors changes.

Even though a crop response estimate remains representative for a given area, the fertilizer recommendation may need to be changed because the

recommendation not only depends upon the physical response but also upon the relationship between nutrient cost and crop prices. Therefore, fertilizer recommendations must be reviewed each time prices change in order to establish the appropriate ratio of nutrient cost to crop price. Procedures described for phases three and four could currently be applied to studies involving N for almost all cropping conditions and P, K, S, and Zn for selected situations where response to their application is fairly certain.

2. Implementation--Fertilizer recommendations developed by national and regional committees are by necessity too general for all farmers to adopt. They simply cannot fit all situations but rather should be used as guidelines in making specific recommendations that will more nearly apply to individual fields and to management ability and physical and economic circumstances of individual farmers.

Soil testing is used in many countries as a guide to estimating the fertility status of individual fields. However, where fields are very small and there are extremely large numbers of farmers, it seems impossible to reach a very large portion of farmers through a soil testing program. An alternative to soil testing is needed for determining more precise fertilizer recommendations than those provided by the general recommendation.

Crop production management practices used by the farmer influence crop yields and response to added fertilizer nutrients. Thus, there is a need to estimate the level of management and its effect upon crop response.

The need for broad-scale soil testing and estimation of farm management level to improve generalized fertilizer recommendations can be overcome, at least in part, by training of extension agents and fertilizer dealers to classify fields by soil type and productivity ratings and to determine the farmers' management capability. To accomplish this, closer working relationships with soil survey and crop production specialists should be encouraged. To deal with the farmers' management capability, the answer to a few simple questions could help to refine fertilizer recommendations. These questions might be included:

- How much fertilizer did you use last year?
- What variety did you plant?
- What yield did you get?
- Did you control insects and weeds?
- What variety will you plant this year?
- What yield do you want this year?

Responses should take into account two or three crop annual rotations and changes from year to year. With proper training in recognizing the few soils and their productivity within an area and with a guide such as that shown in Table IV-6, extension agents and fertilizer dealers could make fertilizer recommendations that would be a great improvement over those general recommendations that now exist. The guide (Table IV-6)--and training in using the guide--should be developed for all extension agents and fertilizer dealers who make fertilizer recommendations to farmers.

Chemical Fertilizer Sources and Nutrient Efficiency

Fertilizer sources refer to the chemical forms or compounds that contain the relevant nutrient. The source may be important because of physical properties that influence handling, storage, and application characteristics. Also, chemical properties are important because they, along with soil properties and method of application, determine the nature of chemical reactions in soil and thus influence the agronomic efficiency of various sources of a given nutrient.

The following are the most important considerations concerning nutrient source:

1. Cost of nutrient applied in the field.
2. In the case of subsidies, cost to the government.
3. Agronomic efficiency.

The nature of costs at the farm and costs to the government is determined by cost of supply (production or world market costs), cost of distribution and marketing, and the nature of government policy on subsidy for the fertilizer products. The agronomic efficiency of sources is determined by the rate of application, the nature of chemical reactions in soil and the method of use (practices for timing and method of application).

Nitrogen Sources

Urea is the leading N fertilizer in Bangladesh and also in Asia. It will remain so for many years because of the economics of production and distribution and the fact that urea production now occupies such a great portion of total N fertilizer production capacity in the region. Urea can be produced in various physical forms, principally various particle sizes. Currently, most

Table IV-6. Example of Local Fertilizer Recommendation Guide

Crop: Boro Rice-BR3
Species and variety

Soil Type: _____

Flooding Depth: _____

Flooding Frequency: _____

Management Capability of Farmer	Field Fertility Status	Rates of Fertilizers to Apply, md-Seer/Acre		
		Urea	TSP	MP
Low	Low	1-0	1-0	0-20
Medium		2-0	1-30	0-30
High		3-0	2-0	1-0
Low	Average	1-0	0-0	0-0
Medium		1-30	1-0	0-20
High		2-25	1-25	0-30
Low	Good	0-0	0-0	0-0
Medium		1-0	0-0	0-0
High		2-0	1-0	0-20

urea (worldwide) and all in Bangladesh is produced as prills. During the last few years granular urea production has been started at a few locations (Europe, North and South America, and Asia), and its production is being considered at other locations for new production facilities. Granular urea has better physical characteristics than prilled urea and thus may have some advantages to farmers from the viewpoint of ease and uniformity of application. Other aspects concerning the choice of form of urea production are discussed in the section dealing with Supply.

Relative agronomic efficiency of N sources (comparison of quantity of usable crop produced per unit of applied N) is determined by how available an adequate supply of N is to the plants in terms of time and quantity. For applied N, availability is mainly influenced by rate and quantity of N lost from the crop rooting zone of the soil. In the case of wetland rice (the principal crop in Bangladesh) N losses via ammonia volatilization from floodwater appear to be a major cause of low agronomic efficiency for urea. Typical farmer practices of broadcasting urea on soil or in floodwater lead to large losses of ammonia by volatilization.

Research approaches to increasing the agronomic efficiency by reducing these losses have included deep placement of urea in soil and coating with sulfur to slow the rate of dissolution of urea. Both approaches have shown considerable increases in agronomic efficiency of applied N when compared with split broadcast applied urea. To establish the validity of deep placement, large particles of urea (granules or briquettes), typically termed urea supergranules (USG), have been hand placed into paddy soil. Farmers may not accept hand placement, however, because it requires a great amount of labor. Therefore, efforts are being intensified to reduce the labor requirements by developing appropriate applicators to deep place various particle sizes of urea and urea-containing solutions.

Research with sulfur-coated urea (SCU) has shown its increased agronomic efficiency over split broadcast applied urea, and the method of application is simple; however, the estimated cost of production results in an N cost which is 30%-50% greater than with prilled urea. This increased cost is considered by many people to be unacceptable. Yet, if the applied sulfur produces crop responses, then the value of the sulfur in the SCU reduces the cost of the slow-release N.

In Bangladesh, deep-point placement of urea and single broadcast applications of SCU have been evaluated and compared with split broadcast applied urea in a number of trials. Results from one series of trials--those conducted

as a part of the IRRI/IFDC sponsored International Network on Soil Fertility and Fertilizer Evaluation for Rice (INSFFER)--illustrate the findings from those approaches to increasing N fertilizer efficiency research for rice. The graphs in Figure IV-4 show that mean responses of rice to the two new practices generally were greater than to split broadcast applied urea. Mean responses to SCU were consistently greater than to urea and mean responses to deep-point placement of USG were similar to SCU in three of the six graphs.

Two possible reasons for more consistent increased yields from SCU when compared with deep-point placement may be hypothesized. Rice responses to applied S have been noted in some areas of Bangladesh. Thus, the additional responses from SCU may be responses to S. On the other hand, the point placement of urea may be less efficient at certain of the locations because of leaching losses. Such losses have been shown to be important in certain trials conducted in other countries at locations where downward water movement is great. More detailed research, including site characterization, is needed. Relative agronomic efficiencies of the treatments are shown in Table IV-7. As the mean for 14 experiments conducted during wet seasons, the two new technologies produced from 65% to 100% more grain than did the split-applied urea within the range of applied N rates used in the experiments. During the dry season, deep-point placement produced 25% and 39% more rice than did the equivalent N applied as split broadcast urea at the low and high rates of N, respectively, whereas SCU resulted in 75% and 46% more rice.

For upland crops incorporation of urea into the soil would be expected to give greater efficiency than would surface broadcast applications. Relatively great losses of ammonia have been shown when urea is left on the soil surface, particularly under moist drying conditions. The authors are unaware of specific research in Bangladesh that demonstrates this phenomenon, but it is generally accepted by soil scientists as a prevailing condition.

Ammonium sulfate (AS) is used almost exclusively for tea plantations in Bangladesh. Ammonium sulfate is a good source of N and S for both wetland and upland crops. One possible disadvantage of AS as a source of N is its high cost if no value is assigned to the S. However, where S needs to be applied as a plant nutrient and is costed, it may be an economical fertilizer for general use in supplying a portion of the N. Ammonium sulfate may often be purchased at a low price but, in the past, supplies and therefore prices have been unpredictable. Its lower N content (about 20% N), when compared with urea (46% N), makes for higher costs of distribution, storage, and application. Agronomically, AS

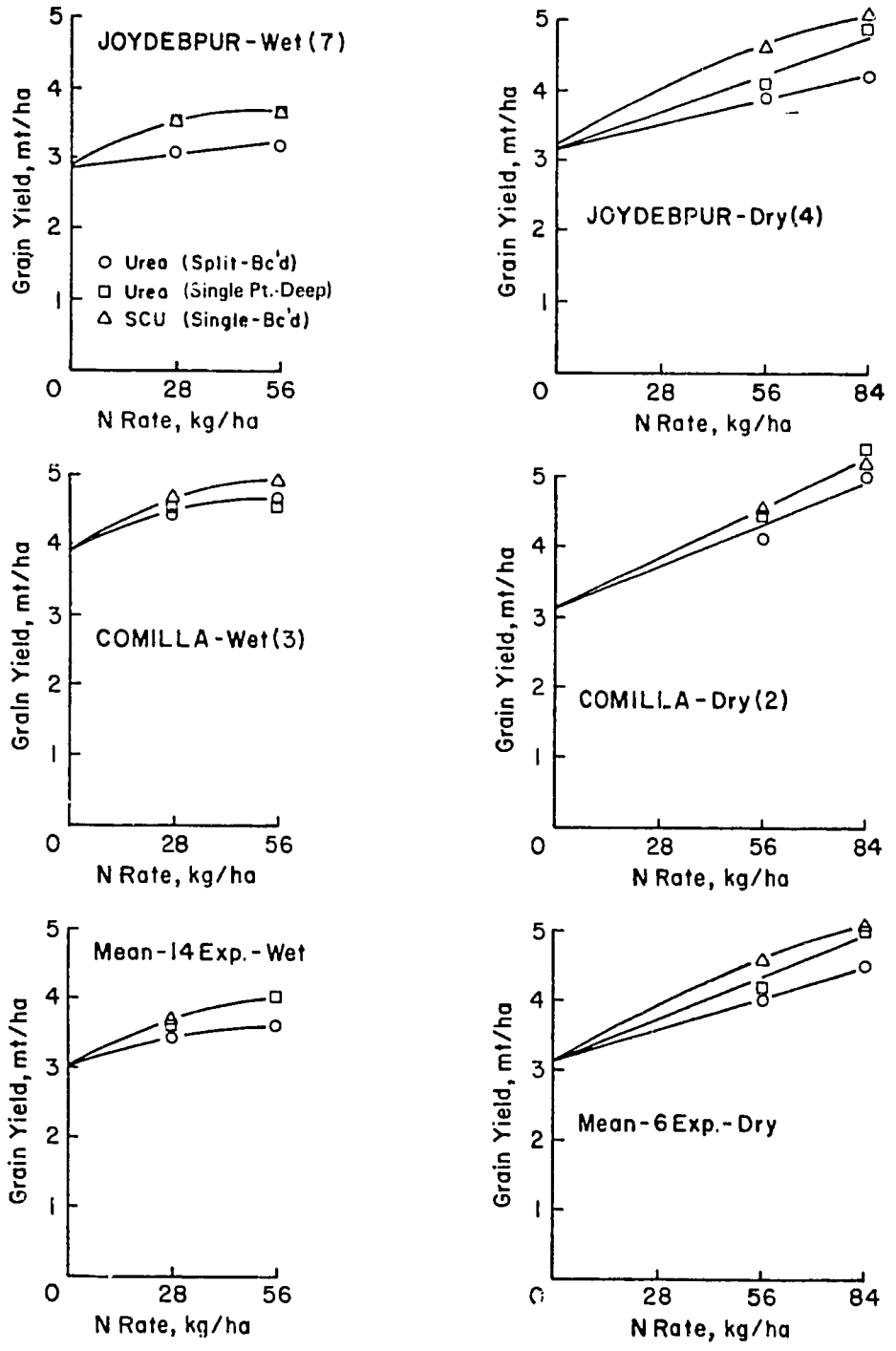

Figure IV-4. Summary Comparison of N Sources and Management for Wetland Rice in Bangladesh (INSFFER Trials, 1975-80).

Table IV-7. Agronomic Efficiencies of N Sources and Management for Wetland Rice in Bangladesh (INSFFER Trials, 1975-80)

Trial Location	Number of Trials	Applied N Rate (kg/ha)	Agronomic Efficiency, kg rice/kg N: Split Broadcast Urea	Single Deep-Point Placement	Single Broadcast SCU
		Wet Season			
Joydebpur	7	28	10.7	25.0	25.0
		56	7.1	16.1	16.1
Comilla	3	28	21.4	25.0	32.1
		56	16.1	14.3	17.7
All	14	28	14.3	25.0	28.6
		56	10.7	17.9	17.9
		Dry Season			
Joydebpur	4	56	13.0	16.7	25.9
		84	11.5	18.4	20.7
Comilla	2	56	16.7	22.2	24.1
		84	20.7	25.3	23.0
All	6	56	14.8	18.5	25.9
		84	14.9	20.7	21.8

has more acid-forming potential in soil than an equivalent quantity of N applied as urea. Also, if AS is used as the exclusive source of N for a crop, S in excess of that needed would be applied even for severe S-deficiency conditions.

Diammonium phosphate has been introduced into Bangladesh only recently. Because DAP is a granular fertilizer and the most concentrated source of N and P nutrients, it offers advantages in terms of cost of handling and distribution. In the world market, DAP is typically the lowest cost granular source of N and P. In a great number of trials around the world, DAP has been shown to be agronomically equivalent to urea as a source of N and to TSP as a source of P when the materials are similarly applied to soil. Few trials have been conducted in Bangladesh to evaluate DAP as a source of N and P. However, a relatively limited number of well-designed trials are needed to compare results in Bangladesh with findings of trials conducted in other places.

Since both N and P exist within the same particle of fertilizer, the application of DAP means that both nutrients must be applied at the same time and in the same way. Thus, if the individual nutrients must be applied differently (time or placement), DAP will not be suitable. Usually, however, this presents no problem to nutrient use efficiency because all the P and a portion of the needed N should be applied prior to planting and each should be incorporated into the soil. The farm survey data indicate that 43% of farmers who apply N on rice also use it as a basal dressing (Sidhu, Baanante, and Ahsan, 1982). If the application of some N prior to planting the crop does not result in increased growth, then the N applied prior to planting may be subject to severe losses. However, low nitrogen levels at planting will result in N deficiency in the crop, and yields will suffer.

Policy Options Concerning N Sources--Urea will be the principal source of N in Bangladesh for many years; therefore, the principal strategy must be oriented toward the efficient use of urea. The potential for increased efficiency of N use for wetland rice, as indicated by past experiments in Bangladesh, suggests that an expanded project should be initiated and should include the testing of deep placement of urea for wetland rice. Details of the testing should be planned by Bangladesh scientists. The project should include hand placement of USG initially and machine placement as soon as suitable applicators are available. The agronomic testing would include trials for Aus, Aman, and Boro rice on several major soil types and under several water regimes to permit an analysis of the effects of these variables upon responses to different N treatments. For situations where deep placement research showed promise, wider

scale testing would be conducted in farmers' fields. Following on-farm trials, pilot programs would be implemented in selected villages. Insofar as possible, villages and farmers would be selected from those for whom detailed information is available from the BARC/IFDC farm surveys.

In addition to agronomic testing, work would be conducted concurrently on placement equipment and, if USG proves attractive, on briquetting equipment also. Storage, handling, and distribution aspects of USG would be studied in pilot village studies. Additionally, economic analyses would be conducted on all agronomic, production, application, and distribution data and potential advantages and disadvantages would be estimated for farmers under various social, economic, and cultural characteristics.

Strategies concerning AS, particularly as a source of N on wetland rice, will largely be determined by its production and distribution costs compared with those for urea. Agronomic consideration of AS as a source of S is discussed later. The production aspect is covered in the Supply Section.

A portion of the N needs of Bangladesh can be supplied by DAP. As discussed in the Fertilizer Recommendations Section, however, additional research is needed to delineate the areas where N should not be applied prior to planting. Where both N and P are needed prior to planting, DAP is an agronomically suitable source of N. Its continued use in the long term may largely depend upon the economics of importing DAP for the P and possibly exporting a nitrogen equivalent such as urea when domestic production of urea reaches that level.

Phosphorus Sources

Triple superphosphate is the major source of P in Bangladesh and should be used as the standard for all comparisons. Local production, in the powdered form, is not sufficient to meet P demand, and P fertilizers must be imported. Although TSP is a good agronomic source of P, the small amount of free acid it contains causes deterioration of jute bags. **Farmers prefer imported granular TSP over domestically produced nongranular TSP, and they pay a premium for this preference.**

Diammonium phosphate characteristics, its introduction, and potential use as a source of N were discussed in the section dealing with N sources. Agronomically, DAP is equivalent to TSP as a source of P. The agronomic issue concerning DAP is whether N should be applied at the same time as P. Objections, on other than agronomic grounds, to the use of DAP in Bangladesh reportedly have arisen following reports of poorer storage and handling properties when compared

with TSP. Also since TSP and DAP are similar in physical appearance, the possibility arises that unscrupulous dealers might sell TSP for DAP and charge the higher price. The mistaken use of TSP as DAP would result in poor crop yields because the farmer would apply less N than he had intended. However, DAP and TSP are easily distinguished by taste and by a test of solution pH.

Phosphate rock is used to a minor extent as a direct application source of phosphate in Bangladesh. It is the lowest cost source of P (on a total P basis) that can be delivered (about \$286/ton of P_2O_5 when compared with \$652/ton of P_2O_5 from TSP). Phosphate rock from different sources varies in its agronomic effectiveness, particularly when only the response of the first crop after application is considered; however, its residual value may be more important than that of soluble P sources. Its effectiveness also varies between crops and soils. Phosphate rock must be used as a powder or as very small granules. Gafsa PR (highly reactive) has been tested on several soils and crops in Bangladesh (Ishaque and Rahmen, 1971). It was found to be an effective source of P for most crops when grown on soils of acid reaction. The PR that is potentially usable for direct application in Bangladesh is available from several external sources.

Partially acidulated phosphate rock products provide a series of potentially economic sources of hosphate which can be used in granular form and are potentially adaptable to a wider range of soils and crops than PR itself. The PAPR materials are partially water soluble and can be produced in TSP granulation plants. These materials have not been evaluated in Bangladesh.

Policy Options Concerning P Sources--Since large quantities of P fertilizers will continue to be imported, and since the P in TSP is agronomically equivalent to that in DAP, the use of both sources should be considered. Where a preplant application of N is unnecessary and possibly inefficient, however, TSP should be used. In those situations where both N and P should be or may efficiently be applied in the same manner and at the same time, DAP should be used since it will generally provide the lowest cost (total) forms of N and P.

The longer term strategy involves agronomic testing of both PR for direct application and PAPR as potential sources of P to possibly decrease the cost of supplying the P requirements for crop production in Bangladesh. Experiments would be conducted on various soils and for various crops to determine the agronomic effectiveness of various "available" P concentrations of PR and PAPR. Initial trials would be conducted by BRRI and BARI Agronomy and Soils Departments. During the second or third year, trials would be extended to farms in

selected areas and conducted under the supervision of the On-Farm Testing Unit of BARI. The farmer trials would be conducted on farms whose profiles are known from the BARC-IFDC farm surveys. Results from experiments and farmer trials would be systematically analyzed to define agronomic efficiency as related to site characteristics, economics of use, and potential farmer acceptance in various cropping systems.

Potassium Sources

The principal source of K is muriate of potash. The standard grade is the lowest cost source of K. Muriate of potash, i.e., potassium chloride, can be used on all crops except tobacco, and for this crop a nonchloride source of K is normally recommended because of the adverse effects of chloride on burning quality. The principal agronomic issue concerning K is that of knowing where and when it should be applied. This was discussed in the Fertilizer Recommendation Section.

Policy Options Concerning K Sources--It is recommended that standard grade MP continue to be used as the principal source of K.

Compound Fertilizers

Compound fertilizers (NPK) are currently little used in Bangladesh. Strictly speaking, compound fertilizers cannot be considered as a source of nutrients as previously defined. However, since the desirability of using compound fertilizers was considered during the course of this study, a brief discussion is presented on this point.

Compound fertilizers are produced in numerous grades and by using various sources of N, P, and K; these sources may vary greatly between fertilizers of the same grade and it is often difficult to distinguish what source is present in each. Compound fertilizers that contain the same sources of nutrients as straight materials will give agronomic results similar to the individual materials applied separately. Because additional processing is entailed in their preparation, compound fertilizers generally are higher cost than an equivalent quantity of nutrients in straight materials. Also, crops and soils in Bangladesh would require many grades of compound fertilizers; marketing of compound fertilizers, therefore, would be somewhat more complicated than marketing of straight materials.

Policy Options Concerning Compound Fertilizers--For the near future, it is recommended that straight materials, supplemented by DAP, continue to supply the major portion of nutrients in Bangladesh.

Sulfur Sources

Ammonium sulfate and gypsum are the only S-containing materials available in Bangladesh. Neither is used to a great extent for S fertilization. Ammonium sulfate is mainly used as an N source for tea, and byproduct gypsum from the TSP factory is used only sparingly at the present time. Zinc sulfate is being used to a small extent to correct zinc deficiency, but the rates of application are too small to consider it in S nutrition. Little research has been done in Bangladesh on a comparison of S sources. Research in other countries indicates that either sulfate (AS, potassium sulfate, or gypsum) or elemental S is suitable as a nutrient supply for wetland and upland crops. If that is found to be the case in Bangladesh, then the principal issue concerning S sources is that of supply at the least cost. One agronomic issue other than the agronomic efficiency of sulfur sources is that of possible adverse effects on soil; AS and elemental S have a greater potential acidity than gypsum which contains the cation calcium. Because of the residual acidity in the soil from AS and elemental S, gypsum may be the preferred source of S, particularly for already acid soils. However, if crop utilization of applied S is rather high, actual residual acidity may be relatively similar for each source.

Policy Options Concerning S Sources--Strategies on the agronomic issues need to cover two principal areas, i.e., (1) the long-term effects on soil properties from additions of S and (2) the agronomic efficiency of S sources as related to costs. Experiments should be established on several soil types with acid reaction and coarse textures to determine the long-term effects of using various rates of S sources under selected practical management conditions. Each experiment should be conducted for 5 to 10 years, and crop yields, soil pH, exchangeable bases, and available P levels should be monitored. Ammonium sulfate, gypsum, and elemental S should be included in the evaluations.

The agronomic and economic efficiency of various potentially available S sources should be determined by conducting evaluation trials on soils and for crops where S deficiencies are known to exist. Various soil properties which may influence crop response to applied S, the hydrological condition, crop responses (yield, S uptake, and N uptake), and management practices would be noted. Yield responses would be correlated with the variables and analyzed in relation to farmer cost and national costs of given sources of S.

From these two activities the best of the alternative sources of S may be selected for promotion and use for given areas. A change in cropping practices

may be all that is needed in the short term. In the meantime, dried gypsum from the Chittagong complex may be used as needed.

Zinc Sources

Typical sources of Zn fertilizers are zinc sulfate, zinc oxide, and zinc carbonate. The sulfate and oxide forms are widely used. The sulfate form is available in granular form and is more desirable than powder from the viewpoint of physical handling. Zinc oxide and zinc carbonate are slowly soluble and thus are used in powder forms to correct acute deficiencies. Also, they are less available to crops on alkaline and calcareous soils than is zinc sulfate, which is agronomically suitable both in granular and powder form. Zinc sulfate may also be used as a foliar spray. Zinc oxide and zinc carbonate are effective for correcting marginal to moderate Zn deficiency when roots of seedlings are dipped into suspensions of these Zn sources. Little research has been done on comparing Zn sources in Bangladesh. However, zinc sulfate has recently been introduced into the market and is being used to a limited extent.

Policy Options Concerning Zn Sources--Research is needed to delineate areas of deficiency, to define appropriate rates and frequencies of applications. Only limited research is needed on Zn sources. Continued use of zinc sulfate should be promoted in areas where crops respond to Zn applications.

Organic Materials and Biologically Fixed Nitrogen

The delta areas of Asia have grown rice, with seed and labor as the sole inputs, for centuries. Yields, although not high by modern standards, were adequate and relatively stable.

Increasing population pressure has led to both an extension and intensification of rice production and, importantly, to a major increase in the removal of organic matter as both straw and animal manure (undigested crop residues) for domestic use.

Soil mineral reserves, soil organic matter, biologically fixed nitrogen (BFN), and accession of minerals from rainfall and flood water can, in many cases, adequately meet the needs of many cropping systems, particularly low productive systems.

The change to higher yields and the exploitation of the poorer soils combined with situations where the organic matter is not returned to the fields

as crop residues, compost, or dung leads to a net drain on the mineral fertility of the soil and the possibility of serious yield decline.

Until relatively recently, the decline in the mineral fertility of fields was mitigated by relatively efficient recycling of all crop residues as manure, compost, and ash, and the use of leguminous crops to build up nitrogen levels.

Since the 1950s, mineral fertilizers (N, P, and K) have increasingly been substituted for both organic recycling and BFN in many intensive farming systems, and the disposal of organic residues has often become a major economic and environmental problem, rather than a beneficial part of the farming system.

Recent large increases in the cost of fertilizers and particularly of nitrogen have led to marked positive changes in attitudes to the role of inorganic fertilizer, nutrient recycling, and BFN. The current approach is to integrate sound inorganic fertilization practices with the use of organics and BFN to the maximum degree possible.

It should be clearly noted that all treatments aimed at improving the fertility of the soil, and hence crop yields, have a cost, and unless the treatments are seen to be profitable by the farmer, they will not be used. Even if the treatments recommended are economically beneficial, and this fact can be adequately demonstrated to the farmer, major changes in habits and practices will come about slowly and only with intensive farmer education and encouragement.

Some practices, such as the recycling of human excrement, may remain socially unacceptable, while the processi' and distribution of urban wastes may prove uneconomical also.

The most efficient nutrient recycling system, however, can never be totally effective, and continual inputs of plant nutrients as fertilizers into the system will be needed. Although BFN is, and will remain, a major contributor to the nitrogen balance, intensive grain production will continue to need relatively heavy inputs of fertilizer nitrogen. Therefore, maximum efficiency of this fertilizer nitrogen is a key goal.

Although the preceding generalized outline is restricted to the role of recycled organic materials in maintaining an adequate supply of plant nutrients for good crop growth, agricultural literature is replete with references also to the beneficial effects of soil organic matter on crop growth. The separation and evaluation of the effects of the plant nutrients contained in the organic matter as distinct from the effects of the organic matter *per se* have

rarely been adequately studied, however, and the situation in Bangladesh is no exception.

High-yielding agricultural soils include those with very high and very low levels of organic matter. Some of the best soils of the Mississippi delta in the United States contain less than 0.5% organic matter and yet give excellent crop yields.

Soil organic matter levels tend to stabilize as the cropping system stabilizes. To increase the organic matter content by adding organic materials is both very difficult and expensive. An illustration of this latter point comes from long-term experiments in India (Gaur, 1982) which showed little or no change in organic matter levels following the addition of 18 tons of farmyard manure applied in alternate years for 16 years.

The role of nutrient recycling and organic matter in maintaining and improving crop yields in Bangladesh is discussed as follows.

Plant Nutrients

Plant Nutrient Sources--For good crop yields, growing crops need adequate supplies of the essential plant nutrients. Currently in Bangladesh the nutrients of practical importance are nitrogen and phosphorus followed by potassium, zinc, and sulfur. No marked modification of this situation is expected up to 1990.

Sources of these plant nutrients available to the farmer are of an inorganic or organic nature. All common fertilizers are relatively pure inorganic salts with the notable exception of urea which is an organic molecule; however, urea when added to the soil is quickly changed into ammonium carbonate which is an inorganic salt.

Organic materials available at the farm level are all of plant origin, and plant and animal residues used on farms, therefore, contain most of the essential nutrients needed for plant growth, though not necessarily in the correct ratios. For example, potash is water soluble and therefore is readily lost from organic matter; in addition, organic combinations of elements, particularly in the case of nitrogen, may not be initially available to crops.

Rainfall, dust, and flood water also add nutrients to the soil, often in very significant quantities, although information on this is lacking for Bangladesh.

The effectiveness of each of these forms of material in supplying plants with nutrients is determined by the varying physico-chemical and biological impact of the material in question on the rhizosphere environment.

Fertilizer material, therefore, cannot be evaluated solely in terms of its plant nutrient content; each material must be evaluated agronomically under the conditions prevailing in the field. Even though the agronomic evaluation may be favorable in terms of nutrient value, the social, economic, logistic, and production constraints can turn an apparently suitable material into one of academic interest only.

Balanced Nutrient Supply--Balanced fertilization is the goal of all agricultural production systems. Balanced fertilization means applying those nutrients to the soil that the soil cannot supply for full plant growth. Balanced fertilization does not necessarily mean the supply of fertilizers in fixed ratios of $N:P_2O_5:K_2O$ of the order 2:1:1 or 2:1:2 For example, if either potash or phosphate is not needed, a 1:0:0 fertilizer would be considered balanced under these conditions.

The final choice of type and quantity of fertilizer to use must be based on the results of careful experimentation in farmers' fields with soils, cropping, and manuring practices typical of the area. With this approach, all of the farmer's actions that improve or deplete the fertility of his fields, including organic matter recycling and crop removal, are taken fully into account.

Soil fertility is dynamic; constant research monitoring is necessary to prevent both farm and national level waste of fertilizer due to an application of unnecessary nutrients and lower crop yields due to an inadequate supply of plant nutrients.

Table IV-8, developed with the latest Bangladesh data, shows that in terms of crop nutrients theoretically removed and actually added as inorganic fertilizer, Bangladesh soils are in an apparent negative nutrient balance for all three major elements. If depletion of soil nutrient reserves is to be reduced, this gap in nutrient supply must be filled by BFN, the recycling of plant nutrients in the organic waste, and fertilizers.

With the exception of the information gained from the BARC/IFDC farm survey (reported later), data generally available to show the amount of nutrients returned to the fields by farmers in the form of farmyard manure (FYM), litter, ash, compost, etc., are only sketchy at best and are not based on the results of careful farm-level surveys and actual chemical analyses.

Table IV-8. Estimate of Major Nutrients Contained in Aerial Portion of Crops and Applied as Fertilizer (Long Tons) in 1980/81[a]

Nutrients	In Aerial Portion of Crop	Used as Fertilizer	Nonfertilizer Nutrients
N	577,000	277,000	307,000
P_2O_5	281,000	123,000	158,000
K_2O	781,000	27,000	754,000

a. From A.J.M.A. Islam (1981).

The nitrogen returned in organic recycling is very difficult to estimate; burning and biological mineralization may result in volatilization or leaching losses of nitrogen that are very heavy. However, much of the phosphate and potash removed in the crops must find its way back to the fields in the forms of litter, ash, compost, and FYM and excreta, with the exception of phosphate coverted into animal tissue and bone.

The recovery of fertilizer-applied nutrients by crops is low. But with phosphate and potassium, there is little loss from the soil profile, and soil reserves of these elements do build up over time with resultant benefits to the level of soil fertility. With nitrogen, however, and particularly in the case of urea use on wetland rice, up to two-thirds or more of the nitrogen applied as urea fertilizer is frequently totally lost to the soil-plant system. This heavy loss is due primarily to ammonia volatilization losses. Thus, in the case of nitrogen the balance of N in Table IV-8 could reasonably be taken as -487,000 tons, i.e. (-577,000 + 90,000). This fact shows that in terms of plant nutrient uptake, fertilizer nitrogen is supplying only about one-fifth of the total estimated nitrogen uptake of crops.

In spite of the potential for losses, the crop production system over most of Bangladesh is relatively stable in terms of yields (in fact, it is increasing by about 3%/annum). This situation indicates that approximately 80% of the nitrogen economy of Bangladesh is coming from essentially biological sources.

Organic Materials and Soil Fertility

Nutrient Effects--The yield-increasing value of the traditional organic materials such as FYM, composts, etc., is due mainly to their plant nutrient content. However, the long history of using organic materials for crop production, combined with the relatively recent understanding of the principles of the inorganic nature of plant nutrition, has led many people to perceive organic

materials as "natural" fertilizers and to perceive the inorganic salts introduced as fertilizer only in the 19th century as "artificial" fertilizers, a term with disparaging connotations for nonscientists.

Recent environmentalist concerns have compounded the unfavorable attitudes of the uninformed to "artifical" fertilizers. The fact remains, however, that there is no economically sound substitute for inorganic fertilizers in our present intensive agricultural systems.

It must be stressed that there is no exclusivity in the organic or inorganic routes to increased crop yields, only complementarity. The national goal is therefore to maximize crop yields using all sources of plant nutrients at their optimum economic level.

The range of organic materials that can be used in agriculture is very wide, varying from the plant-nutrient-rich oilseed cakes to straw and dilute human and animal waste slurries. Some materials are excellent sources of plant nutrients and will help maintain high crop yields when correctly used; others, because of low or imbalanced nutrient content, may actually cause a yield depression if carelessly used.

Physical Effects--Organic materials, such as FYM and particularly straw, because of their relatively low nutrient content, are sometimes added to farmers' fields at levels sufficiently high to make an impact on the physical properties of the soil.

Increasing the organic matter of a soil is generally credited with improving not only the nutrient content of the soil but also its physical characteristics such as structure, water-holding capacity, and cation exchange capacity.

Only rarely do field experiments show that organic matter applications are followed by increases in crop yields over and above those due to the plant nutrient content of the material applied. On the contrary, depressions of crop yields have been recorded following application of straw, particularly under waterlogged conditions.

Organic Recycling and Soil Nutrient Status

While it appears desirable for agriculture to recycle to the maximum the organic wastes it produces, the social, environmental, and economic benefits of such recycling are not always significantly positive. In fact, under many conditions the use of inorganic fertilizers combined with sound crop production practices is all that is needed to improve and then maintain soil productivity.

[Any positive yield influence of applied organic matter under these conditions, i.e., where soil fertility is already high, is unlikely to occur, since high-yielding crops return considerable quantities of organic matter to the soil as roots, stubble, and plant debris.] A high-yielding variety of rice, for example, will give grain to straw to root ratios of 2:2:1.

The use of organic matter is therefore to be seen not as a panacea for increasing crop production but as a logical way to recycle plant nutrients with the added benefit in some localized cases of a general improvement in soil productivity.

Under normal farming conditions, organic recycling does not build up soil reserves of plant nutrients unless the organic material is drawn from a wider area than the area organically fertilized or, in other words, unless one area is depleted of plant nutrients to the benefit of another area.

The value of organic recycling to a cropping system depends on the nutrient involved; nitrogen, phosphorus, and potassium are the major elements, but sulfur and trace elements may also be important.

Nitrogen--The nitrogen cycle is complex. Nitrogen can be lost by burning, ammonia volatilization, or nitrate leaching following microbial mineralization of the organic matter, or it can remain in the soil as organic matter unavailable to growing crops.

Nitrogen can be restored to the cycle through the use of inorganic fertilizers and the biological fixation routes. However, in the absence of a major biological source of N in an intensive cropping system, N fertilizers are invariably needed to achieve high cereal grain yields. This is the current situation in Bangladesh, a situation which will not change before 1990.

Organic recycling is therefore a method of reducing the losses of nitrogen during the N cycle and is complementary to N fertilization of cereal crops and not a substitute for it. Burning of organic matter results in a total loss of all the N contained therein, and use of N fertilizers may depress BFN levels. The practice of deep placement of inorganic N reportedly enhances BNF; further verification is needed.

Phosphate--Bangladesh has large areas of phosphate-deficient soils and the only way to redress this deficiency is by the rational use of phosphatic fertilizers; organic recycling will then help to maintain the level of phosphate fertility developed. Organic recycling by itself cannot improve the phosphate fertility status of a soil; therefore, until the phosphate levels of Bangladesh soils are considered adequate for optimum crop growth, phosphate recycled with

the organic matter is of value, and this should be taken into any economic evaluation of the practice. Because ash contains the phosphate originally present in the organic matter burned, ash recycling is important.

Potash--Potash deficiency in Bangladesh is recorded, but lack of this nutrient is currently not a major constraint to crop production. However, all crops contain large amounts of potassium, particularly in the foliage and straw. Many fields in Bangladesh are completely stripped of all the straw that they produce, and potash removal is therefore heavy.

The potash reserves of Bangladesh soils are generally good, but continual heavy depletion of potash by crop removal will eventually create more widespread deficiency problems, particularly in the highly productive cropping systems. Potash remains in the ash residue of any organic matter burned, and therefore considerable recycling of potash already occurs in Bangladesh.

The potash status of the highly productive cropping systems should be carefully monitored, and in the presence of a detected deficiency the use of the fertilizer potassium chloride should be encouraged.

Excessive use of high potash organic residues can trigger magnesium deficiency in growing crops, particularly on the lighter soils, and the possibility of this negative effect must also be monitored.

Biological Sources of Nitrogen

Rhizobium--Fully nodulated and healthy roots of the leguminous plants can fix a considerable amount of nitrogen, which then becomes available to those plants and other crops.

Crop price factors have caused the area of leguminous crops grown mainly in the rabi season to decline because of competition from Boro rice.

Grain legume rotations are a sound practice for reducing nitrogen fertilizer demand; however, with the types and varieties of legumes grown in Bangladesh, production is so low that any decision to increase grain legume production must be made in terms of human nutritional needs and not on a basis of soil N-supplying capacity.

The contribution of the planned production of grain/legumes to the total nitrogen economy of the crops of Bangladesh, although significant, will be small. No change in this situation is anticipated before 1990.

Green Manuring--This was a popular method of developing soil fertility in the past and is still of value in soil reclamation projects.

The idea of a small farmer growing a crop to plow under seems far-fetched, and the fact that this practice of green manuring has not spread indicates its lack of appeal. There must be an identifiable economic benefit from any crop grown.

Azolla--Widely used in China and Viet Nam, the Azolla-Anabeana system (a small water fern growing in symbiosis with a blue-green algae) is currently being intensively studied as a way to fix nitrogen for later use by the rice crop. It may be useful in the T. Aman crop, but it is unlikely that this system will have a major impact on the nitrogen supply of Bangladesh before 1990.

Blue-Green Algae--These organisms fix nitrogen and indeed they are an important source of BFN in Bangladesh. Their culture and use as a source of nitrogen is being actively developed. The time-horizon for the development of suitable techniques and their widespread adoption by farmers is the same as that for Azolla. Therefore, we anticipate no major increase in BFN from blue-green algae before 1990; in fact as urea use increases, some reduction in BFN is to be anticipated. The use of placed urea supergranules would allow algal BFN to continue undiminished.

The Bangladesh Situation

Population pressures change farm practices. The historical development of organic recycling in China and Japan occurred because the ever-present threat of famine demanded yield maximization and organic materials were the only available source of yield-increasing nutrients, particularly nitrogen.

In comparison, the people of Bangladesh and other deltaic countries used the natural fertility of their soils to achieve a low but adequate yield plateau which sufficed until population pressures began to build. The natural farmer reaction to increased food needs is to expand the acreage of cropped land and develop the use of multiple cropping to the degree possible. Increases in crop yield per unit area become attractive when there is little room left for expanding acreages. The use of labor-intensive activities also is attractive when labor can substitute for purchased inputs and population pressure can push agricultural production in this direction.

The foregoing generalizations all have an economic base to which the farmer, given sound technical guidance, will eventually react. If organic matter recycling is seen to pay in terms of crop yield, then farmers will increasingly use this approach.

In Bangladesh almost all of the straw and litter is removed from many fields for domestic and animal production use. In those areas where the straw is not removed (mainly in the deep water areas), it is burned in order to kill pests and diseases and to facilitate later cultivation activities. In the former case, all plant nutrients contained in the straw and litter are lost from the field; in the latter case, however, only the nitrogen and a varying proportion of the sulfur are lost in burning.

Three types of organic manure are used in Bangladesh: farmyard manure, compost, and ashes. The typical Bangladesh treatment with FYM is only about one and one-half tons of material per acre (of unknown and often relatively poor nutrient content). This is a relatively insignificant quantity of organic matter in terms of physical effect on the soil, but the nutrient contents are probably significant in terms of influencing crop yields. Generally, FYM is credited with containing 0.5%, 0.3%, and 0.5% of N, P_2O_5, and K_2O, respectively, on a dry matter basis. Compost and ash analytical data are not available.

Analysis of the IFDC/BARC farm survey data (Table IV-9) indicates that, in Bangladesh, the overall average use of these three organic manures as fertilizers is very low. The average for the 1979/80 crop year was about 21.3 maunds per acre (17.6 md/acre of farmyard manure, 2.6 md/acre of compost, and 1.1 md/acre of ashes). Farmyard manure, the major organic fertilizer used by the farmers in all crops and seasons, accounted for about 83% of the total use of these three organic fertilizers.

Estimates of farm-level demand functions for chemical fertilizers indicate that farmers use farmyard manure and compost as a supplement rather than as a substitute for the use of chemical fertilizers and that the use of FYM and compost has an insignificant or very small influence on the demand for chemical fertilizers.

The use of organic fertilizers is widespread across locations and in all seasons. However, for the 1979/80 crop year the use of these organic manures was greater in the 1980 Aus season (57%) than in the 1979/80 Boro (28%) and 1980 Aman (15%) seasons. The highest average levels of use of farmyard manure (33.3 md/acre) and compost (6.2 md/acre) occurred in the 1980 Aus season and the highest average levels of use of ashes (2.8 md/acre) in the 1979/80 Boro season. Average levels of use of organic manures (Table IV-10) were higher for potato (60.0 md/acre), chili (40.0 md/acre) and other vegetable crops (34.8 md/acre) of the Boro season, and in the paddy (40.0 md/acre) and jute (42.2 md/acre) crops of the Aus season. The use of organic manures was considerably lower in the

Table IV-9. Use of Farmyard Manure, Compost, and Ashes by Season, 1979/80, Bangladesh

Seasons	Farmyard Manure	Compost	Ash	Total	% of Total Used in 1979, Crop Year
	(md/acre)				
Aman 1979	4.82	0.18	1.06	6.06	
Boro 1979/80	18.08	0.59	2.79	21.46	28.2
Aus 1980	33.29	6.18	0.77	40.24	56.7
Aman 1980	6.16	1.35	0.10	7.61	15.1
Average[a] of 1979/80 Crop Year	17.64	2.59	1.05	21.28	
(%)	(83)	(12)	(5)	(100)	

a. Average weighted by areas cropped in the 1979/80 Boro, 1980 Aus, and 1980 Aman seasons.

Source: Sidhu, Baanante, and Ahsan (1982).

Table IV-10. Crop Use of Organic Manures by Season 1979/80, Bangladesh

Seasons-Crops	Use of Organic Manures			
	Farmyard Manure	Compost	Ashes	Total
	(md/acre)			
Boro Season, 1979/80				
Paddy LV	1.45	0.01	0.30	1.76
Paddy HYV	21.74	0.39	4.03	26.16
All paddy	14.22	0.25	2.64	17.11
Wheat LV	17.05	2.37	0.68	20.10
Wheat HYV	26.33	0.59	3.88	30.80
Pulses	6.77	0.18	1.30	8.25
Oilseeds	12.92	0.33	0.70	13.95
Kawn	23.32	3.34	3.56	30.22
Potato	53.85	1.42	4.76	60.03
Spices	30.67	0	1.20	31.87
Oats Barley	7.61	0	0	7.61
Chili	29.30	3.84	6.84	39.98
Vegetables	26.08	1.89	6.85	34.82
Aus Season, 1980				
Paddy LV	31.93	7.73	0.84	40.50
Paddy HYV	34.19	3.00	0.53	37.72
All paddy	32.38	6.84	0.80	40.02
Jute	37.80	3.70	0.74	42.24
Aman Season, 1980				
Paddy LV	6.45	1.20	0.03	7.68
Paddy HYV	4.70	1.67	0.03	6.40

Source: Sidhu, Baanante, and Ahsan (1982).

paddy crop of the Aman season (7.7 and 6.4 md/acre in local varieties and HYVs, respectively).

Production function estimates for different crops in each season indicate that, holding other factors constant, the use of farmyard manure and compost had a statistically significant positive effect on paddy yields of the 1980 Aus season. However, the direct influence of these organic fertilizers on paddy yields was quite small compared with the influence of chemical fertilizers.

The use of a maund of FYM and compost per acre in the 1980 Aus season increased yields of broadcast paddy by 0.01 md/acre and of transplanted paddy by 0.08 md/acre, whereas a maund of chemical fertilizer per acre increased paddy yields by more than a maund per acre.

At present, the direct contribution of FYM and compost to crop yields in Bangladesh is quite small; it is small mainly because both the levels of use and the inorganic plant nutrient content are low. However, it is important to understand that these organic fertilizers, used at sufficiently high levels, may have significant indirect effects on crop yield through their impact on the physical properties of the soil. Improvements in the structure, waterholding capacity, and cation exchange capacity of the soil, as a result of high levels of use of organic fertilizers, may indirectly increase crop yields by enhancing the effects of other factors of production on crop yields (positive interactions of organic fertilizers with other factors of production on crop yields).

The limitations on expanding the supply of organic manures in Bangladesh and the need for using animal dung as fuel suggest that use of organic manures as fertilizer is expected to remain low. The benefits and costs of policies designed to increase food and agricultural production in Bangladesh by expanding the farmers' use of organic manures in crop production should be estimated and compared with those of alternative policies (improvements in irrigation, drainage and flood control, and price policies, etc.). Important considerations (and problems) in evaluating the benefits associated with the use of organic manures are (1) the possible effects that the use of organic manures may have on crop yields through several seasons (residual effects) and (2) the effects that the use of organic manures may have on crop yields in interaction with other inputs.

The availability of cheap plant nutrients as inorganic fertilizers will retard farmer interest in the use of organics; inorganic fertilizers--when all costs including labor, are taken into account--are seen to be more cost

effective. Greatly increased convenience in handling is just one part of the economic advantage.

Comparison With China

The IRRI data from China quoted by FAO indicate that the production and use of 1 ton of commune compost require 1 workday of labor. The compost contains about 1 kg/N which at that time (1977) was worth US $0.73, as urea. This gave an imputed daily wage equal to that in most developing countries of Asia at that period.

In Bangladesh a kilogram of N from urea currently costs the farmer about US $0.40 or about 8 TK. This figure, which appears to be much lower than the daily cost of labor in rural Bangladesh, is important because it does put the nutrient content of organic materials into some sort of economic perspective, an approach which is very much needed if farm practices are to be understood and changed.

The Chinese practice of organic recycling is very labor intensive and needs a considerable degree of group direction and planning. Bangladesh practices are currently not so organized, but the use of FYM, composted household litter, and ash is very widespread. The common sight of neatly spaced heaps of such materials ready for incorporation into the soil shows that organic recycling is in fact a major agricultural activity in many areas of Bangladesh. This has been confirmed in the BARC/IFDC farm survey.

The following conditions indicate the major obvious ways in which organic recycling in Bangladesh differs from that in China:

1. No formal recycling of human excrement is undertaken.
2. There is considerable use of animal dung and straw as a fuel, meaning a heavy loss of nitrogen.
3. The pig, which is central to much of Chinese organic recycling activities, is absent.
4. Unlike the Chinese farmer who is directed in his daily activities, the Bangladesh farmer has freedom of choice.

Biogas Generators

The anaerobic fermentation of organic residues leads to the production of methane gas, a potentially valuable fuel, and liquid residues which can be used as a source of plant nutrients.

In World War II, German farmers used methane generated from farm wastes as a fuel. The Chinese have developed the use of small-scale biogas units for domestic use (FAO quotes 1 million units in operation), and apparently adoption of this technology is proceeding apace.

The Indian experience, one of more relevance to the Bangladesh situation, is quite different. In India it is believed that about 8,000 gobar gas units have been installed, mostly as individual plants owned by affluent farmers. Only two community plants (Etowah in Uttar Pradesh, and Karimnager in Andra Pradesh) are reported to be operating successfully.

In Gujarat a study indicated that 71 of the 199 plants studied were inoperable (Kurien, 1981).

Given the Indian experience, it seems unlikely that biogas plants will play any significant role in the organic recycling by Bangladesh farmers before 1990. The main advantage is that gas is produced; fertilizer is a byproduct.

Policy Issues and Options

1. Soil reserves, recycled plant nutrients together with biologically derived nitrogen, are the major source of plant nutrients. Therefore, farmers need continual encouragement to increase the rational recycling of plant nutrients through the return of organic residues to fields. Quantitative and qualitative studies of nutrient recycling are also needed.
2. Localized burning of straw or plant residues that carry pests or disease or interfere with farm operations is acceptable, but the practice should be monitored to ensure that unnecessary burning is not taking place.
3. (a) The loss of nitrogen through the use of FYM, etc., as fuel can only be reduced through the development of alternative cheaper energy sources. The development of arboricultural techniques using quick-growing species must be considered a national priority.

   (b) The loss of nitrogen from urea used in rice production is heavy. A strong field action program following the IFDC China workshop in April 1982 is needed.
4. The biological sources of nitrogen are important but, of course, are not expected to change or increase markedly within the period to 1990. Any policy leading to an increase in grain/legume production, while possibly helpful in terms of an increased input into the N economy, must be determined on the basis of population nutritional needs, not in terms of N fixation.

5. Phosphate-deficient areas must receive a rational phosphatic fertilization. Organic recycling will help to maintain the soil phosphate levels established.
6. Although potash is needed by plants in large quantities, natural soil resources and organic matter and ash recycling have maintained available potash levels at apparently adequate levels in many soils. The potash status of Bangladesh crops needs constant monitoring in order to anticipate possible potash stress. Particular care must be taken in those areas of intensive crop removal.
7. Sulfur is recycled with the organic matter and in ash to some degree. Identified deficiencies of S need correcting by using elemental S or sulfur salts. A change in the cropping system practiced may help.
8. Micronutrients are maintained at high levels when organic matter and ash are recycled. Identified deficiencies should be corrected by the use of the relevant inorganic salts. On high pH soils, organic matter *per se* is beneficial in improving trace element availability. With water-logged soils, organic matter can interfere with the trace element nutrition of crops.
9. The best way to improve soil productivity is by the use of modern production techniques. Very high levels of organic matter are maintained in intensive horticultural production, a practice which pays because of the high value of the crops produced.

   Attempts to raise organic matter levels in areas of problem soils may be worthwhile; in general, it can be stated that the nonnutrient role of organic matter in agricultural production in Bangladesh is limited. Encouragement of sound husbandry practices, rational fertilizer use, and the return of crop residues for nutrient recycling is almost certainly adequate to maintain long-term productivity.

   Care must be taken to avoid excessive accumulation of organic matter under intensive flooded-rice cropping.
10. Soil organic matter levels should be monitored on a regular basis at certain benchmark sites and where problems are seen to be developing, changes in the cropping system will be needed.
11. Formal community or family action to recycle human waste does not exist in Bangladesh and is unlikely to exist by 1990.
12. The collection and treatment of urban waste for farm use should be considered, but this activity will certainly need to be heavily subsidized as transport and distribution costs will be high and farm-level value low.

13. Biogas generation appears to be attractive, but Indian experience, which should be continually monitored, is not promising in the short term.

Agronomic Requirements of Nutrients to Meet Crop Production Goals

Agronomic requirements of nutrients to meet crop production goals are related to, yet distinctly different from, fertilizer demand. Although demand is dependent upon physical crop response to fertilizer (as is agronomic requirements to meet crop production goals), demand also depends upon social-economic conditions such as price relationships, farmer attitudes, and availability of supplies of all production inputs.

As used in this document, the agronomic requirements for nutrients to meet crop production goals are sums of estimates of nutrients that are required to produce stated quantities of crops. The estimates must be confined to realistic crop yields, profit-maximizing rates of nutrient applications, and realistic areas for specific cropping conditions. Different requirements may be estimated depending upon the specific areas which are allocated to various crops and upon the allocation of fertilizers to various areas.

Many estimates have been made of nutrient requirements, projected nutrient demand, and other fertilizer use-related projections. Generally, the sources of data used and assumptions made in developing the estimates are given. However, in some instances, there is confusion among various administrators, planners, scientists, and specialists as to the meaning of the estimates and, for that matter, even what the estimates project. Often projections made for one purpose are referred to as projections for another purpose, even by the authors themselves.[4]

Very great care must be taken in referring to estimates and projections in terms that are dictated by the methodology used. It is also important to examine the validity of assumptions used in making estimates or projections.

The components of a nutrient requirement projection include the following items:

1. Targeted production, defined as the quantity of each specific crop to be produced in a specified time period.

4. See, for example, M. A. Islam (1980) and A.J.M.A. Islam (1981).

2. Area available for each crop, including shifts in area from one crop to another, double and triple cropping, nonharvested area, and the yield potential for various crops within each crop production region.
3. Response of various crops to fertilizers, including the effect of variations in time, rate, and method of application on response; effect of nutrient losses due to leaching, volatilization, denitrification, and runoff; effect of variation in weather; effect of balanced or unbalanced nutrient applications; and effect of nutrient source.
4. Factors modifying crop production, including weather, availability of water or drainage, and availability of supporting inputs (pesticides, improved seeds, mechanization, credit).
5. Management ability of farmers in such areas as exposure to new ideas, incentives to adopt new technology, experience in using fertilizers and other practices, and labor supply.

Considerations concerning the stratification of data into groups in which similar crop responses may be expected and the estimates of the crop response within these stratified groups (items 2, 3, 4 and 5 listed above) are discussed in other sections of this document. Considerations concerning the delineation and definition of production targets are discussed in the following section.

Production Targets

The SFYP established production targets for 12 major and minor crops for the terminal year (1984/85). Self-sufficiency in foodgrains (rice and wheat) was a goal; none of the other crops was singled out for special emphasis. The formulation of policy options for the development of the Bangladesh fertilizer sector, however, requires consideration of fertilizer needs for an additional 5-year period up to 1989/90. Thus, production targets for all crops responding to fertilizers must be established for 1989/90.

Production targets for foodgrains and other crops should be based on the rate of population increase and per capita food requirements. Targets for nonfood crops presumably are increased from the base year at the same percentage rate as that used for the food crops. However, there is no guideline concerning the rate of population growth for the 1985/86-1989/90 period nor for per capita food requirement. If the birth-control program is significantly effective (a reduction in population growth rate from 2.5% to 1.8% is targeted for 1984/85), food requirements will be significantly reduced. If per capita consumption is

to be significantly increased, food requirements will be measurably increased. A change in either or both of these assumptions would have a major effect on projections of plant nutrient requirements.

Except for foodgrains, there is no priority listing for the crops on the producton target list; i.e. there are no minimum or maximum production goals. Neither is there any estimate of the cost of reaching targets via full implementation of the fertilizer supply and use scheme versus some modifications in the scheme supplemented by imports.

Policy Options--The Ministry of Agriculture and Forests should establish minimum and maximum goals on a crop-by-crop and year-by-year basis, preferably through the year 1989/90. As an alternative, nutrient projections for policy options should include a high and a low projection with the basic assumptions listed along with an evaluation of the degree of certainty or uncertainty of the assumptions. In addition to the minimum/maximum goals, priorities of production are needed so that fertilizer allocations can be established during shortage conditions. Production goals intermediate between the minimum and maximum would also be useful in developing the priority list.

Estimates of Nutrient Requirements

A review of the various projections and estimates revealed that only four have been made on the basis of using fertilizer nutrients to increase food production. Two were made on the basic assumption that a unit of fertilizer or nutrient produces a given quantity of food (average for country). However, the assumptions differed in quantifying the amount of food produced as a result of fertilizer use, and other assumptions differed also. The other two estimates were based upon nutrient balance, i.e., nutrients removed from fields in crops (requirements) and supply sources other than fertilizers.

The following comparisons are made not as a criticism but as an illustration of the need for a sophisticated approach to the whole problem.

1. M.A. Islam--Crop Response Method--It was assumed that 50% of increased food production would result from fertilizer use and that 5.28 kg of clean rice or 4.5 kg of wheat flour results from each kilogram of fertilizer nutrient. The basis of the estimates was that 2.183 million tons of rice (food) and 0.965 million tons of wheat (food) would be needed in 1984/85 in addition to that in 1977/78 (base year). The additional production would require 413,000 and 214,000 tons of nutrients for rice and wheat, respectively. It was also assumed that an additional 95,000 tons of nutrients would be used

for other crops. Thus, the total additional nutrient requirement to that which was used in 1977/78 was 722,000 tons, and 1,053,000 tons of nutrient would be required to meet the food production goals in 1984/85 as established in the SFYP (Table IV-11).[5] Individual nutrient requirements were estimated by assuming that the ratio of nutrient use would be 5:3:1 by 1984/85. Thus, the estimated nutrient requirements by this method are 585,000, 351,000, and 117,000 tons of N, P_2O_5, and K_2O, respectively.

2. A.J.M.A. Islam--Crop Response Method--The estimate of foodgrain produced by a unit of fertilizer nutrient was obtained from regression of foodgrain (rice plus wheat) production for the period 1969/70 to 1979/80 on quantity of fertilizer used during the same period of time. The resulting regression equation was this: foodgrain production = 9.71 + 5.30 (fertilizer applied), where each food and fertilizer unit is expressed in units of million tons. If fertilizer contains 46% nutrients, this gives 11.52 kg of foodgrain/kg of fertilizer nutrient which is about 43% greater than M. A. Islam assumed. Total fertilizer requirement for 1984/85 was calculated to be 1.926 million tons. To estimate requirements for urea, TSP, and MP, the total fertilizer requirement was partitioned at the ratio of 8:4:1 for the respective products. This resulted in a nutrient ratio of 6.1:3.1:1. Thus, when the fertilizer requirement is partitioned and converted to nutrients, the estimate of nutrient requirement for 1984/85 is 545,000, 273,000, and 89,000 tons of N, P_2O_5, and K_2O, respectively (Table IV-11).

3. A.J.M.A. Islam--Nutrient Balance Method--This method estimates nutrients contained in the quantities of crops required to meet the food production goals and subtracts the estimated quantities of nutrients supplied from soils and use of organic material. This residual is assumed to come from fertilizer. But, since the total fertilizer nutrients are not taken up by plants, an efficiency factor is used to estimate the quantity of nutrients which must be applied (Table IV-12). The nutrient requirements to meet the 1984/85 food production goals, so calculated, are 697,000 and 348,000 tons of N and P_2O_5, respectively. With this method, no requirement was found for K_2O. However, soil K_2O needs do vary, and it was recognized that the requirement may be about 47,000 tons of K_2O (Table IV-11).

5. The figure of 1,053,000 differs from Dr. M. A. Islam's figures because it has been corrected based upon estimated nutrient consumption in 1977/78 which was his base year for estimating increased food need.

Table IV-11. Summary of Estimates of Nutrient Requirements to Meet Food Production Goals, 1984/85 and 1989/90

Method	Nutrient Requirements			
	N	P_2O_5	K_2O	Total
	(thousand tons)			
		1984/85		
1. Crop response[a]	585[c]	351[c]	117[c]	1,053[c]
2. Crop response[b]	545	273	89	907
3. Nutrient balance[b]	697	348	47	1,081
4. Nutrient balance[b]	615	307	42	964
		1989/90		
1. Crop response[a]	760	380	190	1,330
2. Crop response[b]	716	358	116	1,190
3. Nutrient balance[b]	966	482	66	1,514
4. Nutrient balance[b]	875	437	59	1,371

a. From M. A. Islam (1980).
b. From A.J.M.A. Islam (1981). Method 4 is similar to method 3 except that it was assumed that deep-water rice would not be fertilized.
c. In the report these figures were 674, 337, 84, and 1,095 for N, P_2O_5, K_2O, and total, respectively. M. A. Islam summed additional requirements 1977/78 to 1984/85 and nutrients used in 1979/80, but his base crop production year was 1977/78. The above figures are a result of the sum of 1977/78 nutrient use and additional requirements to produce the additional food.

Table IV-12. Estimated Nutrient Removal by Crops for 1984/85 and Estimated Supply From Soil and Organic Materials and Need From Fertilizer

Crop	Crop Production	Nutrient Removed by crop	Nutrient Supply: Soil and Organic Material	Nutrient Supply: Chemical Fertilizer	Fertilizer Nutrient Need to Apply[a]
	(Million tons)	(thousand tons)			
		Nitrogen (N)			
Rice	16.53	470	350	120	400
Wheat	1.96	54	27	27	90
Others	-	135	77	62	207
TOTAL	-	659	454	209	697
		Phosphate (P_2O_5)			
Rice	16.53	189	88	101	252
Wheat	1.96	20	5	15	38
Others	-	42	19	23	58
TOTAL	-	251	112	139	348
		Potash (K_2O)			
Rice	16.53	685	1,964	None	None
Wheat	1.96	40	379	None	None
Other	-	146	227	None	None
TOTAL	-	871	2,570	None	None

a. It is assumed that applied fertilizer N is 30% efficient and fertilizer P is 40% efficient.

Source: A.J.M.A. Islam (1981).

4. A.J.M.A. Islam--Nutrient Balance Method, Excluding Deep-Water Rice Fertilization--Additional estimates of requirements were based upon the same assumptions as above except it was assumed that deep-water rice would receive no chemical fertilizer. The requirements were thus reduced to 615,000, 307,000, and 42,000 tons of N, P_2O_5, and K_2O, respectively, for 1984/85 (Table IV-11).

For 1984/85 there is about a 20% difference between the high and low estimates for total nutrient requirements, and there is more than a twofold difference for K_2O requirements. All of the estimates were made on a macro basis, i.e., assumptions were made for national averages (grain produced per unit of fertilizer, nutrient supply from soil and organic materials, and fertilizer efficiency. None took into account the rate of change of other factors that affect yield or crop response to fertilizer. For the crop response method, somewhat arbitrary allocations were made for individual nutrients. The problems with such estimates are self-evident.

The above estimates could be improved somewhat by modifying the assumptions and by stratifying the country into certain crop production situations. However, it appears that at this time there is not enough sufficiently reliable data on farm-level crop response to significantly improve the estimates or to select one as better than others. When the farm survey data are examined in greater detail, they may present the base for refining the estimates.

Policy Options for Improving Estimates of Nutrient Requirements

Most of the recommendations pertaining to this issue have been previously discussed. These included better definition of land areas by soil fertility status and improved estimates of response of farmers' crops to fertilizers. An example of a tabular model, given in Appendix Table IV-1, may be useful in estimating nutrient requirements by building toward the total from units of soils, crops, degrees of water control, and farmer management capability. Any estimate involves some degree of subjectivity, but the structuring of the methodology and selecting units for which the best possible assumptions can be made will result in improved estimates of nutrient requirements for meeting food production goals.

Optimal Allocation of Fertilizers Under Adequate and Short Supply Conditions

When fertilizer supplies are adequate, there is no need to allocate fertilizers. The marginal return per unit of fertilizer, plus a family's needs for other crop products, will determine how farmers use fertilizers. Adequate fertilizer supplies are predicated upon an equitable distribution system and an "open" market--open to the extent, at least, that GOB may control fertilizer and crop prices but not establish actual production quotas for foodgrains, jute, or other crops. It is also assumed that the other inputs required to produce the farmer's choice of crops, such as seeds, credit, pesticides, etc., are available. Because GOB can control fertilizer and crop prices through its subsidy program, it, in effect, allocates fertilizers regardless of the quantity available. When fertilizers are in short supply, both the marginal return and the minimum production requirement become important. The MAF establishes priorities for production of all crops and oversees the use of fertilizer on selected crops. There is not too much difficulty in allocating fertilizers when supplies are equal to or slightly less than that required to produce the minimum crop requirements. When fertilizer supplies are sufficient to produce more than the minimum crop requirements but are not adequate for unrestrained trade, the allocation is more difficult.

Marginal returns to fertilizer use can be utilized as a guide for making allocations. It has been recommended that an economic analysis be made of the incremental returns from the use of fertilizer. After this has been completed, the marginal returns from each plant nutrient, for all crops, should be ranked in descending order. The ranking might appear somewhat as shown in Table IV-13 when increments of 20 kg of plant nutrients are used. Using this example, the first choice for allocating fertilizers is 20 kg of N/ha for HYV rice in irrigated areas. If more nitrogen is available, the allocation for the same HYV rice in the same area is increased to 40 kg N/ha. The next incremental allocation is 20 kg N/ha for HYV wheat in irrigated areas. If a crop with high marginal returns to fertilizer use under normal conditions appears on the list but is not critical for food production, it receives no allocation and the next choice is made. Thus, mustard in Table IV-13 may not be essential and it would be eliminated from the table. For political reasons it might be wise to allocate fertilizer to producers of local rice varieties in the rainfed area although fertilizer supplies would not reach this far under the recommended

Table IV-13. An Illustration of Ranking of Marginal Returns From 20-kg Increments of Plant Nutrients

Crop	Variety	Geographical Area[a]	Rainfed or Irrigated	Fertilizer Increment N	P_2O_5	K_2O	Marginal Returns[b]
Rice-Boro	HYV	-	I	0-20	-	-	21.0
Rice-Boro	HYV	-	I	20-40	-	-	19.6
Wheat	HYV	-	I	0-20	-	-	19.5
Rice-Aus	HYV	-	I	0-20	-	-	19.0
Rice-T. Aman	HYV	-	I	0-20	-	-	18.7
Wheat	HYV	-	I	20-40	-	-	18.6
Rice-Boro	HYV	-	I	-	0-20	-	18.2
Potato	HYV	-	I	0-20	-	-	18.1
Mustard	Local	-	R	0-20	-	-	18.1
Potato	HYV	-	I	-	0-20	-	18.0
Rice-Boro	HYV	-	R	0-20	-	-	17.6
Rice	Local	-	I	0-20	-	-	17.6
Rice-Boro	HYV	-	I	-	-	0-20	13.3

a. Soil types or groups delineated to give rather uniform response patterns would be a better classification for optimum allocation, but physical problems in distribution of fertilizers to soil areas may dictate selection of geographic areas and estimating average response patterns and marginal benefit/cost ratios.
b. These ratios are artificial and probably have no resemblance to Bangladesh conditions. They are used only to illustrate the technique.

allocation procedure. Such allocations are given priority, and the remaining fertilizer is allocated according to the table.

It must be remembered that marginal returns change whenever there is a change in either the cost of the fertilizer or the price of the commodity. Maximum marginal returns to fertilizer use are obtained when small amounts are applied on as much land as possible. However, this would require an elaborate distribution system. To overcome this problem, crop ranking tables could be made on a regional basis and fertilizer allocated accordingly.

Appendix Table IV-1. Tabular Model of Data Requirements for Projecting Nutrient Requirements

1. Soil unit: _____
(species-variety)
2. Crop: _____
3. Production target for year for this soil unit only:
   a. Minimum, tons _____
   b. Median, tons _____
   c. Maximum, tons _____
4. Productivity (yield without fertilizer):
   Rainfed soils
   a. Local variety, kg/ha _____
   b. HYV, kg/ha _____
   Irrigated soils
   c. Local variety, kg/ha _____
   d. HYV, kg/ha _____
5. Area available (in this soil unit) Currently used for this crop:
   Rainfed area
   a. Local variety, ha _____
   b. HYV, ha _____
   Irrigated area
   c. Local variety, ha _____
   d. HYV, ha _____
   Currently used for other crops
   e. Rainfed area, ha _____
   f. Irrigated area, ha _____
   Planned for this crop this year
   Rainfed area
   g. Local variety, ha _____
   h. HYV, ha _____

(Continued)

Appendix Table IV-1. Tabular Model of Data Requirements for Projecting Nutrient Requirements (Continued)

Irrigated area

i. Local variety, ha _____

j. HYV, ha _____

6. Production expected (without fertilizer):

Rainfed area

Poor weather (__% yield reduction)

a. Local variety (5g x 4a), tons _____

b. HYV (5h x 4b), tons _____

Average weather

c. Local variety (5g x 4a), tons _____

d. HYV (5h x 4b), tons _____

Good weather (__% yield increase)

e. Local variety (5g x 4a), tons _____

f. HYV (5h x 4b), tons _____

Irrigated area

g. Local variety (5i x 4c), tons _____

h. HYV (5j x 4d), tons _____

7. Base production:

a. Low estimate (6a + 6b + 6g + 6h), tons _____

b. Median estimate (6c + 6d + 6g + 6h), tons _____

c. High estimate (6e + 6f + 6g + 6h), tons _____

8. Production deficit:

a. Low estimate (3a - 7a), tons

b. Median estimate (3b - 7b), tons

c. High estimate (3c - 7c), tons

9. Production to be made up by

	a. min.	b. med.	c. max.
Fertilization of planned area, tons	____	____	____
New double cropping, tons	____	____	____
Shift in area from another crop, tons	____	____	____

(Continued)

Appendix Table IV-1. Tabular Model of Data Requirements for Projecting Nutrient Requirements (Continued)

Remainder of table must be completed three times: for minimum target, median target, and maximum target.

10. Area to be fertilized:

Planned, rainfed area

a. Local variety, ha _____

b. HYV, ha _____

Planned, irrigated area

c. Local variety, ha _____

d. HYV, ha _____

Double cropped, rainfed area

e. Local variety, ha _____

f. HYV, ha _____

Double cropped, irrigated area

g. Local variety, ha _____

h. HYV, ha _____

Shifted crop, rainfed area

i. Local variety, ha _____

j. HYV, ha _____

Shifted crop, irrigated area

k. Local variety, ha _____

l. HYV, ha _____

11. Fertilizer rate (N-P_2O_5-K_2O):

Low yield farmer, rainfed area

a. Local variety, kg/ha _____

b. HYV, kg/ha _____

Low yield farmer, irrigated area

c. Local variety, kg/ha _____

d. HYV, kg/ha _____

Average yield farmer, rainfed area

e. Local variety, kg/ha _____

f. HYV, kg/ha _____

(Continued)

Appendix Table IV-1. Tabular Model of Data Requirements for Projecting Nutrient Requirements (Continued)

Average farmer, irrigated area

g. Local variety, kg/ha _____

h. HYV, kg/ha _____

High yield farmer, rainfed area

i. Local variety, kg/ha _____

j. HYV, kg/ha _____

High yield farmer, irrigated area

k. Local variety, kg/ha _____

l. HYV, kg/ha _____

12. Yield increase from use of fertilizer:

	Rainfed	Irrigated
Poor weather, low yield farmer		
Local variety, kg/ha	a. _____	b. _____
HYV, kg/ha	c. _____	d. _____
Poor weather, average yield farmer		
Local variety, kg/ha	e. _____	f. _____
HYV, kg/ha	g. _____	h. _____
Poor weather, high yield farmer		
Local variety, kg/ha	i. _____	j. _____
HYV, kg/ha	k. _____	l. _____
Average weather, low yield farmer		
Local variety, kg/ha	m. _____	n. _____
HYV, kg/ha	0. _____	p. _____
Average weather, average yield farmer		
Local variety, kg/ha	q. _____	r. _____
HYV, kg/ha	s. _____	t. _____
Average weather, high yield farmer		
Local variety, kg/ha	u. _____	v. _____
HYV, kg/ha	w. _____	x. _____

(Continued)

Appendix Table IV-1. Tabular Model of Data Requirements for Projecting Nutrient Requirements (Continued)

Good weather, low yield farmer		
Local variety, kg/ha	y. _____	z. _____
HYV, kg/ha	aa. _____	bb. _____
Good weather, average yield farmer		
Local variety, kg/ha	cc. _____	dd. _____
HYV, kg/ha	ee. _____	ff. _____
Good weather, high yield farmer		
Local variety, kg/ha	gg. _____	hh. _____
HYV, kg/ha	ii. _____	jj. _____

13. Production due to fertilization:

	Rainfed	Irrigated
Poor weather, low yield farmer		
Local variety (12a x 11a, 12b x 11c), tons	_____	_____
HYV (12c x 11b, 12d x 11d), tons	_____	_____
a. Total	_____	
Poor weather, average yield farmer		
Local variety (12e x 11e, 12f x 11g), tons	_____	_____
HYV (12 g x 11f, 12h x 11h), tons	_____	_____
b. Total	_____	
Poor weather, high yield farmer		
Local variety (12i x 11i, 12j x 11h), tons	_____	_____
HYV (12k x 11j, 12l x 11l), tons	_____	_____
c. Total	_____	
Average weather, low yield farmer		
Local variety (12m x 11a, 12n x 11c), tons	_____	_____
HYV (12o x 11b, 12p x 11d), tons	_____	_____
d. Total	_____	
Average weather, average yield farmer		
Local variety (12q x 11e, 12r x 11g), tons	_____	_____
HYV (12s x 11f, 12t x 11h), tons	_____	_____
e. Total	_____	

(Continued)

Appendix Table IV-1. Tabular Model of Data Requirements for Projecting Nutrient Requirements (Continued)

Average weather, high yield farmer		
Local variety (12n x 11i, 12v x 11k), tons	_____	_____
HYV (12w x 11j, 12 x 11l), tons	_____	_____
f. Total	_____	
Good weather, low yield farmer		
Local variety (12y x 11a, 12z x 11c), tons	_____	_____
HYV (12aa x 11b, 12bb x 11d), tons	_____	_____
g. Total	_____	
Good weather, average yield farmer		
Local variety (12cc x 11e, 12dd x 11g), tons	_____	_____
h. Total	_____	
Good weather, high yield farmer		
Local variety (12gg x 11i, 12hh x 11k), tons	_____	_____
HYV (12ii x 11j, 12jj x 11j), tons	_____	_____
i. Total	_____	
j. Low estimate (a + b + c), tons	_____	
k. Medium estimate (d + e + f), tons	_____	
l. High estimate (g + h + i), tons	_____	

Remainder of table must be completed three times for N, P_2O_5, and K_2O.

14. Nutrient requirements for (nutrient)

	Rainfed	Irrigated
Low yield farmer, planned area		
Local variety (11a x 10a, 11c x 10c), tons	_____	_____
HYV (11b x 10b, 11d x 10d), tons	_____	_____
Low yield farmer, double cropped area		
Local variety (11a x 10e, 11c x 10g), tons	_____	_____
HYV (11b x 10f, 11d x 10h), tons	_____	_____

(Continued)

Appendix Table IV-1. Tabular Model of Data Requirements for Projecting Nutrient Requirements (Continued)

Low yield farmer, shifted crop area		
Local variety (11a x 10i, 11c x 10k), tons	_____	_____
HYV (11b x 10j, 11d x 10l), tons	_____	_____
Average yield farmer, planned area		
Local variety (11e x 10a, 11g x 10c), tons	_____	_____
HYV (11f x 10b, 11h x 10d), tons	_____	_____
Average yield farmer, double cropped area		
Local variety (11e x 10e, 11g x 10g), tons	_____	_____
HYV (11f x 10f, 11h x 10h), tons	_____	_____
Average yield farmer, shifted crop area		
Local variety (11e x 10i, 11g x 10k), tons	_____	_____
HYV (11f x 10j, 11h x 10l), tons	_____	_____
High yield farmer, planned area		
Local variety (11i x 10a, 11k x 10c), tons	_____	_____
HYV (11j x 10b, 11l x 10d), tons	_____	_____
High yield farmer, double cropped area		
Local variety (11i x 10e, 11k x 10g), tons	_____	_____
HYV (11j x 10f, 11l x 10h), tons	_____	_____
High yield farmer, shifted crop area		
Local variety (11i x 10i, 11k x 10h), tons	_____	_____
HYV (11j x 10j, 11l x 10l), tons	_____	_____
Subtotal, tons	_____	_____
GRAND TOTAL, tons		_____

15. Summary

	Minimum Target	Median Target	Maximum Target
Crop production, tons			
Poor year	_____	_____	_____
Average year	_____	_____	_____
Good year	_____	_____	_____

(Continued)

Appendix Table IV-1. Tabular Model of Data Requirements for Projecting Nutrient Requirements (Continued)

Nutrient requirements, tons			
N	_____	_____	_____
P_2O_5	_____	_____	_____
K_2O	_____	_____	_____

V. ANALYSIS OF SELECTED AGRICULTURAL DEVELOPMENT POLICIES

An increase in foodgrain production in Bangladesh can be achieved by successfully implementing policies that increase cropped areas and/or crop yields. Over the period 1970-81, total foodgrain production grew at an average annual rate of about 2.6%; 25% of this growth was due to expansion in cropped areas and the remaining 75% was due to increase in yields. The following policies are expected to help achieve the MTFPP 1985 foodgrain production target: an expansion in the irrigated area (3.6 million acres), improvement of 2 million acres through drainage and flood control measures, maintenance of incentive output prices to the farmer, and increased use of HYVs and fertilizers. The first three of these measures are expected to help increase cropped areas and crop yields. The HYVs and fertilizers are important for increasing crop yields but may or may not be important for increasing crop areas. The general belief is that the provision of more irrigation and drainage and flood control are necessary to facilitate the efficient use of fertilizer, HYVs, and other purchased inputs and to reduce agriculture's dependence on the weather. In this context the policies for ensuring adequate farm-level supplies of HYV seeds and fertilizers and for maintaining incentive output prices to the farmer are complementary to the irrigation and drainage and flood control policies.

Irrigation Policy

The proposed 100% expansion in the area irrigated is probably the most important element of the MTFPP strategy. This expansion is expected to greatly increase foodgrain production by increasing crop yields and cropped areas. The increased availability and use of irrigation will have a direct positive effect on crop yields and also will (indirectly) increase crop yields by expanding the use of HYVs, fertilizer, and other inputs.

Elasticity estimates of crop yields, with respect to the use of irrigation, HYVs, and fertilizers, and fertilizer demand elasticity estimates,

with respect to the use of irrigation and HYVs, can be used for estimating the impact that the proposed expansion of irrigated area will have on crop yields. Elasticities of paddy-wheat yields for the 1979/80 Boro season and of paddy yields for the 1980 Aus and Aman seasons, with respect to the use of irrigation, HYVs, and fertilizer estimated by the IFDC/BARC study, are presented in Table V-1. These elasticities estimate the percentage change in crop yields due to a 1% change in the use of irrigation, HYVs, or fertilizer, holding other factors constant. They are particularly important for estimating the expected impact that the proposed expansion of irrigated area in Bangladesh will have on crop yields. These estimates indicate that irrigation may have quite important indirect effects on crop yields by increasing the use of HYVs and fertilizer. Estimates of the influence of irrigation on the use of fertilizer and HYVs are also needed to estimate total effects on crop yields of the proposed expansion in irrigated area.

Although there are no explicit estimates of the effect of irrigation on the use of HYVs, the IFDC/BARC farm survey data show a high correlation between the use of HYVs and irrigation. Therefore, it is not too unrealistic to assume that the use of HYVs will increase in the same proportion that the irrigated area increases. Thus, the proposed 100% increase in irrigated area could probably increase the use of HYVs by 100%.

Fertilizer demand elasticity estimates obtained by the IFDC/BARC study show that, holding other factors constant, the quantity of fertilizer used (demanded) per acre of cropped land increased 0.105% and 0.211% as a result of a 1% increase in the use of irrigation and HYVs, respectively.

These estimates imply that the proposed 100% increase in irrigated area is expected to increase the average level of fertilizer use (demand) per acre of cropped land by 31.6%, 10.5% directly as a result of irrigation and 21.1% as a result of the increased use of HYVs resulting from irrigation.

The effect that the proposed 100% increase in irrigated area should have on crop yields is determined by the influence that these percentage increases in the use of irrigation, HYVs, and fertilizer are expected to have on crop yields. This effect is computed from the crop yields elasticity estimates shown in Table V-1 as follows:

Table V-1. Crop Yield (Production) Elasticities With Respect to the Use of Irrigation, HYVs, and Fertilizer, Bangladesh, 1979/80

	Boro 1979/80	Aus 1980	Aman 1980	Three Seasons Weighted[a] Average
Production elasticities with respect to the use of:				
Irrigation	-	0.018	-	0.005
High-yielding varieties	0.352[b]	0.087	0.047	0.145
Fertilizer	0.117	0.074	0.038	0.071
Weights of area cropped per season	0.28	0.30	0.42	

a. Weighted average obtained by using the sample distribution of the areas cropped by season.

b. In the Boro season, because of the high correlation between irrigation and HYVs, the elasticity estimate for HYVs probably shows the joint effects of irrigation and HYVs.

Source: Sidhu, Baanante, and Ahsan (1982).

Inputs	Crop Yield Elasticities	Percentage Increase in Inputs Use Due to Irrigation Policy	Percentage Increase in Crop Yields Due to Irrigation Policy
Irrigation	0.005	100	0.5
HYVs	0.145	100	14.5
Fertilizer	0.071	31.6	2.25
Irrigation policy effect on crop yields:			17.25

Thus, these estimates based on the IFDC/BARC study, indicate that the proposed 100% increase in irrigated area could increase average paddy and wheat yields by 17.25%. This is the expected increase in yields (production) of paddy and wheat if the proposed increases in irrigated area have no effect on the areas cropped in each season.

However, an increase in irrigated area will probably increase the total areas cropped in each season. Assuming that the additional 3.6 million acres to be irrigated will increase the area cropped per season by about 1.8 million acres (50%), then the total area cropped per year could increase about 20% (about 25% in Boro, 22% in Aus, and 17% in Aman). This expansion in cropped area would result in an additional 20% increase in the total demand for fertilizers, HYV seed, and total paddy and wheat production in Bangladesh.

In summary, the effects of the proposed expansion in irrigated area would be as follows:

1. A 100% increase in the proportion of land cropped with HYVs and a 120% increase in the use of HYV seed.
2. A 31.6% increase in the level of fertilizer use per acre of cropped land and a 51.6% increase in the total demand for fertilizer (20% increase due to possible expansion in cropped area).
3. A 37.25% increase in paddy and wheat production in Bangladesh, 17.25% due to expected increase in yields and 20% due to possible expansion in cropped areas.

It is clear that the expansion in irrigated area can have its full impact on foodgrain production in Bangladesh only if farmers are supplied with fertilizers, HYV seed, and other inputs adequately, efficiently, and on time.

It is also clear from these results that the proposed expansion in irrigated area (irrigation policy) by itself, will not be sufficient to obtain the 53% increase in foodgrain production that is needed to achieve the production target of 20 million tons by 1985. Also, the proposed irrigation policy will not expand fertilizer use (demand) by the 126% needed to meet the 1985 targeted level of fertilizer use of 1.9 million tons.

Drainage and Flood Control Policy

One of the policies proposed to meet the foodgrain production target of 20 million tons by 1985 is to improve 2 million acres by drainage and flood control measures for the Aman and Aus crops. This represents about 20% of the areas cropped in these seasons.

The IFDC/BARC farm survey sample data indicate that in the Aus and Aman crops (paddy), about 25% of the total cropped area is considered by farmers to be poorly drained land. Therefore, the proposed drainage and flood control improvement on about 20% of total cropped area in these seasons can represent a reduction [(20/25) x 100 = 80%] in the poorly drained cropped land of these seasons and an increase [(20/75) x 100 = 26.7%] in the properly drained cropped land.

Improvement in drainage and flood control is expected to increase foodgrain yields, mainly by increasing the use of HYVs and fertilizer. The influence that improvement in drainage and flood control can have on the use of HYVs has not been explicitly estimated. However, the IFDC/BARC farm survey data show a high correlation between poorly drained land and the use of local varieties of paddy in the Aus and Aman seasons. Therefore, it is not unrealistic to assume that the use of HYVs in the Aus and Aman crops may increase in the same proportion as the total properly drained cropped area increases in these seasons through drainage and flood control measures. Then, the proposed improvement of about 27% of the properly drained cropped areas in the Aus and Aman crops could probably increase the use of HYVs in these two crops by 27.0% or 19.4% for the three seasons, considering that 72% of the area cropped annually is cropped in the Aman and Aus seasons, as shown in Table V-1.

The effect of the proposed improvement in drainage and flood control on the use of (demand for) fertilizer per acre of cropped land can be estimated

by using the fertilizer demand elasticities with respect to (1) poorly drained land area and (2) area cropped with HYVs. Such elasticity estimates obtained by the IFDC/BARC study for the Aus and Aman seasons indicate that, holding all other factors constant, the fertilizer use per acre of cropped land was (1) increased 0.053% by reducing the poorly drained area 1% and (2) increased about 0.11% by increasing the use of HYVs 1%.

Thus, the estimated 80% reduction in the poorly drained cropped area, implied by the proposed drainage and flood control improvement policy, could increase the use of (demand for) fertilizer 4.24% in the Aus and Aman seasons. The expected 27% increase in the use of HYVs could increase the use of (demand for) fertilizer 2.97% in the Aus and Aman seasons.

These estimates indicate that the proposed drainage and flood control improvement policy could increase the demand for fertilizers in the Aus and Aman seasons about 7.21%. The farm survey data for 1979/80 show that about 70% of the total fertilizer used in Bangladesh in a year (three seasons) is used in the Aus and Aman seasons. Accordingly, the demand for fertilizer in a year will increase only 5.05%.

The effect that this policy could have on foodgrain production by increasing average yields through increased use of HYVs (19.4%) and fertilizer (5.05%) can be estimated from the crop yield elasticities presented earlier in Table V-1, as follows:

	Crop Yield[a] Elasticities	Percentage Increase Due to Drainage and Flood Control Improvement Policy	Percentage Increase in Foodgrain Yields Due to Drainage and Flood Control Policy
Use of:			
High-yielding varieties	0.064	19.4	1.24
Fertilizer	0.053	5.05	0.27
Percentage increase in yields due to this policy:			1.51

a. Weighted average of estimates obtained for the 1980 Aus and Aman paddy crops (Table V-1).

This policy could increase foodgrain production in Bangladesh by about 1.5%/year through its effect on crop yields. However, foodgrain production is expected to increase more because improved drainage and flood control would have a positive effect on the total cropped areas during Aman and Aus seasons.

HYV Seed Policy

The proportion of land sown to HYVs in Bangladesh has increased substantially since the mid-1960s, resulting in an overall increase in average yields. Significantly increasing average crop yields by substantially replacing local traditional varieties with HYVs is one of the cornerstones of the MTFPP strategy. In recent years as more of the relatively less suitable land has been added to HYV cultivation, the average HYV yields have started to decline. Indigenous research to develop HYV seeds suitable to Bangladesh's soil, water, and climatic conditions, therefore, must be considered as an important component of the MTFPP production strategy. Progress in this area will help to increase the share of land sown to HYVs and to sustain future HYV yields even if there is no increase in irrigated areas or land improvement through drainage and flood control measures.

The use of HYV seeds by farmers depends on the farm-level demand for and supply of HYV seeds. The development of HYVs more suitable to Bangladesh's agroclimatic conditions and the adequate and timely supply of these seeds to farmers will increase the demand for HYV seeds and thus their use.

In the short run, however, the proposed expansion in irrigated area and land improvement through drainage and flood control measures will have an important positive impact on the demand for HYV seeds.

Given the high correlation between the use of irrigation and HYVs, it is not unrealistic to assume that the proposed 100% increase in irrigated area could increase the demand for HYV seeds by 100%. If irrigation were to increase the total cropped area by 20%, then the total demand for HYV seed could increase by about 120% as a result of the proposed expansion in irrigated area; in addition, the policy of land improvement through drainage and flood control measures could increase the demand for HYV seeds by about 19.4%.

Therefore, holding other factors constant, the proposed irrigation and land improvement policies are estimated to increase the demand for HYV seed about 139.4% by 1985.

The timely and adequate supply of HYV seeds to the farmers is a necessary condition for these policies (irrigation and land improvement) to have an effect on foodgrain yields through the increased use of HYV seeds. Policies designed to ensure the adequate and efficient supply of HYV seeds to

the farmers, thus, are of critical importance for the expansion in irrigation and land improvement policies to realize their full potential in increasing foodgrain yields and production in Bangladesh.

The existing limitations on expanding cultivated areas, the low crop yields, and the relatively low levels of use of irrigation, HYVs, and fertilizer suggest that expanded foodgrain production will come from increments in crop yields rather than from increases in the cropped areas.

Irrigation, HYVs, and fertilizers, therefore, are expected to be the three most important factors affecting the future expansion of foodgrain production in Bangladesh.

Fertilizer Use Policy

In order to meet the foodgrain production target of 20 million tons by 1985, the MTFPP calls for a 126% increase in fertilizer use from 840,000 tons during 1979 to 1.9 million tons by 1985.

Between 1963 and 1980 fertilizer sales in Bangladesh increased at the longer term growth trend of about 15%/annum. However, during 1980 and 1981 the rate of growth of fertilizer sales declined to less than 5%/annum. Although policies for promoting fertilizer use have received considerable importance in the MTFPP production strategy, fertilizer sales have slowed down and remained below the MTFPP targets. This slowdown in fertilizer sales appears to be explained in part by the increase in fertilizer prices effected in November 1980.

The use (sales) of fertilizer depends on the farm-level supply of and demand for fertilizer. Since the objective of the MTFPP is to increase foodgrain production by, among other means, increasing the use of fertilizers, policies should be designed and implemented to (1) secure the timely and efficient supply of fertilizers to farmers in adequate quantities and (2) expand the farm-level demand for fertilizers.

The proposed policies of expansion in irrigated area and of land improvement through drainage and flood control measures will have an important

positive impact on the farm-level demand for fertilizers. Indications from the fertilizer demand elasticity estimates obtained in the IFDC/BARC study are as follows:

1. The proposed 100% expansion in irrigated area, holding other factors constant, will increase the demand for fertilizer per acre of cropped land by 31.6%. Thus, if the total cropped area increases by 20%, the total demand for fertilizer will increase by about 51.6%, as a result of the proposed expansion in irrigated area.
2. The policy of land improvement through drainage and flood control measures will increase the demand for fertilizer by about 5.0%.

Therefore, holding other factors constant, the proposed irrigation and land improvement policies are estimated to increase the demand for fertilizers by about 56.6% by 1985.

Policies directed to improving the efficiency of fertilizer production, imports, distribution, and marketing to ensure the adequate and timely supply of fertilizers to farmers are necessary to satisfy the expected increase in the demand for fertilizers. Moreover, policies designed to improve the supply of fertilizers to the farmer should have their own positive effect on fertilizer use. The important policies, in this respect, are all those policies that enable the public and private sector organizations to deliver increased quantities of fertilizers to a larger number of farmers on time and at the least possible cost.

Other policies that may have a significant effect on the expected increase in the use of fertilizers are those affecting the fertilizer and output prices and the availability and cost of agricultural credit.

Fertilizer and Output Price Policy

Fertilizer and output prices may be influenced in a variety of ways by government policies. In Bangladesh the foodgrain prices that farmers receive are influenced by the extent of government involvement in foodgrain procurement. These foodgrain prices are affected by, among other factors, the level of procurement prices set by the government and the level of existing foodgrain stocks. The success of a policy in increasing foodgrain production depends on

(1) the positive impact that such a policy can have on farmers' output prices and on production and (2) the cost associated with the implementation and operation of the policy.

Relevant estimates of price elasticity of supply of output can be used to measure the impact of higher producer prices on production. However, further work is needed to obtain proper supply elasticity estimates.

The impact of higher foodgrain producer prices on the demand for (use of) fertilizer, HYV seed, and other inputs is determined by the relevant elasticities of demand of these inputs with respect to foodgrain prices.

One of the policies of the MTFPP is to maintain incentive output prices to the farmer. Higher output price can be a powerful incentive for farmers to increase foodgrain production through (1) expanded use of fertilizer and other inputs and (2) increased area of cropped land. However, in the absence of relevant estimates of output price supply elasticities and of input demand elasticities with respect to the price of output, it is very difficult to evaluate the impact that a given policy-determined change in the price of output can have on production and on the demand for fertilizer and other inputs.

Governments also use input price subsidies to provide farmers with incentives to increase production. In Bangladesh along with a policy attempting to support the farm price of rice, there is also a policy of subsidies on fertilizer and other modern inputs. In both cases the rationale is to provide the incentive to farmers to increase production.

The policy with respect to fertilizer price, however, appears to be to continue with the progressive elimination (initiated in 1980) of the subsidy. According to the IFDC/BARC farm survey data used in this study, this policy had the following results:

1. The prices farmers paid for fertilizer during the 1980 Aman season were substantially higher than those paid in the 1979 Aman season.
2. The farm-level fertilizer/paddy price ratio increased substantially from about 1.2 in the 1979 Aman season to about 1.8 in 1980 Aman because the price of paddy did not change significantly during this time period.

The policy of eliminating the fertilizer subsidy in Bangladesh should be evaluated in terms of (1) the benefits that result from the saving that the government will have by discontinuing the fertilizer subsidy, i.e., the magnitude of the subsidy and the operating costs of this policy, (2) the costs that may result from the negative impact that the resulting increase in

fertilizer price could have on agricultural production, and (3) the income distribution effects (equity) of this policy.

The impact that a given change in the price of fertilizer may have on agricultural production is determined by the elasticity of supply of agriculture output with respect to the price of fertilizer and by the magnitude of change in the price of fertilizer. A change in the price of fertilizer also will have an effect on the demand for fertilizer and for other inputs. These effects are determined, respectively, by the fertilizer price demand elasticity and by the elasticities of demand for other inputs with respect to the price of fertilizer.

In using elasticity estimates to evaluate output and/or fertilizer price policies, it is very important to understand how these elasticity estimates have been obtained and what they mean. For example, elasticity estimates obtained "holding constant" the level of use of other inputs may be used to estimate the impact of changes in the price of output and/or fertilizer on crop production and on the demand for fertilizer. However, in using these elasticity estimates, it is important to understand that, when the price of fertilizer and/or output changes, the levels of use of other inputs actually do not remain constant.

Elasticity estimates with more relevance for evaluating output and/or fertilizer price policies should be obtained "holding constant" factors that actually are expected to remain constant in the short run, i.e., holding constant fixed factors of production such as land and capital, and exogenously determined prices of variable inputs such as labor and pesticides.[1]

As mentioned previously, proper estimates of output supply price elasticities and those of elasticities of output supply with respect to the price of fertilizer have not been obtained. Therefore, the impact of given output and/or fertilizer price policies on crop production cannot properly be evaluated.

Fertilizer demand elasticities with respect to the fertilizer/paddy price ratio, however, were estimated by the IFDC/BARC study. These elasticities estimate the effect that changes in the relative prices of fertilizer with respect to paddy may have on the demand for fertilizer.

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1. See Sidhu and Baanante (1979) and Sidhu and Baanante (1981).

The fertilizer/paddy price ratio measures the price of fertilizer in terms of the units of paddy the farmer has sold to buy one unit of fertilizer (NPK). Thus, these elasticities estimate the simultaneous effects of changes in prices of fertilizer and paddy on the demand for fertilizer, assuming that a given percentage increase in the price of paddy or decrease in price of fertilizer will have the same effect on the demand for fertilizer.[2] Since the price of paddy (or fertilizer) does not remain constant, these elasticity estimates might be more reliable for estimating the change in fertilizer demand due to a change in the price of fertilizer (paddy) than fertilizer demand elasticities estimated with respect to the price of fertilizer (paddy), holding constant the price of paddy (fertilizer) and other factors of production (Sidhu, 1981).

These fertilizer demand elasticities and crop yields (production) elasticity estimates are used here to estimate the effect of a given change in the fertilizer/paddy price ratio on fertilizer demand and on paddy and wheat yields. In considering these results it is important to keep in mind that elasticity estimates were obtained (1) holding other factors constant and (2) assuming that a given percentage increase in the price of paddy or decrease in the price of fertilizer will affect the demand for fertilizer in the same proportion.

Fertilizer demand elasticity estimates obtained by the IFDC/BARC study show that, holding other factors constant, a 1.0% increase in the fertilizer/paddy price ratio reduced the demand for fertilizer by 0.35% in the paddy and wheat crops of the 1979/80 Boro season, by 1.32% in the paddy crop of the 1980 Aus season, and by 1.0% in the paddy crop of the 1980 Aman season. The average effect of a 1.0% change in the fertilizer/paddy price ratio, for these three seasons, was a 1.02% decrease in the demand for fertilizer.

The three-season average elasticity estimates of (1) the demand for fertilizer with respect to the fertilizer/paddy price ratio (-1.02) and (2) crop yields with respect to the quantity of fertilizer used (0.071%) can be used to

2. This is not an entirely satisfactory assumption. As discussed in Sidhu and Baanante (1979) and Sidhu (1981), output price is a more powerful policy instrument than fertilizer price to influence fertilizer use, output, supply, and returns to fixed farm resources. But, it is not possible at this time to pursue the complicated analysis required to derive that type of result.

estimate the effect that a given policy change in the price of fertilizer and/or paddy would have on the demand for fertilizer and on crop yields, holding all other factors constant. For example, if fertilizer and/or paddy price policies were to increase the fertilizer/paddy price ratio by 10.0% while holding other factors constant, then the demand for fertilizer would decrease by 10.2%, and the average paddy and wheat yields would decrease 0.72%.

A more complete and refined model specification and estimating procedure can be used to obtain elasticity estimates more relevant to evaluate fertilizer and/or output price policy. Cross sectional farm survey data may be used to estimate own individual and cross price demand elasticities for fertilizer and other inputs and paddy and wheat supply elasticities with respect to the price of paddy and prices of fertilizer and other variable inputs, holding constant short-run fixed factors of production (land, capital, family labor, etc.). Once these estimates are obtained, a more complete and accurate estimation of the effects of a price policy on the demand for (use of) fertilizers and other inputs and on foodgrain production in Bangladesh can be carried out.

Agricultural Credit Policy

The timely and adequate availability of agricultural credit is emerging as an important factor in the private sector supply, distribution, and financing of agricultural inputs. The greater emphasis given to the private sector in the supply and distribution of agricultural inputs has increased the importance of agricultural credit as a constraint to the farm-level supply and use of agricultural inputs.

The availability and use of agricultural credit has increased significantly in recent years. In the year 1980/81 an amount of about TK 3.5 billion was disbursed, representing a 31% increase in disbursements over the previous year. However, the agricultural credit expansion is constrained by serious difficulties in the existing credit delivery system. Poor recovery performance and inconsistencies in borrowers' eligibility criteria and in the ranges and levels of interest rates applicable across lending institutions and across beneficiaries are some of the problems of the existing credit delivery system.

Analysis of the IFDC/BARC farm survey data indicates the following:

1. The number of farmers who used agricultural credit during the 1979/80 crop seasons was quite small. During the 1979/80 Boro season only 6.1% of the farmers in the sample used agricultural credit and in the 1980 Aus and Aman seasons, only 2.8% and 4.6%, respectively.
2. There was considerable variation in the use of agricultural credit across sampled locations (District-Thana) and across seasons. Sample distributions of credit used by farmers show that during the 1979/80 Boro season use of credit was the highest in the locations of Chittagong and Jessore, during the 1980 Aus season in the Rangpur and Dinajpur locations, and during the 1980 Aman season in the Chittagong and Dinajpur locations.
3. During all three seasons more credit was used by larger farm size (land owned) groups. There was a strong positive correlation between credit use and farm size. Credit use was also positively correlated with the farmer ownership of other physical assets. Ownership of land and other physical assets provide better security to the lenders and thus enable farmers to have better access to credit.
4. The quantity of credit used per acre had a small but statistically significant influence on the demand for fertilizer in the 1979/80 Boro season and on the overall aggregate three-season fertilizer demand.

In agricultural production, credit is not an input and it should not be treated as such. However, when farmers face financial constraints, as is usually the case in Bangladesh and other developing countries, then the availability and cost of credit become important factors, affecting the use of fertilizer and other modern inputs and, thereby, agricultural production.

An agricultural credit program should be designed and implemented according to the nature and magnitude of the financial constraints (needs) that farmers experience in order to carry out agricultural production to maximize returns to their fixed factors of production (land, family labor, etc.).

The fact that farmers in Bangladesh use little credit and relatively low levels of fertilizer and other modern inputs suggests that improvements in the availability and delivery of credit are needed.

Labor Employment Policy

The small size of landholdings and the widespread prevalence of tenurial arrangements in Bangladesh reflect the lack of employment opportunities outside agriculture and the ever-growing population pressure on rural land.

One of the major objectives of the MTFPP is, therefore, to increase the level of rural employment in Bangladesh. Results from the IFDC/BARC study are used here to estimate the potential effect of the irrigation, drainage, and flood control policies on farm labor employment.

Average point elasticities, presented in Table V-2, measure the percentage change in the quantity of labor used (workdays) per acre of cropped land due to a 1% change in the use of irrigation, HYVs, or fertilizer, respectively. A three-season average, weighted by the areas cropped in each season, is obtained to derive implications about a full crop year.

The three-season-weighted average of employment elasticity estimates presented in Table V-2 is used to estimate, in Table V-3, the possible effects of the proposed irrigation and drainage and flood control policies on employment of farm labor. These results show that these two policies could increase the farm-level employment of labor per acre of cropped land about 10.3%. However, if the proposed expansion in irrigated area were to increase the total area cropped per year about 20%, as previously discussed, then the effect of these policies would be to increase farm labor employment as much as 30.3%.

Although these estimates refer only to the impact of the proposed policies on the employment of farm labor, they are expected to have some positive effect also on the off-farm employment of labor, especially in the distribution and marketing of additional agricultural inputs and output.

Table V-2. Average Point Elasticities of Farm Labor Employment With Respect to the Use of Irrigation, HYVs, and Fertilizer,[a] Bangladesh, 1979/80

	Boro 1979/80	Aus 1980	Aman 1980	Three Seasons Weighted Average
Irrigation	0.142	0.009	0.011	0.048
HYVs	0.060	0.012	0.021	0.030
Fertilizer	0.093	0.037	0.039	0.053
Weights of area cropped	0.28	0.30	0.42	

a. Computed using regression analysis estimates of labor use presented in Table VIII.21, of the IFDC/BARC study and sample means of variables.

Source: Sidhu, Baanante, and Ahsan (1982).

Table V-3. Estimates of the Influence of Proposed Irrigation and Drainage and Flood Control Policies on the Employment of Farm Labor, Bangladesh, 1979/80

	Percentage Effects of Irrigation and Drainage Policies on Use of These Inputs Per Acre of Cropped Land			Farm Labor Employment Elasticities With Respect to These Inputs Per Acre of Cropped Land	Percentage Effects of Irrigation and Drainage Policies on Labor Employment Per Acre of Cropped Land
Inputs-Factors	Irrigation Policy (1)	Drainage Policy (2)	Total (3)[a]	(4)	(5)[b]
Irrigation	100		100	0.048	4.8
HYVs	100	19.4	119.4	0.030	3.58
Fertilizer	31.6	5.0	36.6	0.053	1.94
TOTAL					10.32

a. Column (3) = Column (1) + Column (2).
b. Column (5) = Column (3) x Column (4).

Source: Sidhu, Baanante, and Ahsan (1982).

VI. FF .LIZER DEMAND PROJECTIONS

Any planning effort must be based on estimates of future demand. Without such projections it is impossible to assess the need for additional production facilities, to procure adequate quantities of fertilizers on a timely basis or to judge the adequacy of present mixing, bagging, handling, warehousing, and transportation facilities. In the absence of demand projections it is impossible to judge the size of foreign exchange requirements needed for imports, the cost of government subsidies, or the amount of credit that is needed to finance farmer purchases.

Historical Consumption

Fertilizer consumption in Bangladesh in terms of the three major nutrients (N, P_2O_5 and K_2O) has grown from 144,600 mt in 1970/71 to 412,900 mt in 1980/81 (Table VI-1). This represents a compound growth rate of over 11% annually. However, consumption has been very erratic from year to year. For example, nitrogen consumption has shown declines in 3 of the past 10 years and potash consumption has increased 5 years and declined 5 years (Table VI-2). Annual increases in nitrogen consumption of 30% or more have occurred three times while declines of 20% or more have occurred twice during the past 10 years. Phosphate consumption has grown at a compound growth rate of 13%, and nitrogen and potash have both exceeded a 10% compound growth rate during the past 10 years (Table VI-3). However, it should be noted **that fertilizer consumption growth rates for all three nutrients have slowed considerably during the past 3 years.**

The erratic variations in consumption from year to year have made it difficult to forecast consumption. Most estimates that were examined have not proven to be very reliable. In the past, usage in Bangladesh has been closely related to the amount of donor grants. In addition, fertilizer was generally in short supply or did not reach the farmer by the time he needed it. However, in recent periods supplies have been adequate. Donor funding was US $132.9 million in 1979/80 and US $104.5 million in 1980/81; it is expected to reach US $123.6 million and US $156.1 million in 1981/82 and 1982/83, respectively.

Table VI-1. Bangladesh: Historical Fertilizer Consumption

Year	N	P_2O_5	K_2O	Total
	('000 mt)			
1970/71	99.2	35.0	10.4	144.6
1971/72	79.3	28.1	8.5	115.9
1972/73	128.8	41.5	11.3	181.6
1973/74	125.1	43.8	11.2	180.1
1974/75	82.5	40.6	10.9	134.0
1975/76	147.0	54.8	14.4	216.2
1976/77	166.1	61.6	14.5	242.2
1977/78	222.6	90.9	25.0	338.5
1978/79	227.5	102.8	29.2	359.5
1979/80	254.1	115.0	27.6	396.7
1980/81	266.7	119.1	27.1	412.9

The 1970/71-1978/79 data are from Bangladesh Bureau of Statistics (1979); the 1979/80-1980/81 data are from the BADC Newsletter, July 1981.

Table VI-2. Bangladesh: Percentage Change in Consumption From Previous Year

Year	N	P_2O_5	K_2O
	- - - - - - - -	-(%) - - - - - -	- -
1971/72	-20	-20	-18
1972/73	+62	+48	+33
1973/74	- 3	- 6	- 1
1974/75	-34	- 7	- 3
1975/76	+78	+35	+32
1976/77	+13	+12	+ 1
1977/78	+34	+48	+72
1978/79	+ 2	+13	+17
1979/80	+12	+12	- 5
1980/81	+ 5	+ 4	- 2

Table VI-3. Bangladesh: Fertilizer Consumption Growth Rates

	N	P_2O_5	K_2O
	(%)		
10-year growth rate			
Compound	10.4	13.0	10.1
Average annual	15.2	13.9	11.1
5-year growth rate			
Compound	12.6	16.8	13.5
Average annual	13.2	17.7	13.5
3-year growth rate			
Compound	6.2	9.4	2.8
Average annual	6.3	9.6	3.2
Latest year	5.0	3.6	-1.8

Methods of Projecting Fertilizer Demand

There are many different methods for making demand projections, but there is not a "best" procedure applicable to all cases. Some methods are more accurate this year; other methods may give more accurate results next year. All methods require reliable historical data because all methods assume to some extent that past trends and relationships will continue into the future.

Extrapolation of Trends

Probably the most common approach to projecting future demand in most countries is extending a straight line that best fits the historical data. This line can be fitted statistically with regression procedures. The trend line can be mathematically expressed as a linear equation. Although what happened last year may be the best indicator of what will happen next year, it may not give valid indications for the long run, because large percentage increases can be compounded into astronomical levels of use. Also the time period used in the calculation of the growth rate can distort the real long-run growth pattern, turning cyclical market swings into fictitious growth markets. A slightly different forecast will likely result for each different time period used to compute the regression coefficients.

Once the trend equation is determined, it can be used to extrapolate one or more years into the future. This method is poor in forecasting turning points because it does not account explicitly for the key factors that cause demand to fluctuate from year to year. It is generally quite good for short-term projections, and it is also satisfactory for projecting medium- and long-term demand, particularly when the turning point considerations are not critical. However, it will not provide numerical estimates of the individual contributions of policy measures and other variables affecting fertilizer consumption. This method does not require any time series data other than fertilizer consumption, and curvelinear equations can also be fitted.

Projections using straight-line trends based on the past 10 years data are shown in Table VI-4. Graphs of the historical data as well as projections based on straight-line trends are shown in Figures VI-1 through VI-3. These projections indicate nitrogen consumption reaching 451,000 mt of N by 1990/91. This represents a compound growth rate of less than 6%. Phosphate consumption would reach 212,000 mt of P_2O_5 or a compound growth rate of 6%. Potash would

Table VI-4. Bangladesh: Historical and Projected Consumption Based on Straight Line Trends

Year	Nitrogen Actual	Nitrogen Projected[a]	Phosphate Actual	Phosphate Projected[b]	Potash Actual	Potash Projected[c]
	('000 mt N)		('000 mt P_2O_5)		('000 mt K_2O)	
1970/71	99.2	68	35.0	18	10.4	6
1971/72	79.3	87	28.1	28	8.5	8
1972/73	128.8	106	41.5	38	11.3	11
1973/74	125.1	125	43.8	47	11.2	13
1974/75	82.5	144	40.6	57	10.9	15
1975/76	147.0	164	54.8	67	14.4	17
1976/77	166.1	183	61.6	76	14.5	20
1977/78	222.6	202	90.9	86	25.0	22
1978/79	227.5	221	102.8	96	29.2	24
1979/80	254.1	240	115.0	105	27.6	26
1980/81	266.7	259	119.1	115	27.1	28
1981/82		279		125		31
1982/83		298		135		33
1983/84		317		144		35
1984/85		336		154		37
1985/86		355		164		40
1986/87		375		173		42
1987/88		394		183		44
1988/89		413		193		46
1989/90		432		202		48
1990/91		451		212		51

a. N = -37,745.7 +19.19*YEAR R^2 = .86.
b. P = -19,094.4 +9.7*YEAR R^2 = .90.
c. K = -4,378 +2.225*YEAR R^2 = .83.

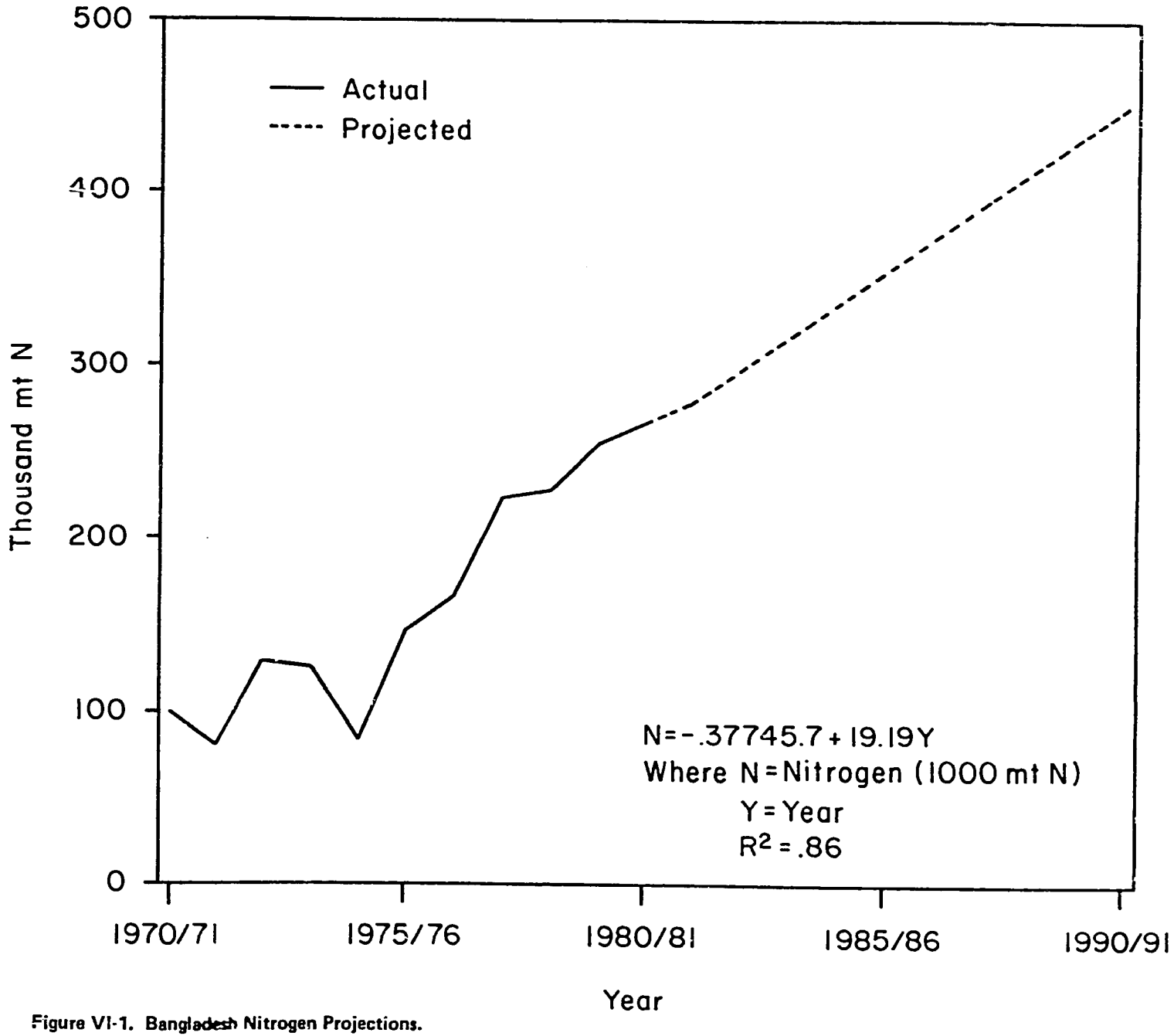

Figure VI-1. Bangladesh Nitrogen Projections.

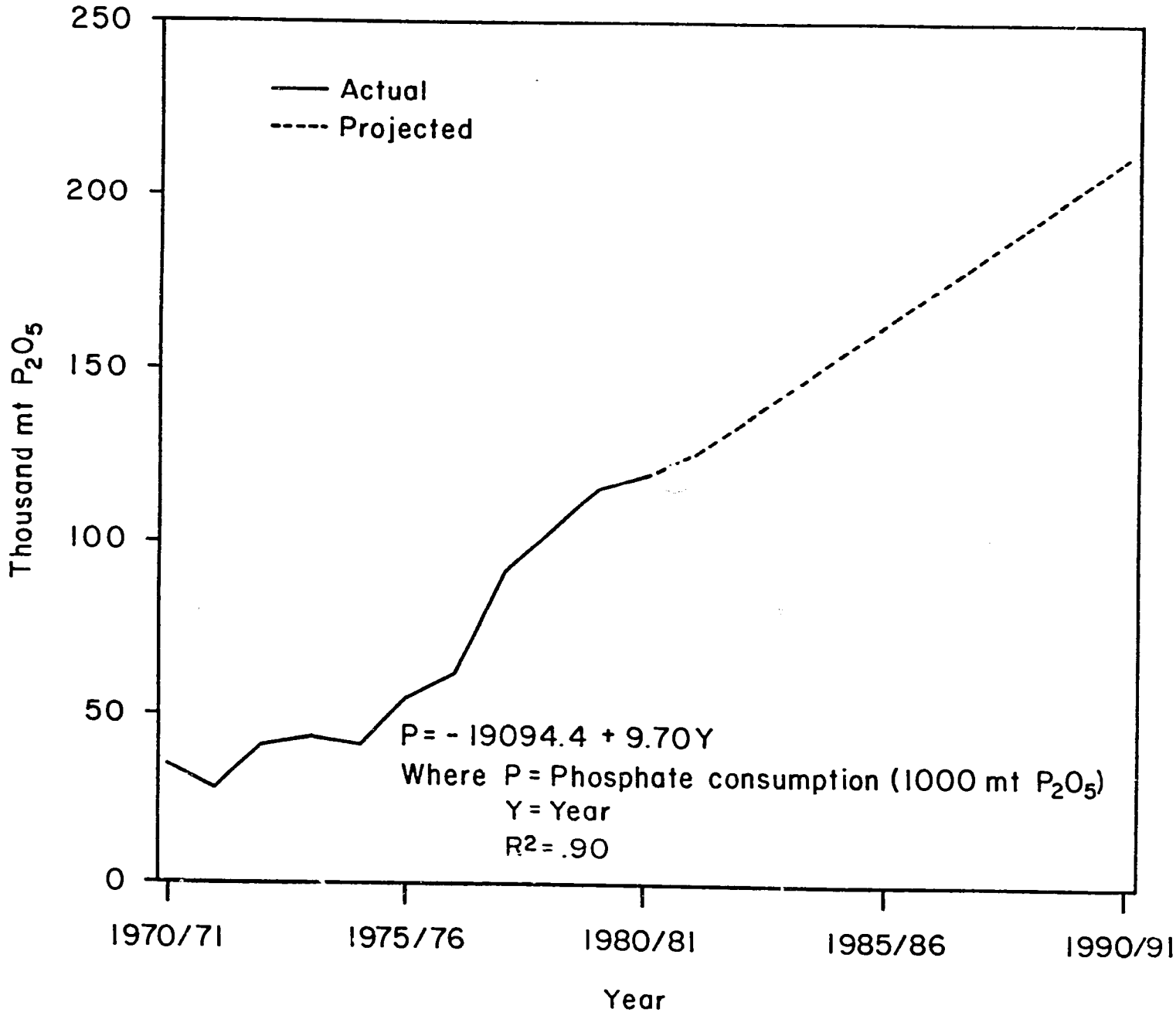

Figure VI-2. Bangladesh Phosphate Projections.

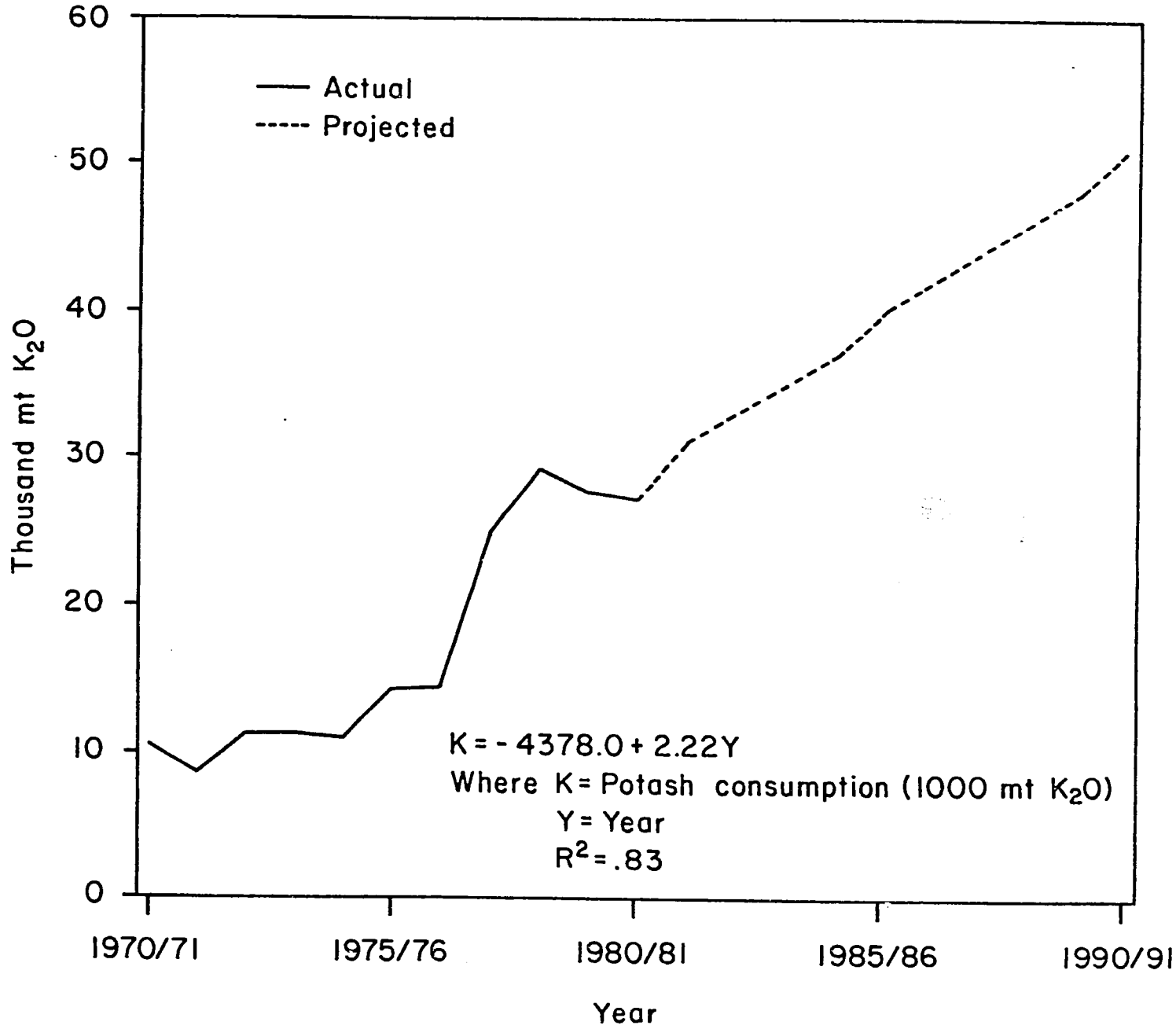

Figure VI-3. Bangladesh Potash Projections.

reach 51,000 mt of K_2O or a compound growth rate of about 6.5%. Note that these rates are considerably lower than most rates shown in Table VI-3.

Historical Growth Rates

A common method of making projections is to look at the growth rate in recent years and to assume that each year in the future consumption will increase at this rate. The resulting curve, however, does not reflect the experience of most countries consuming 100,000 nutrient tons or more. Most countries that consume this amount increase consumption at a slower rate each year. The curve for a country increasing at a constant percentage bends upward (Figure VI-4). A related approach is to project a future year at a compound growth rate and then connect the beginning and ending points.

Appendix Tables VI-1 through VI-3 show the 1980/81 actual consumption and what the consumption of each nutrient would be at various growth rates. The curve in Figure VI-4 was derived from nitrogen, using a 10% annual compound growth rate. Appendix Tables VI-4 through VI-6 use the same 1990/91 consumption that would be attained with each growth rate. However, consumption for each of the other years is the constant absolute annual increase necessary to achieve the 1990/91 consumption. The plot of these figures is a straight line. The straight line in Figure VI-4 was plotted from the 10% growth rate in nitrogen shown in Appendix Table VI-4. Note in Appendix Tables VI-4 through VI-6 how the growth rate from year to year varies with this procedure. Again when a 10% compounded rate is used until 1990/91 and then the same increase is assumed each year (straight line), the rate of growth varies from 15.9% in 1981/82 to only 6.5% in 1990/91 (Appendix Table VI-4).

Area and Use by Crop

Another method of projecting future consumption uses crop area and recommended levels of fertilization for each crop. Ideally, this method should be the most accurate of the forecasting techniques; however, past performance has shown that farmers rarely use fertilizer at the recommended rate. Thus, either some percentage of utilization must be assumed in order to arrive at the forecast, or actual usage levels per crop must be known.

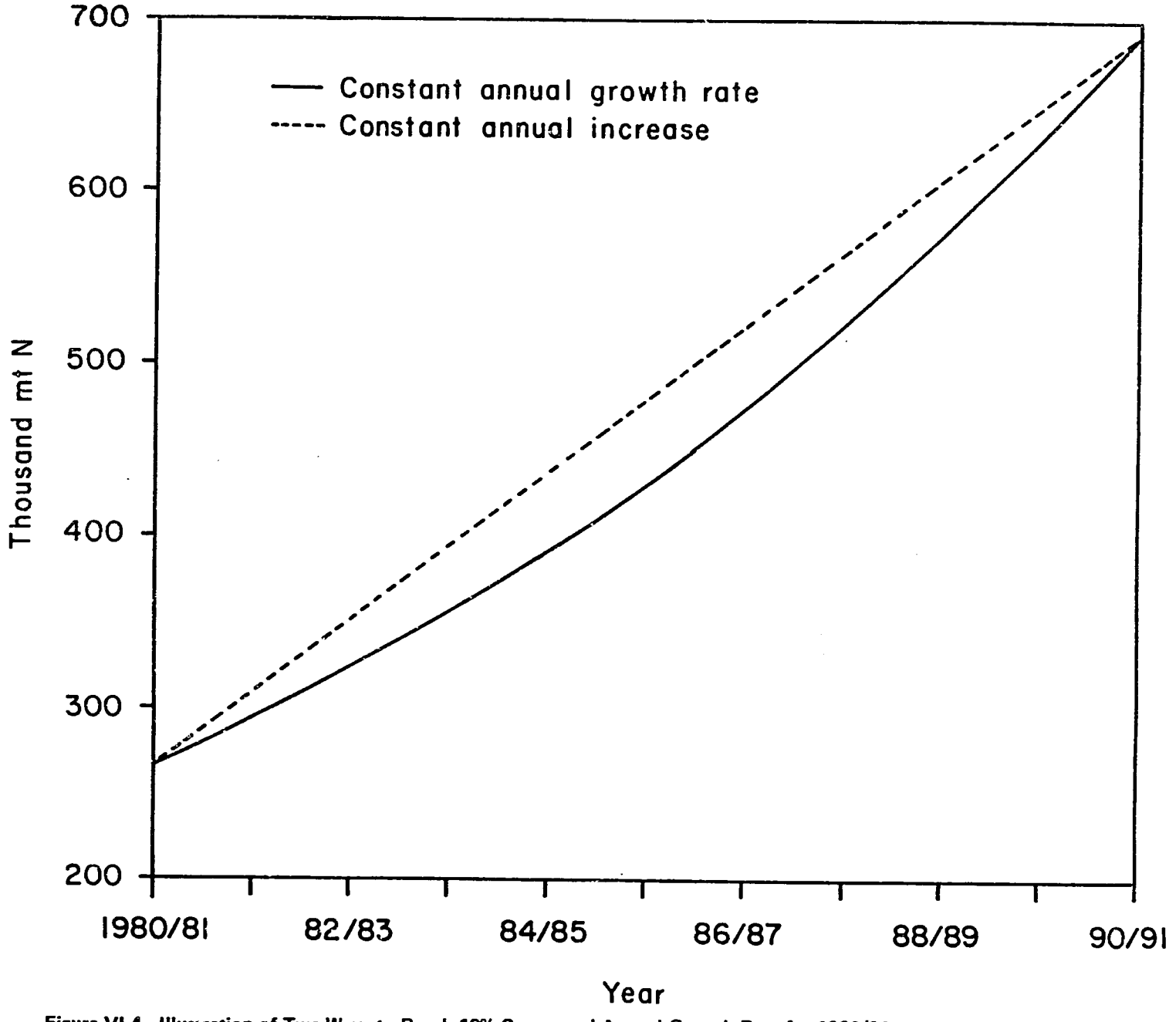

Figure VI-4. Illustration of Two Ways to Reach 10% Compound Annual Growth Rate for 1990/91.

Food Requirements

Another method of forecasting demand is to project food requirements and then estimate the fertilizer needed to produce the required amounts of crops and livestock. Key variables in this type of forecast are food consumption per capita, population growth rates, and shifts in diets to more meat as income levels increase. Again, usage of fertilizer per crop is required, but such data are not available for Bangladesh.

Regression Techniques

These techniques seek to establish a casual relationship between one or more of the demand-influencing factors and fertilizer use. Factors may be socioeconomic, physical, technological, and institutional. They include crop prices received by farmers, fertilizer prices paid by farmers, credit availability, interest rates, farm income, irrigated area, area seeded with high-yielding varieties, the availability of crop markets, fertilizer availability, rainfall, crop mix, government's fertilizer price subsidies, crop support prices, and agricultural extension efforts. For policy analysis and planning, casual models are more meaningful than other methods including trend extrapolation.

However, use of casual models requires a considerable amount of accurate data to determine exact relationships. A major limitation is projecting the values of the demand-influencing factors, which must be done in order to project fertilizer market demand. Indeed it may be harder than projecting fertilizer consumption because (1) there may be more year to year fluctuation in these variables and (2) there are several more variables to estimate. Another problem arises in the use of regression models involving the use of more than one independent variable. Factors such as irrigated crop area and use of high-yielding varieties are correlatable because a good manager may use both together while a poor manager uses neither. The intercorrelation problem must be carefully treated if projection results are not to be distorted. Regression models usually give good to very good results for short- and medium-term projections but not as good for long-term projections. However, these models do a good job in predicting turning points. Inaccurate historical data and inappropriate handling of intercorrelations between market driving forces and other statistical problems will prevent a forecaster from establishing a meaningful casual relationship between fertilizer demand and each demand-influencing factor.

In most countries fertilizer consumption is highly correlated with the ratio of farm product price to fertilizer price. In Bangladesh the correlation of total fertilizer consumption to rice/urea price ratios was -.61 (Table VI-5). In addition to being relatively low the sign is opposite of what would be expected.

Correlation was highest with a variable for trend (.94). Population (.91), crop acreage (.67), urea price (.62), irrigated area (.60), rice farm price (.45), and area of HYVs (.40) were each more highly correlated with trend than with fertilizer consumption.[1] Thus, there may not be a cause and effect relationship but rather increases in fertilizer consumption and in the values of these variables. Perhaps some of the low correlations can be attributed to problems in the data series used.

The BARC/IFDC Equity Study report contains estimates of a fertilizer demand function per acre for Bangladesh during one year based on 3,238 observations (Sidhu, Baanante, and Ahsan, 1982). Variables such as fertilizer prices, irrigation, sharecropping, HYVs, drainage, family labor, capital assets, credit, education, and farm size are used. However, even for one year with this number of variables the R^2 was only .55. There is no way to know if these coefficients would be applicable to other years with different rainfall and weather patterns, but most likely they would not.

The method which uses economic variables has been of limited use for predicting fertilizer demand in Bangladesh primarily because these variables over time have not reflected cause and effect. Fertilizer may simply have been unavailable in past years because Bangladesh did not have sufficient foreign exchange to buy enough fertilizer and adequate donor financing was not available.

It is thus difficult to develop equations with cause and effect variables to predict fertilizer usage in Bangladesh. For example, high prices are thought to discourage usage. In 1974/75 prices were very high and usage declined. However, did it decline because of price or because fertilizer was not available? In 1980/81 fertilizer consumption was a record, yet prices were higher than in 1974/75. The ratio of crop prices and fertilizer prices was the lowest since at least 1972 (Figure VI-5).

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1. Numbers shown in parentheses are correlated with fertilizer consumption. Perfect correlation is 1.0. If two variables are perfectly inversely correlated, the coefficient would be -1.0. No correlation would be .00.

Table VI-5. Bangladesh: Correlation of Selected Variables With Total Fertilizer Consumption

Trend[a]	.94
Population[a]	.91
Crop acreage[b]	.67
Urea farm price[c]	.62
Irrigated area[b]	.60
Rice farm price[c]	.45
Area of high-yielding varieties[b]	.40
Rice/urea price ratios[c]	-.61

a. 1970-1980.
b. 1970-1978.
c. 1972-1980.

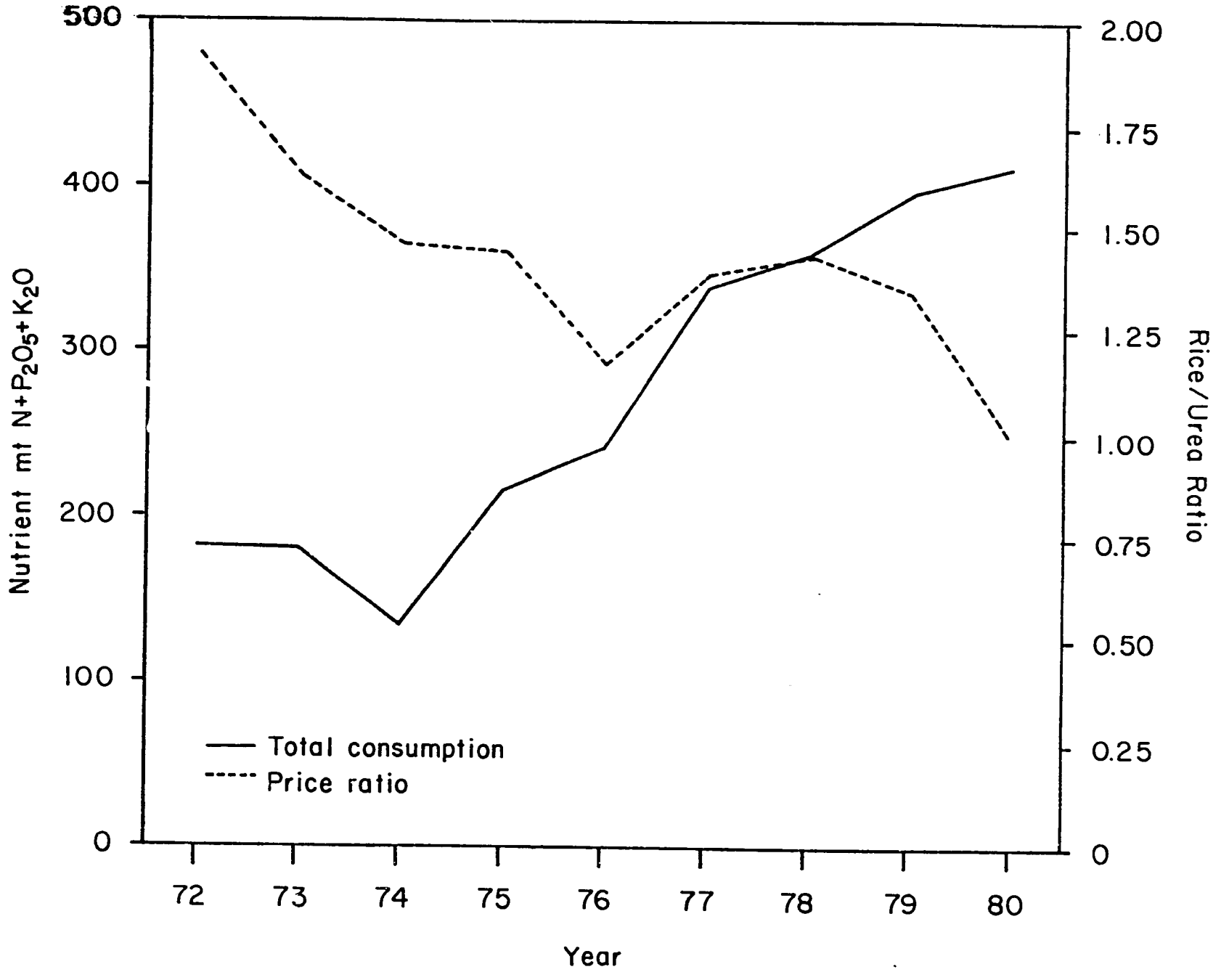


Figure VI-5. Bangladesh Total Fertilizer Consumption and Rice/Urea Price Ratio.

Expert Estimates

Another way to estimate use is to let "experts" who are familiar with farmers and the farming conditions estimate fertilizer use. The estimate is based on their "opinion" rather than on a formalized procedure. These experts can estimate nationally or regionally with regional estimates combined to obtain a national estimate. This method is usually limited to short-term projections.

Delphi Method

A related method is the "Delphi-Method." It takes individual estimates of several "experts" and returns them to each "expert," requesting him to revise his original projection after reviewing the projections of the group. This starts a second round of individual estimates. The degree of consensus should improve with each round.

Leading Indicators

This method identifies and utilizes data that are effective in predicting future fertilizer use. These are called "leading indicators." The possible leading indicators for fertilizer market demand in a country, for example, might be the average farm income of the previous year, the amount of credit used by farmers by a certain date, or the amount of high-yielding seeds sold by a certain date prior to planting time. The leading indicators method is us ally good only for projecting fertilizer market demand 1 year ahead.

Bangladesh Fertilizer Demand Forecast

After consideration of these various methods it appears that there are basically two methods that are most suitable for Bangladesh:

1. Trend regressions
2. Growth rate assumption

The trend projections presented in Table VI-4 appear low in relation to the growth rates shown in Table VI-3. They should be viewed as an alternative set of projections that represent a more conservative estimate.

In view of the historical growth rates presented in Table VI-3, projected compound annual growth rates of 8% for nitrogen, 9% for phosphate, and 9% for potash have been selected for 1990/91 (Table VI-6). Obviously, the rates in Table VI-3 would support a higher growth rate. However, as the base on which percentages are calculated increases, it becomes more and more difficult to maintain growth rates higher than these selected. Indeed only five countries that consumed as much in 1972 as Bangladesh does currently have been able to average these growth rates for all three nutrients during the past 8 years. The lower projections indicated by the regression calculations shown in Table VI-4 also make us reluctant to project higher rates. Although we should not allow a single short period to overly influence our long-term projections, the slow growth during the past 3 years also dampens our enthusiasm for more optimistic projections.

We have chosen to connect the 1990/91 estimates with a straight line rather than assume a constant growth rate (Figures VI-6 through VI-8). This means growth rates during the first years of the projection period are higher than those in later years (Appendix Tables VI-4 through VI-6). For example, with nitrogen the growth rates range from 11.6% in the first year to 5.7% in 1990/91. This is more realistic than having a constant rate of increase each year.

These forecasts can be compared with those shown in Table VI-7 which were made by GOB forecasters in 1979 and have not been revised. When current trends, and particularly growth rates during the last 3 years, are considered, this 1979 GOB forecast seems overly optimistic. The GOB forecasts of fertilizer product demand have been converted to nutrient tons. In this conversion all the phosphate was assumed to come from TSP. In 1979/80 40,644 mt of DAP was used and supplied 7,300 mt of N. If this usage of DAP continues, this amount of N could be added to these nutrient conversions. Phosphate is not affected.

The IFDC projections of total nutrient demand given in this report (Table VI-6) are only 71% of the GOB projections of total nutrient consumption in 1989/90 (the last year of the GOB projection period). However, the IFDC projections are 28% higher than those which would be obtained by fitting a straight line to the past 10 years of consumption (Table VI-4). Projections made for 1989/90 by other investigators are shown in Table VI-8.

Table VI-6. Bangladesh: IFDC Projected Nutrient Consumption, FY 1982-FY 1991

Year	N	P_2O_5	K_2O	Total
	('000 mt)			
1980/81(actual)	266.7	119.1	27.1	412.9
1981/82	298	135	31	464
1982/83	329	152	35	516
1983/84	359	168	38	565
1984/85	390	184	42	616
1985/86	421	201	46	668
1986/87	452	217	49	718
1987/88	483	233	53	769
1988/89	514	249	57	820
1989/90	545	266	60	871
1990/91	576	282	64	922

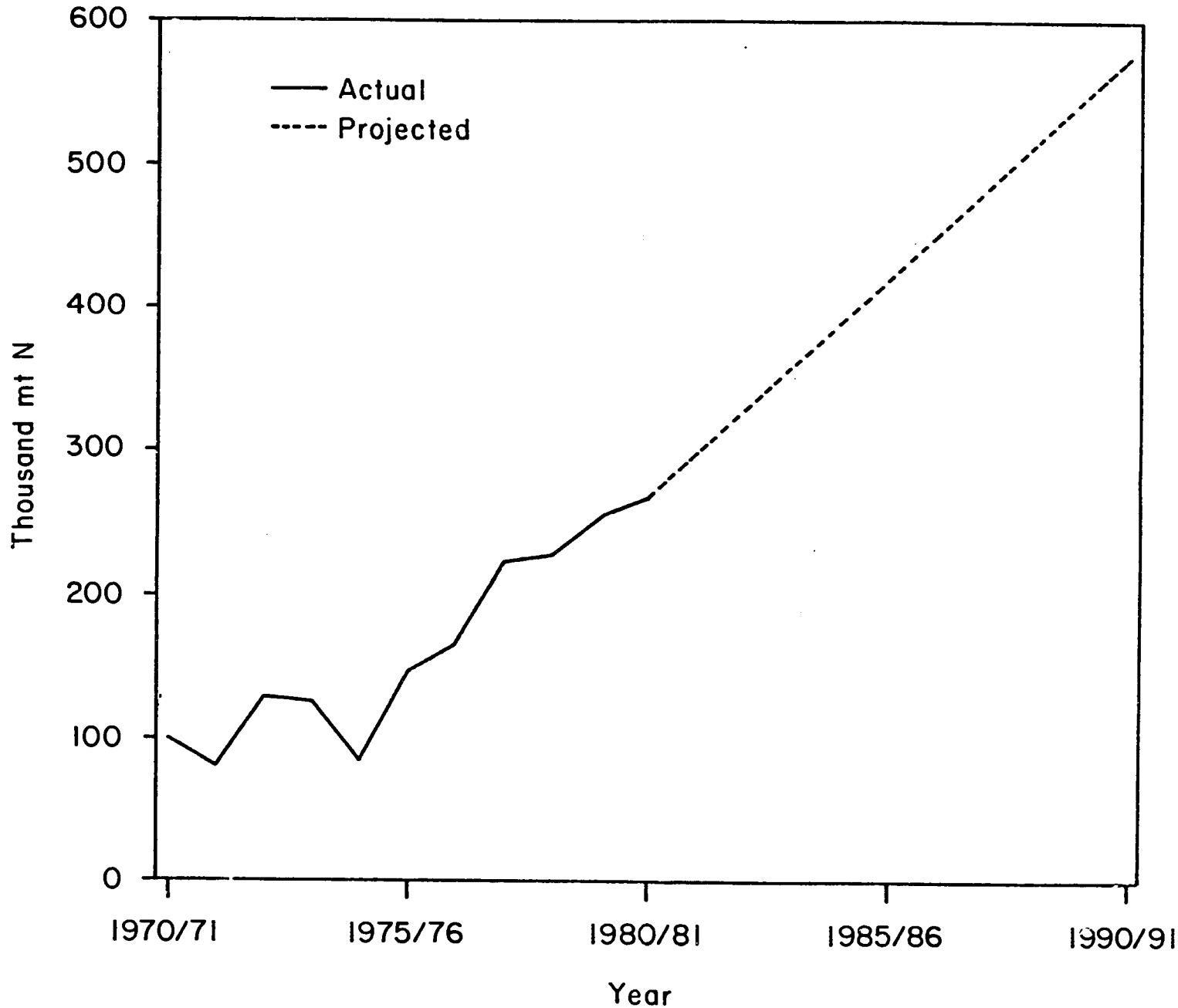


Figure VI-6. Bangladesh Nitrogen Projections Assume 8% Compound Growth Rate to 1990/91.

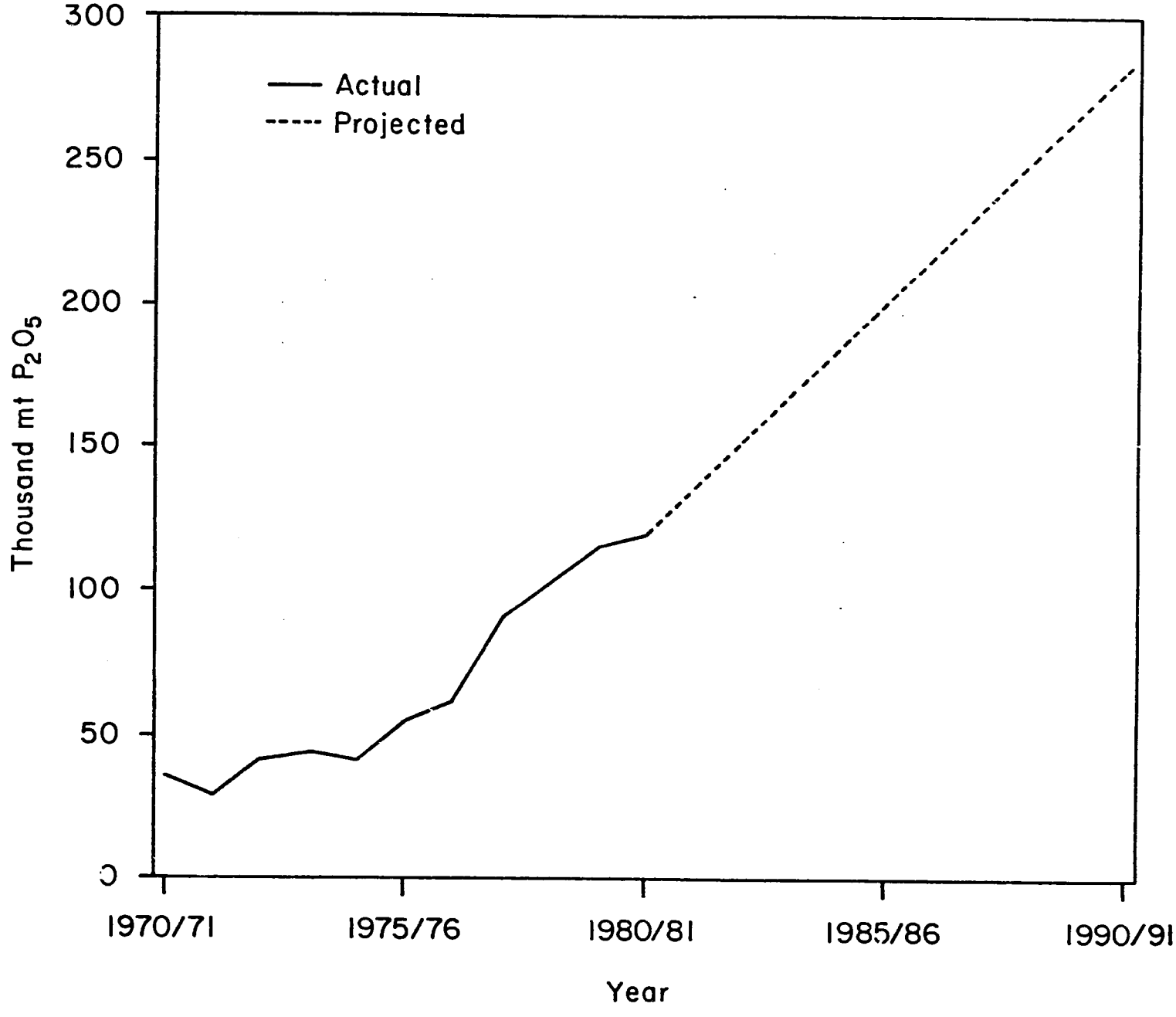


Figure VI-7. Bangladesh Phosphate Projections Assume 9% Compound Growth Rate to 1990/91.

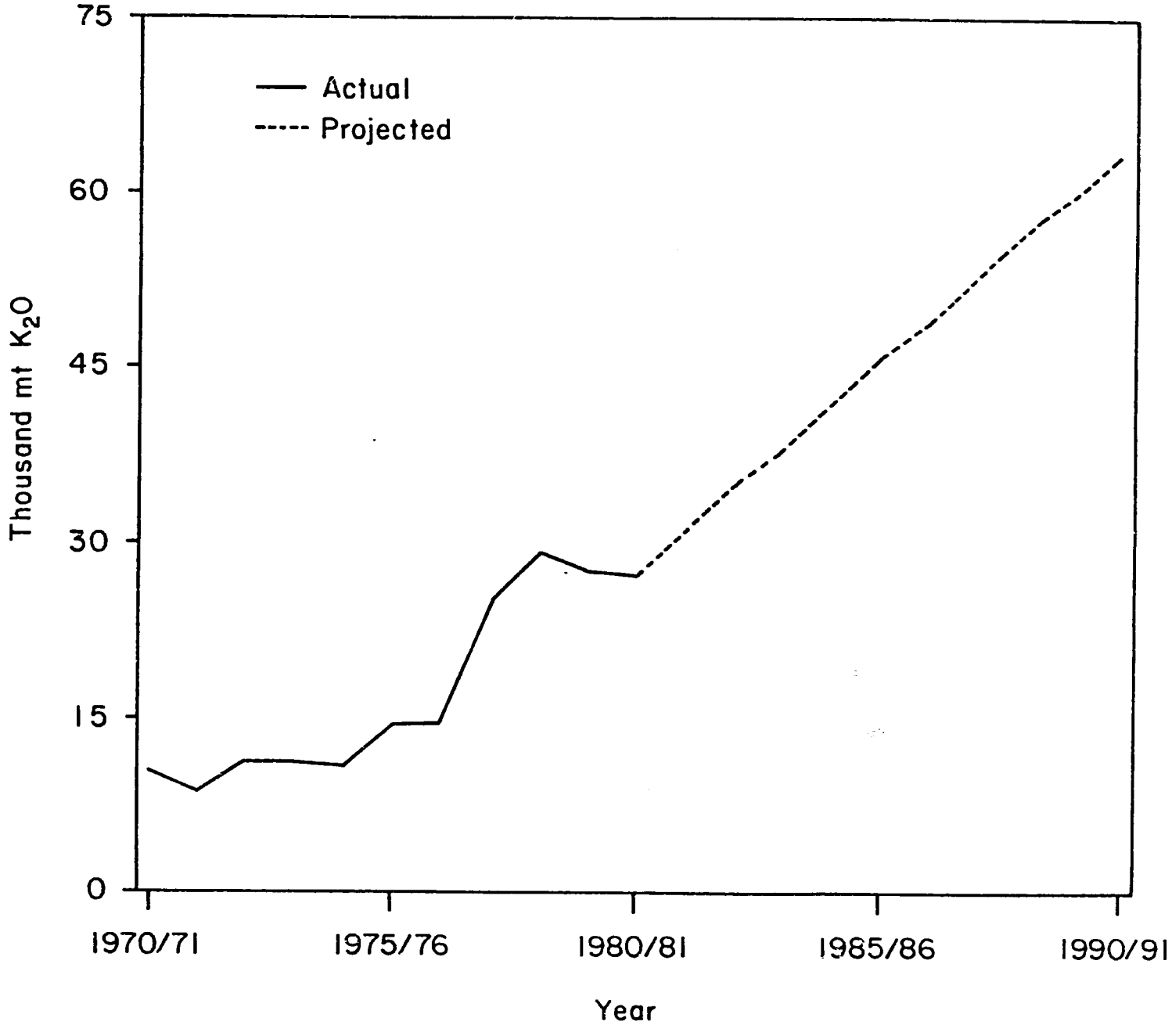


Figure VI-8. Bangladesh Potash Projections Assume 9% Compound Growth Rate to 1990/91.

Table VI-7. Bangladesh: GOB Forecast by Product and Nutrient, 1981/82-1989/90

Year	Urea	TSP/DAP	MP	Total	N	P_2O_5[a]	K_2O	Total
	('000 mt)							
1981/82	740	390	70	1,200	340	179	42	561
1982/83	860	485	85	1,430	396	223	51	670
1983/84	970	580	115	1,665	446	267	69	782
1984/85	1,078	688	134	1,900	496	316	80	892
1985/86	1,170	770	150	2,090	538	354	90	982
1986/87	1,263	847	165	2,275	581	390	99	1,070
1987/88	1,334	914	180	2,428	614	420	108	1,142
1988/89	1,393	968	193	2,554	641	445	116	1,202
1989/90	1,400	1,000	200	2,600	644	460	120	1,224

a. Assumes all TSP.

Source: Hossain (1981).

Table VI-8. Alternative Estimates of Annual Fertilizer Requirements in Bangladesh, 1989/90

Estimator	Product			Plant Nutrient			
	Urea	TSP	MP	N	P_2O_5	K_2O	Total
	('000 mt of product)			- -('000 mt of nutrient) -			
Hossain, BADC (1981)	1,400	1,000	200	644	460	120	1,224
Islam, BRRI (Method I, 1981)	2,100	1,047	110	966	482	66	1,514
Islam, BRRI (Method II, 1981)	1,556	779	194	714	358	116	1,190
Islam, BRRI (Method III, 1981)	1,902	949	99	875	437	59	1,371
Elahi, BARI (1981)	2,283	1,846	1,047	1,050	849	628	2,527
Huq, Soil Survey (1981)	4,281	3,363	1,881	1,969	1,547	1,229	4,745

Sources: Russell (1981) and Hossain (1981).

Policy Options for Improving Demand Forecasting

No one has a crystal ball that is completely accurate in forecasting the future market demand in a country. Nevertheless, continuing efforts to upgrade fertilizer market forecasts in a country like Bangladesh are critical. Without them, it would be difficult to plan and implement policy actions to increase the country's fertilizer use and its movement toward food self-sufficiency. Furthermore, in Bangladesh, where approximately 413,000 mt of plant nutrients was consumed last year and where foreign exchange is scarce, a slight margin of forecasting error can mean a sizable cost to the government and farmers.

Basically, there are four areas where the future fertilizer market forecasting can be improved: (1) assigning forecasting responsibility; (2) collecting, recording, and revising relevant and reliable data on a continuing and consistent basis; (3) increasing fertilizer market planners' and analysts' knowledge of fertilizer and the fertilizer market; and (4) training fertilizer market planners and analysts in data processing and forecasting methods. In some countries, it has been found useful to name one agency to coordinate all fertilizer market activities, including demand forecasting. Even if one agency is not responsible for all fertilizer market activities, one single organization should be assigned as the focal point for national fertilizer supply and demand projections. For example, in Pakistan, the National Fertilizer Development Center (NFDC) in the Government's Planning and Development Division has this task. From the standpoint of efficient utilization of limited manpower skills and financial resources available, such a focal point is important.

For policy analysis and planning, the use of regression models or other casual models is useful in most countries. New data must be collected and recorded accurately and current data must be examined for their accuracy and revised as needed. Fertilizer market planners and analysts must increase their knowledge of fertilizer products and the market areas which their analyses and forecasts cover. No matter how accurate their data may be and how knowledgeable they are of projection techniques, forecasters must understand the marketplace functions, if they are to prepare better forecasts in the future. Projecting or forecasting fertilizer demand is not a statistical gimmick alone; statistical analysis must be blended with knowledge about the marketplace. On the other

hand, if fertilizer market planners and analysts are not knowledgeable of forecasting techniques, they have no choice but to stay with the only technique they know, which may not be the best.

With knowledge of forecasting techniques and insights into market conditions, planners, and analysts will be able to forecast more accurately the market demand in their country.

Appendix Table VI-1. BANGLADESH NITROGEN FERTILIZER CONSUMPTION BASED ON VARIOUS GROWTH RATES (1000 METRIC TONS N)

RATE (%)	80/81	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91
5.00	266.7	280.	294.	309.	324.	340.	357.	375.	394.	414.	434.
6.00	266.7	283.	300.	318.	337.	357.	378.	401.	425.	451.	478.
7.00	266.7	285.	305.	327.	350.	374.	400.	428.	458.	490.	525.
8.00	266.7	288.	311.	336.	363.	392.	423.	457.	494.	533.	576.
9.00	266.7	291.	317.	345.	376.	410.	447.	488.	531.	579.	631.
10.00	266.7	293.	323.	355.	390.	430.	472.	520.	572.	629.	692.
11.00	266.7	296.	329.	365.	405.	449.	499.	554.	615.	682.	757.
12.00	266.7	299.	335.	375.	420.	470.	526.	590.	660.	740.	828.
13.00	266.7	301.	341.	385.	435.	491.	555.	627.	709.	801.	905.
14.00	266.7	304.	347.	395.	450.	514.	585.	667.	761.	867.	989.
15.00	266.7	307.	353.	406.	466.	536.	617.	709.	816.	938.	1079.
16.00	266.7	309.	359.	416.	483.	560.	650.	754.	874.	1014.	1177.
17.00	266.7	312.	365.	427.	500.	585.	684.	800.	937.	1096.	1282.
18.00	266.7	315.	371.	438.	517.	610.	720.	850.	1002.	1183.	1396.

Appendix Table VI-2. BANGLADESH PHOSPHATE FERTILIZER CONSUMPTION BASED ON VARIOUS GROWTH RATES (1000 METRIC TONS P_2O_5)

RATE (%)	80/81	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91
5.00	119.1	125.	131.	138.	145.	152.	160.	168.	176.	185.	194.
6.00	119.1	126.	134.	142.	150.	159.	169.	179.	190.	201.	213.
7.00	119.1	127.	136.	146.	156.	167.	179.	191.	205.	219.	234.
8.00	119.1	129.	139.	150.	162.	175.	189.	204.	220.	238.	257.
9.00	119.1	130.	142.	154.	168.	183.	200.	218.	237.	259.	282.
10.00	119.1	131.	144.	159.	174.	192.	211.	232.	255.	281.	309.
11.00	119.1	132.	147.	163.	181.	201.	223.	247.	274.	305.	338.
12.00	119.1	133.	149.	167.	187.	210.	235.	263.	295.	330.	370.
13.00	119.1	135.	152.	172.	194.	219.	248.	280.	317.	359.	404.
14.00	119.1	136.	155.	176.	201.	229.	261.	298.	340.	387.	442.
15.00	119.1	137.	158.	181.	208.	240.	275.	317.	364.	419.	482.
16.00	119.1	138.	160.	186.	216.	250.	290.	337.	390.	453.	525.
17.00	119.1	139.	163.	191.	223.	261.	306.	357.	418.	489.	572.
18.00	119.1	141.	166.	196.	231.	272.	322.	379.	448.	528.	623.

Appendix Table VI-3. BANGLADESH POTASH FERTILIZER CONSUMPTION BASED ON VARIOUS GROWTH RATES (1000 METRIC TONS K_2O)

RATE (%)	80/81	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91
5.00	27.1	28.	30.	31.	33.	35.	36.	38.	40.	42.	44.
6.00	27.1	29.	30.	32.	34.	36.	38.	41.	43.	46.	49.
7.00	27.1	29.	31.	33.	36.	38.	41.	44.	47.	50.	53.
8.00	27.1	29.	32.	34.	37.	40.	43.	46.	50.	54.	59.
9.00	27.1	30.	32.	35.	38.	42.	45.	50.	54.	59.	64.
10.00	27.1	30.	33.	36.	40.	44.	48.	53.	58.	64.	70.
11.00	27.1	30.	33.	37.	41.	46.	51.	56.	62.	69.	77.
12.00	27.1	30.	34.	38.	43.	48.	53.	60.	67.	75.	84.
13.00	27.1	31.	35.	39.	44.	50.	56.	64.	72.	81.	92.
14.00	27.1	31.	35.	40.	46.	52.	59.	68.	77.	88.	100.
15.00	27.1	31.	36.	41.	47.	55.	63.	72.	83.	95.	110.
16.00	27.1	31.	36.	42.	49.	57.	66.	77.	89.	103.	120.
17.00	27.1	32.	37.	43.	51.	59.	70.	81.	95.	111.	130.
18.00	27.1	32.	38.	45.	53.	62.	73.	86.	102.	120.	142.

Appendix Table VI-4. BANGLADESH NITROGEN FERTILIZER CONSUMPTION BASED ON VARIOUS COMPOUND GROWTH RATES TO 1990/91
(1000 METRIC TONS)
(NUMBER UNDERNEATH IN PARENTHESIS IS ANNUAL GROWTH RATE)
(AMOUNTS SHOWN PLOT AS A STRAIGHT LINE)

RATE (%)	80/81	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91
5.00	266.7	283. (6.3)	300. (5.9)	317. (5.6)	334. (5.3)	351. (5.0)	367. (4.8)	384. (4.6)	401. (4.4)	418. (4.2)	434. (4.0)
6.00	266.7	288. (7.9)	309. (7.3)	330. (6.8)	351. (6.4)	372. (6.0)	393. (5.7)	414. (5.4)	435. (5.1)	457. (4.8)	478. (4.6)
7.00	266.7	292. (9.7)	318. (8.8)	344. (8.1)	370. (7.5)	396. (7.0)	421. (6.5)	447. (6.1)	473. (5.8)	499. (5.5)	525. (5.2)
8.00	266.7	298. (11.6)	329. (10.4)	359. (9.4)	390. (8.6)	421. (7.9)	452. (7.3)	483. (6.8)	514. (6.4)	545. (6.0)	576. (5.7)
9.00	266.7	303. (13.7)	340. (12.0)	376. (10.7)	413. (9.7)	449. (8.8)	486. (8.1)	522. (7.5)	558. (7.0)	595. (6.5)	631. (6.1)
10.00	266.7	309. (15.9)	352. (13.7)	394. (12.1)	437. (10.8)	479. (9.7)	522. (8.9)	564. (8.1)	607. (7.5)	649. (7.0)	692. (6.5)
11.00	266.7	316. (18.4)	365. (15.5)	414. (13.4)	463. (11.9)	512. (10.6)	561. (9.6)	610. (8.7)	659. (8.0)	708. (7.4)	757. (6.9)
12.00	266.7	323. (21.1)	379. (17.4)	435. (14.8)	491. (12.9)	548. (11.4)	604. (10.3)	660. (9.3)	716. (8.5)	772. (7.8)	828. (7.3)
13.00	266.7	331. (23.9)	394. (19.3)	458. (16.2)	522. (13.9)	586. (12.2)	650. (10.9)	714. (9.8)	778. (8.9)	841. (8.2)	905. (7.6)
14.00	266.7	339. (27.1)	411. (21.3)	483. (17.6)	556. (14.9)	628. (13.0)	700. (11.5)	772. (10.3)	844. (9.4)	917. (8.6)	989. (7.9)
15.00	266.7	348. (30.5)	429. (23.3)	510. (18.9)	592. (15.9)	673. (13.7)	754. (12.1)	835. (10.8)	916. (9.7)	998. (8.9)	1079. (8.1)
16.00	266.7	358. (34.1)	449. (25.4)	540. (20.3)	631. (16.9)	722. (14.4)	813. (12.6)	904. (11.2)	995. (10.1)	1086. (9.1)	1177. (8.4)
17.00	266.7	368. (38.1)	470. (27.6)	571. (21.6)	673. (17.8)	774. (15.1)	876. (13.1)	977. (11.6)	1079. (10.4)	1180. (9.4)	1282. (8.6)
18.00	266.7	380. (42.3)	493. (29.7)	605. (22.9)	718. (18.7)	831. (15.7)	944. (13.6)	1057. (12.0)	1170. (10.7)	1283. (9.7)	1396. (8.8)

Appendix Table VI-5. BANGLADESH PHOSPHATE FERTILIZER CONSUMPTION BASED ON VARIOUS COMPOUND GROWTH RATES TO 1990/91
(1000 METRIC TONS)
(NUMBER UNDERNEATH IN PARENTHESIS IS ANNUAL GROWTH RATE)
(AMOUNTS SHOWN PLOT AS A STRAIGHT LINE)

RATE (%)	80/81	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91
5.00	119.1	127. (6.3)	134. (5.9)	142. (5.6)	149. (5.3)	157. (5.0)	164. (4.8)	172. (4.6)	179. (4.4)	187. (4.2)	194. (4.0)
6.00	119.1	129. (7.9)	138. (7.3)	147. (6.8)	157. (6.4)	166. (6.0)	176. (5.7)	185. (5.4)	194. (5.1)	204. (4.8)	213. (4.6)
7.00	119.1	131. (9.7)	142. (8.8)	154. (8.1)	165. (7.5)	177. (7.0)	188. (6.5)	200. (6.1)	211. (5.8)	223. (5.5)	234. (5.2)
8.00	119.1	133. (11.6)	147. (10.4)	161. (9.4)	174. (8.6)	188. (7.9)	202. (7.3)	216. (6.8)	230. (6.4)	243. (6.0)	257. (5.7)
9.00	119.1	135. (13.7)	152. (12.0)	168. (10.7)	184. (9.7)	201. (8.8)	217. (8.1)	233. (7.5)	249. (7.0)	266. (6.5)	282. (6.1)
10.00	119.1	138. (15.9)	157. (13.7)	176. (12.1)	195. (10.8)	214. (9.7)	233. (8.9)	252. (8.1)	271. (7.5)	290. (7.0)	309. (6.5)
11.00	119.1	141. (18.4)	163. (15.5)	185. (13.4)	207. (11.9)	229. (10.6)	251. (9.6)	272. (8.7)	294. (8.0)	316. (7.4)	338. (6.9)
12.00	119.1	144. (21.1)	169. (17.4)	194. (14.8)	219. (12.9)	245. (11.4)	270. (10.3)	295. (9.3)	320. (8.5)	345. (7.8)	370. (7.3)
13.00	119.1	148. (23.9)	176. (19.3)	205. (16.2)	233. (13.9)	262. (12.2)	290. (10.9)	319. (9.8)	347. (8.9)	376. (8.2)	404. (7.6)
14.00	119.1	151. (27.1)	184. (21.3)	216. (17.6)	248. (14.9)	280. (13.0)	313. (11.5)	345. (10.3)	377. (9.4)	409. (8.6)	442. (7.9)
15.00	119.1	155. (30.5)	192. (23.3)	228. (18.9)	264. (15.9)	300. (13.7)	337. (12.1)	373. (10.8)	409. (9.7)	446. (8.9)	482. (8.1)
16.00	119.1	160. (34.1)	200. (25.4)	241. (20.3)	282. (16.9)	322. (14.4)	363. (12.6)	404. (11.2)	444. (10.1)	485. (9.1)	525. (8.4)
17.00	119.1	164. (38.1)	210. (27.6)	255. (21.6)	300. (17.8)	346. (15.1)	391. (13.1)	436. (11.6)	482. (10.4)	527. (9.4)	572. (8.6)
18.00	119.1	170. (42.3)	220. (29.7)	270. (22.9)	321. (18.7)	371. (15.7)	422. (13.6)	472. (12.0)	523. (10.7)	573. (9.7)	623. (8.8)

Appendix Table VI-6. BANGLADESH POTASH FERTILIZER CONSUMPTION BASED ON VARIOUS COMPOUND GROWTH RATES TO 1990/91
(1000 METRIC TONS)
(NUMBER UNDERNEATH IN PARENTHESIS IS ANNUAL GROWTH RATE)
(AMOUNTS SHOWN PLOT AS A STRAIGHT LINE)

RATE (%)	80/81	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91
5.00	27.1	29. (6.3)	31. (5.9)	32. (5.6)	34. (5.3)	36. (5.0)	37. (4.8)	39. (4.6)	41. (4.4)	42. (4.2)	44. (4.0)
6.00	27.1	29. (7.9)	31. (7.3)	34. (6.8)	36. (6.4)	38. (6.0)	40. (5.7)	42. (5.4)	44. (5.1)	46. (4.8)	49. (4.6)
7.00	27.1	30. (9.7)	32. (8.8)	35. (8.1)	38. (7.5)	40. (7.0)	43. (6.5)	45. (6.1)	48. (5.8)	51. (5.5)	53. (5.2)
8.00	27.1	30. (11.6)	33. (10.4)	37. (9.4)	40. (8.6)	43. (7.9)	46. (7.3)	49. (6.8)	52. (6.4)	55. (6.0)	59. (5.7)
9.00	27.1	31. (13.7)	35. (12.0)	38. (10.7)	42. (9.7)	46. (8.8)	49. (8.1)	53. (7.5)	57. (7.0)	60. (6.5)	64. (6.1)
10.00	27.1	31. (15.9)	36. (13.7)	40. (12.1)	44. (10.8)	49. (9.7)	53. (8.9)	57. (8.1)	62. (7.5)	66. (7.0)	70. (6.5)
11.00	27.1	32. (18.4)	37. (15.5)	42. (13.4)	47. (11.9)	52. (10.6)	57. (9.6)	62. (8.7)	67. (8.0)	72. (7.4)	77. (6.9)
12.00	27.1	33. (21.1)	39. (17.4)	44. (14.8)	50. (12.9)	56. (11.4)	61. (10.3)	67. (9.3)	73. (8.5)	78. (7.8)	84. (7.3)
13.00	27.1	34. (23.9)	40. (19.3)	47. (16.2)	53. (13.9)	60. (12.2)	66. (10.9)	73. (9.8)	79. (8.9)	86. (8.2)	92. (7.6)
14.00	27.1	34. (27.1)	42. (21.3)	49. (17.6)	56. (14.9)	64. (13.0)	71. (11.5)	78. (10.3)	86. (9.4)	93. (8.6)	100. (7.9)
15.00	27.1	35. (30.5)	44. (23.3)	52. (18.9)	60. (15.9)	68. (13.7)	77. (12.1)	85. (10.8)	93. (9.7)	101. (8.9)	110. (8.1)
16.00	27.1	36. (34.1)	46. (25.4)	55. (20.3)	64. (16.9)	73. (14.4)	83. (12.6)	92. (11.2)	101. (10.1)	110. (9.1)	120. (8.4)
17.00	27.1	37. (38.1)	48. (27.6)	58. (21.6)	68. (17.8)	79. (15.1)	89. (13.1)	99. (11.6)	110. (10.4)	120. (9.4)	130. (8.6)
18.00	27.1	39. (42.3)	50. (29.7)	62. (22.9)	73. (18.7)	84. (15.7)	96. (13.6)	107. (12.0)	119. (10.7)	130. (9.7)	142. (8.8)

VII. FERTILIZER SUPPLY

Bangladesh derives its fertilizer supply from domestic production and imports (Table VII-1). In 1980/81, local production accounted for about 56% of the total supply of about 769,000 mt of all products, thus reversing the supply pattern of past years when imports provided the bulk of the national supply. The BADC supply procurement in 1980/81 was down about 17% from that of the previous year. Reflecting the lower import volume, the c. & f. value of imports in 1980/81 (Table VII-1) declined to about US $98 million from about US $131 million in 1979/80.

The principal issues of the fertilizer supply policy are obviously those that relate to domestic production and more cost-effective import strategies. The overall Bangladesh fertilizer policy seeks to conserve foreign exchange by building local production capability through the use of indigenous reserves of natural gas and by improving import strategies.

Fertilizer supply planning must be based on accurate forecasts of effective market demand--those quantities of individual fertilizer products that farmers are expected to purchase. As indicated in an earlier section of this report, wide disparities in market demand forecasts from various sources provide grounds for concern as to the reliability of forecasts being used in current GOB fertilizer supply and use planning. The IFDC demand forecasts differ substantially from those prepared and being used by GOB agencies as a basis for determining the quantities of fertilizer needed to support the ongoing MTFPP and the succeeding Third Five-Year Plan (TFYP) now in preparation. These demand forecasts are compared in Table VII-2. For supply planning purposes, the demand projections have been modified to approximate the buffer-stock requirements of a 3-month supply of urea and 5-month supply of other fertilizers.

The fertilizer raw materials base and policy implications of fertilizer supply system planning are considered separately for each of the three primary plant nutrients--nitrogen, phosphate, and potash--since they differ in substance and scope. Sulfur is also considered, for its usage is certain to increase as deficiencies are more fully identified and crop production is intensified.

Table VII-1. BADC Fertilizer Supply Procurement by Source

	Year			
	1977/78	1978/79	1979/80	1980/81
Urea				
Domestic, '000 mt	229.8	278.9	309.3	357.8
Imports				
Volume, '000 mt	260.2	348.3	286.3	63.9
Value, million US $	46.55	70.73	63.21	15.24
TSP				
Domestic, '000 mt	38.4	60.2	58.9	74.2
Imports				
Volume, '000 mt	114.3	105.0	173.6	193.7
Value, million US $	20.37	20.96	43.17	61.24
DAP				
Domestic, '000 mt	0	0	0	0
Imports				
Volume, '000 mt	0	83.7	42.2	36.2
Value, million US $	0	20.25	15.40	13.08
MP				
Domestic, '000 mt	0	0	0	0
Imports				
Volume, '000 mt	37.5	76.7	60.0	42.8
Value, million US $	3.97	8.67	9.44	8.84
All Products				
Domestic, '000 mt	268.2	339.1	368.2	432.0
Imports				
Volume, '000 mt	412.0	613.7	562.1	336.6
Value, million US $	70.85	120.61	131.22	98.40

Source: Volume data from Hossain (1981). Value of imports from private communication, IFDC consultants, Dacca.

Table VII-2. Fertilizer Market Demand and Supply Need Forecasts, 1980/81-1989/90

Year	Nitrogen (N)				Phosphate (P_2O_5)				Potash (K_2O)			
	Market Demand		Supply Needed		Market Demand		Supply Needed		Market Demand		Supply Needed	
	GOB	IFDC	GOB	IFDC	GOB	IFDC	GOB	IFDC	GOB	IFDC	GOB	IFDC
	('000 mt nutrient)											
1980/81[a]	269				119				27			
1981/82	340	298	352	306	179	135	196	142	42	31	45	33
1982/83	396	329	410	337	223	152	241	159	51	35	55	37
1983/84	446	359	459	367	267	168	285	175	69	38	77	40
1984/85	496	390	509	398	316	184	336	191	80	42	85	44
1985/86	538	421	549	429	354	201	372	208	90	46	94	48
1986/87	580	452	591	460	390	217	407	224	99	49	103	51
1987/88	614	483	623	491	420	233	433	240	108	53	112	55
1988/89	641	514	648	522	445	249	455	256	116	57	119	59
1989/90	644	545	651	553	460	266	466	273	120	60	122	62

a. Actual sales for 1980/81.

Source: GOB market demand derived from data in Hossain (1981).
IFDC market demand forecast from Table VI-6.

Fertilizer Raw Materials

Bangladesh's potential for increasing its self-reliance on domestic fertilizer production is limited by its modest raw materials base. Of the important fertilizer materials (natural gas, phosphate rock, sulfur, and potash), Bangladesh possesses only natural gas, and this is currently being used as a feedstock for the manufacture of ammonia for subsequent conversion to urea. All other fertilizer raw materials must be imported.

According to the SFYP, total recoverable reserves of natural gas are estimated at 9.6 trillion ft^3. Current (1980) gas production comes from four fields located in the eastern part of the country; total well capacity is estimated at 225 MMCFD. Gas production and consumption in 1978/79 totaled about 38 MMCF. A new field is to be developed at Bakhrabad to supply ammonia plants planned for Chittagong. Gas use is confined mainly to the immediate production areas for lack of adequate transmission and distribution infrastructure. Although detailed gas utilization data were not available, it is believed that a significant portion of annual output is used in ammonia manufacture.

Interruptions in natural gas supply, caused in part by its diversion for thermal power generation, have led to curtailments in ammonia/urea production at the UFF plant at Ghorasal. This suggests the need to develop and implement policies designed to assure adequate and reliable supplies of gas for use in existing and new ammonia plants. These policies should include expanded exploration programs, particularly in the western region, and the improvement and/or construction of new gas delivery systems. Although the consideration of national energy policy is beyond the scope of this report, it is suggested that natural gas policies be clarified and priorities set for natural gas use based on its economic value for alternate uses. The use of natural gas in planned export-oriented urea plants should be considered within the context of priorities of gas needs for other domestic applications. Ammonia plants must have an assured source of gas supply both now and in the future and should be accorded top gas use priority.

Fertilizer Production

Nitrogen

Urea is the predominant form of fertilizer nitrogen used in Bangladesh. The native reserves of natural gas and production economics suggest that urea will undoubtedly continue to be the mainstay of nitrogen fertilizer supply in the future. Relatively small amounts of ammonium sulfate, also produced domestically, and limited quantities of imported DAP are also used and will probably play supporting roles in the nitrogen supply system in the coming decade. As noted later, DAP may have the potential to gain in importance.

The degree to which local urea production must be increased to satisfy domestic needs will naturally be determined by the market demand forecast and product mix scenarios which are selected in setting and meeting future fertilizer production goals.

Two supply schemes have been postulated to illustrate this point. In the first scheme, which represents the product mix usually used in Bangladesh planning, it is assumed that during the decade of the 1980s all of the nitrogen will be supplied as urea, all of the phosphate as TSP, and all of the potash as MP. Two supply/demand outlook scenarios are developed (Table VII-3) using the previously noted GOB and IFDC market demand forecasts and GOB projections of domestic production.

When the GOB demand estimates are used, urea production marginally outpaces domestic demand beginning in 1986/87. However, when the IFDC demand forecast is used, domestic production exceeds demand in 1983/84 and provides significant exportable surpluses in the ensuing years. In both instances, shortfalls in domestic production in the intervening years will have to be met by imports. If the IFDC market demand forecast scenario is accepted, a considerably larger saving in foreign exchange would accrue at a much faster rate.

In the second nitrogen supply scheme it is assumed that 25% of total P_2O_5 demand will be supplied by DAP. This scheme is somewhat similar to the fertilizer supply pattern that existed in 1980/81 when about 20% of the P_2O_5 was supplied by imported DAP. The substitution of DAP (18-46-0), which contains the equivalent N of 0.39 tons of urea per ton of DAP, for TSP decreases the quantity of nitrogen that must be supplied by urea or another nitrogen carrier to satisfy the market demand for fertilizer nitrogen. The rationale for this substitution

Table VII-3. Bangladesh Urea Supply/Demand Outlook Assuming Total Nitrogen Demand to be Supplied as Urea

Year	N		Urea		Projected Urea Production	Demand/Supply Balance	
	GOB	IFDC	GOB	IFDC		GOB	IFDC
	('000 mt)						
1980/81[a]	262		570		315	255	
1981/82	352	306	765	665	618	-147	-47
1982/83	410	337	891	733	700	-191	-33
1983/84	459	367	998	798	845	-153	+47
1984/85	509	398	1,107	865	915	-192	+50
1985/86	549	429	1,194	933	1,112	- 82	+179
1986/87	591	460	1,285	1,000	1,304	+ 19	+304
1987/88	623	491	1,354	1,067	1,402	+ 48	+335
1988/89	648	522	1,409	1,134	1,420	+ 11	+286
1989/90	651	553	1,415	1,202	1,420	+ 5	+218

a. Actual urea sold in FY 1981. Excludes DAP sales.

Source: See Tables VII-2 and VII-6.

is developed in succeeding paragraphs. Table VII-4 shows the effect of including DAP in the supply scheme on the urea supply requirements as related to the GOB and IFDC nitrogen and phosphate demand forecasts. As expected, the introduction of DAP decreases the indicated gap between urea demand and supply quite rapidly. Exportable surpluses of urea are indicated as early as 1982/83 if the IFDC demand forecast is followed and in 1985/86 if the GOB demand forecast is applied.

Because of the host of imponderables associated with demand forecasting and supply development, it is highly doubtful that either of these supply/demand scenarios will apply in a practical sense. This largely academic exercise is useful in that it indicates the beneficial effect of importing DAP in decreasing the urea capacity required to meet domestic market needs. Any potential excess urea capacity can, of course, be directed to the export market.

An examination of existing and planned urea production capability and related policy issues follows.

Domestic Production--Urea is currently being produced from locally available natural gas at three plants: the NGFF at Fenchuganj, the UFF at Ghorasal, and the recently commissioned (December 1981) ZFCL plant at Ashuganj. The NGFF plant also produces small quantities of ammonium sulfate. All plants are government owned. The NGFF and UFF facilities are operated by the BCIC. The ZFCL plant is independently operated. Existing plants have a combined installed capacity of 874,000 tpy of urea and 12,000 tpy of AS. Salient features of nitrogen fertilizer plant capacity and operation (excluding ZFCL) are given in Table VII-5.

In 1980/81 combined urea production at NGFF and UFF was reported as 315,000 tons. Production in 1981/82, including contributions from ZFCL, is targeted for 618,000 tons. Although improvements in output have been realized at both the recently rehabilitated NGFF plant and the UFF plant, from a historical perspective, production at both locations has been erratic and unacceptably low. Annual capacity utilization rates have averaged less than 60% during the past decade. The performance record of the ZFCL plant remains to be established.

Despite low levels of domestic production, reported urea production costs are significantly lower than the cost of imported urea. In 1979/80, the urea production cost at UFF was reportedly about US $100/ton and at NGFF, about US $120/ton (basis 15 Taka = US $1.00). It is not clear whether this cost

Table VII-4. Bangladesh Urea Supply/Demand Outlook Assuming 25% of Total P_2O_5 Demand Supplied as DAP

Year	DAP Imports				N Demand for Urea				Projected Urea Production	Supply/ Demand Balance	
	mt		N Content		N		Urea				
	GOB	IFDC	GOB	IFDC	GOB	IFDC	GOB	IFDC		GOB	IFDC
	('000 mt)										
1980/81									315		
1981/82	107	77	19	13	333	293	723	637	618	-105	-19
1982/83	130	87	23	16	387	321	841	698	700	-141	+2
1983/84	154	96	28	17	431	350	937	761	845	-92	+84
1984/85	183	104	33	19	476	379	1,035	824	915	-120	+91
1985/86	211	113	38	20	513	409	1,111	889	1,112	+1	+223
1986/87	222	122	40	22	551	438	1,198	952	1,304	+106	+352
1987/88	235	130	42	23	581	468	1,263	1,017	1,402	+139	+385
1988/89	248	139	44	25	604	497	1,313	1,080	1,420	+107	+340
1989/90	252	148	45	27	606	526	1,317	1,143	1,420	+103	+277

Table VII-5. Bangladesh Nitrogen Fertilizer Production

Year	NGFF (Fenchuganj) Urea Production ('000 mt)	NGFF (Fenchuganj) Urea Capacity Utilization, %	NGFF (Fenchuganj) Ammonium Sulfate Production ('000 mt)	NGFF (Fenchuganj) Ammonium Sulfate Capacity Utilization, %	UFF (Ghorasal) Urea Production ('000 mt)	UFF (Ghorasal) Urea Capacity Utilization, %
Startup date	1962		1969		1970	
Rated capacity	106		12		340	
1970/71	56	53	6	50	-	-
1971/72	47	44	3	25	-	-
1972/73	39	37	6	50	175	52
1973/74	61	57	10	83	221	65
1974/75	58	55	5	42	11	3
1975/76	53	50	6	50	229	67
1976/77	77	73	9	75	208	61
1977/78	61	58	10	83	151	44
1978/79	55	52	5	42	236	69
1979/80	104	98	10	83	257	76
Average	61	58	7	58	186	55
Production cost, TK/mt, 1979/80	1,800		1,740		1,500	
August 1982	3,265		-		2,363	

Source: Rahman (1981).

figure includes bags and bagging. The more recent August 1982 production costs, bagged ex-factory, are reported as NGFF US $145.11/mt, UFF US $105.02, and ZFCL US $160.00 (basis 22.5 Taka = US $1.00). The average c. & f. cost of imported bagged urea in 1980/81 was US $238/ton. Although domestic urea production costs will probably rise in response to rising gas and manufacturing costs, the low cost of indigenous natural gas should favor local production over importation and should thereby support the GOB policy of nitrogen self-sufficiency.

Existing urea units have been adversely affected--although to differing degrees--by a wide range of problems including shortages of raw materials, disruptions in power supply, and a host of mechanical, electrical, and instrument failures. These equipment-related problems have been due largely to poor physical condition of equipment and inadequate preventative maintenance. Maintenance downtime has often been excessive because of the lack of availability of foreign currency to purchase necessary replacement parts and plant supplies. Perhaps even more importantly, production has been constrained by lack of plant management and operating expertise. The critical shortage of experienced plant technicians has been exacerbated by the outflow of technical personnel to middle eastern countries where salaries and employment conditions are more rewarding.

The nation's nitrogen supply strategy is based on meeting the anticipated growth in urea demand by raising domestic production through rehabilitation of existing facilities and by constructing new ammonia urea plants at Chittagong and Ghorasal. The Chittagong Urea Fertilizer Limited (CUFL) plant, to be funded by a consortium of international financial organizations, will have a capacity of 1,000 tpd of ammonia and 1,700 tpd of prilled urea. Plant commissioning is targeted for 1985/86. The Ghorasal plant expansion, designated the Polash Urea Fertilizer Project (PUFP), is to be built with the assistance of the People's Republic of China and will have a capacity of 100,000 tpy of urea; completion is stated for 1984/85. Three other plants proposed for Mymensingh, Begumganj, and Sylhet are in the preliminary planning stages, but available information is too scant to consider their possible impact on the domestic supply situation. Contributions to future domestic urea supply, on a plant by plant basis, are shown in Table VII-6, which compares projections of production with the GOB and IFDC demand forecasts discussed earlier in this section.

Table VII-6. Urea Supply and Demand Outlook, 1980/81-1989/90

Year	Production						Demand				Supply/Demand Balance			
							GOB[a]		IFDC[b]		GOB		IFDC	
	NGFF	UFF	ZFCL	PUFP	CUFL	Total	I	II	I	II	I	II	I	II
	('000 mt)													
1980/81	90	225				315	570				-255			
1981/82	90	240	288			618	765	735	665	637	-147	-117	-47	-19
1982/83	70	220	410			700	891	841	733	698	-191	-141	-33	+2
1983/84	85	285	475			845	998	937	798	761	-153	-92	+47	+84
1984/85	85	285	475	70		915	1,107	1,035	865	824	-192	-120	+50	+91
1985/86	85	285	475	80	187	1,112	1,194	1,111	933	889	-82	+1	+179	+223
1986/87	80	280	475	95	374	1,304	1,285	1,198	1,000	952	+19	+106	+304	+352
1987/88	80	275	475	95	477	1,402	1,354	1,263	1,067	1,017	+48	+139	+335	+385
1988/89	75	270	475	95	505	1,420	1,409	1,313	1,134	1,080	+11	+107	+285	+340
1989/90	75	270	475	95	505	1,420	1,415	1,315	1,202	1,143	+5	+109	+218	+277

a. Case I assumes total nitrogen demand under the GOB demand forecast to be supplied as urea. Case II assumes that the nitrogen of nitrogen demand will be met by urea and importing DAP to satisfy 25% of P_2O_5 demand.

b. Same as note a, except that IFDC market demand estimates are used in place of the GOB market demand estimates.

Note: NGFF = Natural Gas Fertilizer Factory; UFF = Urea Fertilizer Factory; ZFCL = Zia Fertilizer Chemicals Limited; PUFP = Polash Urea Fertilizer Project; CUFL = Chittagong Urea Fertilizer Limited.

Source: Production data from Rahman (1981).

Another urea facility, the Karnaphuli Fertilizer Company (KAFCO), is being considered for Chittagong. This plant, a joint venture of the GOB and Swedish/Danish private interests, is intended to produce urea for export. Planned plant capacity has been reported as 570,000 tpy of urea; completion is targeted for mid-1980.

Policy Issues and Options--The overall GOB policy for increasing nitrogen self-sufficiency calls for expanding production by renovating and upgrading existing urea facilities and constructing new plants using indigenous natural gas. The successful implementation of this policy will depend on the speed with which strategies are devised and carried out to (1) relax and/or remove the human, physical, and financial constraints to past plant performance and (2) facilitate the planning, organization, and execution of new plant construction programs.

1. The limited availability of technically competent plant managers and operators has been and continues to be a major impediment to efficient plant operation. The lack of facilities, programs, and materials needed to hire and train workers in the numbers required for proper plant operation is a serious constraint to human resource development. The previously mentioned exodus of skilled technicians aggravates the problem. The GOB recognizes the personnel constraint and is taking steps to expand in-country training facilities and training programs with UNDP, IFAD, and other donor agency assistance. Also, BCIC personnel have participated in IFDC-sponsored production maintenance training programs at home and abroad. The BCIC is reportedly conducting in-company training programs based on knowledge gained from participation in these courses. Although progress in personnel training is being made, the problem remains critical and deserves expanded GOB support. Although worker skills will be improved through the establishment of new training facilities and programs, actions must be taken to stem the outflow of experienced plant personnel to more acceptable levels. This could be accomplished, as has been suggested by others, by increasing worker incentives to remain in Bangladesh, by imposing employment time minimums as a condition of employment, or by restricting the number of technicians permitted to leave the country at a given time. Another alternative is to train greater numbers of workers to take into account anticipated departures.

2. The fertilizer plant rehabilitation programs seek to overcome the earlier noted physical resources constraint to plant performance by (1) adding

and replacing equipment, (2) modifying plants, (3) improving maintenance to enable plants to operate at higher capacity utilization rates, and (4) minimizing plant downtime resulting from interruptions in utilities and raw material supply. Specific plant improvement programs are well defined in the World Bank, USAID, and other donor agency reports and will not be repeated here. Full government policy support will be required to expedite their implementation.

3. The operation of existing urea plants continues to be adversely affected by the uncertain and often inadequate availability of foreign currency funds to purchase imported raw materials, spares, catalysts, and chemicals. If desired production improvements are to be made, the GOB must take steps to assure the timely and adequate availability of foreign exchange funds to purchase those items that are necessary to maintain the plants in proper working condition and meet established production rates. Plant management should accept the responsibility for planning and scheduling plant needs, taking into account the often excessively long purchase and delivery lead times, but other agencies must also work to supply plant needs in a timely manner.

4. The principal policy considerations associated with new plant construction relate to the speed with which these new facilities are built and brought up to suitable and sustainable operating rates. The long and costly delays connected with the construction of the ZFCL plant can be minimized by strengthening and streamlining the technical and financial planning processes involved in new project development and implementation. Closer coordination between the GOB and potential donor agencies is mandatory from project inception to conclusion. Responsibility and authority for conducting the needed technical and economic feasibility studies must be clearly delineated and early agreement reached with the financing organizations on overall procedural aspects including process and contractor selection and project management.

5. Another facet of nitrogen fertilizer production policy relates to the form of urea product to be made in the proposed new plants. Today, most of the urea made worldwide is produced in a prilled form. This is also the case in Bangladesh. However, there is a trend toward production of granular urea, largely because it is physically superior to the prilled form. Urea granules are generally harder and stronger than prills and therefore less susceptible to breakage during transport and handling. Also, urea granulation processes permit the production of a wider range of particle sizes than can be made by prilling.

The agronomic merits of using urea of larger particle sizes have been demonstrated, particularly on rice, in some localities in Asia. It is suggested that granular urea be considered for the proposed new urea plants, particularly those intended to serve the export market where granular urea currently commands a premium price over the prilled form.

6. As plans for the construction of the export-oriented plant proceed, policies and strategies will have to be developed for marketing the product in a manner most beneficial to the GOB. Target market countries will have to be identified, a marketing plan devised, and an organization put into place to carry out this assignment.

Phosphate

The principal source of fertilizer phosphate used in Bangladesh is TSP; DAP is a secondary source. Relatively small quantities of Hyperphosphate, a ground phosphate rock product, have been imported in the past. In 1980/81 (Table VII-1) about 36,000 mt of DAP was imported and about 41,000 mt was sold by BADC. In 1980/81 the c. & f. value of phosphate fertilizer imports (TSP and DAP) accounted for 75% of the total c. & f. value of all fertilizer imports. The need and opportunities for effecting foreign exchange cost savings by judicious phosphate supply planning are evident.

Current phosphate supply policy, which must await clarificatio of the agronomic suitability and farmer acceptance of DAP, is focused on expanding domestic TSP production by renovating and improving existing production units at Chittagong. The gap between supply capability and demand is to be filled mainly by importing TSP.

The large disparity, nearly 50%, between the phosphate market demand forecasts of the GOB and those of IFDC, as discussed earlier (Table VII-2), adds to the difficulties in future phosphate supply planning. If it is assumed that all of the phosphate demand called for by the GOB market forecast is to be satisfied by TSP and that local TSP production conforms to current GOB production projections (discussed later), the void between demand and supply expands rapidly (Table VII-7) necessitating growing expenditures for imports. If the same assumptions are applied to the IFDC phosphate market demand forecast, the imbalance between supply and demand narrows substantially, as shown in Table VII-7 and import costs are correspondingly lower.

Table VII-7. Phosphate Supply and Demand Outlook, Assuming Market Demand for Phosphate (P_2O_5) is to be Supplied as TSP

Year	Projected Domestic Production	Demand		Supply/ Demand Balance	
		GOB	IFDC	GOB	IFDC
	('000 mt)				
1980/81	30				
1981/82	50	426	309	-376	-259
1982/83	90	524	346	-434	-256
1983/84	100	620	380	-520	-280
1984/85	110	730	415	-620	-305
1985/86	105	809	452	-704	-347
1986/87	100	885	487	-785	-387
1987/88	95	941	522	-846	-427
1988/89	95	989	557	-894	-462
1989/90	95	1,013	594	-918	-499

Source: Projected production from Rahman (1981).
GOB and IFDC market demand from Table VII-2.

If it is assumed that DAP is introduced into the supply scheme of the future to supply 25% of market demand for P_2O_5, the imbalance between TSP demand and local production is of course reduced proportionally. Table VII-8 illustrates the supply and demand outlook for TSP and DAP using the GOB and IFDC phosphate demand forecasts.

The import costs associated with the phosphate supply schemes presented above are discussed later.

Domestic Production--Domestic production of TSP is centered at the Chittagong TSP complex built in 1969/70 but, because of the War of Independence and legal disputes, not effectively operated until the mid- to late 1970s. The plant consists of two production units with a combined design capacity of 152,000 tpy. Plant production and operating rates are summarized in Table VII-9. The TSP production is based entirely on imported sulfur and phosphate rock since Bangladesh possesses neither of these raw materials. The government-owned complex is operated by BCIC.

Although statistics from different sources vary, annual TSP production has generally been around 40,000-50,000 tons in the period 1976-79. A new high of 71,000 tons was reportedly achieved in 1979/80. The production cost of TSP in 1979/80 was reported as about US $290/mt (basis 15 Taka = US $1.00). This is substantially above the average c. & f. value of TSP imports of about US $250/mt, bagged, in that year. In 1979/81 the c. & f. value of imported TSP was about US $316/mt. The economics of domestic production versus importation of TSP deserves further scrutiny as noted later in the discussion of alternate phosphate supply strategies.

Plant performance has suffered severely from excessive plant downtime, with capacity utilization rates averaging about 30% during the past 5 years. Equipment failures and maintenance problems accounted for about half of the plant downtime. Shortages of raw materials, power supply disruptions, and BADC's failure to lift fertilizers have been responsible for most of the remaining lost time.

Following several studies on the disposition of the TSP complex by outside consultants, some of which presented conflicting views, a rehabilitation project was prepared by The World Bank to raise production at the Chittagong facilities closer to plant design capacity. This project, scheduled for implementation in 1982/83, is to provide replacement and standby equipment; improve plant utilities including steam, power, and water treatment facilities;

Table VII-8. Phosphate Supply and Demand Outlook Assuming That Market Demand for Phosphate (P_2O_5) is to be Supplied by TSP (75%) and DAP (25%)

Year	Domestic TSP Production	Demand GOB TSP	Demand GOB DAP	Demand IFDC TSP	Demand IFDC DAP	Supply/Demand Outlook GOB TSP	Supply/Demand Outlook GOB DAP	Supply/Demand Outlook IFDC TSP	Supply/Demand Outlook IFDC DAP
	('000 mt)								
1980/81[a]	30	215	41			194	36		
1981/82	50	320	107	233	77	-270	-107	-183	-77
1982/83	90	393	130	259	87	-303	-130	-169	-87
1983/84	100	465	154	285	96	-365	-154	-185	-96
1984/85	110	548	183	311	104	-438	-183	-201	-104
1985/86	105	598	211	339	113	-493	-211	-234	-113
1986/87	100	663	222	365	122	-563	-222	-265	-122
1987/88	95	707	235	391	130	-612	-235	-296	-130
1988/89	95	741	248	417	139	-646	-248	-322	-139
1989/90	95	761	252	446	148	-666	-252	-351	-148

a. Values for 1980/81 are estimated production and actual sales and imports of TSP and DAP.

Table VII-9. Bangladesh Annual TSP Production, '000 mt

Year	Annual Production TSP Unit I[a]	Annual Production TSP Unit II[b]	Average Annual Capacity Utilization, % (Combined)
1974/75		32	27[c]
1975/76		41	34[c]
1976/77		38	32[c]
1977/78		41	27
1978/79		52	34
1979/80		71	47
Production cost TK/mt 1979/80		4,357	

a. Started up in 1969, renovated in 1973, shut down until 1977.
b. Completed 1970, war damage repaired 1973, commissioned 1974.
c. Capacity utilization rates based on capacity of TSP Unit II only.

Note: The startup potential capacities of TSP Unit I (in 1969) and TSP Unit II (in 1970) were 32,000 tpy and 120,000 tpy, respectively, i.e., a combined capacity of 152,000 tpy.

Source: Rahman (1981).

and make improvements in instrumentation. An important component of the plant rehabilitation project is the installation of a granulation unit to convert the powdered TSP product to a more marketable granular form. According to the World Bank estimates, completion of the rehabilitation project will increase the capacity utilization rate of the plant to about 80% or about 120,000 tpy of granular TSP. The BCIC, less optimistic, estimates a capacity utilization rate of about 70%, equivalent to a yearly production of 100,000-110,000 tons. Projected annual TSP production rates for the 1981-90 period were given in Table VII-8.

The SFYP refers to the construction of a TSP facility at Khulna. Presumably the plant would operate on imported phosphoric acid and rock to produce a granular TSP product. Process and plant capacity details have not been determined. The Khulna plant would not be expected to be in operation until after 1984/85.

Policy Issues and Options--In essence, the prevailing GOB fertilizer supply strategy calls for modernizing and upgrading the Chittagong TSP complex to raise production to about 100,000-120,000 tpy of TSP. This represents only a small fraction of projected 1989/90 demand (Table VII-2) as given in both the GOB and IFDC demand forecasts. If present practice is followed, the remaining phosphate fertilizer would be imported primarily in the form of TSP. The addition of the Khulna unit could contribute to local production, but until definite plans are made its impact cannot be evaluated.

The focus of domestic phosphate production policy, as it relates to increasing production at Chittagong, is similar in many respects to domestic nitrogen production policy in that it attempts to alleviate or remove the human, physical, and financial constraints associated with past phosphate production. To increase local phosphate output there is a vital need to (1) expand and intensify manpower development, (2) expedite implementation of plant rehabilitation programs, and (3) provide funds to purchase needed raw materials and plant supplies. These aspects of fertilizer production policy were discussed earlier and will not be repeated here.

A more definitive phosphate fertilizer supply strategy is clearly needed. Further consideration should be given to alternative supply systems which involve (1) the domestic production and/or import of agronomically suitable phosphates that are more cost effective than TSP and (2) the more economical domestic production of TSP.

An IFDC report (Klem, 1981), prepared as a background paper for this report, identifies and presents a preliminary economic evaluation of several alternative supply schemes.

Based on the results of agronomic tests and past use experience with rock phosphate, the report suggests that more economical, less soluble forms of phosphate (as compared with TSP), such as partially acidulated phosphate rock, might satisfactorily be used in large sections of the country where acid soils predominate. Accordingly, an evaluation was made of a phosphate fertilizer supply system based on local TSP and PAPR production. The report also examines the economics of local TSP production using alternative raw material sources and discusses the potential cost benefits of producing a semi-granular rather than a fully granulated TSP product as contemplated in the currently proposed Chittagong plant modification program. The phosphate supply schemes considered in this study, together with estimates of investment and production costs associated with each, are summarized in Table VII-10. The total cost of supplying the nation's phosphate needs, via domestic production and needed supplemental imports, by each of these schemes is given in Table VII-11.

The report presents these conclusions:

1. The cost of producing granular TSP (GTSP) from imported sulfur and phosphate rock is higher than the cost of importing GTSP in bulk and bagging it locally.
2. The cost of producing GTSP from imported phosphoric acid is currently marginally lower than importing GTSP; this cost differential is expected to moderate in the future.
3. A semigranular TSP product (SGTSP) can be produced more economically than a fully granulated product. A SGTSP product can be made by a simple modification of the proposed granulation plant.
4. On the basis of 1981 prices, PAPR can be produced at substantially lower cost than GTSP. Preliminary estimates indicate that about US $50 million/year (based on 1981 dollars and 1990 use rates) might be saved by substituting PAPR for GTSP in those areas where Hyperphosphate has been found to be a satisfactory source of P_2O_5.
5. The cost of facilities to produce GTSP and PAPR can be paid out in about 2 years of operation.

Table VII-10. Alternative Phosphate Supply Schemes for Bangladesh

Scheme	Product(s)	Annual Production, '000 mt		Product Cost	Production Cost, US $/mt		Fixed Capital Investment
		Product	P_2O_5	Million US $	Product	P_2O_5	Million US $
1	GTSP[a]	100	47.5	33.4	334	703	7.7
2	SGTSP	300	142.5	85.2	284	600	12.7
3	GTSP	300	142.5	87.9	293	617	33.8
4	GTSP	120	57.0	-	-	-	-
	PAPR[b]	345	138.0	-	-	-	35.0
		465	195.0	106.1	228	544	
5	GTSP	120	57.0	-	-	-	-
	PAPR	345	138.0	-	-	-	-
		465	195.0	106.1	228	544	55.6
	AS[c]	75	-	11.4	152	-	-
6	GTSP	120	57.0	-	-	-	-
	PAPR	345	138.0	-	-	-	-
		465	195.0	106.1	228	544	35.6
	GYPSUM	102	-	3.9	38	-	-
7	SGTSP	300	142.5	85.2	284	600	33.7
	AS	75	-	11.1	148	-	-
8	GSSP[d]	120	25.2	19.6	164	778	5.7
9	GTSP	320	152.0	-	-	-	-
	PAPR	785	196.3	-	-	-	-
		1,105	348.3	248.4	225	713	136.0
	AS	75	-	11.3	151	-	-

a. GTSP = granular triple superphosphate, 47.5% total P_2O_5.
b. PAPR = partially acidulated phosphate rock, 40% total P_2O_5.
c. AS = ammonium sulfate.
d. GSSP = granular single superphosphate, 21% total P_2O_5.

Source: Klem (1981).

Table VII-11. Cost of 10-Year (1980/81-1989/90) Phosphate Supply[a] by Alternative Phosphate Supply Schemes in Table VII-10

Scheme	Cost Category: Domestic Products[b]	Cost Category: Imported TSP	Total Phosphate Supply Cost
	(million US $)		
1	306	1,813	2,119
2	698	1,360	2,058
3	719	1,360	2,079
4	863	1,084	1,947
5	863	1,084	1,947
6	863	1,084	1,947
7	698	1,360	2,059
8	202	1,929	2,131
9	1,468	364	1,832
All imported TSP		2,083	2,083

a. Total supply for a 10-year period is 6,944,000 tons TSP or TSP equivalent.
b. Domestic production as TSP or TSP equivalent. See Table VII-10 for product breakdown.

Source: Klem (1981).

6. The DAP can be imported more economically than the TSP. Its expanded use in Bangladesh should be encouraged by first resolving the questions which have been raised regarding its agronomic effectiveness and farmer acceptance.

The report recommends that a more thorough study be made of all of the suggested alternative phosphate supply systems. It further recommends that an agronomic testing program be carried out to confirm the utility of PAPR products, but cautions against undue delays in marketing.

Potash

Muriate of potash is the sole source of fertilizer potash currently used in Bangladesh. It is the lowest cost form of potash and will certainly continue to be the major source of fertilizer potash in the years ahead. The use of higher cost forms of potash such as sulfate of potash (SP) and sulfate of potash magnesia (SPM) can be justified only in those instances where agronomic needs for nonchloride potash have been demonstrated or where their dual use as sulfur carriers warrants their substantially higher cost. On an equivalent K_2O content basis, SP usually costs about twice as much as MP.

The potash market demand estimates prepared by the GOB and IFDC show wide variations (Table VII-12). According to the GOB forecast, MP supply needs would reach 203,000 mt in 1989/90. The IFDC estimate sees 1989/90 MP demand at about half that level, or about 103,000 mt.

There are no known reserves or production of potash fertilizer in Bangladesh. The country's potash fertilizer needs will continue to be supplied totally from imports.

Policy Issues and Options--Because Bangladesh has no potash mineral base to support local production, the potash supply alternatives and related policies and strategies are confined mainly to assuring cost-effective procurement and timely delivery of agronomically suitable products.

Muriate of potash is available in three principal grades--standard, coarse, and granular--which differ mainly in particle size. The standard grade is of the smallest size (approximately minus 14- plus 65-mesh, Tyler), followed by coarse grade (approximately minus 8- plus 35-mesh, Tyler), and granular grade (approximately minus 6- plus 14-mesh, Tyler). All grades contain a minimum 60% K_2O content.

Table VII-12. Projected Muriate of Potash Supply Needs, FY 1981-90

Year	Demand[a]	
	GOB Forecast	IFDC Forecast
	- - - - -('000 mt)	- - - - - - -
1980/81[b]	45	
1981/82	75	55
1982/83	92	62
1983/84	128	67
1984/85	142	73
1985/86	157	80
1986/87	172	85
1987/88	187	92
1988/89	198	98
1989/90	203	103

a. To be supplied by imports.
b. Actual sales 1980/81.

Source: See Table VII-2.

The standard grade is the cheapest form, currently selling (ex-Canada) on the export market for about US $5-$10/mt less than the coarse grade. Granular grade is more expensive than the coarse grade, but only relatively minor quantities are traded internationally. Since experience has shown the standard grade product to be entirely suitable for use in Bangladesh, on a cost basis there can be no justification for buying any other MP product.

The particle size of standard grade MP products varies between producers. If supplier prices are the same, the largest particle size should be purchased to minimize dust problems and facilitate handling and farmer application operations.

Sulfur

Crops suffering from deficiencies of sulfur have only recently been observed in Bangladesh, and the full extent of these deficiencies remains to be determined. Agronomists assigned to provide information for this report have estimated a sulfur need of about 18,000 tpy. Agronomic sulfur needs have been discussed in the section of this report which addresses nutrient sources and requirements.

Policy Issues and Options--Bangladesh possesses no known indigenous sulfur reserves. The only locally available sulfur source is the waste gypsum produced at the Chittagong TSP complex. The BCIC estimates that about 250,000 mt of gypsum, containing about 43,000 mt of sulfur, is presently available. This represents a 2½-year supply based on the 18,000 tpy demand estimate cited above.

The IFDC report on phosphate supply alternatives also examined alternative sulfur sources. According to this study, of the many sulfur compounds that can be used as sources of agricultural sulfur, those that appear most promising for Bangladesh are elemental sulfur, single or double superphosphate, gypsum, and ammonium sulfate.

The handling of elemental sulfur with conventional fertilizer plant equipment can lead to plant safety problems. Under some conditions, TSP diluted to less than 40% P_2O_5 with sulfur can result in explosive concentrations of sulfur in parts of the manufacturing equipment. The use of ground elemental sulfur for direct application can lead to similar safety problems in the course of sulfur grinding and handling operations. For these reasons, the processing and use of elemental sulfur as a source of agricultural sulfur in Bangladesh should be approached with caution, if not discouraged.

Supplying sulfur in the form of single or double superphosphate is tantamount to supplying sulfur in the form of TSP and gypsum. If the use of gypsum as a source of sulfur can be economically justified, the use of single and/or double superphosphate may also be economical. Conversely, if the use of gypsum cannot be economically supported, it is unlikely that the use of single or double superphosphate will be justifiable. Thus, the task of evaluating the cost effectiveness of these sulfur supply alternatives can be reduced to comparing gypsum and other sulfur-bearing materials such as ammonium sulfate.

The IFDC study estimated that ammonium sulfate might be produced from gypsum (assuming ammonia production at Chittagong and no cost for the gypsum) for US $130/mt, bagged. The BCIC estimated that gypsum can be sun dried and bagged for US $45/mt. This cost estimate appeared to be excessive and a lower figure for US $25/mt was suggested as more realistic. The average transport cost to BADC distribution centers was taken as US $12.50/mt. To supply the same total sulfur and nitrogen content, 1 mt of ammonium sulfate is equivalent to 1.5 mt of gypsum plus 0.46 mt of urea. Using these product equivalencies and transport costs resulted in delivered costs (Table VII-13) of US $142.50 and US $163.84 to supply equal quantities of nitrogen and sulfur as ammonium sulfate or a combination of gypsum and urea, respectively.

This analysis, subject to the validity of the underlying assumptions, suggests that ammonium sulfate produced from waste gypsum is a more economical source of agricultural sulfur than waste gypsum used in conjunction with urea.

Further in-depth technical and economic feasibility studies are required to more fully assess the economic merits of alternative sulfur supply systems including the possible roles of SP and SPM. A study of the possible role for sulfur-containing potash fertilizers should consider these dual purpose products in light of the agronomic needs for potash and sulfur by crops in various regions.

Fertilizer Imports

Although nitrogen imports should diminish as domestic production capability increases in the years ahead, Bangladesh clearly will need to import increasingly substantial quantities of phosphate and potash fertilizers.

Table VII-13. Comparative Costs of Supplying Equivalent Quantities of N and S

Ammonium Sulfate (AS)		AS Product Equivalents	
1 ton x $130/mt =	$130.00	Gypsum, 1.5 tons x $25/mt =	$ 37.50
Transport cost		Urea, 0.46 ton x $220/mt =	101.84
1 x $12.50 =	12.50	Transport cost 1.96 tons x $12.50/mt =	24.50
Total delivered cost	$142.50	Total delivered cost	$163.84

Source: Klem (1981).

Accordingly, import policies, particularly those which seek to lower import costs through improved product selection and procurement strategies, need further assessment.

The principal import-related constraints to fertilizer supply are (1) a chronic lack of foreign exchange which limits the nation's ability to finance needed fertilizers and forces it to rely in greater measure on donor assistance, (2) deficiencies in procurement procedures including improper planning and scheduling of imports which have, at times, caused disruptions in the orderly flow and availability of fertilizers, and (3) lack of adequate port facilities which adds to the time and cost of unloading and handling imports. Until relatively recently, fertilizers have been imported in bagged rather than the less expensive bulk form, thus exacerbating the foreign exchange constraint noted above.

Import Costs/Foreign Exchange

Nitrogen/Phosphate Policy Issues and Options--Importing DAP to replace TSP to the degree permitted by prudent agronomic practice, i.e., where a single product containing both N and P may be used effectively, deserves consideration because of DAP's favorable transport and handling costs and the generally low cost of its nitrogen component, as compared to urea and other solid nitrogenous fertilizers.

The higher total nutrient content of DAP (18-46-0), as compared to TSP (0-46-0), provides a significant saving in transport and handling costs. Since freight rates (ocean, river, overland) are set on a product weight basis, the transportation cost for DAP is about 30% lower than that for TSP on a per unit plant food basis. Viewed from another perspective, since the phosphatic contents of DAP and TSP are the same, the nitrogen component of DAP is moved throughout the delivery system at no cost. Similarly, the nitrogen component can be warehoused, handled, and bagged at no extra cost, leading to additional savings in these cost categories relative to urea.

The economic implications on nitrogen supply cost of importing DAP as a substitute for TSP are examined from three aspects.

1. The effect of importing DAP on urea import costs in a period of domestic supply deficit.
2. The costs of supplying nitrogen from imported DAP and domestically produced urea.

3. The comparative economics of importing DAP and exporting urea when exportable surpluses are available.

1. Importing DAP/Reducing Urea Imports

The cost of nitrogen in imported DAP may be determined from the average c. & f. costs of TSP (US $316.16/mt) and DAP (US $361.33/mt) imported into Bangladesh in 1980/81. The difference in product cost (US $45.17/mt) may be taken as the cost of the nitrogen (0.18 mt N) in 1 mt of DAP. Under this N cost assignment, the nitrogen in DAP is valued at US $250.94/mt N. In 1980/81, the average c. & f. value of imported urea was US $238.50/mt urea, making the cost of nitrogen in imported urea US $518.48/mt N. In this example, the cost of nitrogen in imported DAP is about one-half that of the nitrogen in imported urea.

Since 1 mt of DAP contains the same quantity of P_2O_5 as 1 mt of TSP plus the nitrogen equivalent of 0.39 mt of urea, every ton of DAP which is imported (in place of TSP) will reduce the import requirement for urea by 0.39 mt. The resultant saving from this substitution of DAP for TSP will depend on the cost of the nitrogen in DAP as compared with the cost of the 0.39 mt of imported urea which it replaces, which depends on the differences in the imported costs of DAP and TSP. Average monthly prices of DAP and TSP, f.o.b. Tampa, are graphed in Appendix Figure VII-1 for the period July 1, 1979-June 30, 1982. Differences in these prices are given in Appendix Table VII-1 and graphed in Appendix Figure VII-2. Significant fluctuations in price differentials may be noted during this period; price differences ranged from about US $75 to US $17/mt and averaged about US $45/mt.

In 1980/81, the difference between average c. & f. costs of DAP and TSP imports in Bangladesh was about US $45/mt. Coincidentally, approximately the same differential applies at the present time. The US $45/mt price differential may be taken to represent the cost of 0.39 mt urea. In 1980/81, the average c. & f. cost of imported urea was US $238.50/mt; thus, the cost of 0.39 mt of imported urea was about US $93. The difference between the cost of N in 1 mt of imported DAP and that in 0.39 mt of imported urea is US $48. In 1980/81 about 42,000 mt of DAP was imported. If urea imports had been in fact reduced by 0.39 mt for every ton of DAP imported, the saving in cost and foreign exchange would have been about US $2 million. Reducing urea imports by substituting DAP for TSP will lower fertilizer import costs and save foreign exchange if the cost of N in DAP is lower than the cost of N in imported urea;

the magnitude of the saving will be governed by the respective world market prices of DAP, TSP, and urea which, in turn, will be influenced by supply/demand factors.

Generally, the world market price of N in DAP (expressed as urea equivalent) has been lower than that of urea as indicated in Appendix Figure VII-3, which shows the monthly average international spot market prices of urea and urea equivalent in DAP for 1979-82, basis f.o.b. bulk, U.S. Gulf. On a c. & f. or farm-gate basis, the difference in cost between N in DAP and N in urea would have been greater because of DAP's aforementioned transport, handling, and storage cost advantages.

2. Comparative Costs of N in DAP and Domestic Urea

Costs of N in imported DAP and in domestically produced urea should be compared at the farm-gate. Estimates of the cost of each are available at the PDP but not the farm level. Therefore, these costs are compared on an ex-PDP warehouse basis.

As noted above, the cost of nitrogen in imported DAP depends on the difference in costs between DAP and TSP. The value of N in DAP, expressed in dollars per metric ton of urea equivalent, is given in Table VII-14 for various differentials in DAP and TSP price. The current cost differential of about US $45/mt is equivalent to a urea value of about US $115/mt. This cost applies at the PDP warehouse level since the nitrogen component of DAP moves at zero cost from port to PDP. There is no difference in the per ton cost of handling, bagging, and storing TSP and DAP except for a higher inventory carrying charge for DAP due to its higher per ton cost as compared with TSP; the difference in inventory carrying charges is ignored in this analysis.

Recently reported ex-factory costs of domestically made urea, by plant, are given in Table VII-15. The average cost of transporting urea to PDP warehouses served by Ghorasal has been estimated at about US $10/mt. The average cost of storage at the PDPs has been estimated at about US $4/mt. Accordingly, a charge of US $14/mt has been added to the ex-factory costs at all plants (Table VII-15) to derive an estimated ex-PDP warehouse cost of domestically produced urea.

A comparison of the ex-PDP warehouse costs of N in imported DAP (Table VII-14) and N in domestically produced urea (Table VII-15) indicates that at a US $45/mt price difference between DAP and TSP, the cost of N in imported DAP (expressed as urea equivalent cost) is modestly lower (about US $4/mt) than

Table VII-14. Value of Nitrogen in DAP

Cost Difference DAP Over TSP ($/mt)	Value of Nitrogen in DAP[a] ($/mt urea equivalent[b])
35	90
40	102
45	115
50	128
55	141
60	154

a. Basis 0.39 mt urea equivalent/mt DAP.
b. Delivered to the farm.

Table VII-15. Estimated PDP Delivered Cost of Domestically Produced Urea

Plant	Cost at Factory ($/mt)	Cost at PDP[a] ($/mt)
NGFF (Fenchuganj)	145.11	159
UFF (Ghorasal)	105.02	119
ZFCL (Ashuganj)	160.00	174

a. Estimated by adding $14/mt to exfactory cost for delivery from factory to PDP.

that in urea produced at Ghorasal and significantly lower than that made at the other domestic urea factories. With the anticipated improvements in plant operation noted in earlier sections, the cost of domestically made urea should be lowered, thereby possibly eliminating or lessening the cost difference between N in imported DAP and in domestic urea. This preliminary appraisal should be reevaluated using more precise actual data for the ex-PDP warehouse cost of domestically made urea.

3. Importing DAP/Exporting Urea

The comparative economics and foreign exchange implications of importing DAP and exporting urea are considered below.

The cost of and foreign exchange outlay for N in DAP will vary with the cost difference between DAP and TSP. Again, at a cost difference of US $45/mt, the foreign exchange cost of the 0.39 mt of urea equivalent in DAP is US $45.

The foreign exchange generated from the export sale of a like amount (0.39 mt) of domestically made urea can be established from the price offered against a recent BCIC selling tender for 45,000 mt of urea. The top price offered was US $160/mt of urea, making 0.39 mt worth US $62.40.

Under the conditions outlined above, importing 1 mt of DAP and exporting a like quantity of N as urea will produce a gain in foreign exchange of US $17.40. Expressed in another manner, the foreign exchange gain in exporting 1 mt of urea at US $160/mt and importing nitrogen equivalent to 1 mt of urea as DAP (2.56 mt DAP) at a cost of US $115 is US $45.

Although the foreign exchange balance between urea exports and DAP imports will vary with product selling and buying prices prevailing in the world market, in all likelihood a positive foreign exchange balance will be achieved by exporting urea and importing DAP since, from a historical perspective, the cost of nitrogen in DAP has generally been lower than the cost of urea nitrogen.

4. Other Considerations Related to DAP

The cost implications of importing DAP in place of TSP are of singular importance; nevertheless, availability and use aspects of these products also must be considered in making purchasing decisions.

For example, DAP is produced by a large number of producers over a broad spectrum of locations; this availability enhances reliability of supply, widens the choice between suppliers, and increases opportunities for obtaining more competitive purchase prices.

The physical, chemical, and handling properties of DAP are generally as good as, or in some cases better than, those of TSP. An important feature of DAP is its compatibility with urea; mixtures of TSP and urea interact to form a wet mixture. Also, the small quantity of free acid generally present in TSP causes deterioration of nonsynthetic bags and sewn bag closures.

Introduced into Bangladesh a few years ago, DAP has received limited acceptance. Some agronomists question its suitability for use in rice fertilization in Bangladesh; farmers reportedly are not aware of DAP's potential agronomic value and cannot readily distinguish it from TSP. To promote farmer acceptance and stimulate demand, BADC is planning, with funding assistance from USAID and other donors, to increase the quantity of DAP to be imported in 1982. It is to be used in a major market test program supported by a dealer and a farmer promotional program in Rajshahi Division. The promotion of DAP based on sound agronomic programs should receive policy support from the government and its implementing agencies.

5. Monoammonium Phosphate (MAP)

The transport and handling cost advantages attributed to DAP also apply to granular monoammonium phosphate (MAP). It is produced in various grades, of which 11-54-0 is probably the most important at the present time. Its possible use in the longer term in Bangladesh should be considered; however, at present the product is available from only a restricted number of suppliers, and it is thinly traded in the international market. Traditionally, before the serious erosion in fertilizer prices in 1981/82, MAP sold in the export market at prices approximately equal to DAP; currently (September 1982) the spot market price of MAP, bulk, f.o.b. U.S. Gulf Coast is about $180/mt compared to DAP at about $175/mt. The differential in price is reportedly due to its tight supply for export purposes. In the U.S. domestic market, MAP commands a premium of between $10 and $15/mt over DAP and is funneled first to that market. Although the foreign exchange implications for MAP may be favorable as compared to TSP and DAP, its utility and acceptance from an agronomic standpoint remain to be confirmed.

Potash Policy Issues and Options--The case for the continued importation of standard grade MP, rather than the more expensive coarse or granular grades of MP, as a means of conserving foreign exchange was made earlier. Currently potash, like most other fertilizers, is in surplus supply on world markets and prices are depressed far below levels of a year ago. As a conse-

quence, price differentials between various grades have seen significant erosion. These differentials will in all likelihood be restored, at least in part, to their more traditional levels as the current gap between supply and demand is narrowed through self-adjusting market actions. The price differential between standard and coarse grade MP was about US $15/mt (f.o.b. vessel, ex-Canada) in late 1981. On that basis, savings of about US $20.3 million and US $10.7 million would be realized if the cumulative potash requirements from 1981/82-1989/90 indicated by the GOB and IFDC market demand forecasts, respectively, were met by importing standard rather than coarse grade MP. The current (August 1982) differential, however, is more in the order of US $5-$10/mt.

Procurement Practices

Procurement Policy Issues and Options--The essential responsibilities of the procurement function are to (1) purchase fertilizer products of defined quantity and quality at the lowest delivered cost and (2) arrange delivery in accordance with established arrival schedules.

Many factors influence purchase price and transport cost of fertilizer imports. The more important include quantity, time, and source of purchase and shipment; form of purchase (bagged or bulk); method and conditions of payment (cash, credit, barter, donor credit or grant, etc.); and other purchase restrictions (source and vessel flag).

Most of Bangladesh fertilizer imports are purchased with donor-supplied credit or grant funds. The quantity of fertilizer that may be purchased under a fixed grant is thus usually determined by its c. & f. cost. The c. & f. cost may be minimized by (1) taking advantage of inventory cycles in supplier countries by scheduling shipments in the offpeak seasons when inventories are highest and prices lowest, (2) arranging for shipments in maximum size lots consistent with the capabilities of port receiving and handling facilities to minimize ocean freight costs, (3) scheduling vessel arrivals to conform to availability of port facilities and warehouse space to minimize demurrage charges, (4) scheduling arrivals to reduce in-country storage time and storage-related losses, (5) purchasing products in bulk form with in-country bagging, and (6) purchasing least cost fertilizer products which meet Bangladesh agricultural requirements.

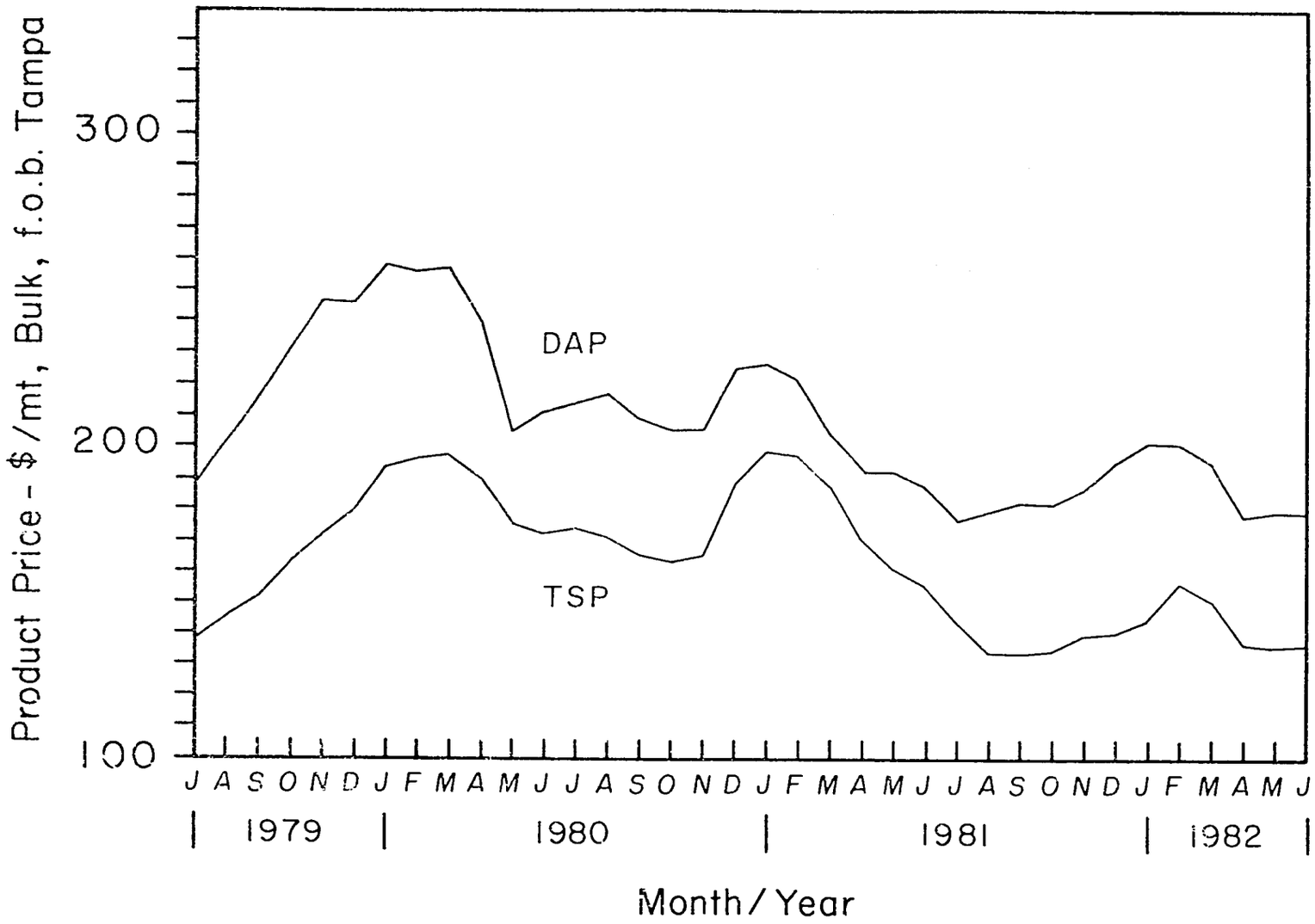
Currently, about a dozen donors provide funds to purchase imported fertilizers. The terms and conditions of these financing agreements often vary in respect to products that may be purchased, product sources, procurement approval and payment procedures, shipping restrictions, monitoring methods, etc. These variations contribute to difficulties in planning and implementing the import procurement program. Efforts should be continued to persuade donors to adopt a more uniform set of standards in their loan and grant agreements.

Procurement planning and import programming have been improved through monthly fertilizer situation reports (the BADC Monthly Fertilizer Newsletter), planning and coordination meetings, and refinement of purchasing procedures. However, the BADC procurement staff and others involved in offshore purchasing need broader knowledge of world market fertilizer sources and availability, product pricing structure, sales organizations and modes of sale, ocean freight rate structure, shipping costs and options, bag and bagging costs, port facilities, and donor supply capabilities and constraints.

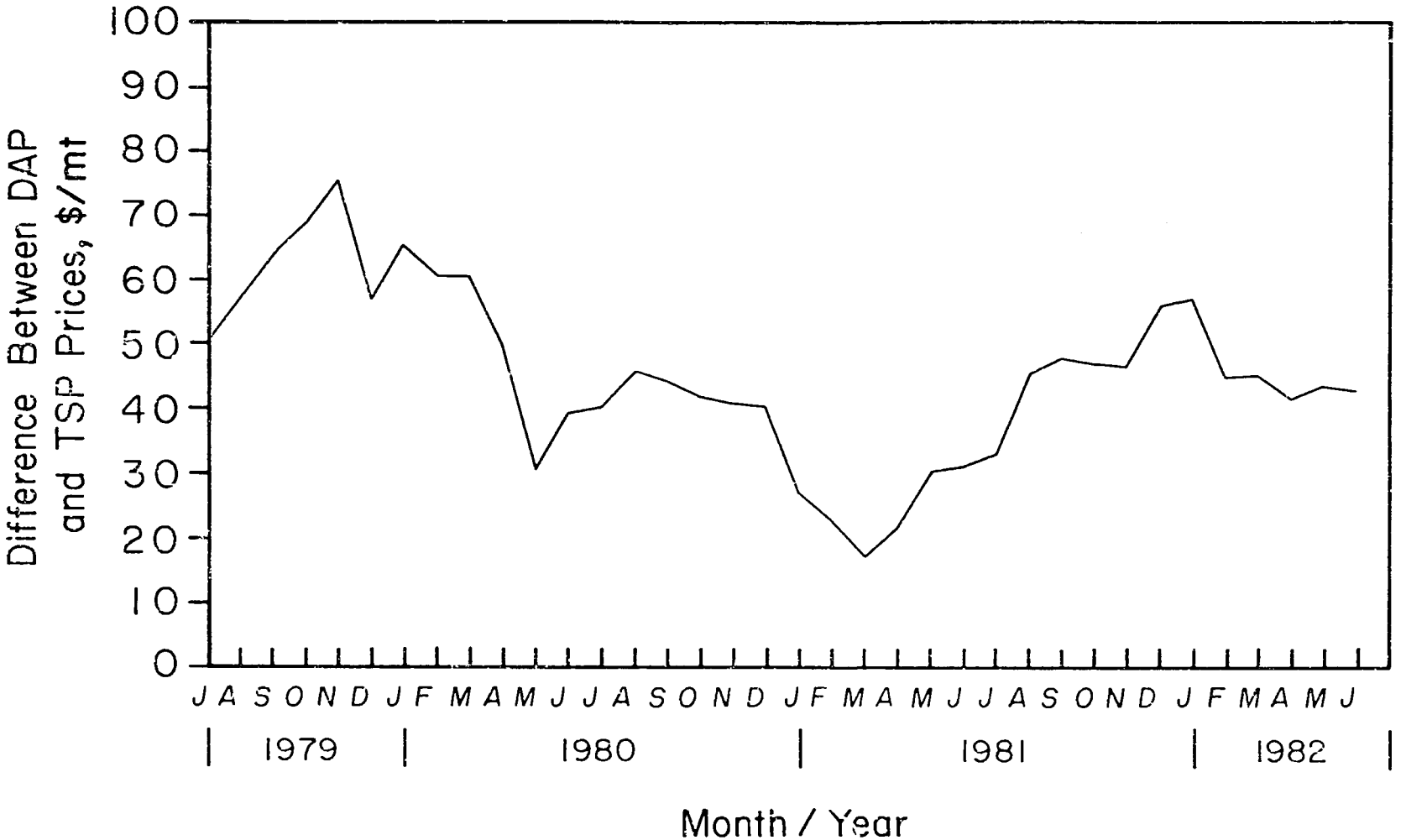
Bangladesh import procurement policies and practices are to be the subject of a 3-month IFDC consultancy scheduled for late 1982. The objectives of this consultancy are to evaluate and recommend improvements in the import procurement and programming system in order to maximize its cost efficiency. The active involvement of BADC counterparts and personnel from other government agencies in the implementation of this consultancy should enhance their knowledge base and thus contribute to the improvement of procurement policies and practices.

Appendix Table VII-1. Difference Between Prices of DAP and TSP

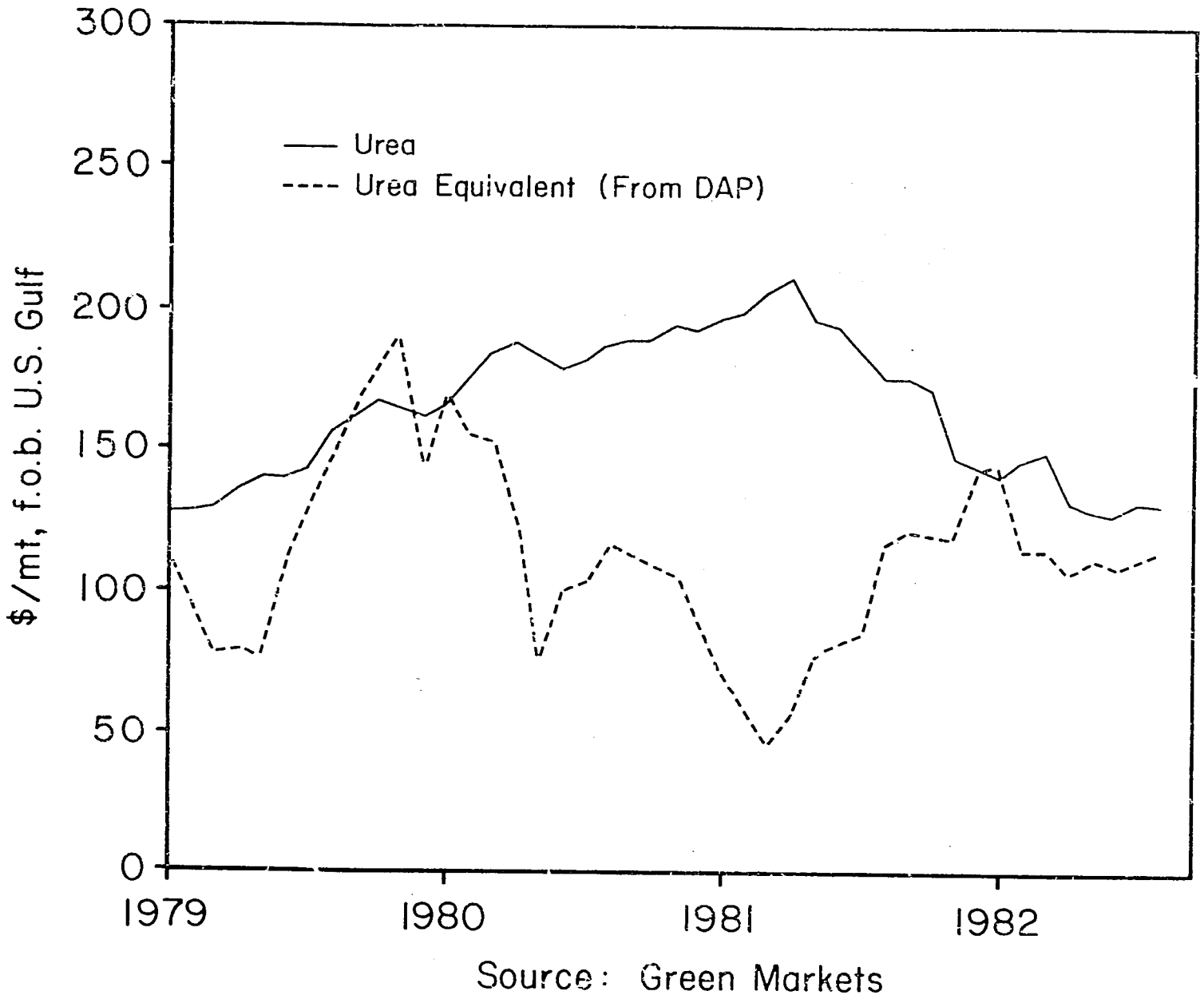
Month/Year	1979	1980	1981	1982
	($mt, f.o.b. Tampa)			
January	-	65.30	27.40	56.87
February	-	60.50	23.10	44.60
March	-	60.80	17.30	45.00
April	-	49.90	21.90	41.50
May	-	30.80	30.50	43.60
June		39.20	31.20	42.90
July	50.20	40.10	33.10	-
August	57.00	45.40	45.50	-
September	63.90	44.10	47.50	-
October	68.50	42.00	47.00	-
November	75.30	40.90	46.30	-
December	56.90	40.40	55.50	-



Appendix Figure VII-1. Monthly Average Prices of DAP and TSP.



Appendix Figure VII-2. Difference in DAP and TSP Prices, f.o.b. Tampa.



Appendix Figure VII-3. Monthly Average Prices for Urea and Urea Equivalent From DAP.

VIII. FERTILIZER MARKETING AND DISTRIBUTION

In Bangladesh, the fertilizer marketing and distribution function is entrusted to the BADC, an autonomous government-owned agricultural inputs body operating under the jurisdiction of the Ministry of Agriculture and Forests. The Supply Wing, one of five wings of BADC, is responsible for procuring, distributing, and marketing all fertilizers except small quantities of ammonium sulfate sold directly by BCIC to tea growers. Other wings carry out similar marketing and distribution functions pertaining to seeds and irrigation equipment. Planning, finance, and administrative duties are handled by separate wings.

In addition to the inadequate and unreliable supplies from domestic and import sources that continue to constrain increased fertilizer use, deficiencies in the marketing and distribution system also impede expanded fertilizer use. Lack of suitable and sufficient transportation and handling equipment and shortages of warehouse space impair BADC's ability to provide the needed fertilizers at the proper time and place. Deficiencies in the organizational structure and operation of the marketing apparatus act against expansion of fertilizer use by failing to build dealer capability and motivation to promote increased sales. Current government input/output policies and programs likewise tend to limit the ability or desire of farmers to purchase and use fertilizers in the most efficient manner. These problems are well recognized by government policymakers as evidenced by the numerous fertilizer sector improvement programs now underway and/or in developmental stages.

With the concurrence and cooperation of BADC, the USAID-funded Fertilizer Distribution Improvement Project, supported by a wide array of other activities sponsored by foreign donors, has identified problem areas and laid the foundation for formulating a comprehensive approach for improving the fertilizer marketing and distribution system. These improvement programs represent an important step in enhancing the equity and expansion of fertilizer availability and use, necessary prerequisites for achieving government plans to increase food production. Under the aegis of BADC, several programs have been launched to upgrade and improve the marketing and distribution system.

This section examines the main objectives of these programs, the progress which has been made in their implementation, and the actions that remain to be taken particularly as they apply to the formulation and conduct of overall

fertilizer supply and use policy. Marketing and distribution are treated separately, for while there is a large measure of interdependence between the two, policy issues and program development differ both in character and implementation strategy.

Policy issues relating to fertilizer procurement, a part of BADC's marketing and distribution responsibility, were covered earlier in the supply section of this report.

Fertilizer Marketing

A brief review of the evolution of the fertilizer market and marketing mechanism is useful in gaining a better perspective of the marketing problems that confront the BADC and the actions that are being taken and need to be taken to resolve them.

Market Features

For administrative purposes, fertilizer sales are divided into the following geographical units (Figure VIII-1): 4 divisions, 21 districts, 418 thanas (each about 125 mi^2 in area), and 4,420 unions (each made up of about 15 villages). There are approximately 65,000 villages throughout the country. In a country with a poorly developed transportation and communication infrastructure, serving the needs of a geographically dispersed fertilizer market poses formidable problems.

Fertilizer sales in Bangladesh have increased from about 460,000 long tons in 1975/76 to about 875,000 long tons in 1980/81 (Table VIII-1). In 1980/81, urea accounted for about 64% of total sales; TSP about 25%; and DAP and MP about 5% each. Relatively minor sales of other fertilizers made up the remainder.

Viewed regionally (Table VIII-2), fertilizer sales since 1975/76 have grown in all divisions, with the highest rates of growth in the Khulna and Rajshahi divisions. In 1979/80, the shares of national fertilizer sales were distributed among the divisions approximately as follows: Chittagong, 31%; Khulna, 28%; Dacca, 26%; and Rajshahi, 15%. On a district basis, sales in

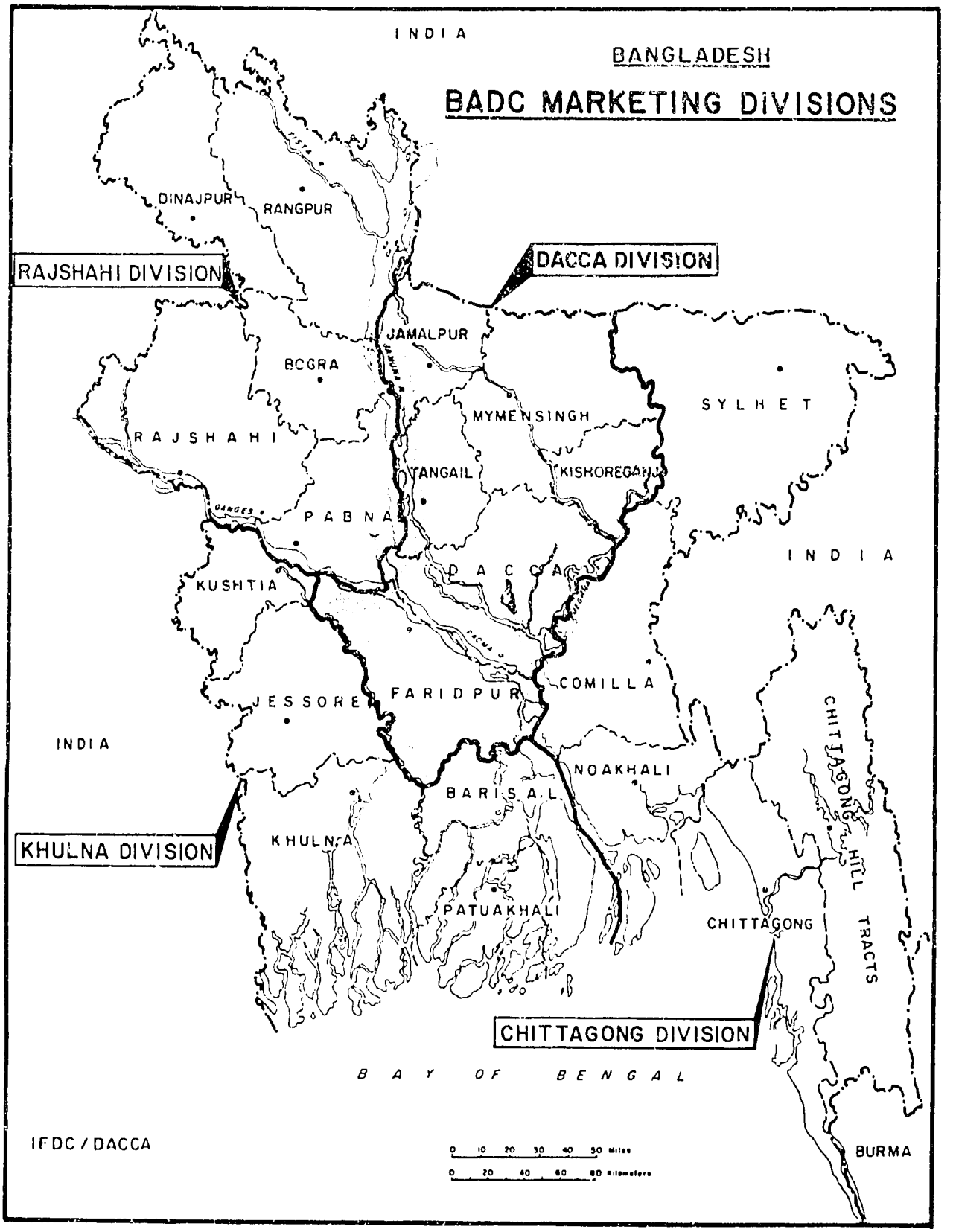


Figure VIII-1. Bangladesh BADC Marketing Divisions.

Table VIII-1. Bangladesh Fertilizer Sales, 1975/76-1980/81

	Year					
	1975/76	1976/77	1977/78	1978/79	1979/80	1980/81
	('000 Tons)					
Urea	312	353	480	469	533	561
TSP	110	126	192	174	205	215
DAP	-	-	-	38	42	41
MP	22	22	41	44	46	45
Other	14	11	6	8	11	13
TOTAL	458	512	719	733	837	875

Source: Data for 1976-80, from Hossain (1981).
Data for 1980/81, from BADC Newsletter, July 15, 1981.

Table VIII-2. Regional Fertilizer Sales Pattern, 1975/76-1979/80

Division	Year				
	1975/76	1976/77	1977/78	1978/79	1979/80
	('000 Tons)				
Dacca	130	140	193	204	216
Chittagong	160	174	227	235	261
Khulna	105	132	190	196	234
Rajshahi	63	67	109	98	131
TOTAL	458	513	719	733	842

Source: Hossain (1981).

1979/80 (Table VIII-3) were highest in the Comilla, Dacca, and Chittagong districts and represented about 15%, 9%, and 8% of total national sales, respectively. Sales in the other districts varied between 3% and 7% of the national total.

Fertilizer sales are seasonal with the volume and ratio of products sold varying from month to month (Figure VIII-2). During the 1978/79 and 1979/80 years, sales in the Aus season averaged 29% of annual sales, and sales in the Aman and Boro seasons accounted for about 32% and 39%, respectively. Boro season sales have grown in recent years as a result of expanded wheat planting.

BADC Marketing Organization

The organizational structure of BADC's Fertilizer Movement, Storage, and Sales Division, headed by the Member Director-Supply, is shown in Figure VIII-3. Headquartered in Dacca, the General Manager-Supply assisted by the managers of movement, storage, and sales, is responsible for the procurement, distribution, and sale of fertilizers throughout the country. Offices and staffs are maintained at the local fertilizer plants and ports to coordinate and expedite movements to and from these supply sources. Fertilizer distribution and sales activities are organized and executed on a divisional, district, and thana level.

Prices

Until recently fertilizers were sold to farmers at country-wide prices fixed and subsidized by the government. Historically, prices moved steadily upward reflecting increases in world market prices (Table VIII-4) and reductions in government fertilizer subsidies. In April 1982 farm-level prices were deregulated on a trial basis in Chittagong Division. Continuous monitoring of deregulated farm-level prices indicates that in heavy use, easy access areas prices have been lowered and that, while prices in high transport cost areas have increased slightly, fertilizer availability has improved. The apparent success in Chittagong suggests that consideration be given to deregulating prices in all other Divisions.

Old Marketing System

Until 1978/79, BADC's marketing system was decidedly public sector oriented. The wholesale function was confined to BADC and 97 TCCAs, which had

Table VIII-3. Fertilizer Sales by District, 1979/80

District	Sales '000 Tons	% of Total
Dacca division		
Dacca	71.7	8.5
Kishoreganj	44.6	5.3
Mymensingh	51.2	6.1
Tangail	29.3	3.5
Faridpur	20.0	2.4
Chittagong division		
Chittagong	65.7	7.8
Hill tracts	3.5	0.4
Noakhali	36.5	4.3
Comilla	127.9	15.2
Sylhet	27.3	3.2
Rajshahi division		
Rajshahi	57.2	6.8
Dinajpur	43.5	5.2
Rangpur	43.5	5.2
Bogra	58.2	6.9
Pabna	31.7	3.8
Khulna division		
Khulna	12.2	1.4
Barisal	25.6	3.0
Patuakhali	8.8	1.0
Jessore	40.6	4.8
Kushtia	43.5	5.2
TOTAL	842.5[a]	100.0

a. Does not agree with total in Table VIII-1 due to rounding.

Source: Hossain (1981).

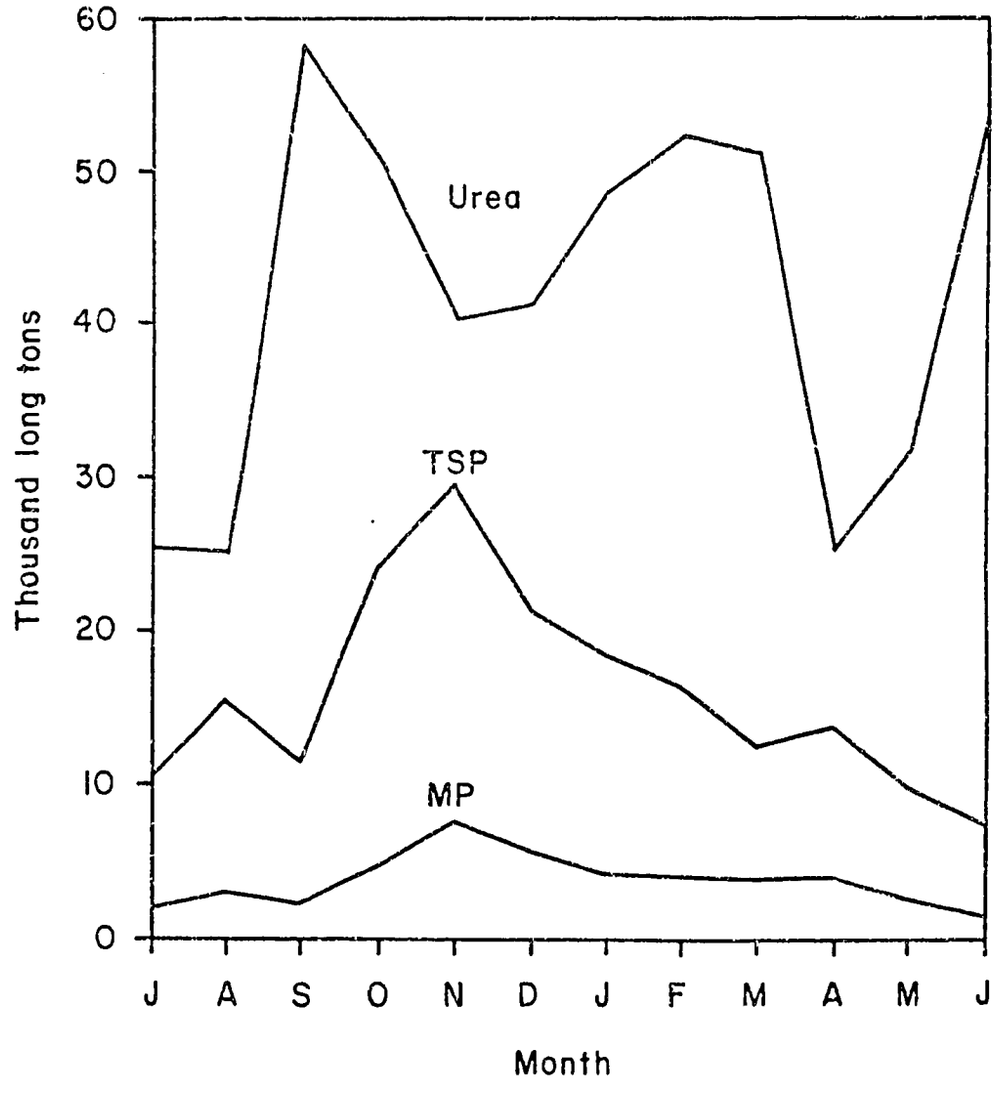


Figure VIII-2. Average Monthly Sales of Principal Fertilizers FY1978/79 and 1979/80.

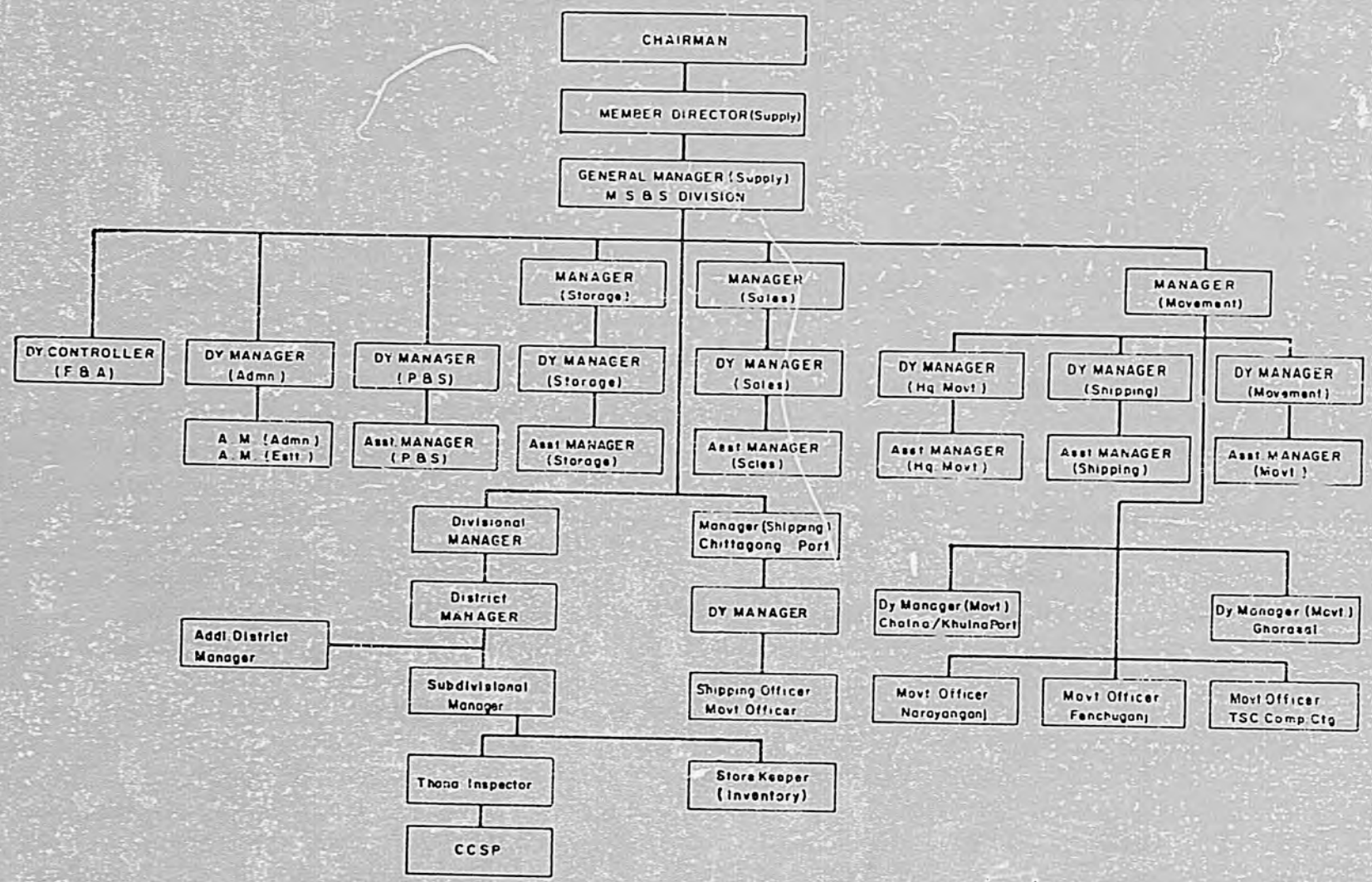


Figure VIII-3. Current Organizational Structure of BADC's Fertilizer Movement, Storage, and Sales Division.

Table VIII-4. Official Government Farm-Level Fertilizer Prices

Effective Date	Urea	TSP Powder	TSP Granular	DAP	MP
	(TK/md)				
April 1, 1974	50	40	40	-	30
July 1, 1976	60	48	48	-	40
July 1, 1978	70	55	55	-	45
Oct. 16, 1978	-	-	-	70	-
Aug. 27, 1979	90	60	70	90	55
Nov. 2, 1980	110	80	90	110	70
Dec. 7, 1981	132	95	115	132	90
July 1, 1982	148	110	140	148	110

Source: (1) Hill and Benton (1980).
(2) Hossain (1981).

been granted wholesale dealerships as a policy decision of the government to promote cooperatives. Private sector involvement was restricted to the retail dealer level. Under this so-called Old Marketing System (Figure VIII-4), fertilizer moved from the supply sources to the market areas in two stages. In the first stage, fertilizer was moved from the primary supply sources (local fertilizer plants and ports of entry) to intermediate warehouses, either directly or via transit warehouses. The second stage involved distribution from the intermediate warehouses to BADC and TCCA Thana Sales Centers. In some cases, fertilizer was transported directly from the primary supply source to the thana level warehouses. The BADC was responsible for all transport and warehousing costs, including the cost of delivery to TCCA thana warehouses, many of which were leased from BADC. The TCCAs had been awarded exclusive sales territories and in effect acted as BADC sales agents in those areas. Reportedly, the TCCAs assumed sales responsibilities in all the thanas of the Comilla district, the largest fertilizer sales district. As wholesalers they were granted a wholesaler's discount of TK 30.5/ton.

At the thana level, the BADC and the TCCAs sold fertilizers to retail dealers and TCCA member village cooperatives, Krishi Samabaya Samity (KSS), who in turn sold fertilizers to farmers. Although farmers could buy fertilizers directly from BADC thana sales centers, few did since the price was the same as that charged by the dealer and since there was added inconvenience, such as arranging transport and obtaining bank drafts for payment, associated with direct purchases. Under the OMS, about 75% of the fertilizer sold annually reached the farmer through the BADC wholesale system and 25% through the TCCA sales network.

Dealer Commissions--Under the OMS, the fertilizer dealer received a commission in the form of a discount from the official fertilizer price to cover the cost of transportation, storage and handling, and other business costs as well as his profit margin. The dealer commission was based on the distance of the dealer's registered shop from the TSCs or the TCCA warehouse from which he was registered to purchase fertilizers. Prior to 1978, a four-tier distance system was used. In 1978, a two-tier distance system was introduced: for distances up to 6 miles the commission was TK 4/md; for distances beyond 6 miles

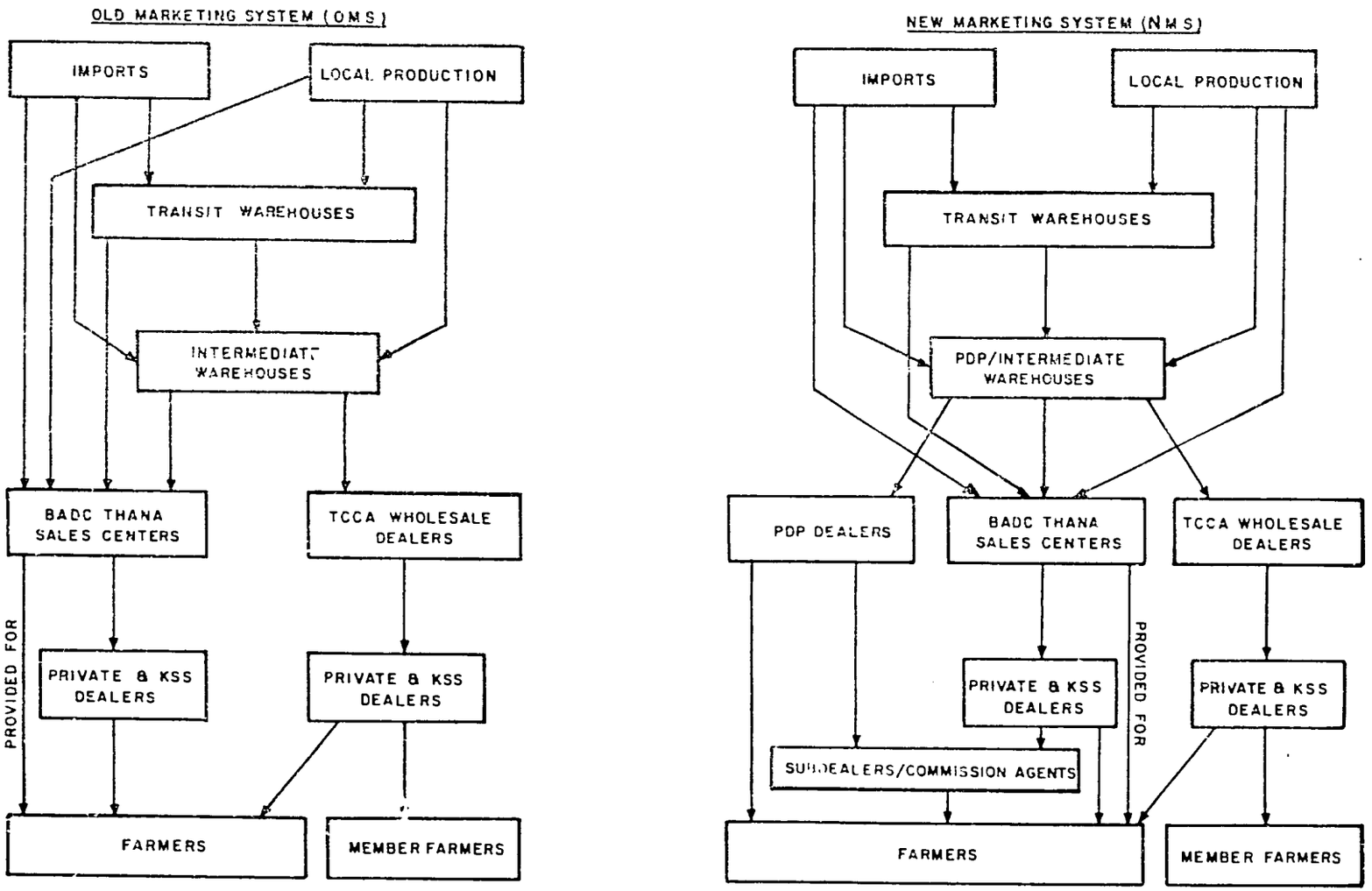


Figure VIII-4. Flow Chart, BADC Fertilizer Distribution System, 1979/80.

the commission was TK 6/md. These commissions applied to all regions of the country except the Chittagong Hill Tracts, where the difficult travel and high transportation cost required that the four-tier distance scale of commissions be retained.

Retail dealer commissions, as reported by BADC, showed significant upward movement under the OMS (Table VIII-5). According to an IFDC study, in 1977/78, the BADC paid dealers an average commission of 8.6% of BADC's gross sales revenue. This low level of commission reportedly left little profit for the dealer after allowing for his fertilizer transport, handling, and other costs.

Dealer Appointments--Under the OMS, dealers were appointed by BADC upon approval of a committee composed of BADC's thana inspector, the Ministry of Agriculture's thana extension officer, the local union council chairman, and a representative of the Deputy Commissioner at the thana level. Following committee approval, the dealer was obliged to enter into an agreement with BADC which included the following stipulations:

1. Fertilizer would be sold only in his specified union at official government prices. Sales would be made only to "bona-fide" farmers, excluding tea estates, sugar mills, and government bodies or others for resale.
2. The dealer's shop would be located within the specified union in a location accessible to farmers. The dealer would maintain normal business hours, post government prices, and distribute BADC promotional materials.
3. Fertilizer purchases would be made only from the TSC in which he was registered. Payments for purchases would be made only by a pay order drawn on a bank as stipulated by BADC.
4. Cash, stock, and sales register would be maintained and subject to inspection by BADC thana inspectors.

The BADC generally limited the number of private dealers registered in a union to 15. No such restrictions applied to the number of KSS dealers that could operate in a given union. According to BADC records, as of July 1978 there were 42,949 registered fertilizer dealers in Bangladesh. About one-half of these dealers were considered active, i.e., dealers who purchased fertilizer at least once every 3 months. Based on an estimated 22,000 active dealers in 1977/78, annual sales per active dealer averaged 32.7 tons.

Dealer Profile--The fertilizer business is a seasonal one. In the offpeak seasons fertilizer sales do not generate a sufficient volume of business

Table VIII-5. Retail Dealer Commissions Under OMS

Year	Average Commission (TK/Ton)
1973/74	45.00
1974/75	60.00
1975-78	120.00
1978/79	141.00

Source: Hill and Benton (1980).

for fertilizer dealers to maintain generally desired levels of income. Thus, for dealers to sell only fertilizers is uncommon. Most find it necessary to engage in other business activities to supplement their income. Under the OMS, the typical fertilizer retail dealer was a small general shopkeeper who sold a wide variety of household and other goods. Fertilizer selling was relegated to a part-time activity. Interviews with active OMS fertilizer dealers, made by IFDC in 1978/79, indicated that only about 38% were full-time fertilizer dealers. About 34% were part-time fertilizer dealers engaged in other commercial activities, and 28% were farmers who sold fertilizers on a part-time basis.

Fertilizer Promotion--The promotion of fertilizer use in Bangladesh rests almost solely with the DA(EM). The BADC and its fertilizer dealers play only a minor role in such activities. The promotional activities of BADC are carried out by its Thana Inspectors, who are responsible for providing dealers with information on fertilizer use through personal contacts and distribution of appropriate literature. Thana Inspectors are also reportedly responsible for promoting use through personal contacts with farmers, farm groups, influential village leaders, and schools.

The effectiveness of Thana Inspectors in carrying out those functions can be improved. At the present time they lack the time and resources to cover the extensive areas assigned to them in an effective manner. Except for leaflets on DAP properties and use to farmers, no other literature or posters are known to have been distributed. Fertilizer dealers reportedly are not sufficiently knowledgeable about the proper handling and use of fertilizers, nor are they adequately informed of the fertilizer recommendations being made by agricultural extension agents. Therefore, they are ill-prepared to provide farmers with the technical assistance needed to expand fertilizer use and efficiency.

The BADC and other government and donor agencies are cognizant of these shortcomings. As noted later, plans have been made and programs initiated to organize much-needed dealer training programs.

Credit--Credit is a powerful force in fertilizer marketing since neither fertilizer dealers nor farmers possess the monetary resources to sustain their activities on a cash basis.

In 1977/78, BADC arranged with the Bangladesh Krishi Bank to provide loans to fertilizer dealers in selected areas and under stipulated conditions.

In that year, only 271 dealers had been granted loans totaling TK 2,134,000. Similarly, participation and borrowing were low in 1978/79. A pilot credit program of FAO operates through selected cooperatives. According to an IFDC consultant survey, banks and other funding programs are disbursing relatively small portions of the funds reportedly available for fertilizer dealer loans. The bulk of the credit sought by dealers is provided by friends, relatives, traders, and professional moneylenders, often at high interest rates.

Institutional credit is available to farmers under so-called Normal Agricultural Credit Programs (NACP) of various government, cooperative, and commercial banks and a Special Agricultural Credit Program (SACP) introduced in 1977. The latter involves the Bangladesh Krishi Bank and six nationalized commercial banks. Under the SACP, TK 1 billion of agricultural credit is to be disbursed annually.

Agricultural credit disbursements under NACP and SACP are summarized in Table VIII-6. The large decline in disbursements in 1979/80 was attributed to the severe drought during the planting season and the lack of fertilizer supply.

It has been estimated that about 14% of total fertilizer purchases (based on retail value) was financed by institutional credit in 1975/76. Under the SACP, credit available for fertilizer purchases increased. In 1977/78, institutional loans for fertilizers accounted for an estimated 15% of total institutional disbursements to the agricultural sector and represented 22% of the retail value of fertilizer purchases. Estimates indicate that fertilizer purchased by institutional loans declined to about 12% of total sales in 1978/79 and suffered a further reduction to about 7% in 1979/80. Although institutional credit is available at attractive interest rates, access to these loans is overly difficult and time consuming. Farmers prefer to borrow from individuals often at considerably higher interest charges.

It can be concluded that institutional credit is not conveniently available to fertilizer dealers and farmers in sufficient quantities to provide the stimulus necessary to rapidly accelerate fertilizer demand.

Marketing Constraints--The many administrative and operational weaknesses of the OMS adversely affected its ability to provide the necessary product supply and to promote the sale of increased quantities of fertilizers required to meet projected food targets. Several of these problem areas were highlighted in the preceding paragraphs. Some of the most important are summarized below:

Table VIII-6. Agricultural Credit Disbursements

	1975/76	1976/77	1977/78	Estimated 1979/80
	(TK million)			
NACAP	513	724	932	625
SACP	-	230	682	287

Source: Economic and Social Commission for Asia and the Pacific (1980).

1. Inadequate and unreliable supplies from local fertilizer plants and imports exacerbated by (a) plant operational problems, (b) poorly programmed imports, (c) improperly coordinated lifting schedules, and (d) inefficient and costly movement and handling systems.
2. Insufficient transportation capability and limited and poorly located warehouse capacity.
3. A poorly organized and generally inefficient retail dealer network resulting from and/or encumbered by (a) burdensome and restrictive dealer appointment policies, procedures, and regulations; (b) restrictions on dealer purchase sources, sales territories, and sales prices; (c) difficulties in lifting fertilizer purchases, including frequent product outages or shortages, lack of freedom in product selection, and inordinate delays in liftings; (d) lack of technical assistance and market development capabilities due, in part, to inadequate product knowledge; (e) inadequate financial resources and profit motivation to maintain desirable stock levels and promote the increased sale of fertilizer; and (f) lack of appropriate and workable dealer and farmer credit programs to support fertilizer purchases.

New Marketing System

Recognizing the limitations of the OMS, the GOB and BADC, aided by funding under USAID's Fertilizer Distribution Project, instituted a broad range of marketing system reforms that gave rise to the so-called NMS. The NMS was introduced on a trial basis first in the Chittagong Division in December 1978; it was expanded to the Dacca and Khulna Divisions in January 1980 and finally to the Rajshahi Division in July 1980. The BADC retained IFDC to provide marketing and distribution consultancy services and to assist in implementing the NMS.

Objectives and Implementation Strategies--The central aim of the NMS is to support the expansion and equity of fertilizer use in Bangladesh by increasing the efficiency of delivering fertilizers to farmers. Most of BADC's local fertilizer distribution and marketing functions will be transferred to private dealers; the conviction is that private dealers, given appropriate incentives, will compete and respond to meeting farmer needs in a more cost-effective manner than was the case in the OMS.

The following concepts were to be embodied in the structure (Figure VIII-4) and management of the NMS:

1. The BADC would discontinue selling to dealers from its large number (418) of local TSCs. Instead, sales would be concentrated at a fewer number of so-called Primary Distribution Points, mainly the intermediate warehouses under the OMS, and the local fertilizer factories. Exceptions were made for BADC to continue to operate TSCs in remote areas and those areas not adequately served by dealers purchasing from PDPs. The reduction in dealer supply points to more manageable levels should promote increased operational efficiency and lower BADC distribution costs as dealers would assume all transportation costs beyond the PDP or factory sourcing points.
2. Dealer licensing limitations and restrictions would be lifted and liberalized. Any individual or organization, public or private, would be allowed to register as a fertilizer dealer and buy from any BADC sales point, PDP or TSC, and sell and transport fertilizer anywhere in the country except within 5 miles of the national border.
3. The BADC would increase dealer commissions so that dealer profits would be commensurate with their needs and increased fertilizer sales would be aggressively promoted. Quantity discounts would be offered to encourage wholesaling. Dealer resale prices would not be restricted as long as they did not exceed official government farm-level prices.
4. The development of institutional credit programs would be encouraged to assist fertilizer dealers and farmers in financing fertilizer purchases.

Before and during the course of implementing the NMS, various government directives were promulgated to establish, and sometimes later change, regulations and procedures governing the implementation process. Some of the most important are summarized below:

1. Dealers were required to purchase a minimum of 1 ton, in any combination of products, from a PDP warehouse and 20 md (1,645 lb) from a TSC. Uniform dealer discounts (commissions) were set at TK 230/ton for liftings from PDPs, and TK 5.0/md (136.1/ton) for liftings from TSCs, except in the Chittagong Hills Tract. Effective December 7, 1981, dealer discounts were increased to TK 280/ton from PDPs and TK 6.0/md (163.3/ton) for TSCs.
2. The Chittagong Hills Tract was withdrawn from the NMS. In this district, the minimum purchase quantity was 10 md. Dealer commissions varied with distance; over 6 miles it is TK 9.0/md and under 6 miles, TK 7.0/md. Dealers in other districts were restricted from buying from TSCs in the Chittagong Hills Tract, and dealers in that district were not permitted to sell fertilizers outside the district.

3. The maximum purchase per lifting was 20 tons; reportedly this proviso was later rescinded.
4. Dealers were required to have a delivery order from the BADC Thana Inspector before obtaining fertilizer from the storekeeper at a PDP. The Thana Inspector's delivery order was not required for purchases from a TSC.
5. A new BADC criterion for closure of TSCs allowed TSCs to remain in operation until sales volume declined to less than 50% of its level under the OMS. This action was reportedly taken to assure fertilizer availability to the farmer.

The BADC's plans for other improvements in the NMS, as expressed by the Ministry of Finance in its contacts with USAID, included (a) the establishment of a staffing pattern and organizational structure to complement the NMS; (b) development and implementation of a dealer training program; and (c) establishment of a dealer classification system to aid in the equitable allocation of fertilizers in times of fertilizer shortage.

Implementation Status and Impact--The IFDC consultants have made three evaluations of the operation of the NMS under the terms of the marketing and distribution consultancy services agreement with BADC. The comments which follow are based largely on the results of those evaluations.

Under the initial concept of the NMS, sales to dealers were to be concentrated at PDPs and factories; TSCs were to be phased out except in remote areas and where adequate farmer service was not being provided by dealers supplied from PDPs.

In implementing the NMS, the BADC determined that more PDPs were required than were available through the conversion of existing intermediate warehouses. Fourteen additional PDPs were established, of which three were subsequently closed. The BADC currently operates 79 PDPs and proposes the establishment of 17 more, bringing the total to 96. The initial NMS plan called for closing 234 TSCs and retaining 88. The original plan was changed by the government directive that TSCs could remain in operation until sales volume declined to less than 50% of the volume under the OMS. As a result of this directive and the reported reluctance of BADC field staff to close any TSCs, only 11 TSCs were closed (Table VIII-7), all in Chittagong Division. Apparently, some TSCs that had been closed in the first-year trial period of the NMS in Chittagong have since been reopened. According to IFDC's third evaluation report, on the basis of BADC's sales volume criteria, 69 TSCs should

Table VIII-7. PDP and TSC Status

Division	Number				
	Thanas	Existing and Proposed PDPs[a]	TSCs to be Originally Retained	TSCs to be Originally Closed	TSCs Closed
Chittagong	103	23	37	46	11
Dacca	112	28	22	61	-
Khulna	90	17	8	63	-
Rajshahi	113	28	21	64	-
TOTAL	418	96	88	234	11

a. Some existings TSCs to become PDPs.

Source: Moots (1982).

be closed. More recently, BADC has taken action to accelerate closure of redundant TSCs. Retaining TSCs beyond those needed to adequately serve the local farmers can only have an adverse impact on the anticipated reduction in BADC distribution costs.

Although PDP warehouses accounted for less than one-third of BADC sales locations in calendar year 1980, about 72% of BADC's sales to dealers were made from PDP warehouses (Table VIII-8). In the second half of 1980, when the NMS was fully operative, sales to dealers from PDPs represented 78% of total sales nationwide. Data available for Chittagong indicate the continued shift of dealer purchases to PDPs. In the first year of operation of the NMS in Chittagong, about 81% of dealer sales were made from PDPs; in the second year the figure had risen to 88%.

Significant increases in sales to dealers from PDP warehouses, as compared with OMS sales to dealers from all TSCs in the thanas in which the PDP warehouses are located, indicate that the NMS is fostering considerable intra-thana movement of fertilizers. Dealers are buying large quantities of fertilizer for sale in thanas other than those in which they are purchased.

The NMS has had a negative impact on the fertilizer sales activities of TCCAs, which enjoyed a favored status under the OMS. Under the NMS, TCCAs have been denied territorial exclusivity and wholesaler commissions; they must pay transportation costs, and they receive the same commissions given to private dealers. Reportedly, BADC continues to provide credit to some in the form of bank loan guarantees. Also, some TCCAs provide farmer credit through the FAO-funded credit program. Most TCCAs maintain larger warehouses and employ a greater number of more highly qualified people than do private dealers. They find it difficult to compete with private dealers whose overhead and operating costs are often considerably lower. For this reason, some TCCAs are reportedly considering withdrawing from the fertilizer business. Sufficient and equitable quantity discounts to TCCAs and qualified private wholesale dealers could provide the needed incentive for TCCAs to continue to operate and could also form the basis for establishing a system of competing public and private wholesalers.

Developing an expanded, proficient and competitive private dealer network is a cornerstone of the NMS, and IFDC's third evaluation of the NMS reports on the degree to which this network has been achieved. Based on interviews with 1,000 active fertilizer dealers and a randomized selection of

Table VIII-8. Comparison of Sales to Dealers From PDPs and TSCs, 1980

Division	Sales Volume ('000 tons)	% of Division Total
Dacca		
PDP	161.5	69.1
TSC	72.2	30.9
TOTAL	233.7	100.0
Chittagong		
PDP	217.5	87.7
TSC	30.5	12.3
TOTAL	248.0	100.0
Khulna		
PDP	78.6	59.3
TSC	53.9	40.7
TOTAL	132.5	100.0
Rajshahi[a]		
PDP	93.4	63.2
TSC	54.5	36.8
TOTAL	147.9	100.0
NATIONAL TOTAL		
PDP	551.0	72.3
TSC	211.1	27.7
TOTAL	762.1	100.0

a. NMS figures for July-December 1980 only. OMS in operation prior to that period.

Source: Moots (1982).

former dealers, the evaluation profiles the private fertilizer dealer and examines the factors that influence his desire and ability to promote the increased use of fertilizer. The major findings summarized as follows, provide a basis for recommending policy and administrative actions to be taken to expand and strengthen the dealer program.

1. Under the liberalized NMS registration procedures, fertilizer dealer registrations rose from about 44,400 to 48,500. An estimated 22,000 registrants are active dealers operating full-time shops; another 5,000-6,000 are shopless, part-time "hat-type" subdealers.
2. Nearly two-thirds of the NMS dealers are engaged in other commercial businesses, exclusive of farming. About 80% of the dealers also engage in farming. The dealer's average investment in the fertilizer business is about TK 19,600 (up from the previous year); average capital investment in his other business activities is about TK 16,700. Nearly two-thirds of multiple business dealers report that their other enterprises are more profitable than the fertilizer business.
3. About 40% of the active dealers sell to subdealers. Each sells to an average of seven subdealers, who buy from an average of two sources. About 20% of the active dealers sell about 60% or more of total sales to subdealers rather than to farmers and might be considered wholesalers. Except for the remote regions, commissions paid by dealers to subdealers ranged between 3.0 to 4.0 TK/md.
4. Under the NMS, dealers made larger individual liftings than under the OMS; NMS liftings averaged 87 md compared with less than 40 md under the OMS. About two-thirds of the dealers reported significant sales increases in FY 1981 over FY 1980. About two-thirds of dealer sales to farmers are in less than full bag quantities.

Dealer Reactions--The IFDC dealer survey indicated that without exception, dealers preferred the NMS to the OMS. However, it also indicated a decline in active dealers due to several shortcomings of the NMS. These complaints, which dealt with both the operational aspects of the system and its limited profit motivation, suggest the need for revisions in BADC dealer policy.

Dealers reported that lack of product, particularly in peak seasons, continues to hold down sales; on a national basis dealers reported that losses of sales averaged about 8%. Excessive interference on the part of Thana Inspectors in inspecting sales and stock records was cited as an operational

problem. Other complaints centered on the inordinate time required to lift fertilizer purchases; three to five days was not unusual. These delays were ascribed to the BADC regulation requiring dealers to obtain a delivery order from a PDP Thana Inspector, rather than directly from the storekeeper, before loading his purchase. Because a PDP usually consists of multiple warehouse locations, the Thana Inspector is often not available when needed at a given warehouse. Another complaint was that dealers were not permitted to lift products of their choice but had to accede to BADC's choice of a product mix.

The profit motivation concerns dealt mainly with lack of capital, low profit margins, and increases in short-weight bags. About two-thirds of the dealers surveyed indicated that they lacked adequate working capital to finance inventory and construct storage facilities. Dealer working capital requirements have increased significantly with increases in fertilizer prices, the latest in December 1981. Dealer commissions were also increased in December 1981; however, in the recent past, increases in dealer commissions have generally lagged behind price increases. Under the NMS, dealer commissions as percentages of sales prices have declined markedly (Table VIII-9). According to the IFDC dealer survey, on a national basis dealer margins, after deducting transport costs, averaged 4.59 TK/md and 1.15 TK/md for fertilizers purchased at PDPs and TSCs, respectively. While capital requirements have risen, access to institutional credit has posed a major problem to dealers. About 40% of the dealers polled stated that they have no institutional source of credit. The large and increasing number of short-weight bags contributes to lowering dealer margins and profitability. Based on loose (less than full bag) sales, shortages in bag weight have increased from between 0.5 to 1 seer/md to 1.5 to 2 seers/md. Losses resulting from receiving less than full measure of purchased quantities are important because over 60% of retail sales are in the loose form. Farmers buying full bags are also being shortchanged when bags are short weighed. According to an IFDC survey of 250 bags of domestic and imported fertilizer, over 50% were underweight by more than the 0.1 kg weight tolerance; the shortages were greatest with domestic products.

Farmer Reactions--As part of the Third Evaluation of the NMS, IFDC consultants interviewed a randomized selection of farmers to ascertain the nature of the factors that constrain increased farm-level use of fertilizer. These responses provide the basis for evaluating the effectiveness of the NMS in serving farmer needs and identifying those areas that need improvement through policy and administrative actions.

Table VIII-9. Dealer's Sales Commission as Percentage of Fertilizer Sales Price

Dealer's Commission as % of Sales Price	Urea	Granular TSP	Powdered TSP	DAP	MP
December 1, 1979					
at PDP	12.0	15.3	15.3	12.0	18.7
at TSC	7.1	9.1	9.1	7.1	11.1
November 2, 1980					
at PDP	7.6	9.3	10.5	7.6	12.0
at TSC	4.5	5.5	6.2	4.5	7.1
December 7, 1981					
at PDP	7.8	9.0	10.8	7.8	11.4
at TSC	4.6	5.2	6.3	4.6	6.7

Source: Moots (1982).

The number of fertilizer retail shops has increased marginally under the NMS, but the number of BADC warehouses remains virtually unchanged from the days of the OMS. There has been no significant change in the farmer's access to fertilizers under the NMS. Lack of product at specific locations, particularly during seasons of peak demand, persists as an important constraint to demand, despite adequate in-country stocks in recent years. Depending on location, between 30% and 50% of the farmers interviewed indicated that they could not buy the fertilizers that they desired. Lack of availability reportedly led to reductions in fertilizer usage ranging from 6 to 9 seers/acre.

Most of the farmers stated that the high price restricted their use of fertilizers. At the time of the IFDC survey, fertilizer prices had increased by about 55% since December 1978, whereas farm crop prices had reportedly risen by about 36%. According to the IFDC report, the fertilizer prices paid by farmers were slightly higher than the posted government retail price (Table VIII-10). In the remote areas, farmer prices often exceeded the official price by 5 to 7 TK/md, but in the high use, easy access areas, farmer prices often were 3 to 4 TK/md lower than the government price and thus reflected lower transportation cost and dealer competition. Fertilizer dealers claim that they lose about 2 kg/50-kg bag when they sell to farmers in loose quantities. They in turn increase the prices charged farmers to make up for this loss.

Lack of farmer credit was cited as another major deterrent to fertilizer use. Sources and use of credit in fertilizer purchasing were discussed earlier. According to the IFDC farmer survey, about 66% of the farmers polled stated that lack of credit restricted their use of fertilizer.

The farmers' need for more technical assistance on the proper use of fertilizer is clearly manifested from the results of the IFDC survey. Less than 10% of the farmers and dealers queried said that they had been visited by extension services personnel. Although farmers need such services, the BADC and its dealers currently offer little in the way of farmer assistance. The expansion and strengthening of the dealer role in technology transfer is viewed as essential to supplementing the extension services offered by other government bodies.

In order for the BADC to supply such farmer assistance services through its dealers, it must first make organization and staffing changes. Training programs are needed so that dealers can provide assistance in an effective and sustained manner.

Table VIII-10. Official Fertilizer Prices and Prices Paid by Farmers, May-June 1981

	Prices	
	Paid by Farmers	Official Price
	(TK/md)	
Urea	111.77	110
Granular TSP	94.97	90
Powdered TSP	83.29	80
DAP	112.22	110
MP	72.71	70

Source: Moots (1982).

Marketing Policy Issues and Options

Marketing system problems continue to impede fertilizer use in Bangladesh. Although a notable degree of improvement has been achieved under the innovative reforms of the NMS, delays and/or deficiencies in the implementation process have limited the realization of the full potential benefits of the system. It must be remembered, however, that the NMS is still in the formative stages; there has not been sufficient time to make several changes needed to improve and strengthen the system. The following sections summarize the most important marketing-related constraints to increased fertilizer use as well as proposals for their relaxation or removal.

Planning--The farmers' full demand for fertilizers has not been met despite the availability of adequate stocks on a countrywide basis. Although distribution system deficiencies (as discussed later in this report) may be largely responsible for this predicament, improvements in the procurement and marketing processes should increase the efficiency of the distribution system and make the desired fertilizers available to farmers in a more timely, convenient, and cost-effective manner. It is suggested that greater emphasis be placed on developing BADC annual marketing plans based on a careful assessment of market needs by region, by product, and by time period. To improve the reliability of market forecasts, changes may be required in market data development and evaluation techniques. This, in turn, suggests the need for adjusting the BADC organizational structure to provide for a stronger market research and planning group to develop and monitor the implementation of both short- and intermediate-term marketing and distribution plans. In formulating and executing a cost-effective annual marketing/distribution plan, market demand must be reconciled with product sourcing (domestic and import); allowance should be made for movement and storage capabilities. This action mandates a close coordination of the BADC purchasing, sales, movement, and storage functions during the plan preparation and execution stages. Effective implementation of the marketing plan will call for improvements in import programming, plant lifting procedures, movement scheduling, and management information systems for the timely collection, maintenance and dissemination of production and marketing and distribution data. The BADC Monthly Fertilizer Newsletter is a very useful planning tool.

As part of the consultancy services agreement with BADC, IFDC is assisting BADC in the formulation, implementation, and monitoring of annual marketing plans.

Operational Efficiency--Under the NMS, increased operational efficiency and a subsequent cost saving were to be realized by closing down most of its vast number of TSCs and consolidating BADC's sales in fewer warehouses (PDPs), efficiently located and operated. Changes in NMS implementation strategy, namely the directive stipulating that TSCs may remain open until sales volume drops to below 50% of its OMS value and the reluctance of BADC field staff to close TSCs even after this criteria has been met, initially led to the closing of only 11 TSCs as compared with over 200 TSCs originally slated for closure under the NMS. The expected efficiencies in operation and cost benefits of the NMS cannot be gained by operating what may be considered a hybrid system that retains many of the inefficiencies and higher costs of the OMS. More recently, actions have reportedly been taken to close those TSCs that qualify for closure under the "50% loss of sales" directive and those otherwise considered redundant. As suggested by the IFDC marketing consultant, some of the TSCs designated for closure might be rented to larger volume private dealers seeking additional storage and sales facilities.

The operating efficiency of PDP sales offices and dealer convenience and cost reductions would be enhanced by rescinding the rule that requires approval by the Thana Inspector prior to dealer lifting. Dealer procedures for buying from the PDPs should be made the same as those that apply to purchases made at the TSCs, where orders are processed directly by the storekeeper.

Consideration should be given to restoring the 3-ton minimum lifting quantity at the PDPs as a means of reducing order processing and handling time, and improving operational cost efficiency.

Market Expansion--To promote increased and more efficient use of fertilizer by farmers will require that BADC expand and intensify its market development functions by (a) organizing and strengthening its internal marketing capabilities and programs, (b) developing and motivating its dealer organization to more effectively promote the sale of its products, and (c) establishing programs to support the activities of other national research and extension agencies charged with responsibilities for providing farmer assistance. The BADC is well aware of the necessity to participate more fully and effectively in such market development activities and has planned and/or instituted such programs as part of its implementation strategy for the NMS.

Under the NMS, the responsibility for promoting increased sales of fertilizers to farmers is shifted from BADC to independent fertilizer dealers. Therefore, it is in BADC's best interest to organize the dealer network and to provide these dealers with the means and inducements necessary to perform their assigned sales and market development functions in the most effective manner. The results of IFDC dealer surveys make it evident that the business management, fertilizer technology, and selling and market development skills of dealers are in need of further enhancement. The BADC dealer development and training program, which is being implemented with IFDC assistance under the USAID funding, is designed to address these dealer knowledge constraints. The dealer training program is to be conducted by BADC personnel; the first step will be the training of a cadre of qualified BADC trainers.

The farmer's limited knowledge of correct fertilizer practices is an important constraint to increased fertilizer use. The fertilizer dealer, by virtue of his frequent contact with farmers and their common interest, is in a unique position to inform the farmer and influence his purchases. An important objective of the BADC dealer training program is to upgrade the fertilizer-use knowledge of dealers in order that they might be better able to provide needed technical assistance to farmers. Carried out in conjunction with the DA(EM), this aspect of dealer training should qualify dealers to supplement the extension services offered by the MAF.

Without readily available credit, farmers have been unable to purchase fertilizers and other agricultural inputs, and dealers have been unable to purchase and maintain adequate fertilizer stocks. The BADC, with the assistance of IFDC consultants, has developed several alternate in-kind schemes that might enable the BADC to provide eligible dealers with short-term credit needed to finance fertilizer inventories and to encourage dealers to extend short-term credit to farmers. One of these schemes is slated for implementation on a trial basis in the Dacca Division in the fall of 1982. If successful it will be extended to other divisions.

Financial motivation is the key factor in encouraging greater dealer involvement in market development efforts. Dealer profit margins should be sufficiently appealing to attract capable and financially responsible individuals to the business. Dealers questioned in Bangladesh indicated that low margins inhibit their selling of fertilizer and that their limited capital and energies are put to more profitable use in other enterprises. There

is a strong need to reexamine the scale and structure of dealer commissions to ensure that dealers are adequately compensated for their investments in capital and time. Volume and seasonal discounts based on cost savings to BADC should be and are being considered. Additionally, dealer awards might be instituted to recognize and reward superior performance against established sales and farmer service criteria.

The classification of dealers is necessary to establish and promote a class of fertilizer wholesalers. These wholesalers would assume an increasing share of the cost of handling and selling fertilizers and would be rewarded accordingly through adequate volume discounts and the other incentives noted above. The BADC, assisted by IFDC marketing consultants, has formulated eligibility criteria for granting wholesaler status to dealers and has delineated dealer responsibilities and perquisites. The expeditious establishment of a class of wholesale dealers and dealer associations is endorsed. A dealer classification system will prove useful in carrying out fertilizer allocation programs in times of national supply shortages.

The negative impact of the NMS on the preferred wholesaler status of the TCCAs under the OMS was noted earlier, as was the possibility of their withdrawal from the fertilizer market. However, the continued participation of TCCAs in fertilizer marketing should be encouraged because the competition which they provide to private dealers is likely to increase fertilizer availability and product choice to farmers. The establishment of wholesale dealerships should enable TCCAs to compete with private dealers on a cost basis. Criteria for wholesale dealer status should be applied uniformly to TCCAs and private dealers.

Organization--Adjustments are needed in the organizational structure and staff of BADC's Supply Wing to support the NMS marketing strategy of expanding and strengthening the role of the fertilizer dealer.

The BADC dealer development and training program, now in its formative stages, will provide training to dealers to upgrade their knowledge of fertilizer products, enhance their business management acumen, and improve their professional selling and market development capabilities. Fertilizer promotion, credit, and farmer assistance programs are important elements of this dealer training effort to be developed and conducted by BADC with technical assistance from IFDC marketing consultants. Timely and regular visits by BADC sales personnel are to be made an

integral part of the BADC program aimed at assisting dealers in sales program development and execution, providing dealer services, and building much needed rapport between BADC and its dealers.

To provide the necessary dealer training and sales service programs will require the addition of a training function to the BADC marketing organization. The IFDC consultant's recommendation to create the position of Manager (Training) with responsibilities for developing and implementing dealer training programs has been implemented and staff appointments have been made. A restructuring of the current sales function into a more broadly based marketing function is suggested to support the expanded dealer sales program at the district and thana levels. The BADC's potential participation in administrating dealer credit programs gives rise to a need for a credit department with responsibilities for establishing, administering, and monitoring credit policies and programs. The IFDC consultant has suggested creation of the post of Manager (Credit) and a support staff at the district level to implement the credit program. The credit function and the staffing needs are under study.

These structural changes in the organization of the Supply Wing should improve BADC's marketing efficiency in promoting sales to and through dealers. The outlook is for significant increases in fertilizer sales in the years immediately ahead. It is therefore prudent to examine the capability of the overall marketing organization to handle the increases in sales volume foreseen for the future. At BADC's request, IFDC consultants are working to determine ways of improving marketing efficiency and maximizing performance and cost effectiveness in the immediate future.

Fertilizer Control Standards--Most large fertilizer-consuming countries have developed standards and enforcement procedures for regulating the chemical analyses and weights of fertilizers to protect consumers against the fraudulent practices of unscrupulous and/or inept fertilizer manufacturers and dealers. As fertilizer sales expand, the development and application of such consumer protection measures will become increasingly important in Bangladesh.

Fertilizer analysis standards and methods of sampling and testing will be needed. Enforcement legislation will have to be enacted and regulatory agencies and implemention procedures established. Information on the standards and regulatory procedures used in other countries is readily available and can serve as the basis for developing fertilizer controls appropriate for use in Bangladesh.

To encourage production of up-to-grade fertilizer, quality control procedures at manufacturing plants should be improved. Bagging scales and weighing operations should be examined periodically to assure accuracy of bag weights within accepted weighing tolerances. To discourage product adulteration or short weighing at the dealer level, inspection services will have to be established within the context of existing enforcement regulations.

Fertilizer Distribution

Overall Situation

Earlier sections of this report have referred to local shortages of supply arising from inadequacies and unreliability of supplies from domestic and import sources and also from deficiencies and constraints in the inland transportation network for fertilizer. Even though these shortages are evidence of real problems that require serious attention, it should be noted that in this past year almost 1 million tons of fertilizer was distributed throughout Bangladesh, and in the majority of cases supplies were available at district and PDP level. In many cases the problems of nonavailability are organizational rather than infrastructural in nature, and many of these difficulties are being addressed by BADC with the assistance of consultants in developing the NMS.

Distribution System Studies

Over at least the past decade, studies on the Bangladesh fertilizer system and transportation systems have proceeded on a continuous basis. There have been several major studies, and all aspects of fertilizer import, handling, transportation, and storage affecting BADC interests have been investigated.

Key studies include the Economist Intelligence Unit (EIU) Report (1978), a comprehensive examination of the total distribution system and the National Fertilizer Storage Plan (NFSP),[1] which includes a very detailed study of movement of fertilizer from all sources to all PDPs by all modes of transport.

1. See International Engineering Company, Inc. (1981).

Other studies have been undertaken for BADC and other government agencies and for transportation and port authorities by private and public agencies and consultants, including USAID, the World Bank, and IFDC.

The transportation problems, therefore, have been not with the availability of studies, but with interpretation and implementation of the many proposals and recommendations. For this reason, in connection with the present policy study, a review was undertaken of existing studies of the overall system for supply, distribution, and storage of fertilizers in Bangladesh (Clayton, 1981). This review was intended to assist BADC in interpreting the studies and developing the recommended systems. This review is the principal basis for recommendations in this section.

As indicated above, although there are difficulties and organizational weaknesses, existing systems are coping with present levels of fertilizer supply and distribution. With improvements projected under USAID, the World Bank, and other donor agency proposals, transportation and storage facilities should meet requirements through this decade.

One of the more important current projects is the World Bank Fertilizer Transport Improvement Project, which concentrates on the key infrastructural constraints and limitations affecting fertilizer transportation and handling throughout Bangladesh. Principal components include port improvements; facilities for import of fertilizer in bulk; development of key transit/storage points (Shiromoni) and distribution centers (Bhagabari) for fertilizer; improvements to the railway system, including the key rail ferry at Bahadurabad Ghat; storage; and technical support for improvement of management and inventory control systems.

Distribution System Concept

In order to make the most efficient use of limited transportation and handling facilities, present and future, it is recommended that fertilizer be moved through the system on a completely regular basis, as far as possible toward the point of final consumption. In the case of BADC, this is the PDP level. For the concept to be effective, it is essential that a reliable forecast of demand down to the PDP level be available. The system is then conceived as a stock-building operation to PDP level, with movements planned in

advance and all operations controlled and monitored centrally by BADC. Creation of a central control unit in BADC Headquarters to undertake this function is recommended.

Transport facilities should all be planned on the basis of regular movement throughout the year, with necessary adjustments during the monsoon period. Output from the production units is already on as regular a basis as can be achieved, and imports should also be phased on as regular a basis as possible. Storage at Chittagong and Chalna ports and at the production units is then viewed as buffer storage for transportation purposes only and is intended to guarantee regular dispatches by the planned transport means. All storage for marketing purposes is at the PDP level. In addition to achieving the most effective and cost-efficient use of transport resources, regularity of movement also allows considerable improvement in handling efficiency throughout the system.

Bulk Imports

Input from the production units has been discussed in an earlier section, as well as improvements in import procurement arrangements. Major benefits to Bangladesh are possible by converting all imports from bagged to bulk as quickly as possible.

Savings in foreign exchange and overall cost arise as a result of much lower labor handling and loading costs for bulk in the developed country and from the lower bagging cost in the developing country. Considerable local employment is generated, and indigenous packaging materials can be used.

A number of bulk shipments have now been handled by BADC, and these efforts should be continued. A study tour for senior BADC managers was made around Indian ports and factories in early 1982 and the tour report contains a number of recommendations on organizational and handling aspects which should be implemented (BADC/USAID/IFDC, 1982). A recent calculation of savings by importing in bulk at 1982/83 levels (275,000 mt) shows a saving of US $9 million in foreign exchange and US $4 million overall.

Recommendations for handling of bulk imports at the anchorage and in the port at Chittagong and at the river offloading berths at Chalna were made in the distribution review and in the tour report. Suitable methods, including bagging on board, bagging alongside, and bagging inside and outside the port area, are available for the various locations.

Rail Movement

The state-owned rail system is mainly single track and of two gauges. The broad gauge system serves the western side of the country. The narrow gauge system serves mainly the eastern side, with a vital rail ferry link across the Jamuna river from Bahadurabad Ghat to serve the agriculturally important area of "North Bengal." The narrow gauge system crosses the broad gauge system at two places in North Bengal.

The system is generally in poor condition in all respects and the potential for movement of goods, including fertilizer, is not being achieved. With the investments and improvements envisaged under the World Bank Project, there is little doubt that future rail-carrying capacities will be more than adequate to meet the growing requirements for movement of fertilizer, particularly with the introduction of unit trains. It is important that BADC maintain contact with the railway authorities, the World Bank, BCIC, IFDC, and others involved in the planning and introduction of unit train services for fertilizers. Attention must be paid to loading requirements at factories and ports, offloading, and storage facilities and operation of the Bahadurabad Ghat ferry--all vital components of the total scheme.

Road Movement

Road transport has developed into a major mode of transportation since Independence, although most of the highway network consists of fairly narrow roads, with the system interrupted by numerous ferry crossings and restricted bridges. There are enough trucks available for movement of fertilizer, and problems of transport procurement appear to be connected with contract arrangements and payment levels rather than with truck availability. The BADC should continue with present efforts toward improvement in this area; however, it is not recommended that BADC acquire their own transport.

Waterway Movement

Bangladesh is as well provided with waterways as any country in the world. Barge transport is then of major importance for movement of all products, including fertilizer. Equipment is generally in a poor state of repair, compounded by problems in management and deficiencies in communications. Separate studies are in general agreement, however, that existing capacity, with

some improvements from various programs underway, is adequate to meet all present and forecast requirements for movement of major commodities, including fertilizers.

As with road movements, BADC is currently addressing problems of contracting and operating procedures and these efforts should continue.

Warehousing

Problems of inadequate storage facilities in the consuming areas were recognized at an early stage, and considerable assistance to BADC has been provided by a range of donors--in particular USAID--to supplement BADC's own construction programs.

The NFSP identified a need for 657,500 tons of storage capacities at port, transit, and PDP locations to meet projected demand at 1985 levels. This includes 495,000 tons of PDP capacity at 88 locations. These figures do not include storage capacities for bulk and bagged fertilizer at the production units, which amount to some 140,000 tons in total.

These figures are shown in Tables VIII-11 and VIII-12.

The capacities calculated under the NFSP are based on a range of safety stocks that take into account the known deficiencies in infrastructural and management systems. With improvements in these areas, it apppears likely that the capacity projected for 1985 should suffice for some years beyond that date. This is particularly the case if the emphasis is transferred to dealer and village level storage.

As discussed earlier, it is desirable for both distribution and marketing purposes to maintain stocks in the market region, located as far forward as possible toward the point of final consumption. With the basic PDP network established, emphasis should now be placed on providing storage at dealer and village level in the 20- to 100-ton size range. Under the NMS, the transfer of TSCs from BADC to dealers is being encouraged and many of these are of 200-ton or 400-ton capacity. The dealer/retailer/cooperative/village storage network is thus seen as being mainly in the 20- to 400-ton range. Many of these may serve for storage of other products, particularly herbicides, pesticides, seed, and agricultural produce.

Table VIII-11. Nominal Storage Capacity at Fertilizer Plants

	Tons	No. Days Storage at Projected Operating Rate
Fenchuganj		
Bulk urea	10,000	35
Bagged urea	2,500	9
Ghorasal		
Bulk urea	50,000	60
Bagged urea	10,000	12
Ashuganj		
Bulk urea	40,000	28
Bagged urea	8,000	6
Chittagong		
Bulk TSP	15,000	53
Bagged TSP	4,000	14
TOTAL	139,500	

Table VIII-12: Warehousing Program to Meet NFSP 1985 Storage Requirement

	Tons
Existing capacity at NFSP sites, including USAID Phase 1	127,800
Remaining BADC Hard Core Program	14,000
USAID Phase II Program	162,000
USAID Phase III Program	120,000
Other donors: World Bank, ADB, IFAD, German and Dutch financing	104,000
Other construction to be funded	129,300
TOTAL	657,500

Organization and Control

The concept of the supply and distribution system developed in earlier sections envisages regular movement through the system throughout the year. This requires effective forward planning together with effective operation once established. The BADC must be fully committed to and involved in the planning of this system and its subsequent operation. It is recommended that a central control unit be established, most logically located in BADC Headquarters.

The basic function of the unit is to control and monitor all operations involving supply, transportation, storage, and offtake of fertilizers. An important function of the unit is to act as a central data bank, providing essential information to many divisions in all wings of BADC. The data function is coordinated with a transportation control section; it will also provide information for procurement, distribution, marketing, financial, stock planning, and auditing purposes.

The transportation control section would be fully coordinated with the control unit for operation of the unit train system proposed in the World Bank Project; in fact, it would logically undertake this function.

The central control unit would also cooperate with the market planning group discussed earlier in this section under "Marketing Policy Issues."

Requirements of Physical Distribution Facilities

Although major capital expenditures are allocated for production purposes, the need for significant matching expenditure on distribution and handling facilities is not always recognized. This is not altogether the case in Bangladesh, where the need for considerable major expenditures is recognized, as for example in the NFSP and warehousing program and the World Bank Fertilizer Improvement Project.

Throughout the whole system, however, from production or import to the PDP storage level, there is a continuing need for major capital investment. It is recommended that BADC maintain a high awareness of requirements and developments in providing distribution facilities. An indication of these requirements is given in Appendix Table VIII-1.

Future Development of the Fertilizer Supply System

Integration of Production and Marketing/Distribution Functions

In Bangladesh domestic fertilizer production responsibilities are shared by BCIC and ZFCL. The operation of the marketing and distribution function is vested in BADC.

The main policy issue facing a fertilizer sector operating under such a division of responsibilities and authorities is the coordination of both functions to effect a least cost overall supply system. Effective coordination of the production and marketing functions can be achieved through an integrated production-marketing-distribution system wherein shipments to field warehouses are made on a regular planned schedule to match highest sustainable production levels. In essence, distribution becomes an extension of the production function. Such an integrated production-marketing system would combine the benefits of high plant capacity utilization rates with maximum efficiency of use of transport and storage facilities.

To facilitate the establishment of a more cost-effective integrated production-distribution system, it is recommended that the GOB conduct an in-depth study of the feasibility of consolidating the fertilizer production and marketing functions under one national fertilizer organization with overall responsibility for the development and operation of all phases of the Bangladesh fertilizer sector. The fertilizer industry consolidation study might be undertaken under the sponsorship of a national fertilizer secretariat including representatives of the PC, the MAF, the Ministry of Industry, BADC, BCIC, and the Ministry of Finance.

Private Control of the Fertilizer Supply System

Short-range policy should deal with the many aspects of implementing the NMS, but consideration should also be given to the longer term development of the marketing and distribution system. The issue remains that of further improving the performance and cost effectiveness of the fertilizer system as it strives to serve an expanding market.

One approach to increasing efficiency and decreasing cost of the marketing and distribution function is based on the belief that farmer interests

are better served by competition in the market place. The NMS represents an application of the thesis that private dealers, vying for the farmers' patronage, can serve farmer needs in a more efficient and less costly manner than a public-sector organization engaged in a similar endeavor. A logical extension of this concept would be to transfer to private hands production and/or the entire procurement, marketing, and distribution system now assigned to BADC. Such actions should be undertaken only after a comprehensive study of the economic, social, and political benefits and impacts of such a change of responsibilities. Important questions to be answered relate to the motivation and capability of the private sector to provide the human, technical, and financial resources necessary to carry out the marketing and distribution and/or production functions more effectively than the public sector can. The Government's role in interacting with a private sector-operated fertilizer supply system requires serious study that should include the future role of cooperatives.

Appendix Table VIII-1. Summary of Requirements: Equipment and Facilities for Import, Handling, and Distribution of Fertilizer

Based on the distribution system envisaged and the assumptions and proposals in "The Review of the Fertilizer Distribution and Handling System in Bangladesh" IFDC, July 1981, the following list outlines the main physical facilities required to handle total fertilizer requirements at the 1984/85 level. Where conveyor systems or "mechanized" loading is specified, this assumes manual stacking in the rail wagon, barge, or truck, but movement by conveyor systems up to that point.

1. Ashuganj Urea Plant
   a. Covered, mechanical, rail loading facilities capable of loading one 60-wagon train/shift.
   b. Covered barge loading facilities capable of loading 1,000 tpd (day hours).
2. Ghorasal Urea Plant
   As for Ashuganj, above.
3. Fenchuganj Urea Plant
   a. Covered rail loading facilities capable of loading 30 wagons/shift.
4. Chittagong Port Area
   a. Two berths in port dedicated to receiving bagged (hand) fertilizer imports, each capable of receiving 1,500 tons/shift from lighter or from vessel alongside. Truck shuttle service to BADC warehouses outside port area.
   b. BADC working area in warehouse outside port area, for "standardizing" fertilizer bags at import handling rate using two berths (2 x 1,500 tons/shift) with direct movement to rail, road, and barge loading facilities and to storage.
   c. Warehouse accommodation for at least 1 month average throughput.
   d. Facilities in port for loading to bay crossing barges and coasters at minimum rate of 1,000 tpd (from BADC and/or TSP plant).
   e. Covered mechanized loading facilities for rail and road at BADC site, supplied directly from import-handling area (b) and also from storage (c). Rail loading to handle one 60-wagon train/shift. Truck loading to handle minimum 200 x 5-ton trucks/day.

5. Chittagong TSP Plant
   a. Covered rail loading facilities capable of loading one 60-wagon train in 24 hours, one/week.
   b. Truck loading to handle minimum 60 x 5 ton trucks/day.
6. Chalna Port
   a. Two berths in port dedicated to receiving bagged fertilizer imports from lighters or from pontoon berth at rate of 1,500 tons/shift each on two-shift operation.
   b. Conveyor system from berths to BADC working area in warehouse for "standardizing" fertilizer bags at import handling rate. Conveyor system to barge loading and to storage.
   c. Third dedicated berth for all-weather loading out to barges, with mechanized/conveyor loading to handle 2 x 1,000-ton barges/day (to Shiromoni), during day hours plus 1,000 tpd average into other barges. Conveyors from working area (b) and from storage (d).
   d. Warehouse accommodation for at least 1 month's average throughput.
7. Shiromoni transit center
   a. Covered facilities for offloading 2 x 1,000-ton barges/day during day hours. Conveyor system direct to rail and truck loading-out facilities, also to storage.
   b. Covered, mechanized, rail loading facilities, capable of loading 2 x 60-wagon trains/day, during day hours.
   c. Covered mechanized, road loading facilities, capable of handling a minimum of 200 x 5-ton trucks/day, during day hours.
   d. Buffer storage capacity for at least 2 weeks throughput at average rates.
8. All source locations for rail dispatches (<u>all above except Chalna</u>)
   a. Adequate rail siding capacity for storage of wagons and marshalling of trainloads.
   b. Shunting facilities.
   c. Wagon maintenance facilities to handle minor and running repairs.
9. All unit train destinations (PDPs)
   a. Covered offloading area, strongly recommended capable of handling full 60-wagon train at one time.
   b. Buffer storage in immediate offloading area capable of accepting one full trainload.

10. Bahadurabad Ghat rail wagon ferry

    a. Essential improvements as in The World Bank project.

    b. Capacity to move one full trainload in each direction <u>every</u> day for 1984/85 levels as minimum requirement.

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Annex I

BANGLADESH FERTILIZER SUPPLY AND USE POLICY CONSENSUS REPORT

Project Summary Sheet

Goal

To develop a National Fertilizer Policy which, if implemented, would be effective in meeting the agronomic requirement of crop nutrients in Bangladesh consistent with GOB's crop production target through 1990.

Objective

In concert with Bangladeshi expertise in engineering, marketing, socioeconomics, and agriculture, develop a consensus document that would define strategies for an optimal allocation of external and internal resources (fiscal, research, organizational extension) for fertilizer supply and use.

Budget Estimate

$130,000.

Background

The maintenance and the improvement of the fertility of the soils of Bangladesh is crucial to achieving food grain self-sufficiency, a cornerstone of the agricultural development strategy of the Bangladesh government. The contribution of fertilizer in increasing yields has been demonstrated and is widely recognized. A host of internally and externally funded programs are focused on relieving various constraints to increased fertilizer use. Fertilizer supplies are being expanded through bilateral grants for fertilizer purchases and programs for expanding domestic fertilizer production. To provide for timely availability of fertilizers at the farm level, projects such as the USAID-funded Fertilizer Distribution Improvement Project have been implemented. A primary goal of this effort is to ensure equitable availability and use of fertilizers by small and tenant farmers, the majority of the Bangladesh farm population.

Though substantial funds are being spent on overcoming fertilizer supply and availability problems, yet uncertainty persists as to fertilizer use in the years ahead. The following issues, among others, seem to require study in this regard:

1. The yield-response ratios of chemical and/or organic fertilizer as related to various crops;
2. The desirability, efficacy, and scope of combining use of chemical and organic fertilizer and other crop nutrients;
3. Likely budgetary burdens for domestic manufacture/importation of chemical fertilizer through 1990;
4. Review of past use and future prospects of organic fertilizers;
5. Access, ability, and willingness of various classes of farmers towards chemical/organic fertilizer;
6. Pricing policies for fertilizer;
7. Soil fertility classification and application rates of fertilizer for various crops;
8. Use of fertilizer with maximum efficiency; and
9. Adequacy of present organizational arrangements in promoting use of fertilizer.

There is a clear and urgent need for a long-term coordinated, national fertilizer supply and use strategy. This strategy needs to be developed by the

integration of the fertilizer-related production, marketing, and use knowledge which exists both in Bangladesh and elsewhere. The need for basing this strategy on as wide a knowledge base as possible becomes even more important as soil fertility and fertilizer use problems become increasingly complex and as rising energy costs escalate fertilizer supply costs. Bangladesh, in the past, has focused attention on only three nutrient elements, N, P, and K, used in the form of simple fertilizers. Today, however, the crop-nutrient situation is becoming more complex, and strategies for low cost supply and delivery systems for the various crop nutrients are needed for meeting the agronomic requirement. In this regard, the potential contribution of organic source of plant nutrients needs to be investigated.

The International Fertilizer Development Center (IFDC) with its diverse experience in Bangladesh in collaboration with BCIC, BADC, and BARC is singularly qualified to assist Bangladesh in the development of a national fertilizer supply and use strategy. IFDC's cadre of experienced engineering, marketing, socioeconomic, and agricultural specialists encompasses the range of disciplines required to formulate an effective national fertilizer policy. Further, the close working relationship between IFDC and the neighboring National Fertilizer Development Center (NFDC) of the Tennessee Valley Authority (TVA) enables IFDC to draw upon a major source of fertilizer knowledge in the United States.

Project Mandate
(Initial Statement of the Terms of Reference)

1. The project mandate is to write a consensus document which sets forth long-range (up to 1990) national fertilizer supply and use strategies aimed at:
   a. Minimizing foreign exchange costs for fertilizer,
   b. Maximizing crop response with existing resources, and
   c. Minimizing the adverse effects of shortage of chemical fertilizers.
2. The set of identified strategies should take into account and be based on an in-depth analysis of the following points:

a. Demand
   (1) Five-year plan figures.
   (2) Historical and other trends.
   (3) Critical analysis of demand figures.
   (4) Modified projections.
b. Supply
   (1) Production (actual and alternatives).
   (2) Imports (actual and alternatives).
c. Estimate cost (foreign exchange and local currency of annual fertilizer requirements.
d. Fertilizer use: Socioeconomics and Agronomics.
   (1) When, where, how, and by whom used: Marketing and equity evaluation.
   (2) Estimation of yield impact.
   (3) Critique of current fertilizer recommendations.
   (4) Improvement of recommendations.
      (a) Research needs.
      (b) Extension needs.
e. The contribution of organic matter (field, household, village, and urban residues) and potential for development.
f. Potential for improving the efficiency of fertilizer nutrient use.
g. Industrial modifications of conventional sources of nutrients and their potential impact on level and efficiency of fertilizer use.
h. Potential for reducing phyiscal inefficiencies in handling, distribution, and use.
i. Rate of use of nutrients: Development of optimal allocation under conditions of adquate and short supplies of N, P, and K fertilizers.

Proposed Activities

The planning of a national fertilizer sector strategy should be based on a critical assessment of the state of the art of those sciences and technologies impinging on fertilizer use in Bangladesh. Therefore, a full review of the following areas as they impact on the Bangladesh fertilizer situation is needed:

1. Soil classification.
2. Soil fertility.
3. Crop production agronomy.
4. Socioeconomics of small farm systems and equity issues.
5. National level fertilizer-related economics.
6. Fertilizer marketing.
7. Fertilizer production engineering.

To handle this activity, Bangladesh counterparts are needed for each of the preceding areas. As the objective of the proposed project is to develop a consensus document, it is essential that the greatest care goes into the selection of the Bangladeshi counterparts. They must be senior and highly respected experts in their subject areas and yet have the breadth of experience needed to develop a consensus report.

To launch the project, IFDC would send two experts (one soil fertility specialist and one economist) to Bangladesh to meet with each Bangladeshi counterpart individually and also in working groups in order to refine the terms of reference with BADC and USAID (Dacca) and to develop the necessary information base for the study.

Thereafter, an IFDC team will develop a National Fertilizer Sector Strategy draft report. This draft report will be forwarded to the Bangladesh counterparts who, after having thoroughly reviewed the document, will attend a 1-week workshop at IFDC. The objective of this workshop will be to write, based on a consensus revision of the draft report, a final project report. IFDC will then edit and reproduce the final project report. The final report will be widely distributed both in Bangladesh and among donors. After a suitable period for within government and donor discussion, a National Fertilizer Strategy Seminar will be held in Bangladesh at which IFDC staff and counterparts will present the findings of the final project report to BADC and USAID/Dacca and to senior officials. Development of followup activities would follow from this seminar.

Project and Schedule and Budget

Project Item	Time Period	IFDC Staff Time	Budget US $
1. IFDC staff to Bangladesh for project initiation	October 1980	2 months (2 x 4 weeks of which two in-country)	2 air tickets Muscle Shoals-Dacca and return plus 15 days per diem
a. Discussions between IFDC and BADC/AID to finalize terms of reference			
b. Identification, nomination, confirmation of counterparts			
c. Development of available information			
2. Develop an IFDC draft project paper	November-end March		
a. Industrial products		1 month	
b. Marketing		2 months	
c. Agroeconomics of fertilizer use		4 months	
d. National fertilizer economics		2 months	
e. Socioeconomics of fertilizer use		2 months	
f. Typing and internal review		0.75 months	
3. Distribution of draft project report	April 1, 1981		
4. Joint IFDC/Bangladeshi counterpart workshop at IFDC: To develop final consensus report	May 18-22		7 air tickets Dacca-Muscle Shoals and return plus 7 x 10 days per diem
TOTAL IFDC Staff Time		2 months	
5. Preparation of final report typing, editing, reproduction	July 1, 1981		$5,000
6. IFDC staff to Bangladeshi for in-country seminar presentation to policymakers and development of followup activities	September 1981	1.5 months (3 x 7 days per diem)	3 air tickets Muscle Shoals-Dacca and return

Annex II

GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH

MINISTRY OF AGRICULTURE AND FORESTS

Memorandum

Government has decided to prepare "Bangladesh Fertilizer Supply and Use Policy Consensus Report" to define strategies for an optimal allocation of external and internal resources for fertilizer supply and use in consistent with the national food production target through 1990. This is to be developed by the intregation of fertilizer related production, marketing, and use knowledge which exists in Bangladesh and elsewhere. The planning of national fertilizer sector strategy should, therefore, be based on a critical assessment of the state of art of those science and technologies impinging on fertilizer use in Bangladesh. A full review of soil characteristics and fertility, crop production agronomy, fertilizer economics, fertilizer production engineering and marketing is, therefore, recommended as the basis of the consensus report.

A committee has been constituted with the following persons to critically assess the specific subject areas to prepare the consensus report on fertilizer supply and use policy with respect to the Terms and References mentioned below:

	Name		Assigned Subject Area
1.	Mr. A. Zaman Khan Member Director BADC	Chairman	
2.	Dr. Munirul Huq Director Soil Survey	Member	Soil Classification
3.	Mr. Ata Elahi Project Director Soil Fertility Inst.	Member	Soil Fertility
4.	Dr. Azizul Islam Agronomist, BRRI	Member	Crop Production Agronomy
5.	Mr. Kobbad Hossain Manager (Sales), BADC	Member	Fertilizer Marketing

	Name		Assigned Subject Area
6.	Mr. Mukhlesur Rahman Executive Director Fertilizer Industries Rehabilitation Project, BCIC	Member	Fertilizer Production
7.	Dr. Ekramul Ahsan Member Director BARC	Member-Secretary	Fertilizer Economics

Terms and References

1. Each member of the committee will review all available information in the assigned subject areas as referred in the job descriptions.
2. Each member will prepare a position paper on the assigned subject areas.
3. The position papers will be presented in a seminar to be held during mid-February, 1981.
4. The revised position papers will be critically reviewed in reconciliation with relevant knowledge elsewhere in a seminar to be held in March, 1981 at the International Fertilizer Development Center (IFDC), Muscle Shoals, U.S.A.
5. The Consensus Report will be finalized after the seminar at IFDC in March, 1981.

The committee will start working immediately. A copy of the project proposal and the job descriptions of each of the members are enclosed herewith.

A.Z.M. Obaidullah Khan
Secretary
Ministry of Agriculture & Forests

Copy forwarded for information and necessary action to:

1. Chairman, Bangladesh Agricultural Development Corporation.
2. Executive Vice-Chairman, BARC.
3. Director, BARI.
4. Director, BRRI.
5. Chairman, BCIC.

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6. Mr. A. Zaman Khan, Member Director (Planning), BADC.
7. Dr. Munirul Huq, Director, Soil Survey.
8. Mr. Ata Elahi, Project Director, Soil Fertility Institute.
9. Dr. Azizul Islam, Agronomist, BRRI.
10. Dr. Ekramul Ahsan, Member Director, BARC.
11. Mr. Kobbad Hossain, Manager (Sales), BADC.
12. Mr. Mukhlesure Rahman, Executive Director, Fertilizer Industries Rehabilitation Project, BCIC.
13. Member Director (Supply), BADC.
14. Director (Production), BCIC.

Annex III

NATIONAL FERTILIZER POLICY STUDY

TERMS OF REFERENCE

Agricultural Economist

1. Review and evaluation of relevant agriculture and fertilizer-related policies in Bangladesh (both macro and micro aspects).

   Macro: Pricing of agricultural commodities
   Pricing of fertilizer
   Subsidy and public finance issues
   Credit issues
   Food production policy

   Micro: Improvement of delivery and extension services to increase equity and efficiency in fertilizer use and to address demand related constraints. (This section will draw heavily on the Adoption Demand and Equity studies.)

2. Socioeconomic and political description of the country and developing relationship between fertilizer and food production.
3. Review of 1st Five-Year Plan (target, achievement) and review of 2nd Five-Year Plan with respect to agriculture, food, and fertilizer.
4. Economic evaluation of crop response to fertilizer use (from equity and adoption-demand study) and comparison with experimental results.
5. Fertilizer demand forecasting--review and critique of fertilizer demand forecasts.

Crop Production Agronomist

Collect and review all available information (both published and unpublished):

1. As related to the estimation of the crop nutrient balance of Bangladesh soils. Nutrients applied in organic matter or as symbiotic N or as fertilizer, in irrigation or floodwater, etc., and nutrients removed as

plant material including all vegetative growth removed for fodder, for litter, for fuel, etc., must be taken into account. The balance should be developed for 1980 and projected to 1990.

2. As related to current day fertilizer recommendations including an evaluation of their agronomic and economic validity and degree of farmer use.
3. As related to the development of crop production targets up to 1990 quantifying the role of crop nutrients in achieving the established targets.
4. As related to improved forms of fertilizer and fertilizer practices and the role of these in the next decade in reducing fertilizer needs while maintaining targeted yield levels.
5. As related to the present and projected role or organic matter in maintaining and improving soil fertility. Include in this section the role of symbiotic N.

Prepare a draft position paper based on the foregoing, quantifying annual crop nutrient needs in terms of fertilizer and organic matter up to 1990 by crop, soil unit, and area.

N. B. Individual plot data from trials and demonstrations must be presented in addition to treatment means.

Soil Fertility Expert

Collect and review all available literature on soil fertility in Bangladesh (both published and unpublished):

1. As related to current capabilities to carry out soil fertility and fertilizer use research, including facilities, staff, and projects now underway or planned.
2. As related to procedures for formulating fertilizer recommendations, including the role of research findings.
3. As related to current day fertilizer recommendations, including an evaluation of their agronomic and economic validity and degree of farmer use.
4. As related to the potential for improvement of fertilizer recommendations and their adoption by farmers.

5. As related to an evaluation of current methods of transmitting the results of fertilizer research to farmers.

Prepare a draft position paper based on the foregoing, quantifying present and future (up to 1990) fertilizer requirements in terms of N, P_2O_5, K_2O, S, Zn, and other needed nutrients by crop, soil unit, and area.

N. B. Individual plot data from trials and demonstrations must be presented in addition to treatment means.

Soil Classification Expert

Collect and review all available soil classification information and knowledge (both published and unpublished):

1. As related to those physical factors controlling cropping systems practiced in Bangladesh.
2. As related to the fertility of the soil in terms of pH, organic matter, nutrient element status, and chemical conditions restricting plant growth.
3. Current status of soil mapping and future plans.
4. As related to the changes imposed on the fertility of the soils by the crops grown and the cropping systems now practiced and expected to be practiced over the period of 1990 and the implications of the changes described on future plant nutrient needs.
5. As related to the changes imposed on the organic matter levels of the soil by crops grown and the cropping systems now practiced and expected to be practiced over the period to 1990 and the implications of the changes described on soil fertility and the future role of organic materials in maintaining and improving soil fertility.

Prepare a draft position paper based on the foregoing, describing the fertility status of Bangladesh soil units as currently mapped and the implications for organic matter and fertilizer use up to 1990.

Marketing Expert

Collect and review all available information (both published and unpublished) as related to the following items:

I. Fertilizer Use

A. Fertilizer requirements

1. State estimates of annual fertilizer nutrient requirements by crop, by region, through 1990 based on production goals identified in the national plan.

B. Fertilizer demand

1. Establish apparent fertilizer consumption for period 1965-80 by region, by product, and, if possible, by crop using sales records of BADC.

2. Forecast annual fertilizer demand for period 1980-90 by region and by crop, where data availability permits. Forecasting techniques may include models using time series data and/or those taking into consideration cultivated area, agriculture infrastructure, availability of credit, irrigation, and fertilizer cost:product price ratios, etc. The effect of possible alterations in the fertilizer subsidy program will be considered as a factor in determining fertilizer cost:product price ratios.

3. Compare estimated fertilizer requirements with demand forecast. Identify potential constraints to achieving goals set in 1980-90, including: unfavorable fertilizer:product price ratios, limitations in research information, inadequacy of fertilizer extension activities, lack of fertilizer availability and insufficient knowledge by the farmer.

II. Fertilizer Supply

A. Domestic production

Establish planned domestic production goals up to 1990 by product. Indicate major constraints which could reduce planned production.

B. Imports

(Receiving facilities and delivery systems to warehouse will be studied during 1981 and the expert's findings will be incorporated in the final report.)

1. Fertilizer imports--For the period 1965-80, tabulate import tonnages by product, by form, by source of origin, and by port of entry, including average annual CIF value. Also, assess procurement practices.

2. Determine annual import requirement of raw materials and finished fertilizers to meet supply needs to 1990.

C. Carryover stocks

1. Year-end inventory--For period 1965-80, determine annual carryover stock tonnage, by grade, at primary production centers and distribution warehouses. This data may be required on a monthly basis.

D. Fertilizer deliveries to domestic market

1. Apparent consumption--For period 1965-80, determine fertilizer delivered annually for farm use based on domestic production, imports, exports, industrial usage, and carryover stocks.

III. Fertilizer Marketing

A. Marketing mechanism

1. Describe the organization and functions of BADC's fertilizer handling operations. Define procedures followed in forecasting annual market needs and procuring fertilizers from domestic and foreign sources. Describe and assess the adequacy of the overall fertilizer marketing system. Assess the administrative capacity of BADC to manage public sector distribution and marketing of fertilizers.

2. (Receiving facilities and delivery systems to warehouse will be studied during 1981 and the expert's findings will be incorporated in the final report.) Assess the adequacy of the physical distribution system to delivering farm needed fertilizers on a timely basis. How might BADC's system of movement contracting be improved. Delineate major constraints and suggest remedial action.

3. Describe the private fertilizer wholesaler and dealer system. Assess the extent to which dealer competition promotes efficient distribution and pricing. Estimate the investments and seasonal inventories of wholesalers and dealers.

B. Fertilizer Prices, Costs, and Margins

1. Fertilizer prices--Describe the national subsidy program and price policy. Give BADC's pricing policy for sales, by grade. Denote the pricing policy and credit terms for sales to other groups, such as banks, farmer grower groups, and private sector dealers.

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2. Farm-gate costs and margins--Establish and verify averages delivered farm-gate prices by sales region, based on f.o.b. warehouse price and costs associated with farm delivery. Determine fertilizer costs and margins with the distribution system, by sales channel.

C. Credit--Determine and evaluate

1. The role of credit in fertilizer purchases.
2. The sources, mechanisms, and types of credit available to dealers and farmers. Comment on present and future availability of credit by source and discuss credit delivery procedures and repayment schedules.

D. Market development activities

1. Describe the role of BADC and its programs for fertilizer market development and promotion.
2. Describe and comment on the role of government programs in fertilizer extension and promotion.
3. Determine the need for additional fertilizer extension promotion, and farmer education, and identify possible mechanisms and funding sources for their execution. Highlight the responsibility of government agencies and delineate the possible role of mechanisms and programs by which BADC might participate in market development and farmer assistance programs (e.g., dealer training, farm meeting, research funding, etc.).

E. Fertilizer control legislation. Evaluate adequacy of current and proposed regulatory controls affecting fertilizer sales and consumer protection.

F. Strategies for Development of the Fertilizer Sector.

Develop an overall strategy through the year 1990, based on short- and intermediate-term strategies and designed to meet possible changes in supply, performance of present and planned production facilities, market demand, and distribution infrastructure. The broad strategy will be composed of a series of short-term strategies dictated by imposed or desired circumstances relative to demand, supply, and marketing. Discuss the potential role that the private sector may develop in the importation, manufacture, distribution, and wholesaling of fertilizer.

G. Project annual fertilization demand by quantities of fertilizers and nutrients through 1990.

H. Fertilizer marketing and distribution strategies.

1. (Receiving facilities and delivery systems to warehouse will be studied during 1981 and the expert's findings will be incorporated in the final report.) Assess adequacy of current distribution system, based on identifiable constraints in modes of transportation and physical infrastructure, to handle current and future increases in projected demand. Recommend delivery system changes required to accommodate handling and timely delivery of increased tonnages.

2. Review the suitability of prevailing marketing policies, strategies, and programs in light of a changing environment which may involve a growth and possible shift in location and demand and product type. Recommend changes where appropriate.

3. Recommend needed changes in, or expansion of, market development activities, fertilizer extension, promotion, technical assistance, and farmer education programs required to facilitate the transition to a projected higher fertilizer use base.

Terms of Reference for Fertilizer Production Engineer

1. Outline history and achievements of present production facilities. Annual production targets by type and quantity of fertilizer to December 1980. Actual annual production by type and quantity of fertilizer to December 1980. Reasons for differences between planned and actual production.
2. Outline of proposed developments in production facilities up to 1990. Planned production by type and quantity of fertilizer to December 1990. Critique of planned production figures based on historical trends and on degree of elimination of past constraints to full capacity utilization. Included will be the identification and impact of fertilizer storage and movement constraints on the production units: (a) Up to December 1980 and (b) anticipated up to December 1990.
3. Economics of local production: (a) Give estimated production costs of TSP, urea, and ammonium sulfate for the period up to December 1980 and (b) give estimated projected costs up to December 1990.
4. (a) Assess the quantity and availability of phosphogypsum for agricultural use and (b) estimate cost of producing standardized phosphogypsum bagged in suitable 50-kg plastic bags ex-factory Chittagong.
5. Make a preliminary assessment of the potentialities for the production in Bangladesh of granular urea, briquetted urea, modified TSP, sulfur-containing fertilizers, and trace element-containing materials for agricultural use in Bangladesh and recommend needed prefeasibility studies.

Annex IV

BACKGROUND REVIEW PAPERS

PREPARED FOR

BANGLADESH FERTILIZER SUPPLY AND USE POLICY CONSENSUS REPORT

Soil Fertility and Nutrient Requirements of Major Crops in Bangladesh, Elahi, M. A., Project Director, On-Farm Division (S.F. and S.T.I.), BARI.

Soils, Cropping Potentials, and Fertilizer Requirements of Bangladesh, Huq, M., Director, Department of Soil Survey, GOB.

Organic Manure and Its Importance, Khan, M. U., Director (Implementation), Population Control and Family Planning Division, Azimpur, Dacca.

Crop Nutrients for Food Self-Sufficiency in Bangladesh, Islam, A.J.M.A., Head, Agronomy Division, BRRI.

Fertilizer Production in Bangladesh, Rahman, M., Executive Director, Fertilizer Industry Rehabilitation Project, BCIC.

Fertilizer Marketing in Bangladesh, Hossain, M. K., Manager (Sales), BADC.

Farm-Level Fertilizer Use in Bangladesh and Some Policy Issues, Ahsan, E., Member Director, BARC.

Considerations in Developing Fertilizer Policy, Diamond, R. B., Coordinator, Fertilizer Evaluation, Outreach Division, IFDC.

Fertilizer Policy Development in Bangladesh and Equity Considerations, Sidhu, S. S., Economist, Agro-Economic Division, IFDC.